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radio operator's license Q & A manual

by Milton Kaufman

SIXTH EDITION – includi[illegible]est revision and question renu[illegible]ering

RADIO OPERATOR'S LICENSE Q & A MANUAL

By MILTON KAUFMAN

Formerly Instructor, RCA Institutes

SIXTH EDITION—including latest revision and question renumbering.

The new edition is in complete accordance with the FCC Study Guide now being used as a basis for radio license examinations. The text has been brought up-to-the minute, particularly with regard to new operating procedures and new frequencies. Questions which have become obsolete since the last edition have been deleted. Questions have been renumbered to make them conform to the latest Study Guide. Discussions to many questions have been amplified so that the reader may achieve maximum background information.

The method of presentation is clear, logical and completely easy to read. Questions follow those presented in the current FCC Study Guide for radio operator's license exams; the answers are given in a wholly understandable way, followed by simplified discussions of the topics. It is this discussion feature of the book that enables the reader to acquire a more thorough explanation of the question. All eight Elements, which include Element 7 on Aircraft Radiotelegraph and Element 8 on ship Radar Techniques, are covered fully in this same method.

The volume offers valuable appendices on Small Vessel Direction Finders, and Automatic Alarm, which are exclusive with this book.

Primarily designed as a study aid, the book covers all the information necessary for the successful completion of the FCC examination for radio operators. As a reference volume, it offers a quick, easy-to-locate review of essential theory. The subject matter is given according to Element, in the same manner as presented on the FCC exams. However, if the reader wishes to study by subject, rather than by Element, the thoroughly complete index enables this procedure to be followed with maximum convenience.

The author, Milton Kaufman, a former instructor at RCA Institutes, department of Radio Operating, writes with complete authority born of years of experience and lecturing on this subject.

(CATALOG No. 130)

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By

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SIXTH EDITION

JOHN F. RIDER PUBLISHER, INC.
116 WEST 14 STREET, NEW YORK 11, N. Y.

First Edition
December 1949

Second Edition
September 1950

Third Edition
June 1951

Fourth Edition
January 1953

Fifth Edition
January 1955

Sixth Edition
May 1957

PRINTED IN THE UNITED STATES OF AMERICA

Library of Congress Catalog Card No. 57-11293

TO

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AND

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PREFACE

This new, Sixth Edition is in full accordance with the latest revisions to the FCC Study Guide. Elements II, III, and VI have been completely revised.

Element I is examined by means of the multiple choice type of test. This element will consist of 20 questions and 5 percent credit will be allowed for each correct answer. Element II consists of 50 questions and 2 percent credit will be allowed for each correct answer. Forty of the questions in Element II are given to all candidates and are of a general nature. The remaining 10 questions are in any one of three fields (aircraft, coastal or ship radio) and the candidate is allowed to choose one of these subjects.

The book incorporates "Discussion" sections for most of the questions, in order to present much important background material which should add considerably to the student's knowledge regarding many varied topics. It is hoped that the discussions will save the student much time and trouble which might otherwise be spent in poring over various reference textbooks.

Each question is divided into two separate sections: a short, but complete answer, and a discussion. Thus, if desired, the student, upon the first reading, may make reference only to the answer, and come back to the discussion for more intensified study at a later date.

In the preparation of this Sixth Edition a painstaking effort was made to present questions in precisely the same order as appears in the most recent FCC Study Guide. Material that appeared in the Addendum of previous editions has been brought up and inserted in its appropriate elements. Thus, the Sixth Edition represents the very latest presentation of questions and answers for radio operators' license examinations.

The study requirements for the various classes of license are as follows:

Radiotelephone first-class operator license: Elements I, II, III, IV.
Radiotelephone second-class operator license: Elements I, II, III.
Radiotelephone third-class operator permit: Elements I, II.
Restricted radiotelephone permit: no written or oral exam.

Radiotelegraph first-class operator license: Elements I, II, V, VI.

Radiotelegraph second-class operator license: Elements I, II, V, VI.

Radiotelegraph third-class operator permit: Elements I, II, V.

Aircraft radiotelegraph endorsement on radiotelegraph first- or second-class operator licenses: Element VII required.

Ship radar endorsement on radiotelegraph or radiotelephone first- or second-class operator licenses: Element VIII required.

For the reader who is interested in a listing of questions arranged by subjects (such as Radio-Frequency Amplifiers, Direction Finders, Instrument Landing System, Meters, Receivers, Transmitters, Vacuum Tubes, etc.), we refer him to the complete Index which appears at the end of the book.

The author wishes to express his appreciation to the following persons for their assistance: Bernard Grob, Richard Blitzer, the late Joseph Powder, Walter Neiman, L. Jerome Stanton, Ben Minor and Pat A. Stock, all of RCA Institutes.

Gratitude is also extended to RCA Review for permission to reprint the articles on the Auto-Alarm and Direction Finder which appear as Appendices, and to the authors of the articles, I. F. Byrnes and H. B. Martin of the Radiomarine Corporation of America, who also deserve special mention for providing valuable assistance in connection with Elements V and VI. Charles Darcy and Victor P. Villandre of Radiomarine Corporation of America were also extremely helpful in providing important information for Element VI.

And last but not least, appreciation is expressed to the author's wife, Hazel, for her assistance in the preparation of the manuscript.

MILTON KAUFMAN

New York, N. Y.
May 1957

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RADIO OPERATOR'S
LICENSE Q & A MANUAL

ELEMENT I

BASIC LAW

(Note: References which appear after questions in Elements I and II give the law or regulation involved in answering the question. Abbreviations used are as follows: Sec. *refers to a section of the Communications Act of 1934;* Art. *refers to an article of the International Radio Regulations (Atlantic City, 1947);* R & R *refers to provision of the Rules and Regulations of the Federal Communications Commission; and* GLR *refers to regulations annexed to the Agreement Between the United States and Canada for Promotion of Safety on the Great Lakes by Means of Radio.)*

Question 1.01. Where and how is an operator license or permit obtained?

Answer. In general, an operator license or permit is obtained by making application to the regional FCC office and by passing such examination elements as are required for the particular class of license desired. In the case of a restricted radiotelephone permit, no written or oral examination is required, but proper application must be made.

Discussion. See "Preface" for a list of requirements regarding the various classes of licenses and endorsements.

Q. 1.02. Must a person designated to operate a radiotelephone station post his operator license or permit, and if so, where? (R & R 13.6)

A. Yes. The original license of each station operator shall be posted at the place where he is on duty or kept in his possession in the manner specified in the regulations governing the class of station concerned.

Q. 1.03. How must a person who receives a Notice of Violation from the FCC reply? (R & R 1.401)

A. The person receiving a Notice of Violation shall send a written answer direct to the office of the Commission originating the official notice.

Q. 1.04. How soon does the FCC require a response to a Notice of Violation? (R & R 1.401)

A. Within 3 days.

Q. 1.05. If a person cannot respond to a Notice of Violation in the time prescribed by the FCC is it necessary to explain the reason for any delay? (R & R 1.401)

A. Yes.

D. If an answer cannot be sent, nor an acknowledgment made within a three-day period by reason of illness or other unavoidable circumstances, acknowledgment and answer shall be made at the earliest practicable date with a satisfactory explanation of the delay.

Q. 1.06. Should the answer to each Notice of Violation be complete and should reference be made to remedial action, if any specific remedial steps are necessary? (R & R 1.401)

A. Yes.

D. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answers to other notices. If the notice relates to violations that may be due to the physical or electrical characteristics of transmitting apparatus, the answer shall state fully what steps, if any, have been taken to prevent future violations, and if any new apparatus is to be installed, the date such apparatus was ordered, the name of the manufacturer, and promised date of delivery. If the installation of such apparatus requires a construction permit, the file number of the application shall be given, or if a file number has not been assigned by the Commission such identification shall be given as will permit ready identification thereof If the notice of violation relates to lack of attention to or improper operation of the transmitter, the name and license number of the operator in charge shall be given.

Q. 1.07. To whom is a response to a Notice of Violation addressed? (R & R 1.401)

A. To the office of the Federal Communications Commission originating the official notice.

Q. 1.08. May the FCC suspend an operator license or permit for due cause? (Sec. 303(m))

A. Yes.

D. The FCC has authority to suspend the license of any operator upon proof sufficient to satisfy the Commission that the licensee—

(1) Has violated any provision of any act, treaty, or convention binding on the United States, which the Commission is authorized to administer, or any regulation made by the Commission under any such act, treaty, or convention; or

(2) Has failed to carry out a lawful order of the master or person lawfully in charge of the ship or aircraft on which he is employed; or

(3) Has willfully damaged or permitted radio apparatus or installations to be damaged; or

(4) Has transmitted superfluous radio communications or signals or communications containing profane or obscene words, language, or meaning, or has knowingly transmitted false or deceptive signals or communications, or a call signal or letter which has not been assigned by proper authority to the station he is operating; or

(5) Has willfully or maliciously interfered with any other radio communications or signals; or

(6) Has obtained or attempted to obtain, or has assisted another to obtain or attempt to obtain, an operator's license by fraudulent means.

Q. 1.09. Can suspension of an operator license or permit take effect prior to notification? (Sec. 303(m))

A. No.

D. No order of suspension shall take effect until 15 days after the actual receipt of said order by the licensee.

Q. 1.10. How soon after receiving notification of suspension of an operator license or permit does a suspension order become effective? (Sec. 303(m))

A. Fifteen days.

D. This is unless an application for a hearing has been mailed to the Commission within this period. In such case, the order of suspension is held in abeyance until the conclusion of the hearing.

Q. 1.11. May a person who has received an order of suspension of operator license or permit request a hearing? (Sec. 303(m))

A. Yes. (See Question 1.10)

D. Upon the conclusion of a hearing, the Commission may affirm, modify, or revoke the order of suspension.

Q. 1.12. Is it prohibited by law to transmit unnecessary and superfluous signals? Is profane and obscene language prohibited?

A. (1) Yes. By international agreement, the transmission of unnecessary, superfluous or unidentified signals is forbidden.

(2) Yes. No person within the jurisdiction of the United States shall utter any obscene, indecent or profane language by means of radio communication.

Q. 1.13. Does the Government have authority to impose fines for failure to comply with the rules and regulations governing the use of radio on compulsorily equipped ships? (Sec. 502)

A. Yes.

D. Any person who willfully and knowingly violates any rule, regulation, restriction, or condition made or imposed by the Commission under authority of this Act, or any rule, regulation, restriction, or condition made or imposed by any international radio or wire communications treaty or convention, or regulations annexed thereto, to which the United States is or may hereafter become a party, shall in addition to any other penalties provided by law, be punished, upon conviction thereof, by a fine of not more than $500 to each and every day during which such offense occurs.

Q. 1.14. What must a person do whose operator license or permit has been lost, mutilated or destroyed? (R & R 13.71)

A. An operator whose license or permit has been lost, mutilated or destroyed shall immediately notify the Commission.

D. A sworn application for a duplicate should be submitted to the office of issue embodying a statement attesting to the facts thereof. If a license has been lost, the applicant must state that reasonable search has been made for it, and further, that in the event it be found either the original or the duplicate will be returned for cancellation. The applicant must also give a statement of the service that has been obtained under the lost license.

Q. 1.15. In applying for a duplicate operator license or permit, what documentary evidence must be submitted along with an application? (R & R 13.71)

A. A properly executed application for a duplicate should be submitted to the office of issue, embodying a statement of the circumstances involved in the loss, mutilation or destruction of the license or permit for which a duplicate is desired. If the license or permit has been lost, the applicant must state that reasonable search has been made for it, and further, that in the event it be found either the original or the duplicate will be returned for cancellation. The applicant should also submit documentary evidence of the service that has been obtained under the original license or permit, or a statement under oath or affirmation embodying that information.

Q. 1.16. Is it permissible to operate pending receipt of a duplicate operator license or permit after application has been made for re-issue? (R & R 13.72)

A. Yes.

D. When a duplicate operator license or permit has been requested, or a request for renewal upon service has been made, the operator shall exhibit in lieu thereof a signed copy of the application for duplicate, or renewal, which has been submitted by him.

Q. 1.17. What provision is made for operation without an actual operator license or permit pending receipt of a duplicate? (R & R 13.72)

A. See Question 1.16.

Q. 1.18. Is the holder of a radiotelephone third-class operator permit authorized to make technical adjustments to the transmitter he operates? (R & R 13.61)

A. He may do so only in the presence of an operator holding a first- or second-class license, either telephone or telegraph. Said operator shall be responsible for the proper operation of the equipment.

Q. 1.19. Should a radio station that is required to be operated by a licensed radio operator be a licensed radio station? (Sec. 318)

A. Yes. Any radio station operated by a licensed radio operator should be licensed.

Q. 1.20. Are communications bearing upon distress situations subject to the secrecy provisions of law? (Sec. 605)

A. No. Distress communications are exempt from the secrecy provisions of the law.

Q. 1.21. What penalty is provided by law for willful and knowing violation of regulations imposed by the Federal Communications Commission and of radio treaties? (Sec. 502)

A. See Discussion 1.13.

Q. 1.22. What penalty is provided by law for willful and knowing violation of the radio laws? (Sec. 501)

A. Any person who willfully and knowingly does or causes or suffers to be done any act, matter, or thing, in the Communications Act, prohibited or declared to be unlawful, or who willfully and knowingly omits or fails to do any act, matter, or thing in this Act required to be done, or upon conviction thereof, shall be punished by such offense, for which no penalty (other than forfeiture) is provided therein, by a fine of not more than $10,000 or by imprisonment for a term of not more than two years, or both.

Q. 1.23. Are radio stations subject to inspection by the Federal Communications Commission? (Sec. 303(n))

A. Yes.

D. The licensee of any radio station shall make the station available for inspection by representatives of the Commission at any reasonable hour and under the regulations governing the class of station concerned.

Q. 1.24. In radiotelephony, what are the distress, urgency, and safety signals? (Art. 37)

A. (1) In radiotelephony, the distress signal shall consist of the spoken expression MAYDAY (corresponding to the French pronunciation of the expression "m'aider"), repeated three times.

(2) In radiotelephony, the urgent signal shall consist of three transmissions of the expression PAN (corresponding to the French pronunciation of the word "panne"); it shall be transmitted before the call.

(3) In radiotelephony, the word SECURITY (corresponding to the French pronunciation of the word "securité") repeated three times shall be used as the safety signal.

Q. 1.25. In radio communication, what does the transmission of the "distress," "urgency" and "safety" signals signify, respectively? (Art. 37)

A. (1) The distress signal (MAYDAY) indicates that the ship, aircraft or any other vehicle which sends the distress signal is threatened by serious and imminent danger and requests immediate assistance.

(2) The urgent signal (PAN) shall indicate that the calling station has a very urgent message to transmit concerning the safety of a ship, an aircraft, or another vehicle, or concerning the safety of some person on board or sighted from on board.

(3) The safety signal (SECURITY) announces that the station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings. Hence, it should precede such a transmission.

Q. 1.26. What information must be contained in a distress message? (Art. 37-14)

A. This message shall include the distress call followed by the name of the ship, aircraft, or the vehicle in distress, information regarding the position of the latter, the nature of the distress and the nature of the help requested, and any other further information which might facilitate this assistance.

Q. 1.27. Under what conditions may a mobile radio station send a distress message for another mobile station in distress?

A. Any station which becomes aware that a mobile station is in distress may transmit the distress message in the following cases:

(1) When the station in distress is not itself in a position to transmit the message.

(2) In the case of mobile stations, when the master or the person in charge of the ship, aircraft, or other vehicle carrying the station which intervenes believes that further help is necessary.

(3) In the case of other stations, when directed to do so by the station in control of distress traffic or when it has reason to believe that a distress call which it has intercepted has not been received by any station in a position to render aid.

Q. 1.28. In the case of a mobile radio station in distress what station is responsible for the control of distress message traffic? (Art. 37-22)

A. The control of distress traffic shall be the responsibility of the mobile station in distress or upon the station which, by application of the provisions of the Commission's rules and regulations has sent the distress call. These stations may delegate the control of the distress traffic to another station.

Q. 1.29. What does the distress call consist of when sent by radiotelephony?

A. The spoken expression MAYDAY (see Question 1.24).

Q. 1.30. How may necessary corrections to the log record be made?

A. Any necessary correction may be made only by the person originating the entry who shall strike out the erroneous portion, initial the correction made, and indicate the date of correction.

Q. 1.31. How soon before expiration of an operator license or permit should application be made for renewal?

A. Within one year before expiration.

D. However, a grace period exists which extends the renewal time to one year after the expiration of the license. Of course, the licensee may *not* operate with an expired license.

Q. 1.32. Is it prohibited by law to transmit false or fraudulent signals of distress? (Sec. 325)

A. Yes.

D. No person within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto.

Q. 1.33. What is the priority of the urgency signal? (Art. 38)

A. The urgency signal is second in priority.

D. The order of priority shall be as follows:
(1) Distress calls, distress messages, and distress traffic.
(2) Communications preceded by an urgent signal.
(3) Communications preceded by a safety signal.
(4) Communications relative to radio direction-finding bearings.
(5) Government radiotelegrams for which priority right has not been waived.
(6) All other communications.

ELEMENT II

BASIC OPERATING PRACTICE—GENERAL

Note: The questions of Element II are divided into General and Special categories so that a candidate who wishes to do so may, in the Special category, select the subject on which he is to be examined from one of three fields, namely ship, coastal, or aircraft radiotelegraphy.

Question 2.01. If a radiotelephone operator desires to make a brief test of a transmitter what would be a good choice of words to use in the test?

Answer: The operator could speak somewhat as follows: KABC testing, one, two, three, four, etc., KABC.

Q. 2.02. Why is it important to avoid unnecessary calls by radiocommunication?

A. Unnecessary calls should be avoided to prevent interference with other stations desiring to use the channel.

Q. 2.03. Is it required that a person listen on a channel before transmitting?

A. Yes.

D. The operator should always listen before calling to insure that he will not interfere with communications already in progress.

Q. 2.04. Why is it advisable to listen on a channel before transmitting?

A. See Question 2.03.

Q. 2.05. Why should a trial of the radiotelephone installation be made every day?

A. To reveal possible faults that might otherwise cause delays in normal communications.

Q. 2.06. How can the radiotelephone installation be tested?

A. By placing the installation in normal operation and speaking somewhat as follows: KABC testing, one, two, three, four, etc., KABC.

Q. 2.07. Before placing the transmitting apparatus of a radio station in operation for a test what precautions must be taken?

A. The operator should listen on the transmission frequency to insure that interference will not be caused to a communication in progress.

Q. 2.08. What is the correct form for transmitting a distress call by radiotelephony?

A. In radiotelephony, the distress signal shall consist of the spoken expression MAYDAY (corresponding to the French pronunciation of the expression "m'aider"), repeated three times. The distress signal must be followed as soon as possible by the distress message. See also Questions 1.24 and 1.26.

Q. 2.09. Why is it a good policy to be brief in radiotelephone conversations?

A. It is a good policy to be brief to permit other stations to operate without interference and also from the standpoint of efficient station operations.

Q. 2.10. What is the significance of the word "clear" when transmitted at the end of a radiotelephone communication?

A. The word "clear" signifies that the transmission is ended and that no response is expected.

Q. 2.11. Are there any ill effects to radio communication if the operator shouts into the microphone?

A. Shouting into the microphone is poor practice, because while it probably will not injure the microphone, it may very well overdrive some speech amplifier or cause overmodulation. Either of these effects may cause severe distortion of the speech and possible interference with adjacent channels.

Q. 2.12. Is it a good practice to shield the microphone with the hands when speaking into a microphone in a noisy location?

A. Yes. This shields the microphone from outside noises and makes communication easier and more intelligible.

Q. 2.13. In radiotelephone communications why should the operator use well-known words and phrases and simple language as much as possible?

A. The operator should use simple language and well-known words and phrases to insure accurate, efficient communications and to eliminate repetition as much as possible.

Q. 2.14. What is the operator's responsibility upon hearing the word "security" repeated three times? (Art. 37-43)

A. All stations hearing the safety signal must continue listening on the frequency on which the safety signal has been sent until the message so announced has been completed; they must also keep silence on all frequencies likely to interfere with the message.

Q. 2.15. What must the operator do if he is told that he is interfering with a distress call?

A. He must cease all transmissions immediately.

D. No station having been notified to cease operation shall resume operation on frequency or frequencies which may cause interference until notified by the station issuing the original notice that the station involved will not interfere with distress traffic as it is then being routed or until the receipt of a general notice that the need for handling distress traffic no longer exists.

Q. 2.16. What is the significance of the word "over" when transmitted at the end of a radiotelephone communication?

A. "Over" means, "My transmission is ended and I expect a response from you."

Q. 2.17. What is indicated by the word "out" when transmitted at the end of a radiotelephone communication?

A. The word "out" means, "This conversation is ended and no response is expected."

Q. 2.18. Can a radio operator always consider his radiotelephone conversation completely confidential and not heard by other persons?

A. No. Radio waves go in many directions and for long distances. They may be intercepted by any number of unauthorized persons.

Q. 2.19. In calling a station by radiotelephony how many times does the calling station generally repeat the call sign or name of the calling station in each calling transmission?

A. The calling station generally repeats its own call sign *three* times.

Q. 2.20. Would you listen on a shared channel before transmitting? Why?

A. Yes.

D. The operator should always listen before calling to insure that he will not interfere with communications already in progress.

Q. 2.21. Under normal conditions would a transmission on a calling frequency be proper if the receiver for that frequency was inoperative?

A. No. The acknowledgment is generally made on the same calling frequency on which the calling station is transmitting. However, if the communication is important, the calling station could request an acknowledgment on another frequency, for example a normal working frequency. Alternatively, a different calling frequency might be employed.

Q. 2.22. What is the difference between calling and working frequencies?

A. A calling frequency is one to which all stations generally listen, for example 500 kilocycles. A working frequency is an assigned frequency other than a calling frequency on which the main body of the communication would take place after the initial calling.

Q. 2.23. Why is it important to clearly give the station call sign?

A. Station identification should always be made clearly and distinctly to avoid unnecessary repetition and to assist monitoring stations in identifying calls.

Q. 2.24. Should a test of the radiotelephone equipment be made each day?

A. Yes.

D. This may reveal faults that might otherwise cause delays in normal communications.

Q. 2.25. Should messages bearing upon safety, including weather information, be given priority over business messages? (Art. 38)

A. Yes.

D. See Question 1.33.

Q. 2.26. If a station is required by law to listen on a calling and distress frequency, when may the listening be discontinued?

A. Listening may be discontinued when the station is engaged in calling, transmitting to or communicating with other stations.

D. Stations licensed for other than continuous hours of service shall not discontinue operation before having finished all operations called for by a distress call.

Q. 2.27. Why should a radiotelephone transmitter be kept off the air when voice transmissions are not in progress?

A. To prevent interference with other stations using the channel.

D. Even if an unmodulated carrier is transmitted, it may cause heterodyning interference with other station carriers, making communication very difficult.

Q. 2.28. Why is it beneficial for the transmitter of a radio station to be in constant readiness for making a call?

A. To reduce delays in answering a call due to warm-up time and possible tuning, which may be required.

D. A state of constant readiness is generally accomplished by maintaining all filaments lit, but removing B+ voltages from one or more stages to prevent transmission of a carrier wave.

Q. 2.29. If a station is required to maintain effective listening on a distress frequency, why is it desirable for the equipment to return automatically to reception on the distress frequency immediately after completing use of the equipment on another frequency?

A. In order that the maximum amount of listening time may be effective on the distress frequency.

Q. 2.30. Why is rapid frequency change of the transmitter and receiver desirable?

A. To reduce any loss of communications time to a minimum.

Q. 2.31. What would you do as radiotelephone operator if you were told that your voice was distorting?

A. Speak more softly and/or further away from the microphone.

D. If your voice was still distorting, this probably would indicate defective equipment or improper adjustment of the equipment.

Q. 2.32. What is the correct form for transmitting a distress call by radiotelephone?

A. See Question 2.08.

Q. 2.33. Under what conditions may a radiotelephone station employ a calling frequency as contrasted to a working frequency?

A. A calling frequency may be used for the following:
(1) Initial calling. (Calling any one station shall not exceed one minute in duration.)
(2) Acknowledging calls received on this frequency.
(3) Exchanging operating signals with other stations, to establish communication on another frequency.
(4) Exchanging "distress" and "safety" communications.

Q. 2.34. In calling a station by radiotelephony should the calling station repeat the call sign or name of the called station in each calling transmission more than three times?

A. No.

D. The calling station generally repeats the call sign of the called station three times.

Q. 2.35. Why should stations using a shared frequency leave an interval between calls?

A. In order to give the other stations on the shared frequency an opportunity to carry on communications.

Q. 2.36. Under what conditions may it be desirable to repeat important words by radiotelephony?

A. Under unfavorable transmission conditions, or when such words may be difficult to pronounce or interpret. This procedure may prevent the necessity of later repeating the entire message or parts of the message.

Q. 2.37. What is the operator's responsibility upon hearing a distress call in the mobile services?

A. Stations of the mobile service which receive a distress message from a mobile station which is unquestionably in their vicinity, must acknowledge receipt thereof at once. If the distress call has not been preceded by an auto-alarm signal, these stations may transmit this auto-alarm signal with the authorization of the authority responsible for the station, taking care not to interfere with the transmission of the acknowledgment of the receipt of said message by other stations.

Q. 2.38. Is it good practice to listen on the working frequency to be later used before making an initial call on the calling frequency?

A. Yes.

D. This will prevent breaking in on a communication already in progress on the working frequency, as well as unnecessary use of the calling frequency.

Q. 2.39. Why is it important to avoid unnecessary calls by radiocommunication?

A. To prevent interference with important communications.

D. The FCC has authority to suspend the license of a radio operator who makes unnecessary calls by radio communication.

Q. 2.40. State why station identification should be clearly made by a radio transmitting station.

A. See Question 2.23.

Q. 2.41. When routine radio communications are unreliable due to static or fading, should the operator continue transmitting or wait for more favorable conditions?

A. The operator should wait for more favorable conditions to avoid interference to other stations not affected by these adverse conditions.

Q. 2.42. What is the order of priority for radiotelephone communications?

A. The order of priority shall be as follows:

(1) Distress calls, distress messages, and distress traffic.

(2) Communications preceded by an urgent signal.

(3) Communications preceded by a safety signal.

(4) Communications relative to radio direction-finding bearings.

(5) Government radiotelegrams for which priority right has not been waived.

(6) All other communications.

SPECIAL

Q. 2.01S. In making a ship-to-ship contact, except in an emergency involving safety, how long may a ship radiotelephone station continue calling in each instance?

A. Calling any one station shall not exceed 30 seconds in duration.

Q. 2.02S. Except in an emergency involving safety, if a ship radiotelephone station does not receive a reply after calling, how long must it wait before calling again?

A. At least one minute.

Q. 2.03S. What types of communications may be transmitted by ship stations on the ship-to-ship frequencies between 2000 and 3000 kilocycles?

A. Distress, safety, or urgent messages; initial calls and answers; and normal radio traffic on working frequencies.

Q. 2.04S. In regions of heavy traffic how long may the ship-to-ship radiotelephone frequencies between 2000 and 3000 kilocycles be used for any one exchange of communications (other than distress and emergency communications)?

A. Any one exchange shall not exceed 5 minutes in duration.

Q. 2.05S. How is a ship radiotelephone station required to be identified in connection with its operation?

A. All radiotelephone emission of a ship station or a marine-utility station on board a ship shall be clearly identified by transmission therefrom in the English language of the official call sign assigned to that station by the Commission; provided that, in lieu of identification of the station by voice, the official call sign may be clearly transmitted by tone-modulated telegraphy in the International Morse Code either by a duly licensed radiotelegraph operator or by means of an automatic device approved for this purpose by the Commission. This identification shall be made:

(1) At the beginning and upon completion of each communication with any other station;

(2) At the beginning and upon conclusion of each transmission made for any other purpose; and

(3) At intervals not exceeding 15 minutes whenever transmission is sustained for a period exceeding 15 minutes.

D. When an official call sign is not assigned by the Commission to a ship station using telephony, the complete name of the ship on which the station is located and the name of the licensee shall be transmitted by voice in the English language for the purpose of station identification.

Q. 2.06S. Do public coast stations normally charge for forwarding messages reporting dangers to navigation?

A. No charge is normally made for this service.

Q. 2.07S. How does the licensed operator of a ship radiotelephone station exhibit his authority to operate the station? (R & R 13.6)

A. When a licensed operator is required for the operation of a station, the original license of each such operator while he is employed or designated as radio operator of the station shall be posted in a conspicuous place at the principal location on board ship at which the station is operated. The foregoing requirement shall not apply in the case of stations of a portable nature, including marine-utility stations, upon the express condition that the licensed radio operator engaged in operating the station shall have on his person either his required operator license or a duly issued verification card (FCC Form 758-F) attesting to the existence of that license.

Q. 2.08S. If a radiotelephone installation provided on board ship for safety purposes, in accordance with treaty, becomes defective what action must the licensed operator take?

A. The master of the ship must be promptly notified.

D. A record shall be made in the log showing the operating condition of the equipment as determined by either normal communication or test communication, and showing that, if an improper operating condition was found, the master was properly notified thereof.

Q. 2.09S. Who signs the radio log of a ship radiotelephone station certifying to entries made therein?

A. Normally, the licensed operator in charge of the watch. However, other duly designated individuals may do so if authorized by the master of the ship and if operating on a channel above 30 megacycles.

D. Each log shall be kept by the person or persons competent to do so, having actual knowledge of the facts required, who shall sign the log when starting duty and again when going off duty. The logs shall be made available upon request by an authorized representative of the Commission.

Q. 2.10S. What are the requirements with respect to listening watch in a ship radiotelephone station during its hours of service in the 2000-3000 kilocycle band? (R & R 8.223)

A. The ship radiotelephone station shall maintain, during its hours of service, an "efficient" watch for the reception of A-3 emission (telephony) on the frequency 2182 kilocycles (calling and distress).

D. The term "efficient watch" is construed to mean that the ship station shall be capable of normally receiving A-3 emission on 2182 kilocycles from other ship stations while it is transmitting on any other authorized frequency or frequencies.

Q. 2.11S. Who may operate the radiotelephone set aboard a vessel? (R & R 13.61)

A. This is normally operated by a properly licensed operator. However, for operation above 30 megacycles, the station may be operated by an unlicensed person under the supervision and authority of the master of the ship.

Q. 2.12S. Is it necessary for all vessels having knowledge of distress traffic to follow the traffic even if they do not take part in it?

A. Yes.

D. All stations in the maritime mobile service which hear a distress signal or message must cease immediately any transmission capable of interfering with the distress signal or message and shall listen on the frequency used for the distress signal and message.

Q. 2.13S. What is the proper form to use in acknowledging a distress message?

A. Receipt of a distress message shall be acknowledged in the following manner:

(1) In radiotelegraphy: call sign of the ship in distress (three times), the word DE, call sign of the station acknowledging receipt (three times), the group RRR, the distress signal, and the signal AR.

(2) In radiotelephony: identification of the ship in distress (three times), the words THIS IS, identification of the station acknowledging receipt (three times), the word ROGER and the words MAYDAY OUT.

Q. 2.14S. What information is required to be sent following acknowledgment of a distress message?

A. Every mobile station which acknowledges receipt of a distress signal or message must, on the order of the master or person responsible for the ship, aircraft or other vehicle carrying the mobile station, transmit in message form, as soon as possible, the following information in the order shown:

(1) Its name;

(2) Its position;

(3) The course and speed at which it is proceeding towards the vessel, aircraft, or other unit in distress; and

(4) Estimated time of arrival at the scene of distress.

D. Before transmitting this message, the station must insure that it will not interfere with the transmissions of other stations which are better situated to render immediate assistance to the vessel, aircraft, or other unit in distress.

Q. 2.15S. Is it necessary that the authority of the master or person responsible for the vessel be obtained prior to sending information required following acknowledgment of a distress call?

A. Yes.

Q. 2.16S. Is it desirable that care be taken to insure that an acknowledgment to a distress message will not interfere with other acknowledgments from vessels better able to assist? (Art. 37-19)

A. Yes. (See discussion of Question 2.14S.)

Q. 2.17S. Is a vessel which hears a distress message but is not in a position to assist required to take all possible steps to attract the attention of stations which might be in a position to assist?

A. Yes.

Q. 2.18S. Is it necessary to make a trial of the ship radiotelephone installation every day?

A. Yes. This must be done to insure that the installation is operating normally.

D. Each calendar day that a vessel is navigated, unless the normal use of the radiotelephone installation demonstrates that the equipment is in proper operating condition for an emergency, a test communication for this purpose shall be made by a properly qualified person. Should the equipment be found by some person other than the master not to be in proper operating condition for an emergency, the master shall be promptly notified thereof.

Q. 2.19S. How can the radiotelephone installation be tested each day?

A. This can be done by transmitting the official call sign of the testing station followed by the word "test" on the radio channel being used for the test.

D. (1) If, as a result of the announcement, any station transmits by voice the word "wait," testing shall be suspended. When, after an appropriate interval of time, such announcement is repeated and no response is observed, and careful listening indicates that harmful interference should not be caused, the operator shall proceed as set forth in subparagraph (2) below;

(2) The operator shall announce the word "testing" followed in the case of a voice transmission test by the count "1, 2, 3, 4, etc." or by test phrases or sentences not in conflict with normal operating signals; or followed, in the case of other emission, by appropriate test signals not in conflict with normal operating signals. The test signals in either case shall have a duration not exceeding ten seconds. At the conclusion of the test, there shall be voice announcement of the official call sign of the testing station, the name of the ship on which the station is located, and the general location of the ship at the time the test is being made. This test transmission shall not be repeated until a period of at least one minute has elapsed; on the frequency 2182 kilocycles or 156.8 megacycles in a region of heavy traffic, a period of at least five minutes shall elapse before the test transmission is repeated.

(3) When testing is conducted on any frequency assignment within the band 2170 kilocycles to 2194 kilocycles, within the band 156.75 megacycles to 156.85 megacycles, within the band 480 kilocycles to 510 kilocycles (lifeboat transmitters only), or within the band 8362 kilocycles to 8366 kilocycles (lifeboat transmitters only), no test transmissions shall occur which are likely to actuate any automatic alarm receiver within range. Lifeboat stations using radiotelephony shall not be tested on the assigned frequency 500 kilocycles during the 500 kilocycle silent periods.

Q. 2.20S. If the radiotelephone ship installation is normally used during the day, is it necessary to make any special test communication for the purpose of trying the radio?

A. No. Normal use will determine the condition of the radiotelephone ship installation.

D. See Question 2.18S.

Q. 2.21S. How would you contact another vessel prior to actually communicating with it for routine communication purposes?

A. The vessel would be contacted by calling it on a calling frequency such as 2182 kilocycles, or 156.8 megacycles. After initial contact, routine communications would be made on a working frequency.

Q. 2.22S. What radio channel is used for communicating with the U.S. Coast Guard?

A. On radiotelegraphy, the U.S. Coast Guard may be contacted on 500 kilocycles. On radiotelephony, the contact may be made on 2182 kilocycles.

D. For distress or emergency only, the frequency of 2670 kilocycles radio telephony may be used.

Q. 2.23S. What procedure would you use in contacting the U.S. Coast Guard?

A. If the call is to *any* U.S. Coast Guard station, you may contact the Coast Guard on 500 kilocycles by employing the calling sign "NCU."

D. If a *particular* Coast Guard station is being called, the frequency of 500 kilocycles may be used. In this case, the correct call sign of the Coast Guard station will be used.

Q. 2.24S. Is it permissible to use 2182 kilocycles for establishing contact prior to communicating on an appropriate public correspondence channel?

A. Yes. 2182 kilocycles is the international general radiotelephone calling frequency for the maritime mobile service.

Q. 2.25S. What procedure would you use in contacting a coast station on 2182 kilocycles and what would you say over the air?

A. A typical call would be as follows: "Call sign or geographical location (as approved by FCC) of the coast station" repeated three times; followed by "this is KABC, KABC, KABC, over."

Q. 2.26S. Is it permissible to communicate with coast stations or any other station on 2182 kilocycles except for safety purposes?

A. Yes. (See Question 2.24S.)

Q. 2.27S. Give a typical procedure you might use to call a vessel when its identity is not known.

A. It is assumed that the vessel is either in sight, or that its approximate geographical location is known by the calling station.

In this case, the procedure would be: "CQ, CQ, CQ; location and/or description of vessel; OVER (or K)."

D. The vessel would be called on a calling frequency such as 500 kilocycles or 2182 kilocycles, since all vessels normally monitor calling frequencies.

Q. 2.28S. What daily attention should be given to the antenna tower lights at a radio station?

A. The licensee shall make a daily check of the tower lights not later than 1 hour after local sunset, either visually or by means of an automatic indicator to insure that all such lights are functioning properly as required.

D. The licensee shall inspect at intervals of at least once each three months all flashing or rotating beacons and automatic lighting control devices to insure that such apparatus is functioning properly as required.

Q. 2.29S. What should be done in case of failure of the antenna tower lights at a radio station?

A. The Airways Communication Station (CAA) should be notified immediately, by telephone or telegraph, of any failure not corrected within thirty minutes.

D. Upon resumption of the required illumination, a similar step should be taken. The failure must be entered into the station log with all pertinent details.

Q. 2.30S. How should station identification be made at a coast station using radiotelephony?

A. The name (geographical location as approved by the Commission), or official call sign assigned by the Commission of a coastal harbor station shall be announced upon the completion of each communication with any other station and at the conclusion of each transmission made for any other purpose.

Q. 2.31S. If a licensed radio operator at the controls of a radio station observes obscene language being spoken by another person and transmitted through the facilities of the station, what action should he take?

A. He should take steps to conclude the transmission and enter the details in the station log. The incident should be reported to the FCC.

Q. 2.32S. If a coast station hears a distress call from a mobile station what action, if any, should the operator on duty take?

A. If a coastal station has heard a distress call or distress message for which acknowledgment of receipt has not been given promptly, and the coastal station itself is not in a position to render assistance, the coastal station subject to the authority of the licensee or his representative shall make every effort possible to attract the attention of any station in the maritime mobile service which appears to be in a position to render assistance, and for this purpose transmission of the distress call and distress message may be repeated on 500 kilocycles and on such other frequencies as may be deemed necessary. The coastal station, if authorized by the station licensee or representative thereof, may transmit for this purpose the international automatic-alarm signal on the frequency 500 kilocycles (using A-2 emission) prior to repetition of the distress call and message. In the event the alarm signal is transmitted, a sufficient period of time to allow operators warned by the alarm signal to go on watch shall be observed after transmission of the alarm signal and before retransmission of the distress message.

Q. 2.33S. Under what circumstances should a public coast station employing radiotelephony use a calling frequency in establishing a communication circuit with a ship or aircraft?

A. For distress signals and traffic; urgency signals and very urgent messages; safety signals and occasional important safety messages; normal calls, replies and brief operating signals; brief test signals; brief announcements specifying the nature of a particular communication of general interest to mobile stations of the maritime mobile service.

Q. 2.34S. What type of radio telephone communications must be handled free by a public coast station which normally charges for its service?

A. Distress messages and replies; the transmission of information concerning dangers to navigation such as dangerous ice, a dangerous derelict or a tropical storm.

Q. 2.35S. When calling a mobile radiotelephone station but receiving no immediate reply, how often may a coast station using radiotelephony repeat the call?

A. If the called station has not answered at the end of a one-minute period, that station shall not again be called until at least 3 minutes have elapsed.

Q. 2.36S. What is meant by "safety communication" in the maritime mobile service?

A. "Safety communications" are construed to mean the transmission or reception of distress, alarm, urgent or safety signals, or any communication preceded by one of these signals, or any form of radiocommunication which if delayed in transmission or reception, may adversely affect the safety of life or property; and occasional test transmission or reception for determining whether or not the radio equipment is in good working order for purposes of safety.

Q. 2.37S. What are the requirements with respect to log-keeping at a coast station using radiotelephony?

A. Public coast stations using telephony shall maintain an accurate radiotelephone log during their hours of service.

Q. 2.38S. Under what conditions may a coast station intervene in a distress situation?

A. See Question 2.32S.

Q. 2.39S. To what extent may a coast station using radiotelephony communicate with stations other than ship stations?

A. It may communicate with any loud station for the purpose of facilitating the transmission or reception of safety communication to or from a ship or aircraft station. Also, with maritime fixed stations when a frequency assignment below 4,000 kilocycles are used, upon the express condition that neither harmful interference nor intolerable delay is caused to communication with mobile stations.

Q. 2.40S. What is indicated by the use of the word "break" in a radiotelephone conversation?

A. The word "break" indicates a separation between portions of a message.

Q. 2.41S. What is indicated by the use of the word "Roger" as a reply to a radiotelephone communication?

A. The transmission of the word "Roger" means, "I have received all of your last transmission."

Q. 2.42S. What is indicated by the expression "words twice" when transmitted by radiotelephone?

A. (1) As a request: "Communication is difficult. Please send every phrase twice."
(2) As information: "Since communication is difficult every phrase in this message will be sent twice."

Q. 2.43S. What is indicated by the use of the words "read back" in a radiotelephone communication?

A. "Repeat all of this message back to me exactly as received after I have given OVER."

Q. 2.44S. For what purpose is the frequency 121.5 megacycles authorized to be used by an aircraft radio station? (R & R 9.312)

A. This frequency is a universal simplex channel for emergency and distress communications. It will provide a means of calling and working between the various services in connection with search and rescue operations, an emergency means for direction finding purposes, and a means for establishing air-to-ground contact with lost aircraft. This frequency will not be assigned to aircraft unless there are also assigned and available for use other frequencies to accommodate the normal communication needs of the aircraft.

Q. 2.45S. What is the national calling and working frequency for air carrier aircraft? (R & R 9.312)

A. 3117.5 kilocycles.

Q. 2.46S. In lieu of using a call sign, how may a private aircraft telephone station be identified in the course of operation?

A. (1) Air carrier aircraft: In lieu of radio station call letters, the official aircraft registration number, or company flight identification may be used, provided, adequate records are maintained by the air carrier to permit ready identification of individual aircraft.

(2) Private aircraft: In lieu of radio station call letters, only the official aircraft registration number may be used.

D. When use is made of the aircraft registration number, the full number must be given upon initial call of each continuous series of communications. In other communications in each series, the last three characters may be used, provided, the practice is first inaugurated by the ground station operator.

Q. 2.47S. What types of communications or messages is an aircraft radiotelephone station authorized to transmit?

A. Communications by an aircraft station in the aeronautical radiocommunication service shall be limited to the necessities of safe aircraft operation. Normally contacts with airdrome control stations shall not be attempted unless the aircraft is within the area served by the station.

Q. 2.48S. When must an aircraft radio station and maintenance records be made available for inspection? (R & R 9.192)

A. All classes of stations in the aeronautical service and the maintenance records of said stations shall be made available for inspection upon request of an authorized representative of the Commission made to the licensee or to his representative.

Q. 2.49S. How is the communication range of an aircraft radio station on a very high frequency dependent upon the altitude of the aircraft?

A. Radio waves in the vhf region (30 to 300 megacycles) are mainly "line of sight" transmission waves. The higher the altitude of the aircraft the greater the "line of sight" distance and therefore, the greater the communication range.

Q. 2.50S. Why should an aircraft station avoid making unnecessary on-the-air tests?

A. To prevent interference with normal communications by other stations.

Q. 2.51S. What is the normal calling procedure of a private aircraft for contacting a control tower?

A. A typical call is as follows: "Teterboro Tower, this is Taylorcraft N26530; over."

Q. 2.52S. How should an air carrier aircraft radiotelephone station normally be identified in operation in lieu of using the call sign?

A. See Question 2.46S.

Q. 2.53S. What is meant by a phonetic alphabet in radiotelephone communication?

A. A phonetic alphabet is one in which each letter is associated with a particular word. For example: A—Able, B—Baker, C—Charlie, D—Dog, etc.

D. A phonetic alphabet is used in radiotelephone communication to insure that certain letters or words are clearly understandable to the receiving station.

Q. 2.54S. What radio channel or channels are used by ships for communicating by radiotelephone with the U.S. Coast Guard?

A. See Question 2.22S.

Q. 2.55S. Is it general practice for a ship to use 2182 kilocycles for establishing contact prior to communicating with a coast station on an appropriate public correspondence channel?

A. While it is permissible to use 2182 kilocycles to establish contact, in general, such calls and replies shall be made on a ship-shore radio channel authorized primarily for working. (See also Q. 2.24S.)

Q. 2.56S. How often should station identification be made at a base or land radiotelephone station? (R & R 10.152)

A. Station identification should be made at the end of each transmission or exchange of transmissions, or once each 30 minutes of the operating period, as the licensee may prefer.

Q. 2.57S. What entries must be made in the logs or records of radio stations required to have antenna tower lights?

A. Recording of tower light inspections in the station record. The licensee of any radio station which has an antenna structure requiring illumination shall make the following entries in the station record.

(a) The time the tower lights are turned on and off each day if manually controlled;

(b) The time the daily check of proper operation of the tower lights was made, if automatic alarm system is not provided;

(c) In the event of any observed or otherwise known failure of a tower light;

(1) Nature of such failure.

(2) Date and time the failure was observed, or otherwise noted.

(3) Date, time and nature of the adjustments, repairs, or replacements were made.

(4) Identification of Airways Communication Station (Civil Aeronautics Administration) notified of the failure of any code or rotating beacon light or tower light not corrected within 30 minutes, and the date and time such notice was given.

(5) Date and time notice was given to the Airways Communication Station (Civil Aeronautics Administration) that the required illumination was resumed.

(d) Upon completion of the periodic inspection required at least once each three months:

(1) The date of the inspection and the condition of all tower lights and associated tower lighting control devices, indicators and alarm systems.

(2) Any adjustments, replacements, or repairs made to insure compliance with the lighting requirements and the date such adjustments, replacements, or repairs were made.

Q. 2.58S. What attention should be given periodically to the antenna tower lights and associated apparatus at a radio station?

A. See Question 2.28S.

Q. 2.59S. What precautions should be taken when a radio station is left unattended in a public place?

A. Adequate precautions shall be taken to insure that unauthorized transmissions will not occur from the radio station. Such precautions may consist simply of locking up the equipment, or of temporarily disabling it by removing such crystals, tubes or other components to render the transmitter inoperative.

ELEMENT III

BASIC RADIOTELEPHONE

Question 3.01. By what other expression may a "difference of potential" be described?

Answer. Common expressions are: voltage, electromotive force, IR drop, voltage drop.

Discussion. Terms such as "voltage," and "electromotive force" usually apply to a source of electrical energy. For example, the terms "generator voltage or emf," and "battery voltage or emf," are in common use. On the other hand, the terms, "IR drop," and "voltage drop" usually apply to a circuit or portion of a circuit, to which the voltage is applied. The distinction is not strict, however.

Q. 3.02. By what other expression may an "electric current flow" be described?

A. Electron flow or electron drift may be used, or the term *amperage* is sometimes used.

D. The term "current flow" is not particularly definite as to the direction of the flow or to the polarity of the charges in motion. So called "conventional current" assumes positive charges to be in motion and the direction externally of the generator is from + to —. On the other hand, the terms "electron flow" or "electron drift" are quite definite. In this case the moving particles are negative charges and the direction external of the generator is from — to +. "Electron flow" is applied most correctly in such cases as vacuum tubes, while the term "electron drift" would more aptly describe the motion of electrons in a solid conductor.

Q. 3.03. Which factors determine the amplitude of the emf induced in a conductor which is cutting magnetic lines of force?

A. There are four basic factors as follows:

1. The flux density, or magnetic strength.

2. The rate or velocity at which the conductor cuts through the magnetic lines of force.

3. The length of the conductor, or if a coil is used, both the number of turns and the length of the coil are important.

4. The angle at which the conductor or coil is cutting through the magnetic lines of force. Maximum emf is induced if the conductor is moving in a direction perpendicular to the lines of force.

D. The formula to determine the emf induced in a conductor is

$$E = \frac{NBlv}{10^8} \text{ volts}$$

where: E equals the induced voltage
N equals the number of turns
B equals the flux density
l equals the length of conductor
v equal the velocity of cutting.

It is seen that E is *directly proportional* to all above factors.

Q. 3.04. Name four methods by which an electrical potential may be generated.

A. Six basic methods are:

(1) Varying of a magnetic field through a circuit
(2) Mechanical separation of electrostatic charges
(3) Chemical Action
(4) Thermal Action
(5) Photo-electric Action
(6) Piezo-electric Action

D. (1) The field through a circuit may be varied electrically (as in the case of a transformer primary with an alternating current) or mechanically (as in a generator, where armature coils and a constant field have motion relative to each other).

(2) Charges may be transferred from one material to another by contact or friction; if the bodies involved are insulators, so that the charge does not leak off, a potential difference will appear as the bodies are separated. The voltage that appears when combing dry hair, when removing a coat, or when sliding the feet across a rug, are examples. Opposite charges may also be put on two bodies by induction, and a potential difference will appear, increasing as the bodies are separated. Certain kinds of apparatus, rarely seen except in academic laboratories, are designed to do this.

(3) In the chemical cell, such as the ordinary dry cell or storage battery, the properties of the substances involved tend to move charges to the electrodes, thereby establishing a voltage.

(4) If two conductors of different materials are joined at the ends to form a closed loop, and the junctions kept at different temperatures, a current will flow. If the circuit is broken at some point, a small voltage will appear across the ends, proportional to the temperature difference of the junctions, and highly dependent on the selection of materials. Such an arrangement is called a thermocouple.

(5) Under appropriate conditions, some substances will emit electrons when illuminated. These may be collected by another electrode, and a potential difference be established.

(6) Certain crystals, when subjected to mechanical strains, will develop opposite charges on opposite faces, resulting in a potential difference.

Q. 3.05. If the diameter of a conductor of given length is doubled, how will the resistance be affected?

A. The resistance will become one quarter of the original value.

D. The resistance of a conductor varies inversely with the cross sectional area of the conductor. Thus any increase in the area will decrease the resistance. However, the area varies as the square of the diameter. If the diameter is doubled the area will be increased by four times. Since the area is four times greater, then the resistance is now four times less, or equal to one quarter of the original value.

Q. 3.06. If the value of a resistance, to which a constant emf is applied, is halved, what will be the resultant proportional power dissipation?

A. The resultant power dissipation will be doubled.

D. This can be best explained with the aid of a simple example. Assume a constant emf of 10 volts and an original resistance of 10 ohms. (The power dissipation is I^2R.) The current is now 1 ampere and the power dissipation 10 watts. Cutting the resistance in half to 5 ohms, we now have a current of 2 amperes and a power dissipation of 20 watts.

The expression I^2R is equivalent to E^2/R, (since $I = ER$). If the power is E^2/R, and E is held constant, the power varies inversely with R.

Q. 3.07. What method of connection should be used to obtain the maximum no-load output voltage from a group of similar cells in a storage battery?

A. The cells should be connected in series.

D. This must be true since in series connection the voltages will be additive.

Q. 3.08. What is the sum of all voltage drops around a simple direct-current series circuit, including the source?

A. The sum will be zero.

D. Refer to the figure. Starting at R_1, there is a drop of 100 volts, giving —100 volts at the junction of R_1 and R_2. A similar drop through R_2 and R_3 gives —200 volts and —300 volts for the junctions of R_2

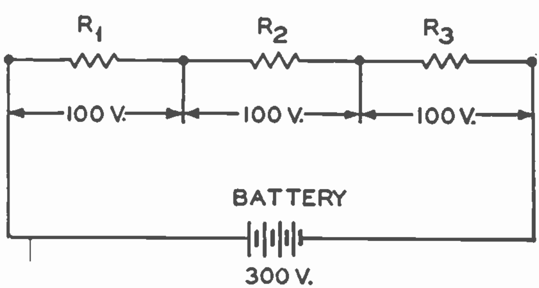


Fig. 3.08. Voltage drops in a series circuit.

and R_3, and R_3 and the battery, respectively. A rise of +300 volts through the battery gives a total of 0 volts.

Q. 3.09. What method of connection should be used to obtain the maximum short circuit current from a group of similar cells in a storage battery?

A. The cells should be connected in parallel.

D. In the case of a short circuit (zero ohms resistance) the current is limited only by the resistance of the cells themselves. If each cell has resistance R, and voltage E, for a series connection of three cells, the short circuit current will be $I_s = 3E/3R = E/R$. For a parallel connection, each cell will deliver E/R amperes, and the total short circuit current will be $I_p = 3 \times E/R$, or $3 \times I_s$. If the external circuit does not have zero resistance, the connection for maximum current will depend on the relation of cell resistance and circuit resistance.

Q. 3.10. If the value of a resistance, across which a constant emf is applied, is doubled, what will be the resultant proportional power dissipation?

A. The resultant power dissipation will be one half.

D. Assume a constant emf of 10 volts and an original resistance of 10 ohms. The current $\frac{E}{R} = \frac{10}{10} = 1$ ampere, and the power dissipation $I^2R = 1^2 \times 10 = 10$ watts. By doubling the resistance to 20 ohms, the current is reduced to .5 ampere, and the new power dissipation $I^2R = .5^2 \times 20 = 5$ watts.

Q. 3.11. Name four materials which are good insulators at radio frequencies. Name four materials which are not good insulators at radio frequencies, but which are satisfactory for use at commercial power frequencies.

A. (a) Pyrex, Micalex, Isolantite, steatite, polyethylene

(b) Rubber, fiber, porcelain, slate.

D. The materials mentioned in (b) are in general not considered to be efficient r-f insulators. This is due to the high dielectric loss which appears as heat in the insulator. Such heat energy must of course be taken from the source of r-f power and is a complete loss.

Q. 3.12. Explain the factors which influence the resistance of a conductor.

A. There are four main factors:

1. Cross sectional area.
2. Length.
3. Material.
4. Temperature.

D. (1) The effect of cross sectional area has already been discussed in Question 3.05. (2) Resistance of a conductor varies in direct proportion to the length of the conductor. For example, doubling the length also doubles the resistance. (3) The resistivity of a material is determined by its atomic structure; some materials have more free electrons than others. The ones with the greater number of free electrons will have less resistance. (4) The resistance of most substances is affected by temperature. Most metals have a positive temperature coefficient; that is, an increase of temperatures will cause an increased resistance. Most non-metals, carbon, for example, have lower resistance at higher temperatures; some ceramic substances which are good insulators at ordinary temperatures become fairly good conductors at a red-heat.

Q. 3.13. What effect does the cross-section area of a conductor have upon its resistance per unit length?

A. The resistance of a conductor varies inversely with the cross sectional area.

D. If the cross sectional area of a conductor is doubled this also doubles the available number of free electrons for a given length, and thus twice as much current will flow for the same applied emf. It is apparent that the effective resistance is thereby cut in half. Likewise, halving the area will double the resistance. (See Questions 3.05 and 3.12.)

Q. 3.14. Name four conducting materials in the order of their conductivity.

A. Silver, copper, gold, aluminum, zinc and platinum.

D. The conductivity of a material is defined as the ratio of current per unit cross-section (amperes per square centimeter) to the emf per unit length which produces the current. It is the reciprocal of resistivity. Experimental work has shown that silver has the highest conductivity of any substance; that is, if the same voltage is applied to two conductors having identical dimensions, one of silver and the other of any other substance, more current would flow in the silver one.

Q. 3.15. What effect does a change in the dielectric constant of a condenser dielectric material have upon the capacitance of a condenser?

A. The capacity varies directly with the dielectric constant.

D. All dielectric materials are compared to a vacuum which has a dielectric constant of 1. For practical purposes, the dielectric constant of air is also 1, the actual value being less than 0.06% greater. Therefore, if a certain capacitor has a capacity of .001 μf with air dielectric, and mica, with a dielectric constant of 7, is then placed in the capacitor, so as to replace the air completely, its capacity will increase by 7 times and become .007 μf. Any increase in the dielectric constant will increase the capacity in direct proportion. For a condenser which is made up of 2 parallel plates, the capacitance may be calculated from the formula, $C = .0885 \times \frac{KS}{t}$ where C is in micro-microfarads, K

is the dielectric constant, S is the area of one plate in square centimeters, and t is the distance between plates in centimeters. From the formula and the explanations, it is seen that the answer to the question is, in substance, a definition of dielectric constant.

Q. 3.16. Explain the effect of increasing the number of plates, upon the capacitance of a condenser.

A. The capacitance will be increased.

D. The capacitance of a condenser is proportional to the *effective* surface area of its plates. Since increasing the *number* of plates increases the effective surface area, the capacitance is increased.

Q. 3.17. If the specific inductive capacity of a condenser dielectric material between the condenser plates were changed from 1 to 2, what would be the resultant change in capacitance?

A. The capacitance of the condenser would be equal to twice its original value.

D. Specific inductive capacity is simply another name for dielectric constant. This term is no longer in very general use. (See Question 3.15.)

Q. 3.18. State the formula for determining (1) the quantity or charge of a condenser. (2) The energy stored in a condenser.

A. (1) $Q = CE$
(2) $W = \frac{1}{2}CE^2$

D. (1) Q denotes *coulombs*. This unit, not often seen in practice, is a measure of quantity, or charge of electricity. One ampere is a current of one coulomb per second. A coulomb is the electric charge of 6.28×10^{18} electrons.

C denotes capacity in *farads*. This quantity, equal to 1,000,000 microfarads, is defined as that capacity which will have a potential of one volt, for one coulomb stored in it. Formula (1) is actually a working definition of capacity, where E is the applied voltage.

(2) In the second formula, the energy, W, is expressed in *joules*. This unit is also rarely found in practice; it is defined as the energy expended in passing one coulomb through one ohm resistance. If one coulomb per second passes through one ohm, this fact can be stated by saying that one ampere passes through one ohm, which is one watt (I^2R), or by saying that one joule per second is the power (power equals energy-units per second). This shows that one watt equals one joule per second. It follows that one watt-hour equals 3600 joules.

The formula could also be written $W = \frac{1}{2}QE$; this shows, as might be expected, that the energy is proportional to the quantity of charge, and to the pressure, or voltage, at which it is stored.

See Question 3.234.

Q. 3.19. Neglecting temperature coefficient of resistance and using the same guage of wire and the same applied voltage in each case, what would be the effect, upon the field strength of a single layer solenoid, of a small increase in the number of turns?

A. There will be a decrease in field strength, if the coil length is increased; if the spacing is reduced to keep the length constant, the field strength will be unchanged.

D. The formula for the field intensity of a solenoid is

$$H = \frac{.4\pi NI}{l}$$

where H = field strength in oersteds.
N = number of turns.
I = current.
l = length of solenoid.

Let us first assume the following original conditions.

1) Wire dia. = ⅛ cm.
2) Voltage = 40 v.
3) Number of turns = 40.
4) Resistance = 1 ohm per turn.

The total original resistance will be then 40 ohms, and the original current will be 1 ampere. The original total length will be ⅛ × 40 or 5 cm. Thus $H = \frac{.4\pi \times 40 \times 1}{5} = 10$ oersteds.

The original field strength is therefore 10 oersteds.

Now let us add an additional 2 turns of wire. The number of turns is now 42; the total resistance is 42 ohms and the current is now $\frac{40 \text{ volts}}{42 \text{ ohms}} = .952$ amp.

The new length is 5.25 cm., therefore $H = \frac{.4\pi \times 42 \times .952}{5.25} = 9.52$ oersteds.

A reduction in field strength of 10 — 9.52 = 0.48 oersteds has taken place. If the turns were added without affecting the length, the field strength would have remained constant.

Q. 3.20. How may a magnetic compass be affected when placed within a coil carrying an electric current?

A. The compass needle will tend to become parallel with the axis of the coil and will point to the north pole end of the coil.

D. The north geographical pole of the earth is actually a magnetic *south* pole. Therefore, the needle of a compass which points towards the north geographical pole is a *north* magnetic pole. The magnetic

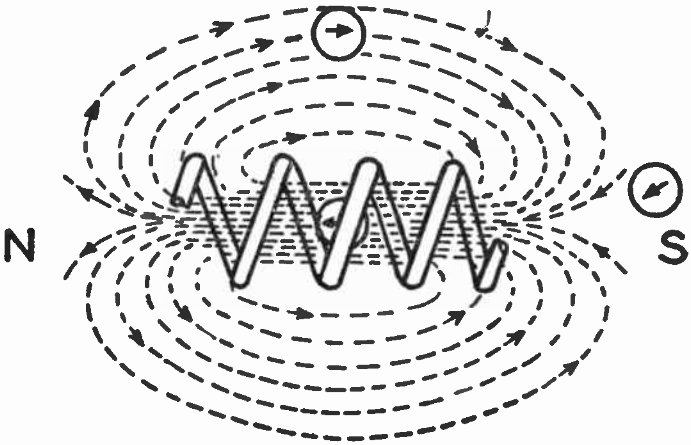


Fig. 3.20. The manner in which a magnetic compass is affected when placed within a coil carrying an electric current.

lines of force within the coil are parallel to the axis of the coil. The compass needle being a bar magnet itself will become aligned with the magnetic lines of force and will point to the north pole of the coil. If the compass were held outside of the coil the needle would point to the south pole of the coil.

Q. 3.21. Which factors influence the direction of magnetic lines of force generated by an electromagnet?

A. There are two main factors involved:

1. The direction of electron flow through the coil.
2. The manner of winding the turns.

D. A simple rule for determining the direction of lines of force of a coil is as follows. With the left hand, grasp the coil so that the fingers curl around the turns in the same direction as electrons are moving through these turns. The thumb of the left hand will then point to the north pole of the magnetic field, or the direction of lines of force *within* the coil. Outside the coil, the lines return to the south pole to form a closed loop.

Q. 3.22. Define the term "permeability."

A. The permeability of a substance is the ratio of magnetic flux density in that substance to the field strength which produces it.

D. Permeability is a property of a material which is somewhat analogous magnetically to conductivity in an electric circuit. If a magnetic field of strength H exists in a certain space, and the space is then filled with a permeable material, the new field intensity will be $B = \mu H$, where μ is the permeability of the material.

Q. 3.23. What unit is used in expressing the alternating current impedance of a circuit?

A. The a-c impedance is expressed in ohms.

D. Impedance of any circuit, either a-c or d-c, is expressed as a ratio. Thus $Z = \frac{E}{I}$, where Z is the impedance in ohms, E is the applied emf in volts, and I is the resultant current in amperes.

Q. 3.24. What is the unit of resistance?

A. Resistance is expressed in ohms.

D. Resistance is the factor of proportionality between voltage and current, in a d-c circuit, giving Ohm's Law: $E = IR$. In an a-c circuit, the "in-phase" component of current must be used, and the resistance is the quantity which determines the power lost or dissipated.

Q. 3.25. Explain the meaning of the prefix "micro-micro."

A. The prefix means one-millionth of a millionth or 10^{-12}.

Q. 3.26. What is the unit of capacitance?

A. The farad.

D. One farad is the capacity which will store one coulomb (6.28×10^{18} electrons) of electricity when one volt appears across it. The farad is too large a unit for practical use, and the microfarad (= one millionth of a farad) is commonly used. See Question 3.18.

Q. 3.27. What single instrument may be used to measure Electrical resistance? Electrical power? Electrical current? Electromotive force?

A. (a) An ohmmeter.
(b) A wattmeter.
(c) An ammeter.
(d) A voltmeter.

Q. 3.28. Define the term "residual magnetism."

A. "Residual magnetism" is the magnetic strength which remains in a substance after the original magnetizing force has been removed.

D. The ability of a metal, particularly iron and steel, to have residual magnetism is referred to as its "retentivity." Soft iron has a low degree of retentivity since the residual magnetic force is relatively weak. On the other hand certain hard steels have a very high degree of retentivity, and relatively strong residual fields.

Q. 3.29. What is the unit of electrical power?

A. The watt or "joule per second."

D. (See also Question 3.234.) The watt is the amount of energy dissipated due to a current of one ampere through a resistance of one ohm.

Q. 3.30. What is the unit of conductance?

A. The mho.

D. It will be noted that the term *mho* is simply *ohm* spelled in reverse. See Question 3.36 for definition.

Q. 3.31. What is the unit inductance?

A. The henry.

D. A henry is defined as the amount of inductance across which one volt of counter-emf will be developed if the current through it is changing at the rate of one ampere per second. A millihenry equals one-thousandth of a henry and a microhenry equals a millionth of a henry.

Q. 3.32. What is the meaning of the prefix "kilo"?

A. The prefix "kilo" means to multiply by one thousand times whatever quantity follows. For instance "Kilocycle" means "one thousand cycles;" "Kilowatt" means "one thousand watts." (See Questions 3.33 and 3.35.)

Q. 3.33. What is the meaning of the prefix "micro"?

A. The prefix micro means to take one millionth of whatever quantity follows. Thus microampere means one millionth of an ampere, and microfarad means one millionth of a farad. (See Questions 3.32 and 3.35.)

Q. 3.34. What is the meaning of "power factor"?

A. Power factor is the factor by which the product of volts by amperes must be multiplied to obtain the true power.

D. If a circuit is purely resistive, or the voltage is direct, its actual power consumption may be found by the formula $P = E \times I$. This is also the *apparent* power of a circuit, since E and I would be measured by a voltmeter and ammeter respectively. However, a pure reactance consumes *no power,* so that if a circuit contains both resistance and reactance, E being alternating, the product of $E \times I$ (apparent power) is not the actual power being consumed. This is so because there is now a phase angle introduced between the voltage and current in the resistance. In order to find the "true" power, the apparent power ($E \times I$) must be corrected by a factor which takes into account the effect of the phase angle. To find the true power of a circuit multiply the apparent power ($E \times I$) by the cosine of the phase angle, which equals $\frac{R}{Z}$. Thus true power equals $E \times I \times \frac{R}{Z}$. For example, a circuit may have one ampere flowing through an inductance and a 3 ohm resistance. If it is d.c., the voltage is 3 volts, the power is 3 watts. If the inductance is such that 5 volts, a-c, is required to give one ampere, the power is still 3 watts ($= I^2R$), but the volt-ampere product is $1 \times 5 = 5$. The power factor to give 3 watts is therefore $\frac{3}{5} = 0.6$.

The power factor is equal to $\frac{R}{Z}$, where Z is the a-c impedance, in this case 5 ohms $= \frac{5 \text{ volts}}{1 \text{ ampere}} \cdot \frac{R}{Z} = \frac{3}{5} = 0.6$, as before.

Since the phase-angle, A, between the current and voltage is such that $\cos A = 0.6$, A is about 53°.

True power is measured directly with a wattmeter, which automatically takes the phase-angle into account. (See Question 6.47.)

Q. 3.35. What is the meaning of the prefix "meg."?

A. The prefix "meg" or "mega" means to multiply by 1,000,000 times whatever quantity follows. Thus megohm means 1,000,000 ohms and megacycle means 1,000,000 cycles. (See Questions 3.32 and 3.33)

Q. 3.36. Define the term "conductance."

A. Conductance is the ratio of current through a conductor to the voltage which produces it. (In a reactive a-c circuit, it is the ratio of "in-phase" current to the applied voltage.)

D. Conductance of a circuit or component is numerically equal to $1/R$, where R is its resistance in ohms. The unit of conductance is the "mho," and the usual symbol is G. Conductance is a measure of the ease with which a circuit is able to pass current. See Question 3.14. Conductance is a property of a given circuit and must be distinguished from conductivity, which is a property of material.

Q. 3.37. What instrument is used to measure current flow?

A. An ammeter is used.

D. An ammeter usually consists of a rotatable coil mounted between the poles of a permanent magnet. The current to be measured passes through the coil and produces an opposing flux which causes the coil to rotate. The amount of rotation is proportional to the magnitude of the current. A needle attached to the coil indicated values of current on a calibrated scale. In radio work, milliammeters and microammeters are more commonly used. These measure thousandths and millionths of amperes respectively

Q. 3.38. Define the term "decibel."

A. Basically, the decibel is a unit used to express the *ratio* between two sound power levels, or two electrical power levels.

D. The formula for calculating decibels when the ratio of two powers is compared is $N = 10 \log_{10} \frac{P_2}{P_1}$. Here P_2 is always the larger power, and N is the ratio in *db*.

If an attenuation is indicated the answer will be in —*db*. If amplification is indicated the answer will be +*db*. Ex.: Find the number of *db* corresponding to a power ratio of 200:2.

Solution: $N = 10 \log_{10}\frac{P_2}{P_1} = 10 \log_{10}\frac{200}{2} = 10 \log_{10} 100 = 10 \times 2 = 20db$.

Db may also be used in expressing the ratio between two voltages or two currents as follows:

$N = 20 \log_{10}\frac{E_2}{E_1} = 20 \log_{10}\frac{I_2}{I_1}$, provided that the values of *E* and *I* are measured at points of equal impedance.

The following will be found useful in treating db problems of power.

1. An increase of 1 db (+) is an increase of power of 25%.
2. A decrease of 1db (—) is a decrease of power of 20%.
3. An increase of 3db (+) doubles the power.
4. A decrease of 3db (—) cuts the power in half.

To apply the above to voltage or current, merely double the number of db involved.

The decibel is often used as a value of power. For this application, it must express a ratio to some level taken as a standard reference level. Several levels have been used as reference, but two are now commonly accepted.

The standard telephone company reference is, 0 db = 6 milliwatts, or 1.732 volts in 500 ohms. The standard broadcast studio reference of Volume Units (V.U.) is, 0 V.U. = 1 milliwatt, or 0.775 volts in 600 ohms. V.U. is figured on the same basis as *db;* that is, it is based upon a logarithmic scale, but, using a highly damped meter, represents an average value.

Q. 3.39. What is meant by "ampere turns"?

A. "Ampere turns" is the product of the number of turns and the current in amperes used to describe the relative magnitude of the magnetomotive force in a magnetic circuit.

D. The magnetomotive force, or mmf, (corresponding to emf in electric circuit) is proportional to the magnitude of the current, *I*, and to the number of turns, *N*, in the coil. The mmf remains the same for coils of the same physical size regardless of the current value, if the product of $I \times N$ remains constant. Thus $F = I \times N$. There are 1.257 gilberts per ampere turn. (A gilbert is the magnetic force between two points 1 cm apart in a unit magnetic field.)

Q. 3.40. Define the term "inductance."

A. Inductance is the property of a conductor or coil which causes a voltage to be developed across its terminals when the number of magnetic lines of force in the circuit or coil is changed. Inductance is also the property which tends to resist a change of current.

D. When the current is increasing, the increasing magnetic field induces a voltage in the conductor, opposed to the applied emf, which tends to decrease the current. When the current decreases, the opposite effect occurs. The unit of inductance is the henry, defined in Question 3.31. The induced emf, which opposes the applied emf is called the *counter-electromotive force* (cemf).

Q. 3.41. Define the term "coulomb."

A. A coulomb is the charge of electricity which passes a given point in one second when a current of one ampere is flowing.

D. See Questions 3.18 and 3.26.

Q. 3.42. State the three ordinary mathematical forms of Ohm's law.

A. The three common forms are: (1) $E = I \times R$, (2) $I = \frac{E}{R}$, (3) $R = \frac{E}{I}$.

D. One volt is the potential difference which will exist across a resistance of one ohm when the current is one ampere.

One ampere is the amount of current (6.28×10^{18} electrons per second) which will flow if a potential difference of one volt appears across a resistance of one ohm.

One ohm is the amount of resistance in a circuit which will limit the current to one ampere if the applied potential is one volt.

Q. 3.43. If a vacuum tube having a filament rated at ¼ ampere and 5 volts is to be operated from a 6-volt battery, what is the value of the necessary series resistor?

A. The series resistor should be four ohms.

D. The tube rating is 5 volts and the emf of the battery is 6 volts. Thereupon, there must be a one volt drop for 0.25 amp. in the resistor.

$$R = \frac{E}{I} = \frac{1}{.25} = 4 \text{ ohms.}$$

Q. 3.44. If the voltage applied to a circuit is doubled and the resistance of the circuit is increased to three times its former value, what will be the final current value?

A. The final current will be ⅔ of the original current.

D. Assume that the original voltage = 10 volts, and the original resistance = 10 ohms. The original current = $\frac{10 \text{ ohms}}{10 \text{ volts}}$ = 1 ampere. The voltage is now doubled to 20 volts and the resistance is tripled to 30 ohms. The new current is $\frac{20}{30}$ = ⅔ amperes.

Q. 3.45. What should be the minimum power dissipation rating of a resistor of 20,000 ohms to be connected across a potential of 500 volts?

A. The minimum rating should be 25 watts, allowing for a good safety factor.

D. The actual power dissipation would be $P = \frac{E^2}{R} = \frac{500^2}{20{,}000} = 12.5$ watts. The nearest higher commercial value would be 15 watts. However to allow for a reasonable safety factor it would be good practice to *double* the theoretical value and actually use a 25 watt resistor.

Q. 3.46. If resistors of 5, 3, and 15 ohms are connected in parallel, what is the total resistance?

A. The total resistance is 1.66 ohms.

D. Using the conventional formula for parallel resistors we have:

$$R \text{ total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{etc.}}. \text{ Substituting values,}$$

$$R_T = \frac{1}{\frac{1}{3} + \frac{1}{5} + \frac{1}{15}}. \text{ The least common denominator is 15.}$$

$$R_T = \frac{1}{\frac{5}{15} + \frac{3}{15} + \frac{1}{15}} = \frac{1}{\frac{9}{15}} = \frac{15}{9} = 1.66 \text{ ohms.}$$

Q. 3.47. What is the maximum rated current carrying capacity of a resistor marked "5,000 ohms, 200 watts"?

A. Maximum current carrying capacity is 200 milliamperes (.2 ampere).

D. Since $W = I^2R$, then $I = \sqrt{\frac{W}{R}}$

Substituting: $I = \sqrt{\frac{200}{5000}} = 0.2$ ampere.

The *normal* current should be about 40% less than this value to ensure a safety factor.

Q. 3.48. A milliammeter with a full-scale deflection of 1 milliampere and having a resistance of 25 ohms was used to measure an unknown current by shunting the meter with a 4-ohm resistor. It then read 0.4 milliampere. What was the unknown current value?

A. The unknown current was 2.9 milliamperes.

D. A basic formula to use in these problems is

$$R_mI_m = R_sI_s \text{ where}$$

R_m = resistance of the meter

I_m = current flowing in the meter

R_s = resistance of the shunt

I_s = current in the shunt.

This is because R_mI_m is the voltage across the meter ($E = IR$) and R_sI_s is the voltage across the shunt. The two voltages must be the same because the two are connected.
The meter drop is $R_mI_m = 25 \times 0.0004 = 0.01$ volt.

Then $R_sI_s = 0.01$; $I_s = \frac{0.01}{4} = 0.0025$ amp.

Both together take 0.0025 amp. + 0.0004 amp. = 2.9 milliamperes, the total current.

Q. 3.49. What will be the heat dissipation, in watts, of a resistor of 20 ohms having a current of ¼ ampere passing through it?

A. The heat dissipation will be 1.25 watts.

D. Using the power formula $W = I^2R$ and substituting $W = .25^2 \times 20 = .0625 \times 20 = 1.25$ watts.

Q. 3.50. If two 10-watt, 500-ohm resistors are connected in parallel, what are the power dissipation capabilities of the combination?

A. Power dissipation capabilities will be 20 watts.

D. Regardless of whether the resistors are in series or parallel, the power dissipation capabilities of two resistors will always be equal to the sum of their individual power dissipation capabilities, provided that the resistors are of equal resistance and wattage rating.

Q. 3.51. What is the formula used to determine the total capacitance of three or more capacitors connected in series?

A. $$C_{total} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \cdots}$$

D. Capacitors in series are figured the same as resistors in parallel. Capacitors in parallel are simply additive, as are resistors in series.

In a series circuit, the same current flows for the same time in all parts. Therefore, each condenser has the same charge, and this value is also the charge in the combination. The voltages are:

$E_1 = \frac{Q}{C_1}$, $E_2 = \frac{Q}{C_2}$, $E_3 = \frac{Q}{C_3}$, etc. The voltage on the combination, since it is in series connection, is $E_1 + E_2 + E_3 \ldots\ldots$ or

$$E_T = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \cdots = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \cdots\right)$$

but $E_T = \frac{Q}{C_T}$, therefore $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots$, and

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \cdots}$$

Q. 3.52. If condensers of 1, 3, and 5 microfarads are connected in parallel, what is the total capacitance?

A. The total capacitance equals 9 microfarads.

D. When condensers are in parallel, each condenser has the same applied voltage as the combination. The charge in the combination is equal to the sum of the charges on the condensers. The combination is equivalent to one condenser which would hold the total of the charges at the applied voltage; such a condenser would have a capacity equal to the sum of the individual capacities.

$C_t = C_1 + C_2 + C_3 + \text{etc.}$

Q. 3.53. If condensers of 5, 3, and 7 microfarads are connected in series, what is the total capacitance?

A. $C_{\text{total}} = 1.479$ microfarads.

D. The formula for condensers in series is:

$$C_T = \frac{1}{\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}} = \frac{1}{\frac{1}{3}+\frac{1}{5}+\frac{1}{7}}$$

The lease common denominator is $3 \times 5 \times 7 = 105$.

$$C_T = \frac{1}{\frac{35}{105}+\frac{21}{105}+\frac{15}{105}} = \frac{1}{\frac{71}{105}} = \frac{105}{71} = 1.479 \text{ microfarads}$$

Q. 3.54. The charge in a condenser is stored in what portion of the condenser?

A. The "charge" is stored upon the inner surfaces of the condenser plates.

D. This question might be misinterpreted as reading: "the *energy* in a condenser is stored in what portion of the condenser?" The conventional answer here is usually given as "in the dielectric" or "on the surface of the dielectric." However, these answers are not sufficiently general to cover all cases. A vacuum capacitor has no dielectric yet functions perfectly. It would be more accurate to say that the energy in a condenser is stored in the form of an electrostatic field which exists in the space *between* the plates.

Q. 3.55. Having available a number of condensers rated at 400 volts and 2 microfarads each, how many of these condensers would be necessary to obtain a combination rated at 1,600 volts 1.5 microfarads?

A. 12 condensers would be needed.

D. First obtain the necessary voltage rating by putting condensers in series. This requires 4 series condensers ratd at 400 volts each to obtain a 1600 volt rating. However, the capacitance of this series group is now only .5 μf. Thus it is necessary to add two more banks of 4 series condensers making 3 banks of 4 series condensers each, or 12 condensers.

Q. 3.56. The voltage drop across an individual condenser of a group of condensers connected in series across a source of potential is proportional to what factors?

A. When the group is connected to an a-c source of potential, the voltage drop will be proportional to two factors.

1. Inversely proportional to the ratio of the capacitance of the condenser being considered, to the total capacitance of the combination.

2. Directly proportional to the applied voltage across the series combination.

D. The general formula to find the voltage across any condenser of a group of series condensers is:

$$E_{Cx} = E_a \times \frac{C_T}{C_x}$$

where C_x is the condenser in question, E_a is the total applied voltage and $C_T = \dfrac{1}{\dfrac{1}{C_1}+\dfrac{1}{C_2}+\dfrac{1}{C_3}}$, etc.

As an example assume 2 condensers in series of .1 (C_1) and .2 (C_2) microfarad each, and an applied emf of 30 volts. The voltage across C_T will be: $E_{C1} = 30 \times \dfrac{C_2}{C_1+C_2} = 30 \times \dfrac{.2}{.3} = 20$ volts.

The voltage across C_2 will be:

$$E_{C2} = 30 \times \frac{C_1}{C_1 + C_2} = 30 \times \frac{.1}{.3} = 10 \text{ volts.}$$

NOTE: For d.c., or where there is a d-c voltage component, leakage will modify the theoretical voltage distribution to such an extent, that the formula cannot be used for practical purposes. See Question 3.184.

Q. 3.57. What factors determine the charge stored in a condenser?

A. The factors are: (1) The capacitance of the condenser, (2) The applied voltage.

D. See Question 3.18.

Q. 3.58. Given two identical mica condensers of 0.1 microfarad capacitance each. One of these is charged to a potential of 125 volts and disconnected from the charging circuit. The charged condenser is then connected in parallel with the uncharged condenser. What voltage will appear across the two condensers connected in parallel?

A. 62.5 volts.

D. The original charge divides equally, as if the condenser value were simply doubled once the charge was put into it.

$$Q = CE, \textit{ therefore } E = \frac{Q}{C}$$

Now if the capacitance is doubled $E = \dfrac{Q}{2C}$ which shows that the voltage is cut in half. In order to find the resultant voltage when one condenser is charged, then disconnected from the charging source and placed in parallel with an uncharged condenser, use the formula: $E_p = \frac{C_1}{C_1+C_2} \times E$, where E_p is the resultant voltage of the parallel condensers, C_1 is the condenser originally charged, C_2 is the condenser placed in parallel with C_1 and E_2 is the original charging voltage.

Q. 3.59. What is the effect of adding an iron core to an air-core inductance?

A. The inductance of the coil will be greatly increased.

D. When a coil has a core consisting of air, the inductance is relatively small because the large value of reluctance of air makes it difficult to set up a strong flux density. However, if iron replaces air as the core, the flux density will be greatly increased, since the reluctance of iron is very much less than that of air. The greater the flux density the larger will be the inductance of the coil. Reluctance in magnetic circuits is analogous to resistance in electric circuits.

Q. 3.60. What will be the effect of a shorted turn in an inductance?

A. A shorted turn may have the following effects:

1. Decrease of inductance.
2. Increase of effective resistance.
3. Decrease the Q.
4. Overheating with possible burn-out.
5. Change of distributed capacity.

D. When a turn becomes shorted upon itself, it becomes in effect a transformer secondary with a very heavy load. The current induced into the shorted turn sets up a magnetic field which opposes the original magnetic field of the coil. This reduces the total flux density and therefore, the inductance. Due to the low resistance of the turn the current value in it is relatively large. This creates large I^2R losses with attendant heating effects. This same effect increases the effective resistance of the coil, because anything which increases the losses causes the effective resistance to increase.

As a result the Q will be lowered because $Q = \frac{X_L}{R_{effective}}$.

Q. 3.61. What is the relationship between the number of turns and the inductance of a coil?

A. The inductance of a coil varies approximately as the square of the number of turns.

D. If the coil consists of only one turn, then its magnetic field will cut this turn, producing a certain counter-emf. However, if the coil consists of 2 turns the flux about *each* turn cuts 2 turns, and the resultant counter-emf is 4 times greater. Therefore, the inductance must also be 4 times greater or vary as the *square* of the number of turns.

Actually, the inductance increases slightly less than proportionally to the number of turns, as in a large many-turn coil, some lines "leak" out and do not cut all the other turns.

Q. 3.62. Define the term "reluctance."

A. "Reluctance is the opposition to the creation of magnetic lines of force in a magnetic circuit."

D. Reluctance is the same in its relation to magnetic circuits as resistance is to electric circuits. Magnetic flux is analogous to current, and mmf is analogous to emf. Thus the greater the reluctance of a magnetic circuit, the weaker will be the magnetic flux. The total reluctance of a magnetic circuit is the sum of all the reluctances which are in series. Thus for an iron core with air gap the reluctance is, $R = \frac{l}{\mu A} + \frac{l_1}{A_1}$ units where

R = the reluctance
l = the length of iron in cm
μ = permeability of iron
A = cross section area of iron in cm squared
A_1 = cross section area of the air gap in cm squared
l_1 = length of air gap in cm.

Reluctance is the ratio of magnetomotive force to magnetic flux, as $R = \frac{\text{gilberts}}{\text{lines per sq. cm.}}$. It is the number by which the desired flux is multiplied in order to compute the necessary mmf.

Q. 3.63. State the formula for determining the resonant frequency of a circuit when the inductance and capacitance are known.

A. $f = \frac{1}{2\pi\sqrt{LC}}$ where, f is in cycles, L is in henrys, C is in farads.

Also expressed as $\frac{.159}{\sqrt{LC}}$

D. The above formula will determine the *series* resonant frequency of a circuit. That is the frequency at which $X_L = X_c, 2\pi fL = \frac{1}{2\pi fC}; f^2 = \frac{1}{4\pi^2 LC}, f = \frac{1}{2\pi\sqrt{LC}}$

It is not necessarily correct for parallel resonance. However, if the Q is reasonably high, say at least 10 or more, it may be used for parallel resonance without appreciable error. Parallel resonance exists when the line current is *in phase* with the applied voltage, that is when the circuit is resistive. In the ordinary parallel resonant circuit this occurs when $X_O = X_L + \frac{R}{Q}$. There is another type of parallel resonance, which gives maximum impedance (least current through the combination). For all ordinary resonant circuits with a coil Q greater than 10, the two cases of parallel resonance both occur when $X_L = X_c$, within a very few percent.

Q. 3.64. What is the formula for determining the power in a direct-current circuit when the voltage and resistance are known?

A. $P = \frac{E^2}{R}$, where P is in watts, E is in volts, R is in ohms.

D. The formula states that the power in a d-c circuit varies as the square of the voltage, but varies inversely with the resistance.

Q. 3.65. What is the formula for determining the power in a direct-current circuit when the current and resistance are known?

A. $P = I^2R$, where P is in watts, I is in amperes, R is in ohms.

D. This formula states that the power in a direct-current circuit is directly proportional to the resistance, and proportional to the *square* of the current. Other power formulas are: $P = \frac{E^2}{R}$ and $P = E \times I$.

Q. 3.66. What is the formula for determining the power in a direct-current circuit when the current and voltage are known?

A. $P = E \times I$ where P is in watts, E is in volts, I is in amperes.

D. This formula states that the power in a direct-current circuit is directly proportional to both the voltage and current of the circuit.

Q. 3.67. What is the formula for determining the wavelength when the frequency, in kilocycles, is known?

A. Three common forms are

$$\lambda = \frac{300{,}000{,}000}{f \text{ (cycles)}}; = \frac{300{,}000}{f \text{ (kc)}}, = \frac{300}{f \text{ (mc)}}$$

where λ is the wavelength in meters, and f is in cycles, kilocycles, or megacycles as indicated.

D. The term in the numerator 300,000,000 (meters per second) is the velocity of radio waves in free space, and is also the velocity of light in free space. See Questions 3.220 and 3.306.

Q. 3.68. State Ohm's law for alternating current circuits.

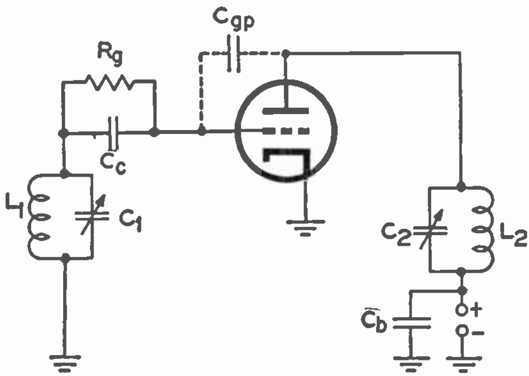
A. The current varies directly with the emf and inversely with the impedance. The basic formulas are: $I = \frac{E}{Z}$, $E = IZ$, $Z = \frac{E}{I}$, where I is in amperes, E is in volts, Z is the impedance in ohms.

D. The terms E and I are simple quantities and are handled the same as in Ohm's law for d.c. However, Z may be a complex term; that is, the circuit may have inductance and capacitance in addition to simple resistance. The terms which make up Z must, therefore, be added vectorially or $Z = \sqrt{R^2+(X_L-X_c)^2}$. Thus $I = \dfrac{E}{\sqrt{R^2+(X_L-X_C)^2}}$

In d.c., R is the ratio of voltage to current. In a.c., the voltage may be greater because of reactance, either capacitive, inductive, or both. The symbol for the ratio E/I in a.c. is Z; it is likewise measured in ohms, and is referred to as impedance rather than resistance.

Q. 3.69. Draw a simple schematic diagram showing a tuned-plate tuned-grid oscillator with series-fed plate. Indicate polarity of supply voltages.

Fig. 3.69. A tuned-plate tuned-grid oscillator with series-fed plate.



A. See the figure.

D. Feedback is accomplished through the interelectrode capacitance C_{gp}. The output frequency is slightly lower than the resonant frequency of either L_1C_1 or L_2C_2. L_2C_2 is tuned slightly higher than L_1C_1. C_b offers a low impedance path for the r.f. to return to the cathode, by-passing the power supply. R_g—C_c is the bias network. Tetrodes or pentodes will not be suitable except at very high frequencies because of the low values of C_{gp}. (See Question 3.72 for this type oscillator, with shunt-fed plate.)

Q. 3.70. Draw a simple schematic diagram showing a Hartley triode oscillator with shunt-fed plate. Indicate power-supply polarity.

A. See the figure.

D. To determine whether oscillator or amplifier is shunt or series fed, merely trace the path of *d-c* plate current. If it passes through any part of a tuning inductance, the circuit is series fed. Otherwise it is shunt fed.

(Compare figures for Questions 3.71 and 3.75). Feedback is accomplished by magnetic coupling between L_a and L_b, and may be increased by lowering the tap, or decreased by raising the tap. The "tank" circuit which mainly determines the resonant frequency, consists of C_1 across the *entire* inductance of $L_a + L_b$. C_b offers a low impedance path for r-f plate current to return to the cathode through L_a. The radio-frequency choke, *RFC*, prevents r-f plate current from passing through the power supply. R_g-C_c is the bias network. See Question 3.367.

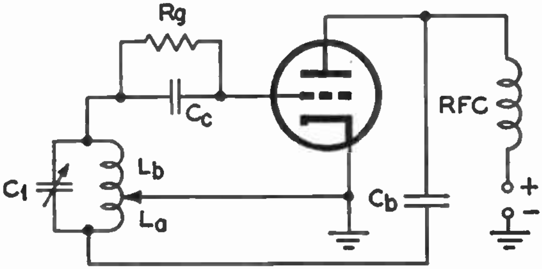


Fig. 3.70. A Hartley oscillator with shunt-fed plate.

Q. 3.71. Draw a simple schematic diagram showing a tuned-grid Armstrong-type triode oscillator, with shunt-fed plate. Indicate power-supply polarity.

A. See the figure.

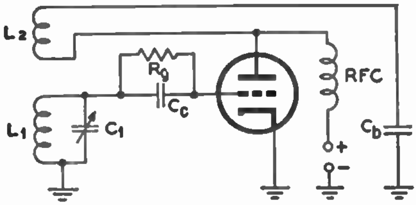


Fig. 3.71. A tuned-grid Armstrong oscillator.

D. Feedback is accamplished by magnetic coupling between L_2 and L_1 and may be varied by changing the degree of coupling. The frequency is determined mainly by L_1C_1. C_b prevents short circuiting the power supply and provides an easy path for r-f plate current to return to the cathode. The radio-frequency choke, *RFC*, prevents r-f plate current from entering the power supply; R_g-C_c is the bias network.

Q. 3.72. Draw a simple schematic diagram showing a tuned-plate tuned-grid triode oscillator with shunt-fed plate. Indicate polarity of supply voltages.

A. See the figure.

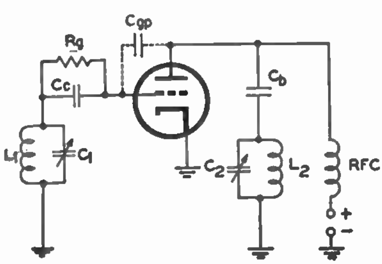


Fig. 3.72. A tuned-plate tuned-grid oscillator with shunt-fed plate.

D. (See also Question 3.69.) C_b prevents short circuiting of the power supply. The value of the inductance of the radio-frequency choke, *RFC*, should be at least 10 times greater than the inductance of L_2 so as not to change the frequency of L_2C.

Q. 3.73. Draw a simple schematic diagram of a crystal-controlled vaccuum-tube oscillator. Indicate power-supply polarity.

A. See the figure.

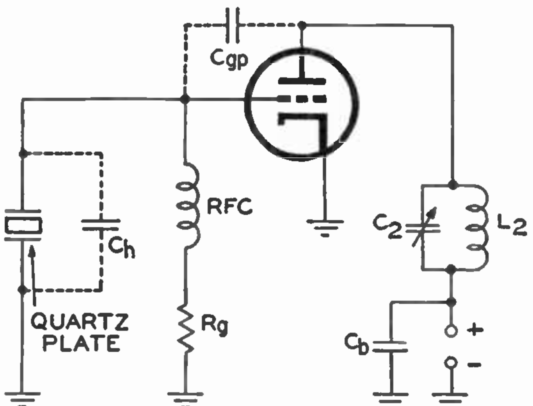


Fig. 3.73. A crystal-controlled vacuum-tube oscillator.

D. This is a tuned-plate, tuned-grid oscillator with the crystal and its holder replacing the original grid tank circuit. Feedback is accomplished through C_{gb}. The bias condenser here is C_h, the capacity of the crystal holder, and the bias resistor is R_g. The purpose of the r-f choke, *RFC*, is to maintain a high impedance across the crystal and so maintain a high *Q*. (See also Questions 3.69 and 3.420.)

Q. 3.74. Draw a simple schematic diagram showing a Colpitts-type triode oscillator, with shunt-fed plate. Indicate power-supply polarity.

A. See the figure.

D. Feedback is accomplished by a capacitive voltage divider action between C_1 and C_2. To increase feedback, decrease the value of C_2 in

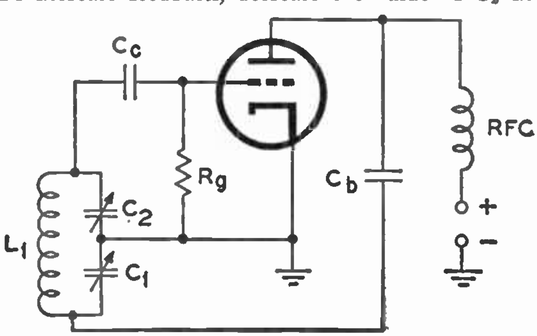


Fig. 3.74. A Colpitts oscillator with shunt-fed plate.

relation to C_1. To decrease feedback increase C_2 in relation to C_1. R_g must be connected between grid and cathode otherwise the grid will have no d-c return to ground. C_c is often eliminated, in which case C_2 will also serve the function of bias condenser. The frequency is determined mainly by L_1 in parallel with the series combination of C_2 and C_1. In changing frequency, C_2 and C_1 are moved simultaneously. C_b offers a low impedance path for r-f plate current through C_1 to the cathode. The r-f choke, *RFC*, keeps r-f plate current out of the power supply. See Question 3.367.

Q. 3.75. Draw a simple schematic diagram showing a tuned-grid Armstrong-type triode oscillator, with series-fed plate. Indicate power-supply polarity.

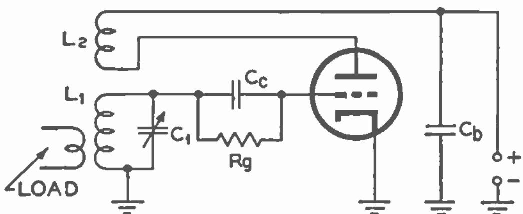


Fig. 3.75. A tuned-grid Armstrong oscillator with series-fed plate.

A. See the figure.

D. See Question 3.71, which is similar except that it is a shunt-fed plate.

Q. 3.76. Draw a simple schematic diagram of an electron-coupled oscillator, indicating power-supply polarities where necessary.

A. See the figure.

D. The oscillator proper is a series-fed Hartley with the screen grid acting as the plate of the oscillator. Coupling into the plate tank circuit occurs by virtue of the electron stream variations caused by the swing of the control grid, hence the name "electron-coupled." The main advantage of this circuit arrangement is its excellent frequency stability. Its features are: (1) Buffer action because oscillator tank is isolated from the load; (2) Frequency multiplication may be obtained by tun-

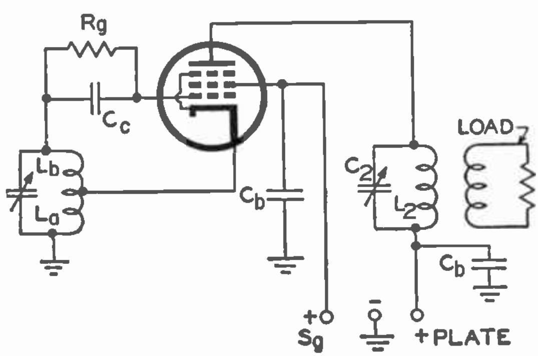


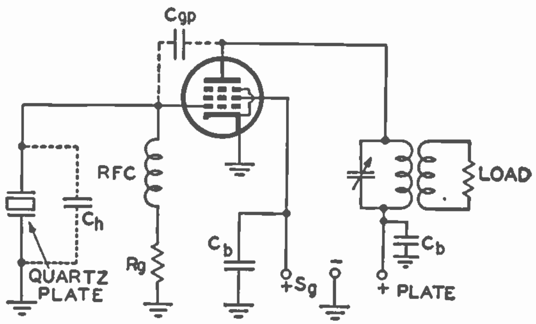
Fig. 3.76. An electron-coupled oscillator.

ing L_2C_2 to a harmonic oscillator frequency; (3) Frequency is substantially independent of power supply variations; (4) Combination of oscillator and amplifier using only one tube.

Q. 3.77. Draw a simple schematic diagram of a pentode-type tube used as a crystal-controlled oscillator, indicating power-supply polarities.

A. See the figure.

Fig. 3.77. A pentode tube used as a crystal-controlled oscillator.

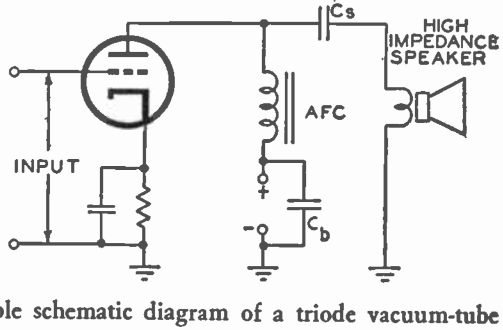


D. (See also Question 3.73.) A pentode or tetrode has a higher power sensitivity and a much lower value of C_{gp} than a triode. This means that it is possible to reduce the amount of crystal voltage and current for a given output power and consequently reduce crystal heating. The grid circuit is also less affected by changes in load than when a triode is used, due to the reduced C_{gp}. However, C_{gp} may be too small to allow sufficient feedback especially at the lower frequencies, and in this case a small capacitor in the order of 2 $\mu\mu$f should be connected between grid and plate.

Q. 3.78. Draw a simple schematic circuit showing a method of coupling a high impedance loud-speaker to an audio-frequency amplifier tube without flow of tube-plate current through the speaker windings, and without the use of a transformer.

A. See the figure.

Fig. 3.78. Method of coupling a high-impedance loud-speaker to a-f amplifier.



Q. 3.79. Draw a simple schematic diagram of a triode vacuum-tube audio-frequency amplifier inductively coupled to a loud-speaker.

A. See the figure.

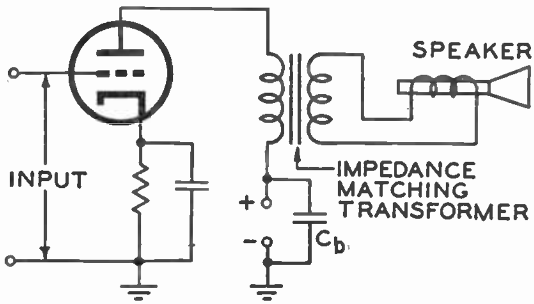


Fig. 3.79. An a-f amplifier inductively coupled to a loud-speaker.

Q. 3.80. Draw a simple schematic circuit showing a method of resistance coupling between two triode vacuum tubes in an audio-frequency amplifier.

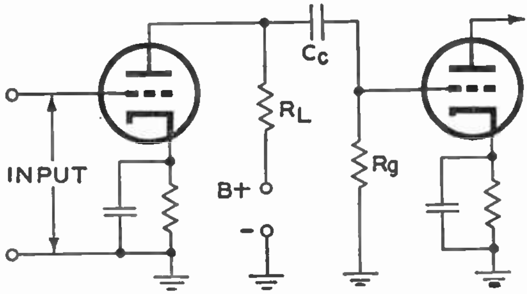


Fig. 3.80. Resistance coupling between two triode stages in an a-f amplifier.

A. See the figure.

Q. 3.81. Draw a simple schematic diagram showing a method of transformer coupling between two triode vacuum tubes in an audio-frequency amplifier.

A. See the figure.

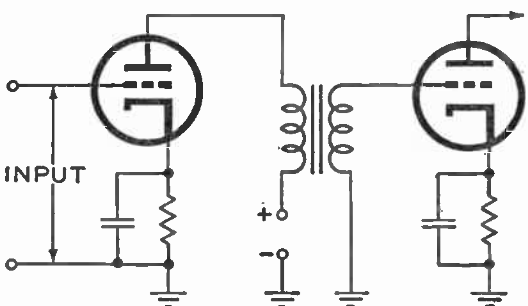
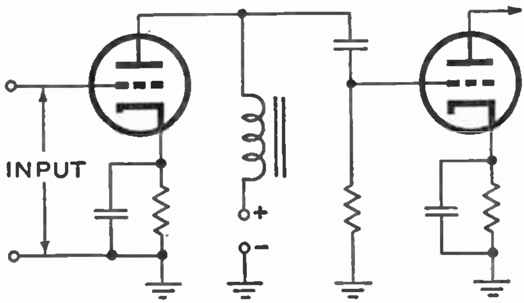


Fig. 3.81. Transformer coupling between two triode stages in an a-f amplifier.

Q. 3.82. Draw a simple schematic diagram of a method of impedance coupling between two vacuum tubes in an audio-frequency amplifier.

A. See the figure.

Fig. 3.82. Impedance coupling between two stages in an a-f amplifier.



Q. 3.83. Draw a simple schematic diagram showing a method of coupling the radio-frequency output of the final power-amplifier stage of a transmitter to an antenna.

A. See the figure.

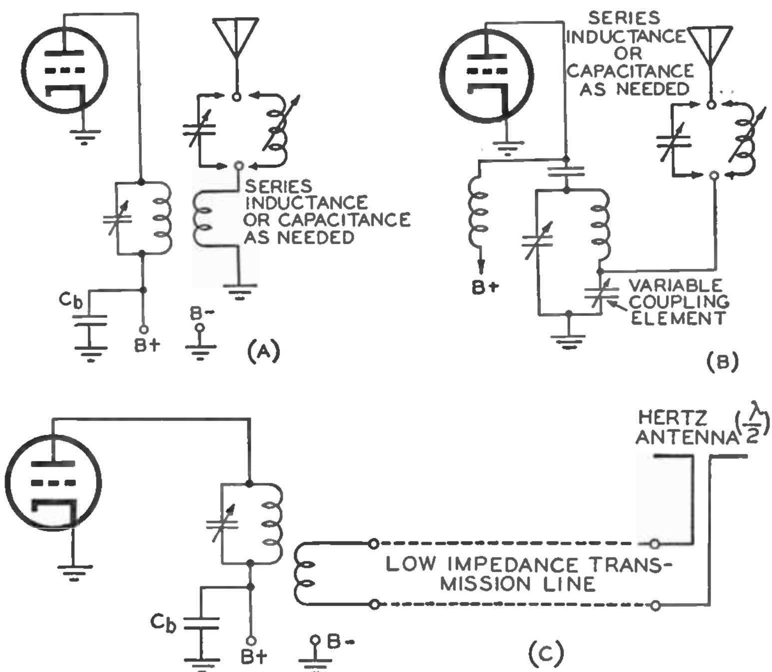


Fig. 3.83. Methods of coupling the r-f output of a transmitter to an antenna.

Q. 3.84. Draw a simple schematic diagram showing a method of coupling between two tetrode vacuum tubes in a tuned radio-frequency amplifier.

A. See the figure.

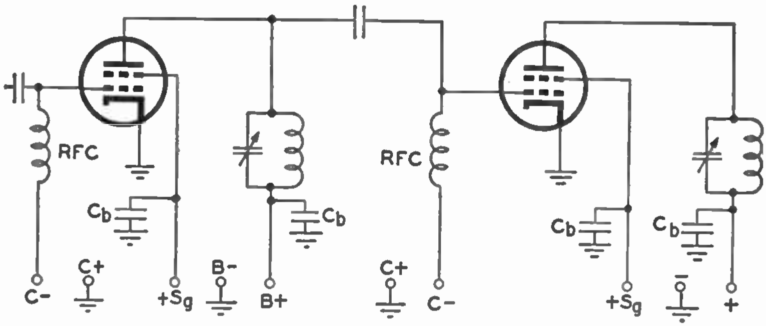


Fig. 3.84. Coupling between two tetrode stages in a trf amplifier.

Q. 3.85. Draw a simple schematic diagram showing a method of coupling between two triode vacuum tubes in a tuned-radio-frequency amplifier, and a method of neutralizing to prevent oscillation.

A. See the figure.

D. See Question 3.307.

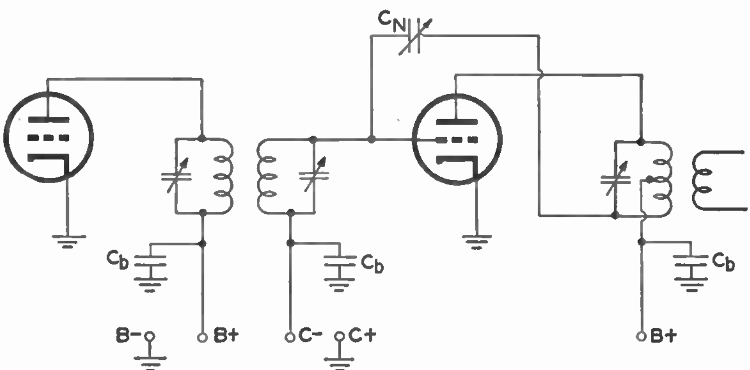


Fig. 3.85. Coupling between two triode stages in a trf amplifier, showing a method of neutralization.

Q. 3.86. Draw a simple schematic diagram of a diode vacuum tube connected for diode detection, and showing a method of coupling to an audio amplifier.

A. See the figure.

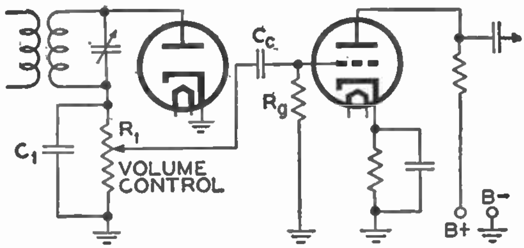


Fig. 3.86. A diode detector.

D. The diode load resistor consists of R_1 which in this case also acts as the volume control. The time constant of R_1C_1 is such that it will respond to audio-frequency variations, but not radio-frequency variations. For a discussion of diode detection see Question 3.133.

Q. 3.87. Draw a simple schematic diagram of a triode vacuum tube connected for plate or power detection.

A. See the figure.

D. See Question 3.131.

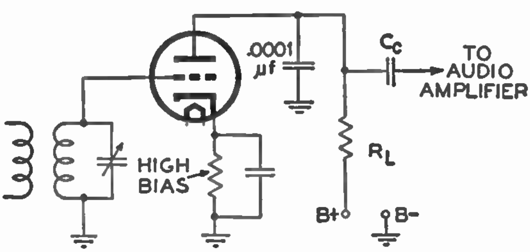


Fig. 3.87. A triode tube connected for plate detection.

Q. 3.88. Draw a simple schematic diagram of a triode vacuum tube connected for grid-leak condenser detection.

A. See the figure.

D. See Question 3.128.

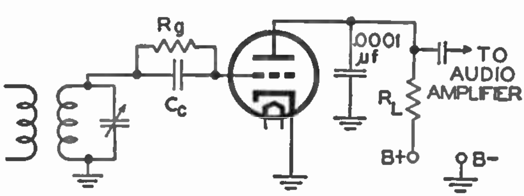


Fig. 3.88. A triode tube connected for grid-leak detection.

Q. 3.89. Draw a simple schematic circuit of a regenerative detector.

A. See the figure.

D. See Question 3.267.

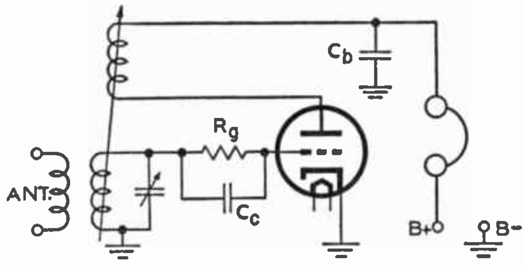


Fig. 3.89. A regenerative detector.

Q. 3.90. Draw a simple schematic circuit of a radio-frequency doubler stage, indicating any pertinent points which will distinguish this circuit as that of a frequency doubler.

A. See the figure.
D. See Question 3.138.

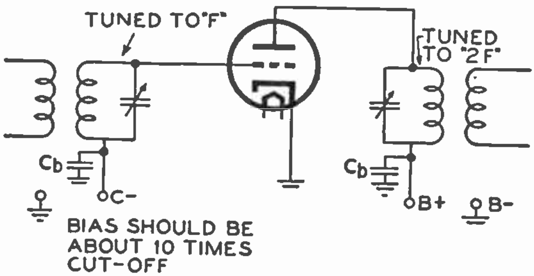


Fig. 3.90. An r-f doubler stage.

Q. 3.91. Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be two-thirds the resistance of one unit.

A. See the figure.

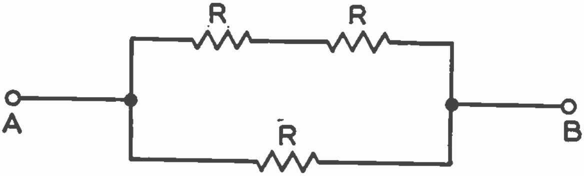


Fig. 3.91. Resistor connection to fulfill stated requirements.

Q. 3.92. Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be 1½ times the resistance of one unit.

A. See the figure.

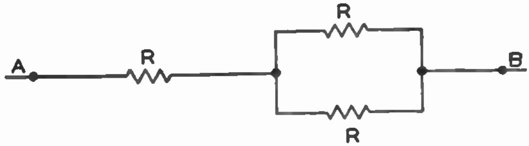


Fig. 3.92. Resistor connection to fulfill stated requirements.

Q. 3.93. Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be one-third of one unit.

A. See the figure.

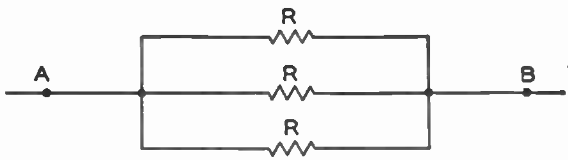


Fig. 3.93. Resistor connection to fulfill stated requirements.

Q. 3.94. Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be three times the resistance of one unit.

A. See the figure.

Fig. 3.94. Resistor connection to fulfill stated requirements.

Q. 3.95. Draw a diagram of a single-button carbon-microphone circuit, including the microphone transformer and source of power.

A. See the figure.

D. See Question 3.338.

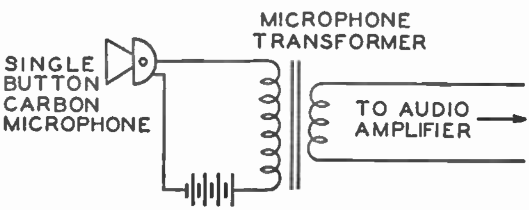


Fig. 3.95. Single-button microphone connection.

Q. 3.96. What is meant by a "soft" vacuum tube?

A. A "soft" vacuum tube is one which either deliberately or accidentally contains some amount of gas.

D. During the manufacturing processes, many precautions are taken to exclude the presence of air from tubes, even those which are designed to contain gas after evacuation. The presence of such air or other undesired gases will interfere with the normal action of the tube due to ionization under the impact of the emitted electrons. Most gases are driven off by heating the tube to a high degree during evacuation. Any gases which remain are absorbed by the "getter," usually consisting of barium, "flashed" inside the tube after evacuation is complete. Deliberate introduction of gas is then made if desired.

Q. 3.97. Describe the electrical characteristics of the pentode, tetrode, and triode.

1. The triode is a three-element amplifier tube, consisting of plate, grid, and cathode. The magnitude of plate current which flows in the tube is dependent upon both the grid bias and the plate supply voltage. Triodes have in general less distortion than other types, but are capable of less plate efficiency and amplification. The interelectrode capacitance is relatively high, making it necessary to neutralize r-f amplifiers, even at low frequencies. (See Question 3.276 for explanation of its operation.)

2. The tetrode has an additional screen grid. This grid is usually operated at about ⅓ of plate supply voltage for voltage amplifiers, and approximately equal to plate supply voltage for power amplifiers. The screen grid has two important functions: first it greatly reduces the grid to plate capacitance, thus making it unnecessary to neutralize r-f amplifiers except at very high frequencies, and second, it makes the plate current substantially independent of plate voltage. This factor makes it possible to obtain much higher values of amplification than with triodes. The plate efficiency is about 10% greater than with triodes.

3. The pentode is a 5-element tube, the added element being the suppressor grid. The suppressor grid is usually at cathode potential making it extremely negative relative to the plate. The suppressor grid further reduces interelectrode capacitance between control grid and plate, and also makes possible greater power output and higher gain than a tetrode tube. Primarily the suppressor grid acts to return secondary electrons to the plate rather than to permit them to be picked up by the screen grid. Pentodes can be operated at higher r-f frequencies without neutralization than tetrodes.

Q. 3.98. What are the visible indications of a "soft" tube?

A. A glow from within the tube, often a purplish color, indicates a "soft" tube.

D. If the tube was not originally designed to be a "soft" tube, other indications would be: excessive plate current, erratic or non-operation, and a possible red heat observable in the plate. In certain applications the cathode or filament may be destroyed due to positive-ion bombardment. Sometimes fluorescence occurs in the glass itself, also bluish or purplish; this does not indicate a soft tube. (See also Question 3.96.)

Q. 3.99. Describe the physical structure of a triode vacuum tube.

A. A triode is a three-element tube. It contains either a filament or cathode structure, a grid, and a plate.

D. If the emitter is of the filament type, it is usually made of thoriated tungsten. This is formed by dissolving a small amount of thorium oxide and carbon in a tungsten filament. The conventional cathode is formed in two sections. The outer section consists of a hollow nickel cylinder which is coated with thorium oxide. Within the cylinder is a tungsten wire suitably insulated from the cylinder. This wire may be heated by either a.c. or d.c. and in turn causes the cylinder to become properly heated. The usable emission comes from the outer surface of the cylinder. The grid which surrounds the cathode is usually made of molybdenum wire which is spirally wound upon two vertical supporting wires. The plate is usually made of nickel or iron pressed out of sheet material and crimped or flanged to increase rigidity. It is usually blackened to increase the heat radiation. Some large power tubes have graphite plates which are superior under high temperature conditions. Connections to all elements are usually made through a base at the bottom of the tube.

Q. 3.100. Describe the physical structure of a tetrode vacuum tube.

A. A tetrode is similar in physical construction to a triode with the addition of a spirally wound screen grid placed between the plate and control grid. Connections to elements are usually made to a base at the bottom, although in some high frequency tubes connections to grid and plate are brought out through the sides and top.

D. See Questions 3.97 and 3.99.

Q. 3.101. Does a pentode vacuum tube usually require neutralization when used as a radio-frequency amplifier?

A. Not generally.

D. Whether or not a pentode r-f amplifier may require neutralization depends upon the operating frequencies involved. There are r-f amplifiers operating in excess of 100 megacycles, using pentodes especially designed for these frequencies, and which do not require neutralization. As a general statement, however, it may be said that ordinary pentodes do not require neutralization except when used at ultra high frequencies. See Question 3.279.

Q. 3.102. What is the meaning of "secondary emission"?

A. "Secondary emission" is the emission of electrons from a material, due to the impact of high velocity electrons upon its surface. The original electrons are called primary electrons.

D. If an electron is in an evacuated space containing a positively charged material, the electron will be attracted with ever-increasing velocity until it strikes the surface of the material. At the point of impact, the moving electron will impart its kinetic energy to other electrons and atoms within the material. If the impact is great enough, one or more electrons within the material will be dislodged with enough energy to be emitted from the surface. The number so emitted will depend upon the velocity of the primary electron and upon the type and temperature of the material. While secondary emission in an amplifier tube is usually detrimental, such is not always the case. For example, the dynatron oscillator relies upon one effect of secondary emission, called "negative resistance," for its feedback energy. Some structures are built to take advantage of this effect. For instance, in the RCA "image orthicon" television camera tube, there is incorporated an electron multiplier which deliberately produces secondary emission in order to amplify the magnitude of the camera signal.

Q. 3.103. What is the meaning of "electron emission"?

A. When free electrons in a conductor acquire sufficient energy to leave the conductor and pass into the surrounding space, the phenomenon is called "electron emission."

D. Under normal conditions there are certain forces existing at the surface of materials which prevent the escape of free electrons. These forces are referred to as the *potential barrier.* If sufficient energy is supplied to the material the free electrons will acquire sufficient velocity to break through the potential barrier and be emitted into space. This additional energy may be supplied to overcome the potential barrier in the form of heat (ordinary filament), light (photo tube), high velocity electrons (secondary emission), or by strong electric fields (ionization of gases).

Q. 3.104. Describe the characteristics of a vacuum tube operating as a class C amplifier.

A. The outstanding chraacteristics are:

1. High plate circuit efficiency, up to 85%.
2. Large grid driving power.
3. Plate current exists for less than 180° of the grid excitation cycle, usually for approximately 120°.
4. Grid bias on the average is about twice cut-off value.
5. Large power output in comparison to class A.
6. Great distortion of plate current waveshape.

D. In class C amplifiers the plate current is permitted to flow *only* during the time that the instantaneous value of plate voltage is at or near its *minimum* value. At all other times the tube is non-conducting.

This permits a relatively small loss on the plate and high plate efficiency. However, in order that the above conditions be met, a large value of bias must be used, in some cases equal to 4 times cut-off value, but usually about twice cut-off value. Since grid current must flow at some time in each cycle, a relatively large value of grid driving power must be available from a low impedance source. Appreciable r-f power is consumed in the grid circuit. Although the plate current wave is a pulse and rich in harmonics, the plate voltage waveshape will be sinusoidal since the plate load will in most cases be a tank circuit with a reasonably high Q. An interesting feature is that the maximum positive value of grid voltage ($e_{c\ max}$), is approximately equal to the minimum value of the plate voltage ($e_{b\ min}$). Class C amplifiers may not be used in audio amplifiers due to the high distortion, but are commonly used for r-f amplification in transmitters; they are often applied to special circuits such as clippers and peakers. See Questions 3.106 and 3.107.

Q. 3.105. During what approximate portion of the excitation voltage cycle does plate current flow when a tube is used as a class C amplifier?

A. In class C operation, plate current flows for less than 180° of a cycle. On the average, plate current flows for about 120° when the grid bias is about twice cut-off value.

D. See Questions 3.104 and 3.137.

Q. 3.106. Describe the characteristics of a vacuum tube operating as a class A amplifier.

A. The outstanding characteristics are:

1. Low plate circuit efficiency, about 25% on the average.
2. Practically no grid driving power.
3. Plate current flows for 360° of each cycle.
4. Grid bias is adjusted to be well up on the linear portion of the tube characteristic.
5. Relatively low power output, compared to class C.
6. Practically no distortion of the output wave shape.

D. The most general use for a class A amplifier is as a voltage amplifier, although single-ended power amplifiers which feed speakers must also be class A. The average plate efficiency for triodes is about 20%, while that of pentodes is about 30 to 35%. Unlike either class B or C, the average plate current and voltage remain constant regardless of the magnitude of the grid signal. The grid signal must be so confined that it does not cause grid current in its positive swing, or cut off the tube in its negative swing. The power amplification ratio is high since no grid current is drawn.

$$\text{Power amplification ratio} = \frac{\text{Power delivered to plate load.}}{\text{Power consumed in grid circuit.}}$$

See Questions 3.104 and 3.107.

Q. 3.107. Describe the characteristics of a vacuum tube operating as a class B amplifier.

A. The outstanding characteristics are:

1. Plate circuit efficiency, about 50 to 60%.
2. Used as *linear* r-f amplifiers in modulated stages.
3. Can be used for audio if push-pull circuit is used.
4. Grid current flows, so driver must supply power.
5. Plate current flows for slightly more than 180° of a cycle (projected cut-off).
6. Grid bias is set slightly above cut-off value.
7. Medium power output compared to class A and C.

D. Class B amplifiers are used in r-f circuits as buffer amplifiers, and linear modulated r-f amplifiers. In audio systems, very large power outputs may be obtained by using two class B tubes in push-pull. The distortion, however, is greater than for class A. When used in modulated r-f stages, the plate load must be a tank circuit in order to preserve the symmetry of the input wave shape. The average plate current and voltage varies with the magnitude of the grid signal, and the power output varies as the square of the grid voltage. The shape of the plate current pulse is about the same as the positive half of the grid signal. See Questions 3.104 and 3.106.

Q. 3.108. During what portion of the excitation voltage cycle does plate current flow when a tube is used as a class B amplifier?

A. In a class B amplifier, plate, plate current usually flows for slightly more than 180° of a cycle.

D. See Question 3.107.

Q. 3.109. Does a properly operated class A audio amplifier produce serious modification of the input waveform?

A. No. The output wave form is substantially a true reproduction of the input wave form, thus practically no distortion is present provided that the grid swing is kept relatively small.

D. See Question 3.106.

Q. 3.110. What is the meaning of the term "maximum plate dissipation"?

A. Maximum plate dissipation is the maximum power that can be safely and continuously dissipated in heat on the plate.

D. When the high velocity electrons in a tube strike the plate, they transfer their energy to the plate in the form of heat. Each tube has a certain safe dissipation rating which is specified by the manufacturer. For prolonged life of the tube this rating should not be continuously exceeded. The useful power output from a tube circuit is the difference between the d-c power input and the power dissipated in heat on the plate. The output power may be several times greater than the dissipation in class C operation.

Q. 3.111. What is meant by a "blocked grid"?

A. This usually refers to a case where the grid is held at an excessively negative value for some period of time, thereby cutting off plate current. This effect is usually undesirable, but not always, as with a blocking oscillator, or as in the case of blocked grid keying.

D. In undesired grid blocking there are two general possibilities. The first is that the grid has lost its d-c return to the cathode. In this case electrons collect quickly on the grid, charging it highly negative and cutting off the tube for an indefinite period of time unless leakage paths are present. In this case "motorboating" may occur in the form of relaxation oscillations. The second possibility is that a class A amplifier may be overdriven so as to draw considerable grid current. In this case, if there is a long time constant ($R \times C$ product) in the grid circuit, a high value of grid bias is developed which may take some time to leak off.

Q. 3.112. What is meant by the "load" on a vacuum tube?

A. The "load" on a vacuum tube commonly refers to the impedance through which plate current flows in order to produce a useful output. Properly, it denotes the power transferred into the external circuit.

D. The load may be either resistive or reactive, or an impedance combining both resistance and reactance. The load may be wholly in the plate circuit, which is most conventional. It may be wholly in the cathode circuit as in a cathode follower, or it may be divided between plate and cathode circuits as in some phase inverters. In any case the original definition as given above will hold.

The term "load" is generally used as a slang expression for load impedance and is so described above. Actually, the load is the power transferred to the load impedance.

The load on a vacuum tube increases as the load impedance approaches the internal plate impedance in value.

Q. 3.113. What circuit and vacuum-tube factors influence the voltage gain of a triode audio-frequency amplifier stage?

A. Assuming normal plate and grid voltages to be present, the gain of a triode audio amplifier is a function of (1) tube transconductance, (2) plate load impdeance, and (3) transformer step up ratio (if used).

D. While it is true that radical changes in plate supply voltage will change the voltage gain to some extent, this factor is of minor importance in comparison to those mentioned above. For resistance coupled amplifiers the gain is $G = g_m \times R_{eq}$, where g_m is the transconductance, and R_{eq} is the internal plate impedance, the plate load impedance and the grid resistance of the following stage taken in parallel. This formula only holds for mid-range frequencies, that is the *flat* portion of the frequency characteristic of the amplifier. For transformer coupled amplifiers the gain with a triode and well designed transformer is $G = \mu \times N$, where N is the turns ratio. Pentodes are not generally used with transformers, the usual exception being the output audio power amplifier. However, there is no question here of voltage gain. The only consideration is one of impedance matching for maximum power transfer.

Q. 3.114. What is the purpose of a bias voltage on the grid of an audio-frequency amplifier tube?

A. To determine the operating conditions of the tube.

D. There are two main factors involved:

(1) In voltage amplifiers the correct value of bias is essential for undistorted (class A) output since the bias determines the operating point of the tube on its dynamic characteristic curve, (I_p vs. E_g).

(2) In power amplifiers an additional element is involved. The bias must be set so as to limit the plate current to a safe value, and so that the rated plate dissipation of the tube will not be exceeded. The bias also sets the operating conditions which determine whether the amplifier is class A, AB or B.

Q. 3.115. What is the primary purpose of a screen grid in a vacuum tube?

A. The screen grid has two important functions; first it greatly reduces the grid to plate capacitance, thus making it unnecessary to neutralize r-f amplifiers except at very high frequencies, and second, it makes the plate current substantially independent of plate voltage. The second function makes it possible to obtain much higher values of amplification than with triodes. The plate efficiency is about 10% greater than with triodes.

D. See Question 3.101.

Q. 3.116. What is the primary purpose of a suppressor grid in a multi-element vacuum tube?

A. The suppressor grid being highly negative with respect to the plate returns secondary electrons to the plate and increases the permissible gain and the efficiency of the tube.

D. See Question 3.97.

Q. 3.117. What is the meaning of the term "plate saturation"?

A. For any given filament or cathode temperature "plate saturation" occurs when the plate current is equal to the electron emission.

D. Under normal operating conditions for an amplifier tube, the cathode temperature and plate supply voltage are fixed. Saturation effects may occur when a further positive swing of the grid can no longer produce an appreciable increase of plate current.

Q. 3.118. What is the most desirable factor in the choice of a vacuum tube to be used as a voltage amplifier?

A. High value of transconductance.

D. As described in Question 3.113, the transconductance is one of two vital factors affecting voltage gain. The other factor is the equivalent load impedance. Another desirable factor is low input and output tube capacitance for extended high frequency response. The above requirements usually indicate the use of a pentode.

Q. 3.119. What is the principal advantage of a tetrode over a triode as a radio-frequency amplifier?

A. The lack of necessity for neutralizing, except possibly at ultra high frequencies.

D. See Questions 3.97, 3.101, and 3.120.

Q. 3.120. What is the principal advantage of the tetrode as compared to the triode, when used in a radio receiver?

A. Neutralization is not required for the r-f and i-f amplifiers.

D. It should be pointed out that pentodes rather than tetrodes have been used in radio receivers for a good many years. Pentodes, of course, have even less necessity of neutralization than tetrodes. Another advantage of the tetrode, if used, is higher gain than can be obtained with triodes. See also Questions 3.97 and 3.119.

Q. 3.121. What is the principal advantage in the use of a diode detector instead of a grid-leak type triode detector?

A. A diode detector ordinarily produces lower over-all distortion of the audio output wave than a triode detector.

D. A disadvantage of the diode detector is that it draws current through the tuned input circuit, loading it down and causing broad tuning. However, this effect may be greatly reduced by the use of a high value of diode load resistance which also reduces distortion and increases the output. The grid-leak detector also has this same disadvantage of broad tuning. The reason for the additional distortion in the grid-leak detector is due to the fact that the bias for the triode is correct only *one* value of input signal amplitude. See Question 3.130.

Q. 3.122. Draw a grid voltage-plate current characteristic curve of a vacuum tube and indicate the operating points for class A, class B, and class C amplifier operation.

A. See the figure.

D. Class A is usually near the center of the linear portion of the curve.

Class B can be either at actual cut-off bias or as shown in the figure at "projected cut-off" for linear operation.

Class C can be any value greater than cut-off bias but is usually about 2 × cut-off.

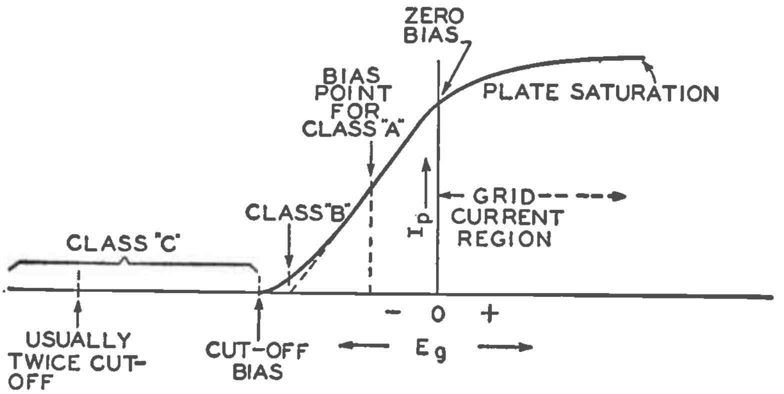


Fig. 3.122. Tube characteristic curve, with certain significant bias points.

Q. 3.123. What operating conditions determine that a tube is being used as a power detector?

A. Bias about at cut-off, high input grid resistance, and plate circuit rectification.

D. (1) The grid bias is such that with no signal the plate current is very low. (About .2 ma with no signal.)

(2) The input grid resistance is much higher than for a diode since no grid current flows.

(3) Bias is usually obtained by a relatively large value of cathode resistance and a cathode by-pass condenser.

(4) Distortion is greater than for a diode detector, especially for weak signals.

Q. 3.124. Why is it desirable to use an alternating current filament supply for vacuum tubes?

A. Mostly for practical reasons. Since an a-c supply is almost always easily obtainable, it is a relatively simple matter to provide a step-down transformer to obtain the correct value of filament voltage. D-c supplies are usually bulky or in battery form.

D. There are disadvantages to using an a-c filament supply, the main one being the possibility of introducing hum into the amplifier circuits even when an indirectly heated cathode is used.

Q. 3.125. Why is it advisable periodically to reverse the polarity of the filament potential of high-power vacuum tubes when a direct-current filament supply is used?

A. In order to lengthen the life of the filament.

D. When d.c. is used to heat a filament, there will be a greater potential difference existing between the positive side of the filament and the grid than between the negative side of the filament and the grid. This means that the effective bias is grater on the positive side of the filament than on the negative side of the filament. Therefore, more current will tend to be drawn from the negative side of the filament due to the decreased bias on that side. Another factor is that the effective plate voltage is greater on the negative side of the filament. By occasionally reversing the polarity, the use is disturbed more uniformly over the active area of the filament.

Q. 3.126. Why is it important to maintain transmitting-tube filaments at recommended voltages?

A. To realize the greatest life expectancy of the filament without sacrifice of performance.

O. If the filament voltage is excessive, its useful life will be shortened. On the other hand if the filament voltage is too low, the emission will be reduced and the operation of the circuit in which the tube is used may be adversely affected.

Q. 3.127. When an alternating-current filament supply is used, why is a filament center tap usually provided for the vacuum-tube plate and grid return circuits?

A. To prevent hum voltages from modulating the normal signal.

D. If the plate and grid returns were made to one side of the filament rather than the center, the filament voltage at the other side of the filament would vary at the rate of the supply frequency. This is equivalent to having the bias change at the supply frequency (usually 60 cycles) and thus the plate signal is modulated at supply frequency rate variations, which becomes *hum* in the speaker.

On the other hand, if the plate and grid returns are connected to the center tap, the voltage change on one side of the filament will be effectively cancelled out by an equal and opposite voltage change at the other side of the filament. Thus the bias remains substantially constant, and no hum will appear.

Q. 3.128. Explain the operation of a grid-leak type of detector.

A. (See Question 3.88 for diagram.) The functioning of a grid-leak detector depends upon the ability of the grid leak and condenser to follow the *average* grid current variations which are directly proportional to the modulation envelope.

D. (See Question 3.368 for full discussion of grid-leak bias.) The grid-leak detector is basically a triode tube used as a diode detector with a built-in amplifier. The grid acts as the plate of a diode with the other elements of the triode performing their normal functions. The grid circuit is considered first. Here a tuned circuit which acts as a generator is connected to the cathode and to the grid in series with the parallel network R_g-C_c. Assume first than an unmodulated carrier is applied to the detector. Rectification will take place in the grid circuit with the grid drawing current on the positive portions of the r-f cycles. As a result of the grid current, capacitor C_g will become charged almost to the peak value of the unmodulated carrier. Because of the direction of electron flow, the condenser will assume a negative charge at the grid side. This negative value is now the operating bias for the triode and remains constant as long as the r-f input voltage does not vary. Thus there will be certain definite value of d-c plate current flowing. R-f components appearing in the plate circuit will be effectively eliminated by the plate by-pass condenser. The d-c current flowing through the plate load resistor will provide a steady value of d-c voltage at the plate (e_b).

Summing up this far: an unmodulated r-f input in the grid circuit produces a steady value of d-c voltage in the plate circuit. Now if the r-f carrier amplitude should begin increasing due to modulation, an increasing r-f voltage is applied to the grid, causing the grid current to increase and a larger negative voltage to appear across R_g-C_c. This corresponds to an instantaneous increase of bias resulting in a decrease of plate current, and a consequent increase of plate voltage. The greater the increasing modulated carrier becomes, the more positive is the plate voltage. Thus plate voltage follows the average increasing value of the r-f wave, which is the audio component. As the modulated carrier begins decreasing in strength (on the descending part of the audio modulating cycle) the condenser C_c begins to discharge through R_g, thus reducing the instantaneous value of bias. This results in an increasing plate current and a descending plate voltage, which effectively follows the original audio modulation component at the grid. The condenser C_c must be able to discharge fast enough so that each decreasing r-f cycle will draw grid current and thus maintain the proper shape of the audio wave. However, it must discharge neither too fast nor too slowly or distortion will result. Typical values are 1 megohm for R_g and .0001 μf for C_c.

The disadvantages of a grid-leak detector are:

(1) Considerable second harmonic distortion.

(2) Distorts excessively on large signals.

The main advantage is that the detector is very sensitive to weak signals.

Q. 3.129. List and explain the characteristics of a square-law type of vacuum-tube detector.

A. The characteristics of square-law detection are:

(1) The audio output signal amplitude is proportional to the square of the r-f input voltage.

(2) High sensitivity is provided due to the above.

(3) High percentage of second harmonic distortion .

(4) Works on weak signals *only.*

D. *Any* detector may be square-law. The term square-law merely refers to the curvature of the lower end of the tube characteristic. This curve is essentially a parabola whose equation is $y = X^2$, where y represents the output signal and X represents the input signal. Thus if three input readings were 2, 4, and 6, the corresponding output would be 4, 16, and 36. A diode detector is square law on weak signals, as is a plate detector or a grid-leak detector.

Q. 3.130. Explain the operation of a diode type of detector.

A. The diode detector operates in the same manner as the grid-to-cathode section of the grid-leak detector. The audio component across the *R-C* network (Question 3.86) is not amplified within the same tube, but is fed into a separate amplifier through a condenser to eliminate the d-c component. The separate amplifier can then be operated class A, independently of the d-c component due to rectification by the diode. The diode detector is "square law" on weak signals and practically linear on strong signals.

D. See Question 3.128.

Q. 3.131. Explain the operation of a power or plate rectification type of vacuum-tube detector.

A. (See diagram, Question 3.87.) A power detector (also plate or bias detector) may be operated as either a square law or lineal detector. The bias is usually supplied by a cathode resistor and condenser, or sometimes from a negative power supply. The bias value is such that plate current is almost cut-off, and is usually about 0.2 milliampere with no signal input. With a weak signal input the average plate current is low, whereas with a strong signal input the average plate current rises. That is, the average plate current varies in proportion to the magnitude of the grid signal voltage which means that the average plate current follows the modulation envelope at the grid. The by-pass condenser for the plate small (.0001 μf) and is only effective for r.f. while the cathode by-pass condenser is large (1 μf) and is effective for r.f. and a.f. The power detector is less sensitive than the grid-leak detector, but is able to handle greater overloads. Under normal signal conditions, it draws no grid current, and does not affect the sharpness of tuning.

Q. 3.132. Is a grid-leak type of detector more or less sensitive than a power detector (plate rectification)? Why?

A. The "grid-leak" detector is more sensitive than a "power" detector, because of the tube amplification.

D. With a weak input signal the grid-leak detector is operating at nearly zero bias. This means operation on the steepest portion of the dynamic characteristic curve of the tube. The steeper the slope, the higher is the transconductance and consequently the gain.

The power detector bias does not vary with input signals and is almost at cut-off value where the slope of the curve is the least. This corresponds to a low transconductance and gain.

Q. 3.133. Describe what is meant by a class A amplifier.

A. A class A amplifier is one in which the grid bias and alternating grid signal are such that plate current flows for the entire 360° of an input sine wave voltage applied to the grid. Operation is confined as nearly as possible to the most linear portion of the tube characteristic.

D. See Questions 3.106, 3.109, and 3.445.

Q. 3.134. What are the characteristics of a class A audio amplifier?

A. Low plate efficiency, very little distortion, high voltage gain, low power output compared to class B or C.

D. See Question 3.133.

Q. 3.135. What will be the effect of incorrect grid bias in a class A audio amplifier?

A. In a voltage amplifier incorrect bias will cause distortion of the output wave shape. In a power amplifier it may also cause excessive plate dissipation if the bias is too low.

D. See Questions 3.106, 3.122, and 3.133.

Q. 3.136. What are the factors which determine the bias voltage for the grid of a vacuum tube?

A. The following factors apply:

1. The class of operation (A, B, or C).
2. The plate supply voltage.
3. Permissible distortion.
4. Grid signal magnitude.
5. Permissible plate dissipation (in power tubes).
6. Desired amplification factor. (In variable μ tubes.)
7. The no-signal plate current desired.
8. The desirability or not of drawing grid current.

D. The amount of bias needed for a given class of operation is inversely proportional to the amplification factor (μ) of the tube. For example, in class C operation where the bias is equal to twice cut-off, it may be found from the formula, $E_c = \frac{2\ E_b}{\mu}$. See also Questions 3.122 and 3.484.

Q. 3.137. Why are tubes operated as class C amplifiers not suited for audio-frequency amplification?

A. Because of excessive distortion.

D. The plate current in the average class C amplifier flows for only 120° or ⅓ of a cycle. Even in push-pull operation there would still be only 2/3 of the cycle reproduced. The resultant distortion would be far beyond the tolerance allowed for audio. Class C r-f amplifiers have tank circuits which replace the missing portions of the cycle through storage action. The tank circuit can not be similarly used for audio frequencies, because it operates at one frequency only.

Q. 3.138. Draw a circuit of a "frequency doubler" and explain its operation.

A. See Question 3.90 for diagram, and 3.139 for use.

D. A pure sine wave contains only one frequency, the fundamental. However, any distortion of the sine wave indicates the presence of other frequencies, which are multiples of the fundamental and are called harmonics. Thus any amplifier which distorts the input wave is actually a harmonic generator. The desired harmonic may be selected with a suitable resonant circuit. In a frequency doubler the grid tank is tuned to the fundamental while the plate tank is tuned to the second harmonic. In triodes the grid bias for most efficient doubling is 10 times cut-off value, with a plate efficiency of 50%, a relative power output (compared to ordinary class C amplifier) of 70%, and a plate current pulse length of 90°.

For a triode tripler, the grid bias is 20 times cut-off, plate efficiency of 50%, relative power output of 36%, and a plate current pulse length of 75°.

Due to the high bias, very large values of grid excitation voltages must be used.

Q. 3.139. For what purpose is a "doubler" amplifier stage used?

A. A doubler is used to multiply the fundamental frequency by 2.

D. From a practical consideration, a doubler is most often used in connection with crystal oscillators. The high frequency limitations of quartz crystals are due to the fact that the crystal plate becomes thinner as its resonant frequency is increased. Thus it becomes extremely fragile and easily subject to overheating and cracking. To overcome this important limitation, the crystal frequency is kept relatively low, usually under 20 megacycles, and the crystal oscillator may be followed by one or a series of doublers to increase the output frequency. Triplers and quadruplers may also be used when desired. (See also Question 3.138.)

Q. 3.140. Describe what is meant by "link coupling" and for what purpose(s) it is used.

A. "Link coupling" is a low impedance transmission line method of coupling together two circuits which may be separated by a relatively large distance. It may be considered to be a step-down transformer and a step-up transformer interconnected.

D. A link system consists of a very few turns of wire which is coupled to the low impedance point of a tank circuit, then connected to a length of low impedance transmission line and terminated by another few turns which is again coupled to the low impedance point of the input tank circuit. The low impedance point is that point to which the r-f bypass condenser is connected. In push-pull operation, the low impedance position is at the center of the tank. Advantages of this system are extreme flexibility of mechanical construction and a reduction of tube capacitance effects on the L/C ratio of the tank circuits. See diagram, Question 3.360.

Q. 3.141. What factors may cause low plate current in a vacuum-tube amplifier?

A. The following factors may cause low plate current:

1. Low filament emission.
2. Low filament voltage.
3. Excessive value of bias.
4. In class C amplifiers, low excitation voltage.
5. Open grid circuit.
6. Low plate supply voltage.
7. Low screen grid supply voltage.
8. Shorted screen by-pass condenser.

(Compare Question 6.459.)

Q. 3.142. Given the following vacuum tube constants: $E_p = 1{,}000$ volts, $I_p = 150$ milliamperes, $I_g = 10$ milliamperes, and grid leak = 5,000 ohms, what would be the value of direct-current grid-bias voltage?

A. $E_c = 50$ volts.

D. The plate current and voltage values are unnecessary to solve this problem. By Ohm's law, the bias is equal to the voltage drop across the grid resistor of $E_c = 5000 \times .010 = 50$ volts.

(Compare Question 6.465.)

Q. 3.143. Explain how you would determine the value of cathode-bias resistance necessary to provide correct grid bias for any particular amplifier.

A. The bias is equal to the *IR* drop across the cathode resistance and is found by dividing the desired d-c bias voltage by the total d-c, no signal cathode current.

D. For a triode the bias resistance will equal the d-c bias voltage divided by the no signal d-c plate current or $R_K = \frac{E_c}{I_{b1}}$ where E_c = d-c bias voltage as desired, and I_{b1} is the no signal value of d-c plate current.

For tetrode or pentode the screen current must be added to the plate current, giving:

$$R_K = \frac{E_c}{I_{1b} + I_{so}}$$

Q. 3.144. What is the chemical composition of the active material composing the negative plate of a lead-acid type storage cell?

A. The active material is composed of pure spongy lead (Pb).

D. The plates are constructed of a lattice-work made of lead or lead alloy (antimony) in the form of flat plates. The openings in the lattice-work are originally filled in with a paste made of lead oxide which hardens like cement. Upon charging, the positive plate is converted to lead peroxide (PbO_2) and the negative plate to pure spongy lead. (Pb). Upon discharging, the active materials are both converted to lead sulfate, $PbSO_4$. See Questions 3.146, 3.150, and 6.281.

Q. 3.145. What is the chemical composition of the active material composing the negative plate of an Edison-type storage cell?

A. The composition of the active material of the negative plate is finely powdered pure iron (Fe).

D. Iron oxide is pressed into pockets in sheets of perforated nickel-plated iron. The pockets are pressed into windows of a nickle-plated steel grid. The first time the cell is charged, the oxide is reduced to pure powdered iron. See Questions 3.148, 3.149, and 6.281.

Q. 3.146. What is the chemical composition of the active material composing the positive plate of a lead-acid type storage cell?

A. The active material in the positive plate is lead peroxide (PbO_2).

D. The positive plate is formed in the same manner as the negative plate. See Questions 3.144, 3.150, and 6.281.

Q. 3.147. How does a primary cell differ from a secondary cell?

A. A primary cell cannot be recharged after use, while a secondary cell can.

D. A primary cell cannot be recharged because the substance of one of the electrodes is chemically eroded; this occurs because the products of the chemical reaction are soluble in the electrolyte. An attempt to recharge it would not restore it to its first condition.

A secondary, or storage, cell, when it is discharged, has undergone a chemical change, but the new products are not soluble in the electrolyte. When the charging current is supplied, the chemical action is reversed; since the electrode material has not been dissolved, the cell will be restored to its charged condition.

Q. 3.148. What is the chemical composition of the active material composing the positive plate of an Edison-type storage cell?

A. The active material in the positive plate is a green oxide of nickel (NiO_2).

D. The green oxide of nickel is alternated with layers of nickel hydrate, in order to increase the conductivity, since the green oxide is a poor conductor. This material is stuffed into quarter-inch tubes, about 4½ inches long, made of perforated spirally-wound strips of nickel-plated iron, and is reduced during the first charge to pure nickel. See Questions 3.148, 3.152, and 6.837.

Q. 3.149. What is the chemical composition of the electrolyte used in an Edison-type storage cell?

A. The electrolyte is a 21 percent solution of potassium and lithium hydroxides, in distilled water. The specific gravity is about 1.200. The container for the battery is a strong, welded, nickel-plated sheet-steel tank.

D. For composition of the plates, or electrodes, see Questions 3.145 and 3.148. For the lead-acid storage cell see Question 3.150.

Q. 3.150. What is the chemical composition of the electrolyte of a lead-acid storage cell?

A. The electrolyte is a dilute solution of sulphuric acid (H_2SO_4) in distilled water, which reaches a specific gravity of about 1.300 when fully charged.

D. See also Question 3.208. For composition of the plates, see Questions 3.144 and 3.146. For the Edison storage cell, see Question 3.149.

Q. 3.151. What is "polarization" as applied to a primary cell and how may its effect be counteracted?

A. "Polarization" is the formation of hydrogen gas around the positive electrode. It is counteracted by the use of a depolarizing agent, such as manganese dioxide.

D. "Polarization" is usually though of in terms of a dry (primary) battery although its effects are also present in secondary cells. Considering a dry cell, composed of a positive carbon rod and a negative zinc container, it is found that in the normal chemical cycle, hydrogen bubbles are formed about the surface of the positive carbon rod. The hydrogen has a high resistance which greatly increases the internal cell voltage drop, and lowers its efficiency. The effects of "polarization" can be greatly reduced by the use of a depolarizing agent which is usually manganese dioxide and which gives up oxygen to the hydrogen, forming water.

Q. 3.152. Describe three causes of a decrease in capacity of an Edison-type storage cell.

A. Several causes are:

1. Adding impure water to electrolyte.
2. Frequent overheating.
3. Weak or aged electrolyte.
4. Temporary loss in capacity results from being allowed to stand idle in a *charged* condition.
5. Capacity is reduced at operating temperatures over 115° F.
6. Charging at less than normal rate. (The "trickle charge," useful in maintaining the activity of the lead-acid type cell, is a disadvantage in this case.)

Q. 3.153. What is the cause of the heat developed within a storage cell under charge or discharge condition?

A. The heat developed is due to I^2R losses as well as to the energy transfer due to chemical reactions while charging and discharging the battery.

D. When a cell is being charged, the charging current must pass through the positive and negative plates and the electrolyte. Since these represent a finite value of resistance, and also because of the heat developed by the chemical reaction, the charging or discharging current should not be allowed to exceed the manufacturer's rating for any length of time.

Q. 3.154. How may a dry cell be tested to determine its condition?

A. A dry cell must be tested under normal load conditions. If the terminal voltage has dropped about 20% the battery should be discarded. The reading may be taken by any conventional voltmeter.

D. If a dry cell is tested under *no-load* conditions, the terminal voltage will be approximately equal to the normal rated cell voltage regardless of the age of the battery. This would give an erroneous impression of the condition of the cell.

Q. 3.155. What will be the result of discharging a lead-acid storage cell at an excessively high current rate?

A. The effects are:

1. Reduction of output power. If the discharge rate is 8 times normal, the output power is only 50% of the normal output power.
2. Excessive heating.
3. Excessive evaporation of water.

D. If the battery is also overdischarged, this will result in the formation of excessive sulphation which will probably be difficult to remove with normal charging. See Question 3.162.

Q. 3.156. What is the approximate fully charged voltage of an Edison storage cell?

A. The average voltage on discharge is about 1.2 volts.

D. See Questions 3.152 and 3.160.

Q. 3.157. A 6-volt storage battery has an internal resistance of 0.01 ohm. What current will flow when a 3-watt, 6-volt lamp is connected?

A. The current will be .4995 ampere.

D. $I_T = \frac{E}{R_T}$, where R_T = combined resistance of lamp and battery.

The resistance of lamp is: $R_L = \frac{E^2}{W} = \frac{36}{3} = 12$ ohms.

Therefore $R_T = 12.01$ ohms. The total current, I_T, is equal to $\frac{6}{12.01}$ or .4995 ampere.

Q. 3.158. What is the approximate fully charged voltage of a lead-acid cell?

A. The fully charged terminal voltage is about 2.06 volts.

D. The cell is considered to be fully discharged when the terminal voltage drops to 1.75 volts. The actual fully charged voltage depends upon temperature and individual cell characteristics, but is close to the figure given. (See Question 3.163.)

Q. 3.159. Why is low internal resistance desirable in a storage cell?

A. To increase the power output and terminal voltage (under load) of a battery.

D. Any resistance in the battery is an obvious cause of power dissipation, due to I^2R losses. This power is not available to the load. Also the IR drop in this internal resistance must be subtracted from the terminal voltage, which reduces the available output voltage of the battery.

Q. 3.160. How may the condition of charge of an Edison cell best be determined?

A. The charge of an Edison cell can be learned by reading the terminal voltage under load and checking the reading against a standard discharge curve.

D. The specific gravity electrolyte in an Edison cell does not change with charge and discharge and so hydrometer readings are of no use in determining the state of charge. The terminal voltage of an Edison cell when fully charged is 1.4 volts, while average voltage under discharge is 1.2 volts. When fully discharged, the terminal voltage falls to slightly under 1 volt.

Q. 3.161. If the charging current through a storage battery is maintained at the normal rate, but its polarity is reversed, what will result?

A. In an Edison cell, reversing the polarity of the charge will cause no damage as long as the electrolyte temperature is kept below 115°F. The cell will charge slightly the reverse way. The battery should be completely discharged and then recharged correctly.

In a lead-acid cell reversing the charging polarity will cause no damage if the discharging effect is not permitted to become excessive. If permitted to continue in reverse direction, the battery will take on a reverse charge and become very sulphated. It should be fully discharged and then charged correctly at a low rate for as much as 48 hours. If the reverse charge is excessive the negative plates will be ruined.

Q. 3.162. What are the effects of sulphation?

A. The effects are: (1) reduced terminal voltage, (2) increased internal resistance, (3) reduced power output, (4) possible buckling of the plates.

D. *Sulphation* is the formation of lead sulphate on the positive and negative plates of a battery during discharge. It is a normal process in the lead-acid cell and is caused by sulphuric acid molecules combining with lead dioxide and sponge lead to form lead sulphate ($PbSO_4$). If proper charging is neglected, the sulphate eventually hardens on the surface of the plates and prevents proper contact of the electrolyte with the active material of the plates. Sulphation is increased by allowing the battery to remain in a discharged condition, and by adding acid instead of properly charging the cells. See Question 3.207.

Q. 3.163. **How may the state of charge of a lead-acid storage cell be determined?**

A. The following methods may be used:

1. By hydrometer readings, which should be about 1.300 when fully charged, and 1.100 when discharged.

2. By measuring the terminal voltage with a voltmeter under a heavy load.

D. See Questions 3.158 and 6.322.

Q. 3.164. **Why is laminated iron or steel generally used in the construction of the field and armature cores of motors and generators instead of solid metal?**

A. To reduce eddy current losses.

D. It is customary in iron cores to construct these cores of layers or laminations which are insulated from each other by a process such as shellacking. The reason for this is to offer a number of high resistance paths to eddy currents rather than one low resistance path. This reduces the eddy current power loss to a relatively small amount. See also Question 3.295.

Q. 3.165. **What is the purpose of "commutating poles" or "interpoles" in a direct-current motor?**

A. "Commutating poles" or "interpoles" are added in order to reduce brush sparking without the necessity of moving the brushes.

D. Commutating poles are small field poles consisting of a few turns of heavy wire which are located between the main field poles of the machine. The commutating poles are connected in series with the armature, and in a motor are of the same polarity as the preceding main field pole. In a simple motor, as the load increases, the brushes have to be pushed backward to keep them in a neutral position for sparkless commutation. The commutating poles in a motor effectively twist the field forward, in proportion to the current taken, to keep the neutral position at the fixed brushes. ("Neutral position" refers to the position of the brushes on the commutator of a d-c motor or generator, relative to the field poles, at which minimum brush sparking will occur.)

When the motor or generator is stationary and no current flows through the armature, the neutral position occurs when the armature coil in contact with a brush is exactly half way between two adjacent field poles. At this position no emf is induced in the armature coil. In any other position, as the brush transfers to another commutator segment, it is momentarily shorting the armature coil and causes a strong magnetic field to be set up which collapses when the brush reaches the next commutator segment. It is this collapsing field which induces a large counter-emf and causes sparking. If a heavy current is flowing through the windings, the inductance will maintain a current flow, regardless of absence of external field poles; the brushes must leave the commutator segment at the time that the induced voltage has brought the current to zero. This position is not the same for different loads. As the load increases, the brushes should be moved forward in the direction of rotation to reduce sparking, in the case of a generator, while in a motor the brushes should be moved backwards against the rotation. The commutating poles keep the neutral position fixed, by effectively shifting the field.

Q. 3.166. How may the output voltage of a separately excited alternating-current generator at constant output frequency, be varied?

A. The most practical means would be to vary the output of the d-c exciting generator by means of a series field rheostat.

D. The output voltage of an a-c generator depends upon (among other things) the magnetic strength of the generator field. A simple method of varying the output voltage therefore, would be to vary the current of the exciter supply by means of a series rheostat. Any other means of varying the alternator field current would have equivalent effect.

Q. 3.167. If the field of a shunt-wound direct-current motor were opened while the machine was running under no load, what would be the probable result(s)?

A. The motor would race at an ever-increasing speed; and if unchecked it may destroy itself due to centrifugal forces, provided that fuses or circuit breakers did not act sooner to protect it.

D. Ordinarily the armature current is greatly limited due to the counter-emf developed in the armature as the field is cut by the windings. Since the armature current is limited, the torque and thus the speed is limited. If the field coil opens, most of this cemf disappears, and the armature current rises to very high values, increasing the torque and speed almost without limit.

Q. 3.168. Name four causes of excessive sparking at the brushes of a direct-current motor or generator.

A. Several causes are:

1. Brushes not properly set at neutral point.
2. Weak spring tension on brushes.
3. Worn brushes.
4. Motor overloaded or started too rapidly.
5. Open or short circuit in armature coil.
6. Dirt on commutator or worn brushes.
7. Commutator worn eccentric.

8. High (protruding) mica insulation between commutator bars or commutator bars of uneven height.

D. See Question 3.165 for item 1; Question 3.391 for item 4; Question 6.377 for item 5. The other items need no special comments.

Q. 3.169. What is the purpose of a commutator on a direct-current motor? On a direct-current generator?

A. The function of the commutator is to periodically change the armature coils which contact the brushes and thus maintain a condition of uni-directional current in the output of a generator, and an alternating current in the armature of a motor.

D. All generators and motors are essentially a-c devices, and thus the commutator is really a mechanical inverter. In a d-c generator, the windings have a.c. induced, and the output would normally be a.c., were it not for the fact that the commutator action switches in a new set of armature coils just when the current in the original coil starts to reverse direction.

In a motor the switching action is such that the current in the armature is made to reverse periodically, and thus becomes a.c., so that as an armature coil leaves one field pole, it will be repelled from it and attracted to the next.

Q. 3.170. What is meant by "counter emf" in a direct-current motor?

A. When the armature of a d-c motor is rotating in the magnetic lines set up by the field, a voltage is induced into the armature which is in the opposite direction to the line voltage. This partially counteracts the line voltage and so limits the armature current.

D. In a shunt-wound motor running at normal speed without a load, the counter emf is almost equal to the line voltage, and thus the armature current is very small. The only power taken from the line under these conditions, is that needed to overcome the friction and wind-resistance of the rotating parts.

Q. 3.171. What determines the speed of a synchronous motor?

A. The speed is determined by the line frequency and the number of pairs of poles.

D. R.P.M. $= \frac{60f}{P/2}$, where f equals the line frequency, and P equals the number of poles, and 60 is the number of seconds in a minute.

Q. 3.172. Describe the action and list the main characteristics of a shunt-wound direct-current motor.

A. The main advantage of a shunt-wound d-c motor is its practically *constant speed* under widely varying load.

D. Assuming first, no load on the motor and full speed, it will be

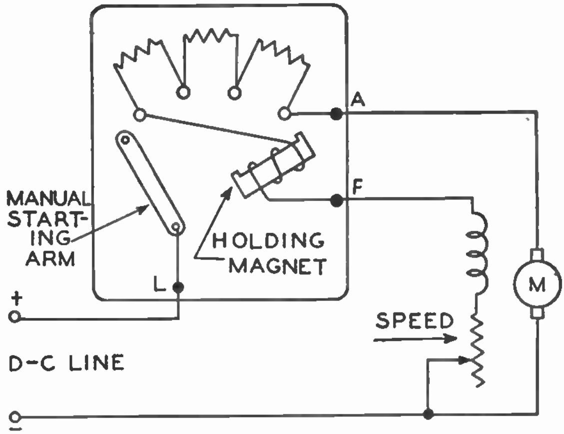


Fig. 3.172. Shunt motor starter and speed control.

found that the counter emf in the armature will almost equal the line voltage and the current drawn from the line is very small. If a load is now placed on the motor the tendency is to slow down. However, if the armature slows, the counter emf decreases, the armature current and the torque increase; hence the motor attempts to regain speed, but actually runs at a slightly lower speed since more power must be taken from the line to supply the load. The result is that the speed of such a motor falls only slightly under the load. A schematic diagram of such a motor with starting control and speed control is given in the figure. In certain cases, a shunt is connected across the field to increase the speed above the maximum value obtained with the starting resistance all cut out.

Q. 3.173. Describe the action and list the main characteristics of a series direct-current motor.

A. The main characteristics are, maximum torque at low speed, quick starting, and poor speed regulation under varying load conditions.

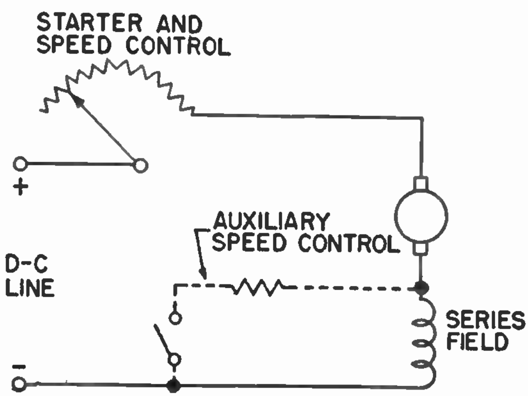


Fig. 3.173. Series motor starter and speed control.

D. Under heavy loads the speed is slow and consequently the counter emf in the armature is small causing large armature currents and correspondingly high values of torque. When the load is released the armature tries to reach a speed at which the cemf is almost equal to the line voltage; as the cemf rises, the current goes down, weakening the field and requiring a still higher speed. The speed increases until (in very small motors) friction and wind resistance form a sufficient load to prevent further acceleration, or until (in larger motors) the motor destroys itself by centrifugal force.

The high starting torque makes series motors desirable for use with permanently connected loads, such as railways, cranes, elevators, blowers, etc.

A schematic diagram of such a motor with starting control and speed control is given in the figure.

Q. 3.174. Describe the action and list the main characteristics of a series direct-current generator.

A. The main characteristics are: the output voltage rises and falls with an increase or decrease of load, and the load current flows through field and armature in series.

D. The field consists of relatively few turns of heavy wire in order to carry the load current without overheating. Series generators cannot be used to supply power to constant voltage systems, but were once used to supply power for street lighting. Series generators are sometimes used as boosters to raise the voltage at the ends of long feeder lines under load. See Question 6.380, which includes a discussion of a compound generator which makes use of a series field.

Q. 3.175. List the main advantages of a full-wave rectifier as compared to a half-wave rectifier.

A. The main advantages are:

1. Better output voltage regulation.
2. Smaller filter components for a given ripple percentage.

D. The ripple frequency for any full-wave rectifier is always twice that of a half-wave system, whose ripple is at line frequency. Consequently, the spaces between pulses of rectifier current are comparatively small and so the filter condensers have less opportunity to discharge between pulses. The reduction of ripple voltage is found by the formula:

$A = \frac{1}{(2\pi f)^2 LC\text{-}1}$, where A is the ratio of output ripple to input ripple, f is the ripple frequency, and L and C are the filter inductance and capacitance respectively. It is apparent from the equation that if f, the ripple frequently, is doubled, it is then possible to reduce the values of both L and C in half to maintain the same ripple attenuation. This is true because the amount of output ripple is inversely proportional to the *square* of the ripple frequency.

Q. 3.176. Why may a transformer not be used with direct current?

A. A transformer requires a changing current through its windings, which sets up changing magnetic flux. Direct current cannot satisfy this requirement.

D. If direct current is periodically interrupted by some mechanical means such as a vibrator or commutator it will then be possible to use an original d-c voltage source with a transformer. This is the principle used with automotive radio power supplies. The rising and falling of current through the primary induces an a-c voltage in the secondary of the transformer.

Q. 3.177. What are the primary advantages of a high-vacuum rectifier as compared to the hot-cathode mercury-vapor rectifier?

A. Advantages are as follows:

1. Higher peak inverse voltage rating for a given size of tube.
2. Will stand more abuse without breakdown.
3. Does not generate r-f interference (hash).

D. For use in circuits operating under 400 volts d.c., the high-vacuum type can be designed to have an internal drop which is little, if any, greater than the internal drop of a mercury-vapor tube. However, this is not true of higher voltage operation in which high-vacuum tubes have a greater voltage drop than the mercury-vapor tube. The peak inverse voltage is the maximum safe negative voltage which can be applied to the plate of a rectifier tube without danger of arcing from plate to cathode. This value is always lower, for a given size, in a mercury-vapor tube due to the ionization of the mercury, which offers a better conduction path than a vacuum. The mercury-vapor tube generates r-f interference as a result of ionization, and it must be properly shielded and its output filtered. See also Question 3.179.

Q. 3.178. What are the primary characteristics of a gas-filled rectifier tube?

A. 1. Low, constant internal drop; about 15 volts for mercury-vapor tubes.

2. Produces radio-frequency interference due to ionization of mercury or gas.

3. Permits use of oxide coated cathodes.

4. High current ratings.

5. Lower filament power.

6. More economical (in high voltage, high current applications).

7. Relatively low inverse peak voltage rating.

8. Filament may be damaged if not pre-heated before plate voltage is applied.

D. See Questions 3.177, 3.179, and 3.401.

Q. 3.179. What are the primary advantages of a mercury-vapor rectifier as compared to the thermionic high-vacuum rectifier?

A. The primary advantages are:

1. A low internal voltage drop of 10 to 15 volts which remains constant under varying load conditions, thus making for good voltage regulation.
2. Permits the use of oxide coated cathodes, with their lower filament power requirements.
3. Cooler operation due to the low internal drop.
4. Greater efficiency and economy in high voltage, high current operation.

D. See Questions 3.177, 3.178, 3.386. For a discussion of filters, see Questions 3.399 and 3.401.

Q. 3.180. Why is it desirable to have low-resistance filter chokes?

A. In order to improve the voltage regulation and increase the output voltage.

D. All of the load currents must flow through the filter chokes and thus any *IR* drop due to the internal d-c resistance of the chokes must be subtracted from the output load voltage. If a choke has a high d-c resistance, any small change in the load current will cause a relatively large change in the d-c drop across the choke and thus in the output voltage. The regulation, therefore, is made worse with a high resistance choke.

Q. 3.181. When filter condensers are connected in series, resistors of high value are often connected across the terminals of the individual condensers. What is the purpose of this arrangement?

A. The purpose is to insure that the voltage across each individual condenser will be correct.

D. If all of the condensers of a series-connected group had infinite leakage resistance, the applied voltage would divide approximately in inverse ratio to the value of capacitance; that is, the smaller the capacitance, the larger would be its voltage drop for either a.c., or d.c. However, in the practical case there are finite values of leakage resistances present in condensers which may vary considerably between supposedly similar condensers. The effect of this leakage resistance is to form a voltage divider and thus distribute the voltage across series condensers according to leakage resistance ratios, rather than capacitance ratios. To override the resulting indeterminate voltage distribution, a resistor of proper value is connected across each condenser, forming a voltage divider which causes the voltage across each condenser to have the correct value. If the series condensers are all of the same voltage rating then the resistors will be of equal value. Although the value of the resistors is high, it is low in comparison with the actual leakage resistance and thus predominates, since the two are in parallel.

Q. 3.182. What is the primary purpose of a bleeder as used in a filter system?

A. The primary purpose of a "bleeder" resistance in conventional power supplies is to improve the regulation of the voltage output.

D. A bleeder resistor is connected directly across the load terminals. It is usually designed to draw at least 10% of the total current. In this way the bleeder acts as a minimum load on the power supply when the normal load is removed. Since the output voltage of a rectifier tends to rise when the load is removed, the bleeder draws a constant current and prevents the voltage from rising as much as it would if no bleeder were present. The bleeder also serves the important function of discharging the filter condensers when the power is turned off.

Q. 3.183. Describe the construction and characteristics (1) of a thermocouple type of meter; (2) of a wattmeter.

A. (1) A thermocouple meter is made up of three main parts: a heater wire or strip, the themocouple which is immediately adjacent to the heater, and a d-c milliameter or galvanometer. In one typical thermocouple meter, the heater is a strip of platinum alloy of short length. It is through this heater strip that the r-f currents to be measured must flow. The thermocouple proper consists of a pair of wires usually of constantan and a platinum alloy tied together at one end and this junction welded to the center of the heater strip. The two "cold" ends of the thermocouple are soldered to a pair of copper strips. These two ends are connected through the copper strips to a d-c milliameter or galvanometer. The current which is to be measured is passed through the heater strip whose temperature is raised in proportion to the square of the current passing through. The rise in junction temperature of the thermocouple causes a d-c current to flow which is directly proportional to the temperature. Thus, the reading on the d-c milliameter or galvanometer is proportional to the *square* of the r-f current. If the r-f current doubles, the d-c reading will increase by 4 times. Thermocouple meters may be made very sensitive and are commercially available in sensitivities as great as 200 microamperes full scale d-c reading, and go as high as 1,000 amperes.

(2) A wattmeter is basically a voltmeter and ammeter so connected that power factor is automatically compensated for in the indicating device. The usual type of wattmeter consists of two stationary coils made of a few turns of heavy wire which are connected in series with each other and with the line, and a movable coil inside of the two fixed ones, which is connected in series with a high resistance across the line as a voltmeter. The current in the stationary coils produces a field which is proportional to the line current, while the current in the movable coil produces a field which is proportional to the line voltage. The torque tending to deflect the needle of the moving coil is proportional to the product of the instantaneous line voltage and current, or to the instan-

taneous power. However, the moving element has sufficient damping so that the needle indicates only the *average* power, and thus compensates for power factor. Wattmeters of this type may be used on either a.c. or d.c.

Q. 3.184. Describe the construction and characteristics of a D'Arsonval type of meter.

A. The D'Arsonval type meter consists of three basic parts: (1) a permanent magnet, (2) a movable coil with pointer attached, rotating in jewel bearings, (3) two spiral springs, one at each side of the movable coil. The current to be measured is caused to flow through the movable coil, connection to which is made through the two spiral springs. The magnetic field set up in the movable coil is proportional to the current flowing through it, and causes the coil to turn against the two spiral springs by reacting against the field of the permanent magnet. The amount of coil rotation (and needle), therefore, depends upon the motor force developed to overcome the resistance of the spiral springs. The movable coil rotates about a stationary soft iron core, to increase the magnetic force and thus the sensitivity of the meter. The movable coil is wound of very fine silk covered copper wire upon a light aluminum frame. The frame also performs the function of damping. As the coil moves in the permanent magnetic field, eddy currents are set up in the frame which in turn produce magnetic fields tending to oppose the original field of the permanent magnet, thus tending to stop the rotation. Without such damping, the needle would oscillate many times before finally coming to rest at the proper reading.

Q. 3.185. Describe the construction and characteristics of a repulsion-type ammeter.

A. The repulsion type of ammeter consists of three basic parts:

1. A stationary current coil.
2. A stationary iron vane within the coil.
3. A movable iron vane with pointer attached, which is concentric with the stationary iron vane.

The current to be measured is applied to the coil. The field thus produced magnetizes both iron vanes with the same polarity so that they repel and the movable vane changes its position with the pointer, indicating a suitable value of current on a scale. When alternating current is used, the polarity of the iron vanes changes at the line frequency and thus they are always in a state of repulsion. The deflection is proportional to the *square* of the current. This type meter is only suitable for relatively low-frequency measurements or for d.c.

Q. 3.186. Describe the construction and characteristics of a dynamometer-type indicating instrument.

A. A dynamometer consists of two basic parts:

(1) Two stationary coils connected to be series aiding,

(2) A movable coil to which a pointer is attached.

When used as a conventional voltmeter or ammeter the stationary coils are connected in series with the movable coil. When current flows through the coils, the field in the movable coil opposes that in the stationary coil so that the movable coil will rotate against spring action by an amount which is proportional to the current squared. Damping is secured by means of a light aluminum vane which is attached to the movable coil. This vane is enclosed in a box to protect it from air currents, within which it swings as the coil rotates. The air-resistance thus provided quickly damps any oscillation of the moving coil.

Q. 3.187. If two voltmeters are connected in series, how would you be able to determine the total drop across both instruments?

A. The total drop across the two voltmeters is found by simply adding the two individual readings.

D. Each meter indicates the voltage across its terminals, independently of the external circuit of which the other voltmeter is a part.

Q. 3.188. What type of meters may be used to measure radio frequency currents?

A. The most common type of meter used today to measure r-f currents is the thermocouple type. Another type which is no longer in general use is the hot-wire ammeter.

D. See Question 3.183. The hot-wire meter utilizes the thermal expansion of a piece of wire, as it is heated by the current passing through it, to permit a pointer to move under spring tension.

Q. 3.189. Why are copper oxide rectifiers, associated with direct-current voltmeters for the purpose of measuring alternating current, not suitable for the measurement of voltages at radio frequencies?

A. Because of the relatively large shunt capacitance of the copper oxide rectifier.

D. Copper oxide rectifiers will operate correctly at line frequencies and low audio frequencies. However, at the higher audio frequencies the meter begins to read low due to the bypassing effect of the rectifier shunt capacitance, by an amount in the order of ½ to 1 per cent for each 1000 cycles increase. Thus at radio frequencies, the rectifier becomes practically shorted by the low capacitive reactance.

Other limitations on the use of copper oxide rectifiers for a-c metering are that the accuracy is usually not better than 5%, and that the rectifier characteristics vary considerably with temperature.

Q. 3.190. If two ammeters are connected in parallel, how may the total current through the two meters be determined?

A. The total current through the two parallel meters is the sum of the two individual readings. This may not be entirely accurate for alternating and radio frequency currents unless the meters and connections are exactly alike.

Q. 3.191. Is the angular scale deflection of a repulsion iron-vane ammeter proportional to the square or square root of the current, or merely directly proportional to the current?

A. The angular scale deflection is about proportional to the *square* of the current passing through the stationary meter coil.

D. The deflection of an iron vane meter is proportional to the torque produced on the needle mechanism. The torque is proportional to the product of the magnetic pole strengths of the movable vane and the fixed vane, and each of these is proportional to the current. Hence, torque is proportional to the square of the current. This is based on the assumption that the torque is not affected by the position of the pointer, an assumption which is only approximately true; as the pointer moves, one vane moves, and this change in relation of the vanes will affect the torque. Refer to Questions 3.185 and 3.186.

Q. 3.192. Does an alternating-current ammeter indicate peak, average, or effective values of current?

A. The conventional type of a-c ammeter is calibrated to indicate effective (rms) values of current. Effective value is equal to .707 of peak value, in the case of sine-wave currents.

D. The meter itself responds to the average torque. For pure sine-wave currents, the indicated reading is dependent upon the scale calibration, which usually gives rms value. What a meter does, relatively, on non-sine-wave currents depends on the meter, but in the usual case, the meter indicates the effective value of current.

Q. 3.193. If two ammeters are connected in series, how may the total current through the two meters be determined?

A. Assuming each meter to be correctly calibrated, the total current is the reading of either meter alone, since the same current flows through each meter.

Q. 3.194. How may a direct-current milliammeter, in an emergency, be used to indicate voltage?

A. By connecting in series with the meter a suitable multiplier resistor.

D. All standard voltmeters are basically milliammeters or microammeters. The resistance of the meter would probably not be known, but could be measured if equipment were available. However, the full scale current rating is always available on the face of the meter. Neglecting the meter resistance, the value of multiplier resistor could be calculated from, $R = \frac{E_{fs}}{I_{fs}}$, where R is the value of multiplier resistance, E_{fs} is the full scale voltage reading desired, I_{fs} is the full scale current rating of the meter in question. See Question 3.195.

Q. 3.195. What is the purpose of multiplier resistance used with a voltmeter?

A. A multiplier resistance is used in series with a voltmeter in order to increase its voltage indicating range.

D. In a "1000 ohms-per-volt" meter, one milliampere is required for full scale deflection. The current rating is found by taking the reciprocal of the sensitivity rating. Thus, $\frac{1}{1{,}000} = .001$ ampere or 1 milliampere. The expression means that the meter resistance is 1,000 ohms for each full scale volt. For example, if the meter has 250 volts full-scale deflection, the resistance is 250,000 ohms. At full scale the current is $I = \frac{E}{R} = \frac{250}{250{,}000} = \frac{1}{1000}$ amperes = 1 milliampere. This indicates that the current required for full-scale deflection is $\frac{1}{\text{number of ohms per volt}}$. A 20,000 ohms-per-volt meter requires $\frac{1}{20{,}000}$ ampere, or 0.05 milliampere, or 50 microamperes for full-scale deflection.

Q. 3.196. What type of indicating instrument is best suited for use in measuring radio-frequency currents?

A. The thermocouple type of r-f ammeter is the most widely used.

D. See Question 3.188.

Q. 3.197. What is the purpose of a "shunt" as used with an ammeter?

A. A shunt across an ammeter permits an increase in the indicating range of the meter which is almost inversely proportional to the resistance of the shunt.

D. The following problem illustrates this answer:

Problem: Given a milliammeter of full-scale deflection equal to 1 milliampere, and an internal resistance of 50 ohms, what value of shunt resisance must be connected across the meter terminals to permit full-scale deflection at a current value of 51 milliamperes?

Solution: The basic formula for calculating shunts $R_m I_m = R_s I_s$, from which, $R_s = \frac{R_m I_m}{I_s}$, where R_s is the shunt resistance, R_m is the meter resistance, I_m is the full scale current of the meter alone, I_s is the current which is in excess of full scale meter current and which must flow through the shunt. In this example the shunt current will be 50 milliamperes.

$$R_s = \frac{50 \times 0.001}{0.05} = 1 \text{ ohm}$$

Another way of looking at it, is this. Since the shunt must carry 50 times the current that the meter does, it must have 1/50 the resistance of the meter (the voltage across each is identical).

Q. 3.198. What effects might be caused by a shorted grid condenser in a three-circuit regenerative receiver?

A. The receiver would be mostly or completely inoperative.

D. Shorting the grid condenser has the effect of placing the grid at cathode potential for d.c. Thus it is not possible for the grid leak bias to vary and grid leak detection cannot take place. Since zero bias will now be present, there will be a high value of plate current. But, since the tube will be operating on the upper curved portion of the tube characteristic, it is likely that some form of plate detection will occur, but at considerably reduced sensitivity and volume.

Q. 3.199. What would be the effect of a short-circuited coupling condenser in a conventional resistance-coupled audio amplifier?

A. The results would be:

(1) Excessive plate current.

(2) Extreme distortion.

(3) Very low gain.

(4) Large value of grid current.

D. If the coupling condenser shorted, the positive plate voltage of the preceding stage would be applied directly to the grid of the amplifier. This voltage will usually be sufficient to overcome the normal tube bias and cause the tube to operate in the extreme upper part of its characteristic. Thus high plate current would flow and the distortion would be extreme, while the gain will be very small if any. If this were a power stage the tube might become damaged.

Q. 3.200. What might be the cause of low sensitivity of a three-circuit regenerative receiver?

A. Low sensitivity might be caused by:

(1) Faulty tube.

(2) Insufficient plate, screen, or filament potentials.
(3) Insufficient feedback.
(4) Out of phase feedback.
(5) Shorted grid condenser.
(6) Open grid condenser.
(7) Open or incorrect grid resistor.

D. The above faults, plus the possibility of an open coil, might also prevent regeneration or oscillation. A detailed discussion of the effect of an open grid leak follows.

An open grid resistor would not permit the grid condenser to discharge. Assuming perfect insulating and non-leakage conditions, the grid condenser would charge up to the peak value of the strongest input signal and "block" the receiver provided that the amplitude of the input signal diminished *considerably*. Under these conditions, the receiver would probably continue to operate, but the output would be distorted. The theoretical performance, in this event, would be dependent upon the shape and position of the tube characteristic curves, upon the magnitude of the maximum signal, and upon the magnitude of the new reduced signal. An analysis would be difficult.

In practical cases, leakage conditions of various degrees always exist and thus the operation of the receiver might vary from almost normal to "motorboating" or non-operation, depending upon the degree of leakage present.

See Questions 3.267 and 3.268.

Q. 3.201. What is the effect of local action in a lead-acid storage cell and how may it be compensated?

A. Local action causes a slow discharge in the cell accompanied by a formation of very hard sulphate on the plates which is difficult to get rid of. The effects of local action may be reduced by maintaining the battery on a trickle charge when not in actual use.

D. "Local action" is a chemical action going on at all times within a battery, and is due to the presence of impurities in the electrodes. If impurities are present in the electrodes of a battery, a local current will be set up due to the action of the electrolyte upon the dissimilar substances. In a dry cell it will actually cause the casing to disintegrate in time, while in a lead-acid cell, a very hard white crystalline sulphate is formed which is extremely difficult to remove.

In a dry cell local action is reduced by combining mercury with the zinc plate. In a lead-acid cell, local action is reduced by trickle charging and keeping the cell fully charged at all times.

Q. 3.202. Why should adequate ventilation be provided in the room housing a large group of storage cells?

A. To prevent gas accumulation and overheating of the battery.

D. During the charging process gases are given off from the battery. These include considerable hydrogen which is inflammable and can be explosive if confined. Fire of any type including lighted tobacco should not be allowed within the vicinity of batteries, particularly on charge. Battery covers should be opened when the battery is charging to prevent gas pressure from building up.

Q. 3.203. When should distilled water be added to a lead-acid storage cell and for what purpose?

A. The level of the electrolyte in a lead-acid cell should be kept about ¼ inch above the top of the plates. During charge and discharge some of the water (not acid) evaporates and so must occasionally be replaced with pure water. If the level is allowed to be continously low, the useful plate area will diminish and the capacity of the battery will be reduced.

D. See Question 3.150.

Q. 3.204. How may the polarity of the charging source to be used with a storage battery be determined?

A. By the voltmeter or salt water method.

D. The safest and most convenient method would be to use a suitable voltmeter. Connect the voltmeter to the line until it (voltmeter) reads in the right direction. The polarity of the voltmeter is also then the polarity of the line.

Another method, which is not recommended because of the hazard, is to dip the two terminals into a container of water into which a minute quantity of salt has been dissolved. The greater amount of gas bubbles will collect upon the negative terminal.

Q. 3.205. Describe the care which should be given a group of storage cells to maintain them in good operating condition.

A. The following items should be carefully checked in order to maintain a group of storage cells in good operating condition.

(1) Electrolyte should be kept about ¼ inch above plates by adding pure water when needed.

(2) Cells should always be kept fully charged, and on trickle charge when not in use.

(3) Cells should be frequently checked to determine state of charge.

(4) Any cell showing unusual conditions should be removed from the circuit.

(5) If electrolyte is spilled, it should be replaced after the battery is fully charged, using electrolyte of the rated specific gravity.

(6) Proper ventilation must be provided.

(7) Observe correct charge and discharge rates.

(8) Overcharge somewhat about once each month to remove sulphation.

(9) Keep exterior of battery dry and terminals coated with vaseline or other suitable lubricant.

(10) Keep all terminal connections clean and tight.

Q. 3.206. What may cause the plates of a lead-acid storage cell to buckle?

A. The plates may buckle due to the formation of excessive sulphation and from overheating. This is usually caused by overdischarging of the battery.

D. See Questions 3.153 and 3.162.

Q. 3.207. What may cause "sulphation" of a lead-acid storage cell?

A. Sulphation is a normal process in a lead-acid cell. However, excessive sulphation will be caused by overdischarging and by local action through improper charging.

D. The battery should be given an overcharge about once a month if in continual use, or kept on trickle charge when not in use for any extended period. See Question 3.162.

Q. 3.208. What chemical may be used to neutralize a storage cell acid electrolyte?

A. Ammonium hydroxide (ammonia), baking soda (sodium bicarbonate), or washing soda (sodium carbonate) may be used to neutralize acid electrolyte.

D. Great care must be taken to allow none of these substances to get inside the battery. See Question 3.150.

Q. 3.209. What steps may be taken to prevent corrosion of lead-acid storage cell terminals?

A. The cell terminals should be occasionally cleaned and coated with vaseline or other suitable lubricant.

D. Connections should be made before the terminals are coated and care must be taken to see that all terminal connections are tight.

Q. 3.210. Why are by-pass condensers often connected across the brushes of a high-voltage direct-current generator?

A. To protect the generator windings from high voltage surges, and reduce radio-frequency interference.

D. The armature of a high voltage generator consists of coils which have a great many turns of wire. These armature coils are suitably insulated against normal voltages and reasonable amounts of excess voltage. However, if there should be a high frequency impulse in the high voltage circuit, such as might be caused by simply opening the high voltage switch, the collapsing magnetic fields in the armature would develop voltages across the armature coils considerably in excess of the normal insulation rating. As a result, the armature insulation might break down and put the generator out of service.

To protect against such a failure, by-pass condensers are connected across the brushes and to ground. The reactance of these condensers should be high with respect to the generator ripple frequency but very low with respect to any high frequency impulses, which are effectively short circuited by the condensers. See also Question 3.212.

Q. 3.211. What may cause a motor-generator bearing to overheat?

A. The most obvious cause would be lack of lubrication or incorrect type of lubrication. Other causes might be: consistent overload, lack of ventilation, dirt in bearings, or misalignment which may result from warping or distortion of base or frame.

D. The first rule in treating an overheated bearing is never to stop the machine, as the bearings might seize (or "freeze") when contraction takes place. If possible, remove the load and slow down the machine considerably. While running slowly make every effort to cool the machine by forced air cooling or other means available. A large quantity of oil and graphite, if available, should be continuously applied while the machine is running slowly. Continue this treatment until the bearing cools to normal temperature. Flush out with flush oil or kerosene, and then lubricate with the proper grade of oil. If the heating has not been too severe the bearing will still remain in good condition. If the cause of overheating was due to any overload condition, the overload should be removed before bringing the machine back to normal speed.

Q. 3.212. How may the radio-frequency interference, often caused by sparking at the brushes of a high-voltage generator, be minimized?

A. By the use of brush by-pass condensers, and high and low frequency filters.

D. Sparking interference is usually caused by the fact that certain elements within the generator form tuned circuits of various frequencies, and that connections and power leads behave as antennas to radiate these frequencies. The action of the spark in this case is similar to a regular spark transmitter, supplying the energy to keep the tuned circuits oscillating. If spark interference suppression is to be successful, the radiating leads must be effectively terminated (as far as radiating frequencies are concerned) very close to the generator.

If a commutator motor is being used, a low-pass filter should be installed close to it, in the motor supply line. With respect to the generator proper, ripple filter (low-pass) should be connected in the high voltage line, as close to the generator as possible. Shielding of long connecting leads will reduce radiation and interference. Brush by-pass condensers should be connected from each brush to ground. If some interference is still present, a "pi" filter made up of an r-f choke and two r-f by-pass condensers can be located close to the generator in the high-voltage line and ahead of the ripple filter. See also Question 3.121.

Q. 3.213. Why are high-reactance head telephones generally more satisfactory for use with radio receivers than low-reactance types?

A. High reactance head telephones are more satisfactory because they can usually be operated without the necessity of an impedance matching transformer.

D. In the usual case, the head telephones are so connected, that they represent the plate load impedance for the tube which is delivering the necessary driving power. To achieve the maximum driving power into the phones with tolerable distortion, it is necessary that a certain relationship exist between the plate load impedance (phones) and the internal plate impedance of the tube. For a medium mu (20) triode, the load impedance should be from 2 to 4 times the internal plate impedance. For a high-mu (100) triode the load impedance may be approximately equal to the internal plate impedance, and for a tetrode or pentode, the load impedance is in the order of 1/10 of the internal plate impedance. The lowest of any of these values would be in excess of 1000 ohms. No proper matching could be made in any of the above cases by using phones with a low impedance of say, 75 ohms. Therefore, for a given type of tube and without the use of an impedance matching transformer, the high impedance phones represent a much better match for the tube impedance than a pair of low impedance phones. The low impedance phones would require an impedance matching transformer if reasonable efficiency is to be achieved.

Q. 3.214. What may cause packing of the carbon granules in a carbon button microphone?

A. Four causes are:
(1) Excessive button current.
(2) Accumulation of moisture.
(3) Jarring the microphone while current is applied.
(4) Sudden puffs of breath striking the diaphragm.

D. See Questions 3.216 and 3.338.

Q. 3.215. Why should polarity be observed in connecting head telephones directly in the plate circuit of a vacuum tube?

A. Polarity should be observed in order to maintain maximum sensitivity when d-c plate current flows through the windings of the headphones.

D. The magnetic type of headphones consists of a permanent magnet and an electromagnet through which the audio-frequency currents flow. These currents cause the total magnetic field to increase and decrease at voice or music (or code) frequencies, and thus cause the metal diaphragm to vibrate in synchronism with the modulating frequencies. If d-c plate current is caused to flow through the electromagnet of the phones, it should be in such a direction as to aid and not oppose the field strength of the permanent magnet. If the electromagnetic d-c field opposes the field of the permanent magnet, it is possible that the magnetic field will be cancelled, and the audio currents flowing in the winding will attract the diaphragm on both positive and negative peaks. The effect is to give a note of twice the applied frequency. If the polarity of the phones is not apparent, it may be experimentally determined by making momentary contact between the two phone leads and the terminals of a low-voltage battery. The polarity which results in the loudest click causes the correct direction of current flow. The lead which was connected to the negative terminal of the battery should be connected to the plate and the other lead to the positive end of the power supply.

Q. 3.216. What precautions should be observed in the use of a double-button carbon microphone?

A. A carbon microphone should not be jarred or tapped while in operation, or subjected to violent sound intensities. The button currents should be equal and within specified limits (usually less than 30 ma).

D. A double-button carbon microphone is connected into a center tapped push-pull type transformer. To realize the advantages inherent in this type of connection, the individual button currents should be equal, and provisions are usually made by means of jacks to check these currents. (10 to 20 ma.) A common cause of button "packing" (or caking) is breaking the circuit while current is flowing through the microphone. A simple filter consisting of .02 μf condensers and three coils of .0014 henry each will effectively protect the button against this cause of "packing." See also Question 3.214. Question 3.338 concerns the construction and characteristics of a carbon-button microphone.

Q. 3.217. If low-impedance head telephones of the order of 75 ohms are to be connected to the output of a vacuum-tube amplifier, how may this be done to permit most satisfactory operation?

A. Low-impedance head telephones may be satisfactorily coupled to an amplifier tube by the use of an impedance matching transformer.

D. In order to achieve maximum output with tolerable distortion it is necessary that a certain value of plate load impedance be presented to the amplifier tube. This value varies with the type of tube and is discussed in Question 3.213. An impedance of 75 ohms will not be satisfactory as a plate load with any of the common types of tubes. Therefore, it is necessary for the tube to work into its proper load impedance and for the phones to work into their proper impedance which is 75 ohms. This is accomplished by making use of the impedance reflecting properties of a transformer. If the load across the secondary of the transformer is 75 ohms, then the primary impedance is found by $Z_p = Z_s \times N^2$. Thus if the turns ratio, which is equal to the voltage ratio, is 10 to 1, the primary impedance will be 75×10^2 or 7500 ohms. If it is desired to find the turns ratio the following formula is applied: $N = \sqrt{\frac{Z_p}{Z_s}}$, where N is the turns ratio, Z_p is the correct plate load impedance and Z_s is the impedance of the driven device (headphones).

Another way of using the 75-ohm phones without a transformer is to connect them as a cathode bias resistor in the output stage. In this case, the B+ goes directly to the plate, and there is no cathode by-pass capacitor. This is the cathode-follower connection, useful for feeding low impedance loads and to reduce distortion.

Q. 3.218. What is the effect on the resonant frequency of adding an inductor in series with an antenna?

A. Adding an inductor in series with an antenna has the effect of reducing the resonant frequency of the antenna.

D. An antenna can be considered to be a resonant circuit. Taking a halfwave (dipole) antenna in free space as a basic example, it will be found that the antenna will resonate at a frequency whose wavelength is equal to *twice* the *physical* length of the antenna. In free space the velocity of wave travel from one end of the antenna to the other and back is almost equal to the velocity of light (if wire is very thin) which is 300,000,000 meters per second. Thus in *free space* the *physical* length of a *half-wave antenna* in *meters* may be calculated from the formula, $l = \frac{300{,}000{,}000}{2 \times (\text{freq. in cycles})}$. This is so because the antenna will resonate at a frequency determined by the length of time required for a wave to travel from one end of the antenna to the other (180°) and to return (360°). From the above, it must be realized that the resonant frequency of any antenna is a direct function of the velocity of the wave along the antenna wire. In the practical case, the antenna is never completely isolated from the surrounding objects, and this causes the velocity of the wave along the antenna wire to *decrease* somewhat. Thus the *physical* length of the antenna must be *shortened* if it is still to resonate at the same frequency as in free space. The exact amount of the reduction of length is difficult to state, but a rough approximation of 5% may be used as a starting point. The approximate *physical* length of a *half-wave* antenna in *feet* may then be found from the formula $l = \frac{468}{f\,(\text{mc})}$

It has been stated above that the resonant frequency is dependent upon the velocity of the wave along the antenna. Thus any factors tending to *reduce* the velocity along a given *length* of wire will cause the antenna to resonate at a *lower* frequency. The addition of series *inductance* will produce this effect and thus reduce the resonant antenna frequency. Any factors tending to *increase* the velocity along a given length of wire will cause the antenna to resonate at a higher frequency. The addition of series *capacitance* will produce this effect and *increase* the resonant frequency of the antenna.

The following method, while possibly not strictly accurate, will provide a means of remembering the above facts. Consider the resonant frequency of an antenna to be expressed by the formula, $f = \frac{1}{2\pi\sqrt{LC}}$

Now if *inductance* is added in *series* with the antenna (and its inductance) the effect is to *increase* the total antenna inductance. If L *increases* in the formula, the frequency *decreases*. If *capacitance* is added in *series* with the antenna (and its capacitance), the total antenna capacitance is *decreased*. If C *decreases* in the formula, the frequency *increases*.

Q. 3.219. What is the effect on the resonant frequency of adding a capacitor in series with an antenna?

A. A series capacitor increases the resonant frequency of an antenna.

D. See Question 3.218.

Q. 3.220. What is the velocity of propagation of radio-frequency waves in space?

A. The velocity in free space is 300,000,000 meters per second or 186,284 miles per second. This is the same as the velocity of light in free space.

D. The velocity of propagation of radio waves along a transmission line may be considerably different. For example the following values of K express the ratio of the actual velocity of the energy on the line to the velocity of light.

Line	K
Parallel line	0.975
Parallel tubing	0.95
Concentric line	0.85
Twisted pair	0.56 to 0.65

See Question 3.67.

Q. 3.221. What is the relationship between the electrical and physical length of a Hertzian antenna?

A. The radiated wave from a Hertz antenna has a wavelength which is approximately twice the physical length of the antenna.

D. The physical length of an antenna is actually somewhat less than its electrical length due to "end effect," which results from the capacitance between the ends of the antenna and the earth. The end effect varies with the height of the antenna, the diameter of the antenna, and the excitation voltage. As an average figure the physical length is usually about 5% less than the electrical length.

Q. 3.222. If you desire to operate on a frequency lower than the resonant frequency on an available Marconi antenna, how may this be accomplished?

A. An inductance added in series with an antenna will lower the resonant frequency of the antenna and make it possible to operate on a lower frequency than the original resonant frequency of the Marconi antenna.

D. See Question 3.218.

Q. 3.223. What will be the effect upon the resonant frequency if the physical length of a Hertzian antenna is reduced?

A. If the physical length of a Hertz antenna is reduced its resonant frequency will be increased.

D. The length of a Hertz antenna may be found by the formula, $l = \frac{462}{f\,(\text{mc})}$, where l is the half-wave length in feet, and f is the frequency in megacycles. If the frequency is less than about 30 megacycles, the formula becomes $l = \frac{468}{f\,(\text{mc})}$.

Q. 3.224. **Which type of antenna has a minimum of directional characteristics in the horizontal plane?**

A. A single element vertical antenna radiates equally well in all horizontal directions and so has a minimum of horizontal directional characteristics.

D. The directional characteristic of an antenna or antenna system is its ability to discriminate between various directions of receiving or transmitting.

Q. 3.225. **What factors determine the resonant frequency of any particular antenna?**

A. The resonant frequency of an antenna is determined by its *equivalent electrical* length.

D. The physical length is always less than the electrical length and is affected by such factors as: the antenna diameter, height above ground, composition of ground and surrounding territory, and operating frequency. (See Question 3.218.)

Q. 3.226. **If the resistance and the current at the base of a Marconi antenna are known, what formula could be used to determine the power in the antenna?**

A. The power in the antenna may be figured by the formula, $P = I^2R$, where I is the r-f antenna current, and R is the radiation resistance of the antenna.

D. Radiation resistance is a value which is defined as $R_R = P_R/I^2$, where P_R is the power radiated from the antenna. If a resistive load were substituted for the antenna and adjusted to draw the same current as the antenna, then the value of radiation resistance would be approximately equal to the resistor value. For a Hertz antenna (½-wave) the radiation resistance is about 73 ohms in free space, and about 36 ohms for a Marconi antenna (¼-wave). See also Question 3.321.

Q. 3.227. **Does the resistance of a copper conductor vary with the variations in temperature and if so, in what manner?**

A. Copper has a positive temperature coefficient; that is, the resistance increases as the temperature increases, and decreases as the temperature decreases.

Q. 3.228. **What material is best suited for use as an antenna strain insulator which is exposed to the elements?**

A. Glazed porcelain is widely used for insulators exposed to the elements.

Q. 3.229. What material is frequently used for relay contacts? Why?

A. Tungsten is often used as well as silver. These metals have a low amount of corrosion, low contact resistance, and do not pit readily during operation.

Q. 3.230. Describe the operation of a crystal detector (rectifier).

A. A crystal made of suitable substances, such as galena, silicon, or carborundum, exhibits properties similar to a diode vacuum tube. That is, the crystal has a voltage vs. current characteristic which is a square law curve at the smaller values, and then becomes quite linear, as the voltage increases. The current flow when an a-c voltage is applied is mostly unidirectional so that the crystal acts as a rectifier. Instead of a parallel *RC* network such as is shown in Question 3.86, the crystal detector load is made up, usually, of a pair of high impedance headphones in parallel with a condenser similar to that in a diode detector. The incoming modulated r-f carrier is applied to the crystal rectifier and the network (in which *R* is the resistance of the phones) charges and discharges at the audio modulating rate through the phones and thus causes an audible output. Crystals are relatively unstable, and so are not used today except for emergency use. Refer also to Question 3.130, since the crystal and the diode behave similarly as detectors. A diagram of a very simple crystal receiver is given in question 6.563.

Q. 3.231. Why is rosin used as soldering flux in radio construction work?

A. Rosin is non-corrosive, allows a perfect soldering bond to be made, and possesses good insulation qualities.

D. It is important that a soldering flux be a good insulator so as not to offer a conductive path for current in various circuit elements. Acids or salts may affect some components so that no amount of cleaning will remove all traces of the material. Noise and erratic operation may result, and the parts concerned must be replaced.

Q. 3.232. What is meant by an "harmonic"?

A. An harmonic is a whole multiple of an original frequency, called the fundamental. Thus, if the fundamental frequency is 1 megacycle, the second harmonic is 2 megacycles, and the third harmonic is 3 megacycles.

Q. 3.233. Why should all exposed metal parts of a transmitter be grounded?

A. For protection of personnel handling the equipment.

D. Metal parts or a transmitter which are not grounded frequently build up a charge which may be at a rather high potential above ground. Thus anyone coming in contact with such metal parts and ground may receive a dangerous shock. Grounding of all metal parts also greatly reduces electrostatic coupling between units.

Q. 3.234. What is the difference between electrical power and electrical energy?

A. Electrical power is the *rate* of doing work (the rate of expending energy) by electricity. Electrical energy is the *capacity* or *ability* to accomplish work by electricity. ("Work" in this sense includes production of heat, or conversion into any other form of energy.)

D. Electrical power is measured by a unit called the *watt*. One watt is the power expended in heat in a circuit when a current of one ampere (6.28×10^{18} electrons per second) flows through a resistance of one ohm. One watt is one joule per second.

Electrical energy is measured by a unit called the *joule*. Energy in electrical circuits is transferred into the form of heat. A joule is the *amount* of energy expended in moving one coulomb (6.28×10^{18}) of electricity through a resistance of one ohm. One joule = .7376 ft. pound; 3600 joules = 1 watt-hour.

Q. 3.235. How can the direction of flow of DC electricity in a conductor be determined?

A. By means of a magnetic compass and the application of the "left-hand rule."

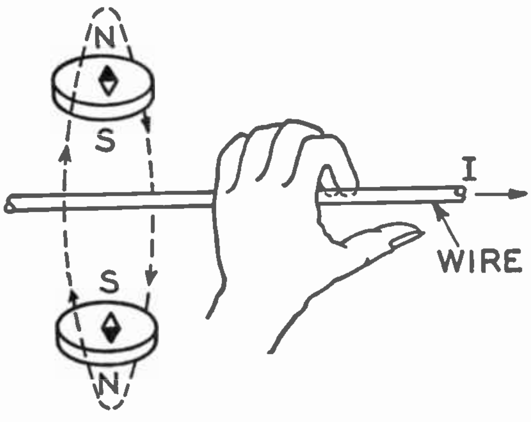


Fig. 3.235. Left-hand rule for relation between current in a wire and the surrounding magnetic field.

D. The magnetic compass is held either above or below the conductor. The pointer of the compass will tend to line up at right angles to the conductor in the direction of the magnetic field. The fingers of the left hand are curved around the conductor in the direction of the compass pointer. The thumb now points in the direction of the electron flow.

A simpler and more obvious means would be to connect an ammeter with marked polarities in series with the circuit so that the needle deflected properly. The direction of electron flow would then be from minus to plus through the meter.

Note that the "conventional" direction of current flow is opposite to direction of electron flow.

Q. 3.236. What instrument measures electric power?

A. A *wattmeter* measures electrical power.

D. See Question 3.183.

Q. 3.237. What instrument measures electrical energy?

A. A watt-hour meter measures the expenditure of electrical energy.

D. The operating principle of an a-c watt-hour meter is usually that of the induction motor. The torque developed in the motor at any instant is proportional to the power passing through the meter at that instant, since it is produced by the combined action of a series (current) field, and a shunt (voltage) field. (Power $= E \times I \times$ *Power-Factor.*) An aluminum disk is attached to the motor shaft and revolves between the poles of two permanent magnets. As the meter operates, eddy currents are set up in the aluminum disk which produce a resisting force and tend to limit the speed of the motor. For any given power being consumed, this resisting force and the driving torque are equal. Since driving torque is proportional to power, and resisting force is proportional to speed, the result is that the speed is proportional to the power. Attached to the motor shaft is a gear-and-dial mechanism which operates the various pointers indicating the energy consumed, which is the product of elapsed time and power in terms of watt-hours and fractions of watt-hours.

Q. 3.238. What is an electron? An ion?

A. An electron is a minute subdivision of matter, having the smallest known unit of a *negative* electric charge. Electrons are ordinarily found as an essential part of the structure of an atom; they are about 1/2000 as massive as the smallest atom. Electrons having like charges have a tendency to repel each other. An ion is an atom or a chemical group of atoms, which has either an excess or a deficiency of electrons.

D. Ions are commonly thought of as being positive in electronic circuit and vacuum tubes. Here it is usually a case of an atom being struck by a moving electron, the impact liberating one or more electrons from the atom. This leaves the atom with a net *positive* charge and it is then called a positive ion. There are also negative ions, which are atoms containing an excessive number of electrons. These *negative* ions are more commonly found in electrolyte solutions.

Q. 3.239. With respect to electrons, what is the difference between conductors and non-conductors?

A. A good conductor has a large number of "free" electrons, while an insulator or non-conductor has very few free electrons.

D. In any substance, the outer ring of electrons of an atom of that substance determines its electrical characteristics. If the outer ring is lightly bound to the atom, it is possible that one or more electrons in the outer ring will leave the atom without much urging from an external source. Such an electron is called a "free" or conduction electron. If many of these electrons are present within a substance, their movement under an applid emf constitutes an electric current, and the substance is then a good conductor. On the other hand, if there are very few of these "free" electrons, the current will be extremely small; in such a case, the substance is called an insulator or non-conductor.

Q. 3.240. Describe an electrolyte.

A. An electrolyte is a liquid capable of conducting electricity, but which undergoes decomposition while so doing.

D. Pure water is a very good insulator. However, when a small quantity of acid, a base, or a salt is added to the water it becomes a fairly good conductor. When the added substance goes into solution it is dissociated into positive and negative ions. For example with a salt solution, positive ions of sodium and negative ions of chlorine are formed. Electrolytes find their greatest usefulness in plating solutions, in electrolytic capacitors, and in batteries, and are almost always water solutions.

Q. 3.241. What is an "A" battery? A "B" battery? A "C" battery?

A. An "A" battery is used for filament power, a "B" battery for plate and screen power, and a "C" battery for a grid bias voltage.

D. Basically, all of these batteries are alike, except that they are specifically constructed to serve a particular function. An "A" battery must supply considerable current at low voltages and thus the cells are few in number and large in plate area. A "B" battery must supply a relatively low current at a much higher voltage and thus consists of many small cells. A "C" battery usually is not called upon to supply any current but maintains a particular d-c potential; it is similar to a "B" battery.

Q. 3.242. What are the lowest radio frequencies useful in radio communication?

A. The lowest useful radio frequencies are in the order of 15 kilocycles.

D. These frequencies are usually produced by high speed mechanical generators. These generators are capable of producing very large output powers. Such very low frequencies are not used much at present, because of the size of antenna required to radiate a significant amount of power.

Q. 3.243. What radio frequencies are useful for long distance communications requiring continuous operation?

A. The most reliable frequencies for long distance radio communication are in the low frequency range in the order of 15 kilocycles.

D. Communication at these low frequencies is usually accomplished by means of ground waves. This requires the generation of extremely high power outputs for reliable and continuous operation. (See also Question 3.242.)

Q. 3.244. What frequencies have substantially straight-line propagation characteristics analogous to that of light waves and unaffected by the ionosphere?

A. These frequencies are the so called ultra-high and micro-wave frequencies ranging from about 50 to 30,000 megacycles, or higher.

D. Microwave systems may employ parabolic reflectors in conjunction with the antenna. The parabolic reflector has substantially the same effect on radio waves that the reflector of a searchlight has on light waves. It directs the radio waves in substantially straight "beams." At these frequencies the ionosphere layers have very little effect upon the waves, which apparently pass directly through it, without being refracted or reflected to any appreciable degree.

Q. 3.245. What effect do sun spots and aurora borealis have on radio communications?

A. The effect of sun spots on low frequency radio communication has been analyzed by the Bureau of Standards. It appears that on an average yearly basis the received trans-Atlantic signals increased in strength in proportion to the degree of sun spot activity. These correlations were made on the basis of the so called 11-year cycle of sun spot activity.

Disturbances in the earth's magnetic field (magnetic storms) are frequently accompanied by a display of aurora borealis. When this occurs, sky wave transmission may become impossible on high frequencies. "Fadeouts" may be caused by sudden disturbances on the sun and are characterized by the rapid disappearance of skywaves. These occur only in daylight and are comparatively short lived. In general, sun spot and aurora borealis activity are accompanied by an instability of receiving conditions. The low frequencies seem to be the least affected.

Q. 3.246. What type of modulation is largely contained in "static" and "lightning" radio waves?

A. "Static" and "lightning" radio waves are mostly amplitude modulated.

D. While some frequency modulation is also present in static and lightning radio waves, the majority of the modulation components are amplitude modulated. Most of these waves are also vertically polarized. Polarization of a radio wave is determined by the direction of the electrostatic field. Antennas which are horizontally polarized reject to some extent interference caused by static and lightning radio waves.

Q. 3.247. What type of radio receivers do not respond to static interference?

A. There is no receiver which is *entirely* unresponsive to static interference.

D. There are two general types of interference which tend to obscure the desired signal in radio receivers. These are (1) static interference, both atmospheric and man-made, and (2) tube noises. Both types of interference are present in AM and FM receivers. However, ordinary AM broadcast receivers have no special provisions to cause the effects of such interference to be minimized in the output. On the other hand, FM receivers have very little sensitivity to such interference, because of the use of circuits such as the ratio detector and de-emphasis network, and others. See discussion under Question 3.498.

Q. 3.248. What crystalline substance is widely used in crystal oscillators?

A. The most widely used crystalline substance is quartz.

D. Certain crystalline substances such as quartz, rochelle salts, and tourmaline have a property known as piezo-electricity. If a pressure is applied to such a substance along one of its axes, a potential difference is developed across another axis. Conversely, a potential difference applied across one axis produces a mechanical displacement along another axis. This phenomenon is known as the "piezo-electric effect." Of all the various substances, quartz is the most generally satisfactory for use in oscillators.

Q. 3.249. Why is the crystal in some oscillators operated at constant temperature?

A. To maintain a constant frequency output from the oscillator.

D. There are many different types of crystal cuts in use each having its own stability characteristics. Most of these change their operating frequency in varying degrees, with changes of operating temperature. Where extreme frequency stability is desired, the crystal may be kept in a constant-temperature oven. See Question 3.421.

Q. 3.250. What is meant by "negative temperature coefficient" of a quartz crystal when used in an oscillator?

A. This indicates that the frequency of the crystal will decrease with an increase of temperature, and increase with a decrease of temperature.

D. See Question 3.417.

Q. 3.251. What is the seventh harmonic of 360 kilocycles?

A. The seventh harmonic of 360 kilocycles is 2520 kilocycles.

D. The seventh harmonic is simply the seventh multiple of the fundamental frequency.

$$360 \times 7 = 2520 \text{ kilocycles.}$$

Q. 3.252. Describe the directional characteristics of the following types of antennas: (a) Horizontal Hertz Antenna, (b) Vertical Hertz Antenna, (c) Vertical Loop Antenna, (d) Horizontal Loop Antenna, (e) Vertical Marconi Antenna.

A. (a) Horizontal Hertz antenna has a bi-directional pattern which is broadside to the antenna. There is minimum radiation or reception in the direction of the ends on the antenna, and maximum radiation in the broadside directions, or at right angles to the line of the antenna.

(b) A vertical Hertz antenna has a pattern which is non-directional with regard to all compass points. It has minimum radiation or reception vertically.

(c) A vertical loop antenna has a bi-directional pattern which is maximum in the directions in the plane of the loop, and minimum in the directions broadside to the loop. (See Question 6.648.)

(d) A horizontal loop antenna is non-directional along the plane of the loop. It has minimum radiation or reception vertically.

(e) A vertical Marconi antenna has a non-directional pattern and minimum radiation or reception vertically. (See Question 6.649.)

Q. 3.253. What is meant by the efficiency of a radio device?

A. The efficiency of a radio device is the ratio of the useful power output to the power input. If a percentage figure is desired, the ratio is multiplied by 100.

D. For example, find the efficiency of a class C amplifier if the carrier output power equals 100 watts and the d-c input equals 133 watts.

$$\text{Efficiency} = \frac{100}{133} \times 100 = 75\%$$

Q. 3.254. What form of energy is contained in a sound wave?

A. Sound wave energy is actually composed of the two general forms of energy, potential and kinetic. Sound, or acoustical, energy is a form of mechanical energy.

D. Sound waves are composed of air vibrations; kinetic energy components are due to the motion of the molecules; potential energy components are due to the elastic properties of air, appearing at compression and rarefaction.

Q. 3.255. What characteristic determines the pitch of a sound?

A. The "pitch" of a sound is determined by the fundamental frequency together with the various harmonic frequencies which combine to make up the sound. The fundamental frequency is usually by far the most important in determining pitch.

D. Many notes on a piano except for the very low tones are made up of three strings. These strings are actually tuned to slightly different frequencies to produce a single note, and are adjusted to give the most pleasing combination of fundamental and harmonic frequencies.

Q. 3.256. How many micromicrofarads are there in one microfarad?

A. There are one million micromicrofarads in one microfarad.

D. The prefix "micro" means to take one millionth of whatever quantity follows.

Q. 3.257. What is the difference between a milliwatt and a kilowatt?

A. A milliwatt is one thousandth of a watt, and a kilowatt is one thousand watts.

D. The prefix "milli" means to take one thousandth of whatever quantity follows.

The prefix "kilo" means to multiply by 1,000 times whatever quantity follows.

Q. 3.258. What precaution should be observed when connecting electrolytic condensers in a circuit?

A. The correct polarity must be observed when connecting electrolytic condensers in a circuit.

D. Electrolytic condensers go through a *forming* process which establishes a dielectric film of an oxide upon the positive aluminum plate. If the polarity connections are reversed, the dielectric film is destroyed, and the condenser becomes practically a short circuit.

Q. 3.259. Show by a diagram how to connect battery cells in series.

A. See the figure.

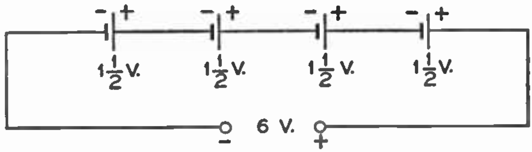


Fig. 3.259. Series connection of battery cells.

Q. 3.260. Show by a diagram how to connect battery cells in parallel.

A. See the figure.

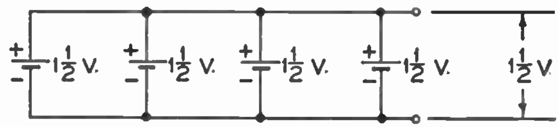


Fig. 3.260. Parallel connection of battery cells.

Q. 3.261. What material is used in the electrodes of a common dry cell?

A. In the usual type of dry cell, the negative electrode is made of zinc and the positive electrode is made of carbon.

D. See Question 3.151.

Q. 3.262. If the period of one complete cycle of a radio wave is 0.000001 second, what is the wavelength?

A. The wavelength is 300 meters.

D. $Frequency = \frac{1}{time}$ or $\frac{1}{.000001} = 1{,}000{,}000$ *cycles*, or 1 *megacycle.*

$$Wavelength = \frac{300{,}000{,}000}{frequency} = \frac{300{,}000{,}000}{1{,}000{,}000} = 300 \text{ meters.}$$

See discussion under Question 3.306.

Q. 3.263. Compare the selectivity and sensitivity of the following types of receivers: (a) Tuned radio frequency receiver. (b) Superregenerative receiver (c) superheterodyne receiver.

A. In the order of *selectivity*, the receivers are: superheterodyne, tuned radio frequency and superregenerative.

In the order of *sensitivity*, the receivers are: superheterodyne, superregenerative, and tuned radio frequency.

D. The superregenerative receiver is extremely sensitive, considering the number of amplifiers used. However, its tuning is extremely broad, due mainly to the fact that the oscillations take place on varying frequencies (frequency modulation).

Q. 3.264. What type of radio receivers contain intermediate frequency transformers?

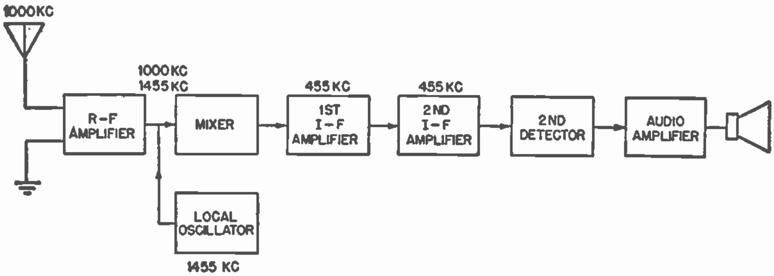


Fig. 3.264. Block diagram of superheterodyne receiver.

A. "Superheterodyne" receivers contain intermediate frequency transformers.

D. A block diagram of a superheterodyne receiver is shown in the figure. Basically the operation of the type of receiver is as follows: The incoming signal from the transmitting station is picked up by the antenna and amplified by the r-f amplifier, after which it is applied to the grid of the mixer stage (1st detector). A locally generated signal produced by the "local oscillator" is also applied to the input of the mixer stage, either to the same grid as the incoming signal, or to another grid depending upon the type of tube used. The mixer is operated basically as a "plate" or "power" detector and as a result of its non-linear operation, a number of frequencies will be present in the mixer plate circuit. These include the two original frequencies, their sum and difference, and various harmonics. Audio frequencies are also present as can be ascertained by connecting a pair of high impedance head phones into the mixer plate circuit. The "intermediate frequency" tuned circuits select one frequency for amplification, which is usually the difference frequency between the local oscillator and incoming signal frequencies. This frequency is then amplified by the i-f amplifiers and applied to the "second detector," usually a diode, and detected and amplified in the usual manner. Advantages of a superheterodyne are good selectivity and sensitivity combined with good stability of the receiver. Disadvantages are complication of circuits and possible reception of "image" frequencies. See also Question 3.273 for further discussion of the mixer stage, and Question 6.587 for a complete schematic diagram. Question 3.492 gives a block diagram of a superheterodyne receiver for f-m signals.

Q. 3.265 What type of radio receiver is subject to image interference?

A. A "superheterodyne" receiver is subject to image interference.

D. The intermediate frequency delivered by the first detector, and selectively amplified by the i-f stages, is the difference between the input signal frequency and the oscillator frequency. There are two signal frequencies which will give the same intermediate frequency for a given oscillator frequency—one higher, and one lower than the oscillator. The input system is designed to select one and reject the other; but it sometimes happens that, due to misalignment of the receiver or to a very strong signal that the unwanted signal will get through to the first detector. When this happens, it causes an intermediate frequency signal which passes through the receiver normally. Such a signal is called "image interference." An incoming signal causing image interference is twice the intermediate frequency above or below the frequency to which the receiver is tuned, depending on whether the oscillator frequency is designed to be above or below that of the desired signal. See Question 3.354 for a numerical example.

Q. 3.266. What type of radiotelephone receiver using vacuum tubes does not require an oscillator?

A. A tuned radio frequency receiver requires no oscillator for the reception of radiotelephone signals.

D. A "tuned radio frequency" receiver does not have intermediate frequency stages. The original incoming signal frequency is amplified without change until detected, or demodulated. A regenerative receiver is in a non-oscillating condition during the reception of radiotelephone signals, and functions in a manner similar to the tuned radio frequency receiver with the exception that some of the output is returned "in phase" to the input circuit, thereby improving the sensitivity and selectivity of the receiver.

Q. 3.267. Describe the operation of a regenerative type receiver.

A. The usual type of regenerative receiver consists of a single stage regenerative detector followed by suitable audio amplification. The detector is basically a grid-leak type, with provision made for feeding back a controllable amount of "in phase" r-f voltage to the grid circuit. A circuit is shown in Question 3.89. It will be noted that this circuit is almost the exact duplicate of the Armstrong oscillator (Question 3.75), the most significant exceptions being that the amount of feedback in the regenerative detector is variable, and that an external carrier frequency is applied to its grid circuit. By providing a controllable amount of r-f feedback (regeneration), the incoming carrier can be amplified many times more than in an ordinary r-f amplifier, thereby greatly increasing both the sensitivity and selectivity of the detector. Briefly the operation is as follows: An incoming r-f carrier is coupled into the tuned grid circuit and applied to the grid. It is then amplified in the usual manner. However, a controllable portion of the plate signal is coupled back into the grid circuit, in phase with the original grid signal thus actually amplifying the original input signal and providing a greater output signal in the plate circuit.

Q. 3.268. How may a regenerative type receiver be adjusted for maximum sensitivity?

A. Maximum sensitivity in a regenerative receiver is obtained at a critical point, which is the condition where the circuit is just about to oscillate. In practice the station is tuned in with the receiver in the oscillating condition. The regeneration control is then slowly backed off until the receiver just breaks out of oscillation and it also below the "fringe howl" point.

D. "Fringe howl" may be caused by the receiver breaking in and out of oscillation at an audible rate. See Questions 3.200 and 3.267.

Q. 3.269. What effect does the reception of modulated signals have on the plate current of a grid-leak grid-condenser type of detector? On a grid bias type of detector?

A. (a) For any fixed value of modulated carrier wave strength, the instantaneous values of plate current in a grid leak detector vary in accordance with the modulation component of the carrier wave. If the carrier is unmodulated, the plate current will be unvarying and will be in inverse proportion to the strength of the carrier wave. The *average* value of plate current varies in inverse proportion to the strength of the modulated carrier wave applied to the grid circuit.

(b) In a grid bias detector, detection takes place in the plate circuit, and thus there are two main frequency components in the plate current, the r-f and the audio (or other modulation) components. Due to the action of the plate circuit filter the average plate current has the same characteristic variation as the modulation component of the carrier wave. The average d-c plate current varies in proportion to the strength of the applied signal. In a grid bias (plate or power) detector responding to weak signals the plate current varies as the square of the applied grid signal voltage. With strong input signals the relationship is approximately linear.

Q. 3.270. What is meant by double detection in a receiver?

A. "Double detection" is the process whereby the original carrier frequency is reduced to a lower frequency and amplified before being applied to a "second detector" where the modulation components of the carrier wave are extracted.

D. "Double detection" is the process used in superheterodyne receivers. (See Question 3.269.) Here the original incoming carrier signal is applied to the first detector (mixer), together with a locally generated oscillating signal, usually at a higher frequency. Since the first detector is operated in a non-linear fashion, various frequencies will appear in its plate circuit. The most important of these frequencies are: (1) The two original frequencies, (2) their sum, (3) their difference, (4) various harmonics. The desired detected signal, which is usually the *difference* frequency, is selected by means of the intermediate frequency transformers and amplified. This lower intermediate frequency still contains the modulation components. The intermediate "carrier" frequency after being amplified is then applied to a second detector and detected in the usual manner. See also Question 3.273.

Q. 3.271. What is the purpose of a wave trap in a radio receiver?

A. In general, the purpose of a wave trap is to prevent the effects of any undesired frequencies from appearing in the output of a receiver.

D. An additional function of wave traps as found in some television receivers is to assist in the shaping of the proper bandpass characteristic of the picture i-f section. Three simple wave traps, to keep unwanted signals from entering the receiver, are given in Question 3.513.

Q. 3.272. What is the purpose of an oscillator in a receiver operating on a frequency near the intermediate frequency of the receiver?

A. The function is to "beat" with the intermediate frequency in the second detector and produce an audible beat note.

D. This oscillator is commonly called a "beat frequency oscillator." The main function of a beat frequency oscillator is to make it possible would otherwise be heard at the output of a receiver as a series of hissing sounds or perhaps "thumps," which would be very difficult to interpret and easily obscured by noise. When the beat frequency oscillator is turned on, a high pitched audible note is produced which is relatively easy to "read."

Q. 3.273. Explain the purpose and operation of the first detector in a superheterodyne receiver.

A. The purpose of the first detector is to act as a mixer by operating in a non-linear fashion and providing the action which produces the desired intermediate frequency.

D. If two frequencies are applied to a perfect class A amplifier, there will be no beating action in the tube, and the only frequencies available in the output circuit will be the original two frequencies. This is because a perfect class A amplifier is a linear circuit. In order to produce "beating" which is necessary for detection or modulation, the two frequencies must be combined in a *non-linear* device. Such a non-linear characteristic may be obtained, for example, by operating a vacuum tube on the non-linear portion of its characteristic. This is exactly what is done in the first detector of a superheterodyne (and the second detector as well). The first detector is operated with a relatively large bias, so that the operation takes place along the lower curved portion of the tube characteristic. If two different frequencies are introduced into such a non-linear device, a distortion of the input voltages will take place so that new frequencies are produced in the plate circuit, which were not originally present in the input circuit. These are mainly: (1) the *sum* of the two original frequencies, (2) the *difference* between the two original frequencies, (3) various *harmonic* frequencies. In addition, the two *original* frequencies will also be present in the plate circuit of the first detector. The desired frequency, which is usually the difference frequency in radio receivers, is selected and amplified by the intermediate frequency amplifiers. See Questions 3.270 and 3.275.

Q. 3.274. What is a "getter" in a vacuum tube?

A. A "getter" in a vacuum tube is a material which is "flashed" by the application of heat after the tube is evacuated, and absorbs any gases remaining inside of the tube.

D. Many "getters" are made of a compound of barium, a common one being barium berylliate. The getter in glass tubes is usually flashed by the application of radio frequency heating. This method is not applicable to metal tubes due to the shielding effect of the outer metal covering. In the case of metal tubes a tantalum ribbon is formed into the shape of a trough and filled with barium berylliate. The ribbon is welded between the ground pin of the octal base and the metal shell. A current is sent through the tantalum between the shell and the pin, causing the barium berylliate to react with the tantalum, producing free barium. It is the condensed barium which produces the mirror-like surface on the glass envelope of some tubes. It is the barium vapors which react with any remaining gases, forming a solid deposit.

Q. 3.275. What is "space charge" in a vacuum tube?

A. "Space charge" is a charge due to the accumulation of negative electrons in the space between certain vacuum tube elements.

D. In a diode which is not operating under saturation conditions, it will be found that a "cloud" of electrons exists between the cathode and the plate; the cloud is concentrated in a thin layer immediately surrounding the emitting surface. This cloud of electrons is called the "space charge" and exists due to the inability of the plate potential to attract all of the electrons leaving the emitter. The space charge has a negative potential and partially cancels the effectiveness of the plate potential in attracting electrons. Under conditions of equilibrium it is found that the space charge is continuously returning electrons to the emitter as well as receiving them from the emitter so that the total space charge remains constant.

In beam power tubes the space charge effect produces a negative gradient of potential at the plate that eliminates the necessity of utilizing a suppressor grid to reduce secondary emission from the plate. Beam power tubes are constructed so that the wires of the control and screen grids lie in the same plane. This causes the electrons to move in concentrated layers. The screen-plate distance is considerably greater than in conventional screen grid tubes, and so called "beam forming" plates are employed, at cathode potential, to assist producing the desired "beam" effect.

Q. 3.276. Explain the operation of a triode vacuum tube as an amplifier.

A. A triode tube amplifies by virtue of the fact that the control grid has a much greater degree of control upon the space charge, than the plate, for any given applied potential.

D. Consider first the conditions existing in a diode. Assume that the plate voltage is zero and that the cathode is properly heated. Electrons will be emitted by the cathode, and attracted back to the cathode in such a way that an electron "cloud" of constant density will form around the immediate vicinity of the cathode. This "cloud" is called the space charge. If a relatively low positive potential is applied to the plate (with respect to the cathode), the plate assumes a positive charge, as in any condenser, and an electrostatic field will exist between the plate and cathode. The forces acting in this field will be in such a direction as to urge electrons to move toward the plate and away from the space charge. With a low value of plate voltage applied, the forces will be relatively weak and a comparatively small number of electrons will move into the plate and form in the external circuit a small value of plate current. If the plate voltage is increased, the positive charge of the plate will also be increased and this in turn will increase the forces acting in the electrostatic field. More electrons will be removed from the space charge during any given period of time (and replenished from the cathode emission) and thus cause an increased plate current. On the other hand if the original plate voltage were maintained, but the spacing between the plate and cathode were reduced, the plate current would again be increased and in inverse proportion to the spacing. (This would be similar to decreasing the spacing between the plates of a condenser and thereby increasing its charging capabilities by increasing its capacitance.) A simple expression which describes the electrostatic forces acting upon the space charge is $F = \frac{E}{300d}$, where F is the force acting upon the space charge and is measured in dynes (one dyne $= 1/28{,}000$ ounce), E is the potential difference between cathode and plate, and d is the plate-to-cathode spacing in centimeters. The formula shows that the electrostatic forces acting upon the space charge (and producing plate current) vary directly as the applied plate potential, and inversely as the plate-to-cathode spacing. For example, if the plate potential and the plate-to-cathode spacing were simultaneously cut in half, the plate current would remain unchanged. If the plate-to-cathode spacing were reduced to 1/10 of its original distance, the original plate current magnitude could be maintained with only 1/10 of the original plate potential. In other words, for any given applied potential, the degree of control which an electrode possesses with regard to the space charge increases as the electrode is brought closer to the space charge.

The triode has three elements: a cathode; a plate, which is relatively distant from the cathode; and a grid located quite close to the cathode. The grid might be considered to be another plate, but so constructed as to permit the passage of electrons through its wires. The fact that the grid is located so much closer to the cathode than the plate means that, for a given applied potential, the grid will exert a much greater influence upon the space charge and plate current than the plate. Thus a relatively small change of grid voltage is capable of producing a large change in plate current (see definition of trans-conductance, Question 4.182). If an impedance is placed in series with the plate current flow, a relatively large voltage drop will appear across its terminals for each small change of grid potential. Thus, the tube is able to amplify because the control electrode (grid) is placed relatively close to the space in comparison to plate.

Q. 3.277. What is the approximate efficiency of a Class A vacuum tube amplifier? Class B? Class C?

A. (a) For a class A triode the approximate efficiency is 20%. For a class A tetrode or pentode the approximate efficiency is 30%.

(b) For class B the efficiency may be as high as 60%.

(c) For class C the efficiency may be as high as 85%.

Q. 3.278. Does d-c grid current normally flow in a Class A amplifier employing one tube?

A. In the usual class A amplifier there is no grid current.

D. Where minimum distortion is desired, the a-c voltage applied to a class A amplifier must have a positive peak value which will not cause grid current to exist, and a negative peak value which will not cause the plate current to be cut off for any part of the input cycle. The interval between the grid current point and the plate cut-off point determines the maximum peak-to-peak saving of the input signal; the d-c bias locates the center of swing at the proper operation point. The number of tubes used in a class A amplifier is immaterial as far as the existence of grid current is concerned. See Question 3.125.

Q. 3.279. Why must some radio frequency amplifiers be neutralized?

A. In order to prevent sustained oscillations from occurring in the amplifier.

D. If an r-f amplifier is operated with its plate and grid circuits tuned to approximately the same frequency, there is a strong likelihood that the amplifier will act as a tuned-grid tuned-plate oscillator. This is particularly true of triode amplifiers, where the value of grid-to-plate capacitance is relatively large; this would cause large energy feedback from the plate to the grid circuit, and thus permit sustained oscillations to occur. The problem is less serious in tetrodes or pentodes, where the grid-to-plate capacitance is much smaller. Question 3.312 includes a full discussion of several methods of neutralizing.

Q. 3.280. Describe how a vacuum tube oscillates in a circuit.

A. The term "vacuum tube oscillates" is a *slang* expression in radio, and is not meant to indicate that the tube itself oscillates, which would not be true. All oscillators (except relaxation types) require a tuned circuit made up of inductance and capacitance for their operation. It is this tuned circuit which is actually the oscillator. The frequency of an oscillator with reasonably high Q (greater than 10) is found from the approximate formula $f = \frac{1}{2\pi\sqrt{LC}}$, where f is in cycles, L is in henrys, and C is in farads. A conventional type of oscillator operates as follows: when the power switch is turned on, high-frequency current surges pass through the tuned circuit (tank) and shock-excite it into oscillation. If no means were provided to make up energy losses, this oscillation would gradually die out at a rate which would be proportional to the Q of the tank, and the resultant wave train would be called a "damped wave." In order to produce sustained oscillations, it is necessary that the losses which occur in the tuned circuit be replenished from the power supply by means of a vacuum tube. These losses are mainly due to: (1) d-c resistance, (2) a-c resistance (skin effect), (3) coupling into a load, (4) grid power requirements, (5) radiation.

The function of the vacuum tube is to act as a valve which releases pulses of energy into the tank circuit in the correct phase. This energy is usually applied indirectly to the tank circuit by means of a feedback network. These networks usually consist of inductive or capacitive coupling elements which connect the tube with the tank circuit. Many oscillator tubes operate as class C amplifiers and are "cut off" for a large percentage of each cycle. When the potential at the grid side of the tank circuit is passing through its most positive values, the class C bias is overcome and the tube is permitted to conduct for a short period of time, feeding energy into the tank circuit. It should always be borne in mind that the tube itself is *not* the oscillator; the tuned circuit *is*.

Q. 3.281. Is the d-c bias normally positive or negative in a Class A amplifier?

A. The d-c bias in a class A amplifier is usually negative as measured at the grid with respect to the cathode.

D. The same is also true of class B and class C operation. There is a so called "zero bias" tube, such as the 6N7, which operates substantially class B with zero bias between grid and cathode. "Bias" is the grid potential with respect to the cathode. It should theoretically be measured between the elements. There are cases when this is not practical, as for example with cathode bias, and a high resistance from grid to ground; in this case, the meter may cause a voltage drop through the resistor, giving a false reading.

Q. 3.282. What is the composition of filaments, heaters, and cathodes in vacuum tubes?

A. (a) Filaments are usually made of thoriated tungsten.
(b) Heaters are made from tungsten wire.

(c) Cathodes are made of a hollow nickel cylinder, coated on the outside with thorium oxide.

D. See Question 3.99.

Q. 3.283. What is the direction of electronic flow in the plate and grid circuits of vacuum tube amplifiers?

A. (a) The direction of electron motion in the plate circuit of an amplifier is as follows: (1) *Series fed amplifier.* From cathode to plate, through the load impedance, through the power supply and back to the cathode. (See Question 3.306.) The a-c component path is similar except that the power supply impedance is bypassed by a condenser. (2) *Shunt fed amplifier.* From cathode to plate, through the plate choke coil, through the power supply, and back to the cathode. The a-c component path is from cathode to plate, through the plate blocking condenser, through the load impedance to ground, and back to the cathode.

(b) The direction of grid current is from cathode to grid, through the grid condenser (if any), through the grid driving circuit, through the grid bias bypass condenser (if any), and back to the cathode.

Q. 3.284. Draw a diagram showing a method of obtaining grid bias to an indirectly heated cathode type vacuum tube by use of a resistance in the cathode circuit of the tube.

A. See the figure.

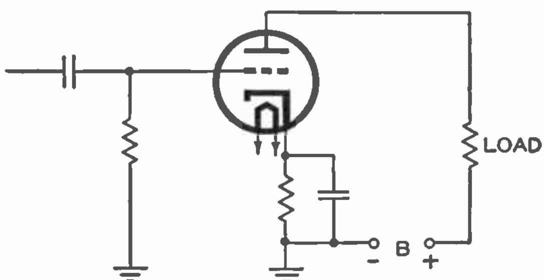


Fig. 3.284. Tube bias by cathode-resistor method.

Q. 3.285. Draw a diagram showing a method of obtaining grid bias to a filament type vacuum tube by use of a resistance in the plate circuit of the tube.

A. See the figure.

Q. 3.286. What is the impedance of a solenoid if its resistance is 5 ohms, and 0.3 ampere flows through the winding when 110 volts at 60 cycles is applied to the solenoid?

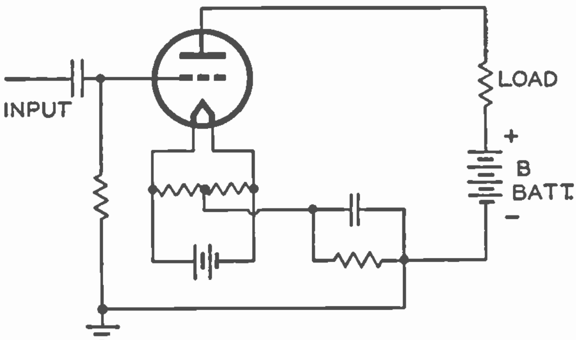


Fig. 3.285. Tube bias by series plate-return resistor.

A. The impedance is 367 ohms.

D. To find the impedance use the formula $Z = \frac{I}{E} = \frac{110}{.3} = 367$ ohms. The resistance and frequency are given but are not needed to solve this problem; they would be required to find the reactance and inductance.

Q. 3.287. What is the conductance of a circuit if 6 amperes flow when 12 volts d.c. is applied to the circuit?

A. The conductance is .5 mho.

D. The conductance, *G*, of a circuit is the ratio of current to voltage. In this case, $G = \frac{I}{E} = \frac{6}{12} = 0.5$ mho.

Q. 3.288. What is the relationship between the effective value of a radio frequency current and the heating value of the current?

A. The effective value (rms) is the same as the heating effect of an r-f current.

D. The effective value of an a-c current is that value which would cause the same heating effect as a d-c current of the same nominal value.

Q. 3.289. What safety precautions should a person observe when making internal adjustments to a television receiver to avoid personal injury?

A. Most modern television receivers utilize Kinescope accelerating potentials which may be as great as 30,000 volts (projection receivers). Therefore, great care should be taken to discharge any high voltage (and low voltage) condensers with a well-insulated screwdriver before attempting to make any internal adjustments.

D. The high voltage condenser is not always obvious. For instance in receivers using a 10BP4 Kinescope tube, the high voltage condenser is actually part of the tube, being graphite coatings on the inside and outside of the glass forming the sides of the tube. Before attempting to remove such tubes, care should be taken to discharge the high voltage condenser. *Never trust a bleeder.*

Q. 3.290. With measuring equipment that is widely available, is it possible to measure a frequency of 10,000,000 cycles to within one cycle of the exact frequency?

A. It is not possible with widely available equipment.

D. This would require an accuracy of one part in ten million, or of $\frac{1}{100,000}$ %. Such accuracy would be extremely difficult to obtain even with the most expensive precision laboratory equipment.

Q. 3.291. Do oscillators operating on adjacent frequencies have a tendency to synchronize oscillation or drift apart in frequency?

A. Oscillators which are operating on adjacent frequencies have a tendency to synchronize oscillation or "lock-in." The resultant frequency is usually that of the oscillator having the highest Q tank circuit.

Q. 3.292. What form of energy is stored in lead-type storage batteries?

A. Chemical energy is stored in a battery by the effect upon the chemical composition of the plates and electrolyte.

D. The chemical energy produces, as a result, an electrical potential energy between the terminals. Depending on the load, this may be converted into one or more different forms of energy:

Mechanical (motor), magnetic (solenoid), heat, light, or even chemical (plating, or charging a weaker battery.)

Q. 3.293. What precaution should be observed when using and storing crystal microphones?

A. Crystal microphones, in use or in storage, should be protected from shock, vibration, humidity, or very warm temperatures.

Q. 3.294. If a 1,500 kilocycle radio wave is modulated by a 2,000 cycle sine wave tone, what frequencies are contained in the modulated wave?

A. The following important frequencies are present: (1) 1500 kc., (2) 1502 kc., (3) 1498 kc.

D. When a radio wave is modulated (or demodulated, or "beat") with another sine wave frequency in a non-linear system, new frequencies are generated which were not originally present. The most important of the frequencies present are the two original frequencies, their sum and difference, and various harmonic frequencies.

Q. 3.295. Why are laminated iron cores used in audio and power transformers?

A. To reduce eddy current losses in the iron core.

D. If the iron core is made of one solid piece of iron, the eddy currents will attain very large amplitudes, the I^2R losses in the core will be excessive, and the effective inductance of the coil will be reduced. In order to minimize this effect the core is made up of laminations, which are thin, insulated layers of iron. The eddy currents have a much higher resistance path in which to flow and consequently are much decreased in amplitude. See also Question 3.164.

Q. 3.296. What are cathode rays?

A. The term "cathode ray" usually applies to a fairly high velocity electron beam, such as is found in cathode ray tubes. The effect of the cathode rays is made visible by allowing the electrons to bombard a a fluorescent screen.

Q. 3.297. Why is a high ratio of capacity to inductance employed in the grid circuit of some oscillators?

A. To improve the frequency stability of the oscillator.

D. A major cause of oscillator "drift" is due to changes in the total tuning capacitance of the oscillator. These include such factors as tube capacitance, wiring capacitance, and reflected reactance. If the original tuning capacitor is made relatively large, then any such capacity changes will cause a smaller percentage change of the total capacitance than if the original tuning capacitance were much smaller. Thus the percentage of oscillator frequency change is less when the oscillator tank has a high C to L ratio.

Q. 3.298. What is the purpose of a buffer amplifier stage in a transmitter?

A. A buffer amplifier is used to improve the frequency stability of the oscillator stage.

D. A buffer amplifier is located immediately following the oscillator. It has low gain and low Q circuits and draws no grid current. Thus it presents a very high impedance load upon the oscillator and does not affect the oscillator Q to any great extent. Any changes in tuning of the succeeding amplifier or antenna stages have little or no effect upon the output frequency of the oscillator. If a buffer amplifier were not present, such tuning changes, or even motion of the antenna, might change the oscillator frequency.

Q. 3.299. What determines the speed of a synchronous motor? An induction motor? A d-c series motor?

A. (a) The speed of a synchronous motor is determined by the number of pairs of poles and the line frequency. (b) The speed of an induction motor is determined by the number of pairs of poles, the frequency, and to some extent, the load. (c) The speed of a d-c series motor is determined chiefly by the load.

Q. 3.300. What is the total resistance of a parallel circuit consisting of one branch of 10 ohms resistance and one branch of 25 ohms resistance?

A. The total resistance is 7.14 ohms.

D. The most convenient formula to use when two resistances are in parallel is: $R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{250}{35} = 7.14$ *ohms.*

Q. 3.301. Draw a diagram of a resistance load connected in the plate circuit of a vacuum tube and indicate the direction of electronic flow in this load.

A. See the figure.

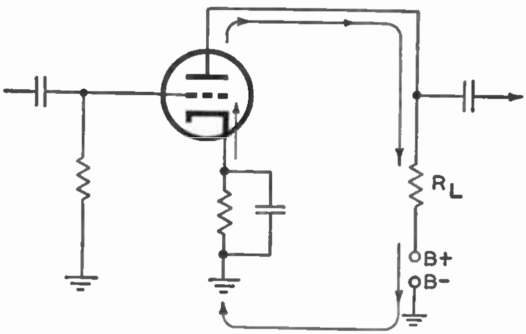


Fig. 3.301. Plate load of tube, and electron flow.

Q. 3.302. Indicate, by drawing, a sine wave of voltage displaced 180 degrees from a sine wave of current.

A. See the figure

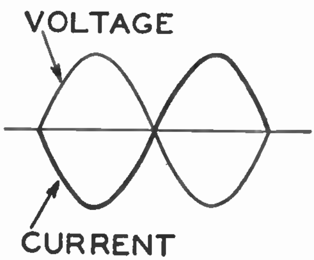
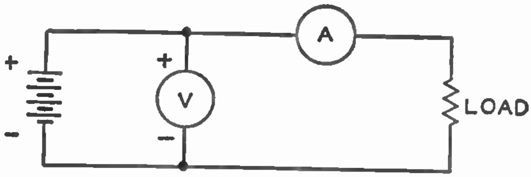


Fig. 3.302. Voltage and current sine waves displaced 180°.

Q. 3.303. Show by a diagram how a voltmeter and ammeter should be connected to measure power in a d-c circuit.

A. See the figure.

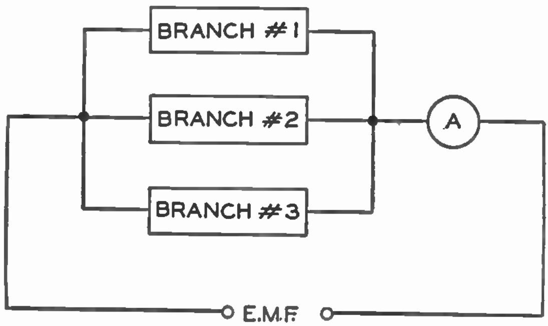
Fig. 3.303. D-c power measurement with voltmeter and ammeter.



Q. 3.304. Indicate by a diagram how the total current in three branches of a parallel circuit can be measured by one ammeter.

A. See the figure.

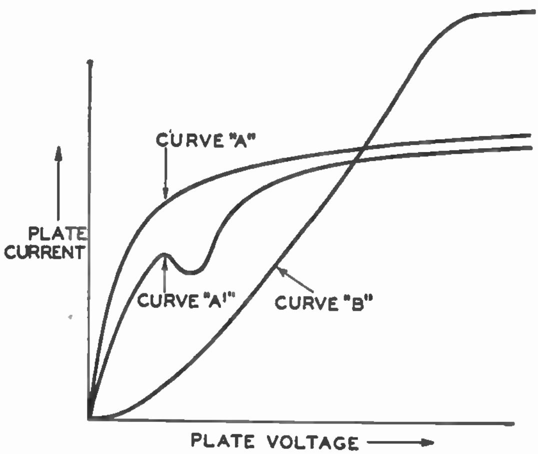
Fig. 3.304. Measurement of total current in a parallel circuit.



Q. 3.305. Draw a graph indicating how the plate current in a vacuum tube varies with the plate voltage, grid bias remaining constant.

A. See the figure. Curve *A* is for a pentode, curve *A′* is for a tetrode, and curve *B* is for a triode.

Fig. 3.305. Typiplate-current-plate-voltage curves.



D. The function of the suppressor grid in determining tube characteristics is plainly shown by comparing curves *A* and *A′*. The effect of the screen grid is seen by comparing either curve *A* or *A′* with curve *B*.

Q. 3.306. Indicate, by drawing, two cycles of a radio frequency wave and indicate wavelength thereof.

A. See the figure.

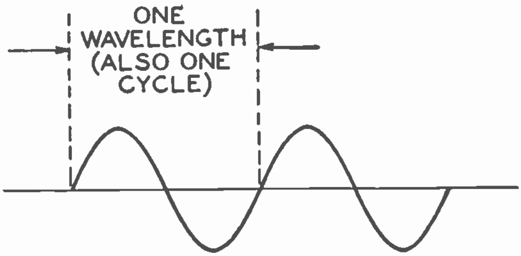


Fig. 3.306. Graph of sine wave.

D. One wavelength is the distance a wave will travel in the time required for one cycle. See Questions 3.67 and 3.220.

Q. 3.307. Explain the purpose and methods of neutralization in radio-frequency amplifiers.

A. The purpose of neutralization in a radio-frequency amplifier is to prevent the amplifier from generating self-sustained oscillations. Without neutralization but with the tuned transformers customarily used, the circuit usually will act as a tuned-plate tuned-grid oscillator. (See Question 3.279.) Three common methods of neutralization are known as: (1) Hazeltine or plate neutralization, (2) Rice or grid neutralization, (3) Cross neutralization or push-pull neutralization.

D. Conventional triode r-f amplifiers with both plate and grid circuits tuned to the same frequency invariably require neutralization. The reason for this is obvious when the r-f amplifier of Question 3.85 is compared with the diagram of a tuned-grid tuned-plate oscillator as shown in Question 3.69. Except for the neutralization connections, the two circuits are identical. Feedback through C_{gp} will cause the circuit to oscillate. If the amplifier is permitted to oscillate, there will be several undesirable effects: (1) Excessive plate current, (2) Overheating with possible burnout of tube, (3) Possible damage to circuit parts, such as meters, r-f chokes, etc. (4) Generation of spurious frequencies, (5) Distortion of a modulated wave (if this stage is modulated) during peaks of modulation. Since the tendency to oscillate is caused by an r-f voltage applied through C_{gp} to the grid, in phase with the original grid voltage, then a bucking voltage must be provided which is equal in amplitude and opposite in phase to the feedback through C_{gp}. The means of providing for such a bucking voltage is to tap the lower end

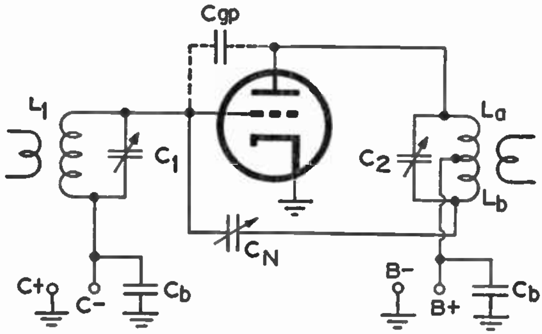


Fig. 3.307(A). Schematic diagram of a plate-neutralized amplifier.

of the plate tank circuit and feed this new voltage into the grid circuit. (1) A schematic diagram and equivalent bridge circuit of a plate-neutralized amplifier are shown in parts (A) and (B) of the figure. The currents flowing into the input circuit through C_{gp} tend to cause

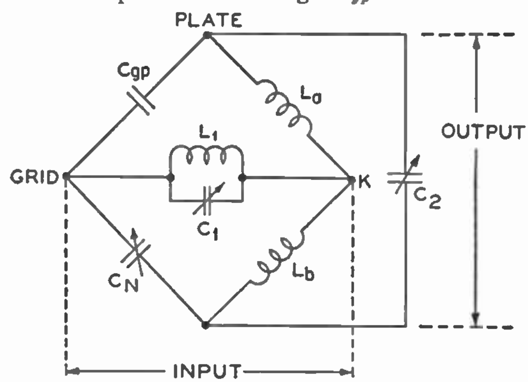


Fig. 3.307(B). Equivalent bridge circuit of a plate-neutralized amplifier.

oscillation. This effect is cancelled by opposing currents fed back to the input circuit through C_n. If the bridge is properly balanced (by adjusting C_n), no oscillations can appear in the output circuit. The relationship for balance is: $\frac{L_a}{L_b} = \frac{C_n}{C_{gp}}$

(2) The schematic diagram and the equivalent bridge circuit of a grid-neutralized r-f amplifier are shown in parts (C) and (D) of the figure. This circuit operates in a manner similar to the plate neutralized system. For a balance, $\frac{L_a}{L_b} = \frac{C_n}{C_{gp}}$, as before.

(3) Push-pull neutralization does not require the addition of any special circuits other than the neutralizing condenser; a schematic diagram is shown in part (E) of the figure. It can be considered to be a form of plate neutralization. Advantage is taken of the fact that the voltages on the two sides of a push-pull amplifier are of opposite polarity, and thus automatically provide the correct phase relations for neutralizing.

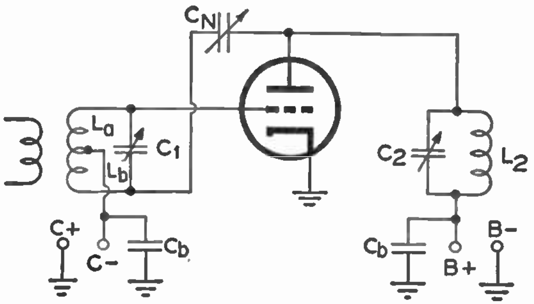


Fig. 3.307(C). Schematic diagram of a grid-neutralized amplifier.

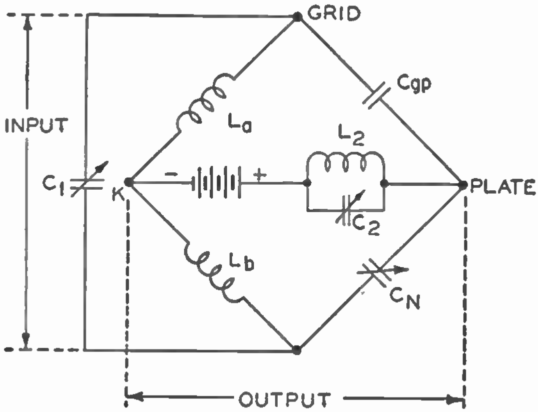


Fig. 3.307(D). Equivalent bridge circuit of a grid-neutralized amplifier.

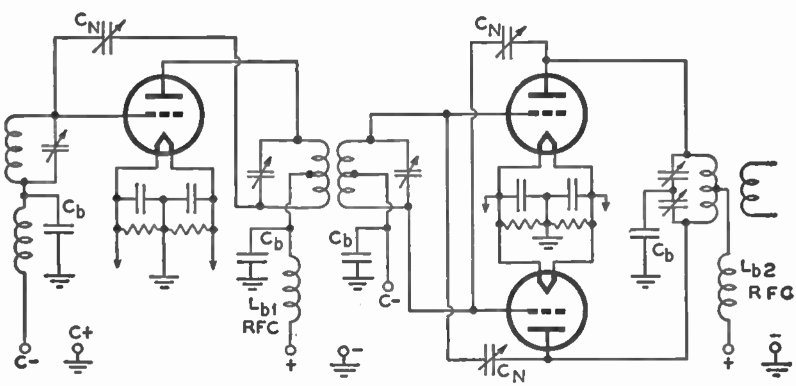


Fig. 3.307(E). Amplifier employing push-pull neutralization.

Q. 3.308. In a circuit consisting of an inductance having a reactance value of 100 ohms and a resistance of 100 ohms, what will be the phase angle of the current with reference to the voltage?

A. The current will lag the applied voltage by 45°.

D. The phase angle is the angle whose tangent is equal to the inductive reactance divided by the resistance or

$$\theta = \tan^{-1}\frac{X_L}{R} = \tan^{-1}\frac{100}{100} = \tan^{-1} = 45°.$$

Q. 3.309. What is the effective value of a sine wave in relation to its peak value?

A. The effective value of a sine wave equals 0.707 × peak value.

D. The effective value of an a-c sine wave is that value which when applied to a resistance would produce the same heating effects as a d-c value of the same magnitude.

Q. 3.310. What is the meaning of "phase difference"?

A. In comparing two sine waves of the same frequency, "phase difference" means that the two waves do not reach their maximum or minimum values simultaneously.

D. The amount by which the maximum or minimum values of the two waves differ, measured in electrical degrees, is their "phase difference." The maximum "phase difference" between two waves is considered to be 180°.

Q. 3.311. What factors must be known in order to determine the power factor of an alternating-current circuit?

A. In order to determine the power factor of an a-c circuit, the values of circuit resistance and the reactance must be known. *Power factor* $= \cos\theta$, where $\cos\theta = \frac{R}{Z}$, and $Z = \sqrt{R^2 + (X_L - X_C)^2}$. Practically, the power factor can be determined by measuring voltage, current and, with a watt meter, the actual power. $P.F. = \frac{Watts.}{I \times E}$

D. See Question 3.34.

Q. 3.312. What are the properties of a series condenser, acting alone in an alternating-current circuit?

A. When a series condenser is acting alone in an a-c circuit and a voltage is applied, a current will exist which will lead the applied voltage by 90°. The magnitude of the current will vary in direct proportion to the capacity of the condenser.

D. If a resistance is added in series with the condenser, the phase angle will become less than 90°, approaching 0° as the resistance becomes larger. See also Question 6.94 for comparison.

Q. 3.313. What is the reactance value of a condenser of 0.005 microfarad at a frequency of 1,000 kilocycles?

A. The reactance is 31.8 ohms.

D. The formula for capacitive reactance is: $X_C = \frac{1}{2\pi fC}$, where X_C is in ohms, f is in cycles, and C is in farads. Substituting the given values,

$$X_C = \frac{1}{6.28 \times 1000 \times 10^3 \times .005 \times 10^{-6}} = 31.8 \text{ ohms.}$$

Q. 3.314. State the mathematical formula for the energy stored in the magnetic field surrounding an inductance carrying an electric current.

A. $W = \frac{1}{2} LI^2$, where W is in joules, L is in henrys, I is in amperes.

D. See Question 3.18 for a capacitor.

Q. 3.315. What is the current and voltage relationship when inductive reactance predominates in an alternating-current circuit?

A. In an inductive circuit, the current lags the applied voltage by an angle which approaches a maximum of 90° when the resistance of the circuit approaches zero.

D. The phase angle in an inductive circuit will decrease as the value of series resistance is increased. When the resistance is at least 10 times greater than the reactance, then for most practical purposes the phase angle can be neglected.

Q. 3.316. Given a series circuit consisting of a resistance of 4 ohms, an inductive reactance of 4 ohms, and a capacitive reactance of 1 ohm, the applied circuit alternating emf is 50 volts. What is the voltage drop across the inductance?

A. The voltage drop across the inductance is 40 volts.

D. Step 1: Find the series impedance $Z_T = \sqrt{R^2 + (X_L - X_C)^2}$, $Z_T = \sqrt{4^2 + (4-1)^2} = \sqrt{16+9} = 5$ *ohms.*

Step 2: Find the series current $I_T = \frac{E}{Z_T} = \frac{50}{5} = 10$ *amperes.*

Step 3: Find the voltage drop across the inductance. $E_L = I_T \times X_L = 10 \times 4 = 40$ *volts.*

Q. 3.317. What would be the effect if direct current were applied to the primary of an alternating-current transformer?

A. Excessive current would be drawn from the line.

D. If uninterrupted d-c were applied to the primary of an a-c transformer the only current limiting factor would be the d-c resistance of the primary winding. Since this resistance is usually in the order of a few ohms, the current value will become very high. If this condition is permitted to continue, the transformer will become overheated and will possibly burn out. If the d-c source is interrupted regularly, as by a vibrator, an a-c transformer may be used, since the interruptions will cause a changing magnetic field which will develop a counter-emf in the primary and thus limit the primary current; this is discussed in Question 3.176.

Q. 3.318. If a power transformer having a voltage step-up ratio of one to five is placed under load, what will be the approximate ratio of primary to secondary current?

A. The primary to secondary current ratio will be about 5 to 1.

D. If the losses in the transformer are neglected, it can be assumed that the power which the primary draws from the line is all transformed to the secondary. If the power ratio is the same and the voltage ratio is 1 to 5, then the current ratio must be in inverse proportion to the voltage ratio, or 5 to 1. The voltage ratio is proportional to the turns ratio or, $\frac{N_p}{N_s} = \frac{E_p}{E_s}$. The current ratio is inversely proportional to the turns ratio, of $\frac{N_p}{N_s} = \frac{I_s}{I_p}$.

Q. 3.319. What is the meaning of "skin effect" in conductors of radio-frequency energy?

A. "Skin effect" is the tendency of alternating currents to exist in the area of a conductor approaching the surface, rather than in the entire cross sectional area of the conductor.

D. The term "skin effect" is most generally used in connection with radio frequencies. However, "skin effect" is present at all frequencies, the magnitude of the effect decreasing as the frequency decreases. At extremely high frequencies, the dept of current penetration is very small, most of the current existing practically on the surface of the conductor. It is for this reason that tubular conductors with large surface areas are used at ultra high frequencies. "Skin effect" exists due to the fact that more magnetic lines of force cut the center of the conductor than cut the outer sections. Thus the self inductance of the conductor is greatest at the center and decreases toward the outer edges. There is more counter-emf developed at the center of the conductor and, therefore, the least amount of current exists at this point. As the frequency increases, the cemf at the center approaches the magnitude of the applied voltage and current practically does not exist at the center. Where the conductor is a round wire or tube, the high frequency resistance at high frequencies in ohms per centimeter $= \frac{83.2\sqrt{f} \times 10^{-9}}{d}$, where d is the outside diameter in centimeters, and f is the frequency in cycles.

Q. 3.320. Neglecting distributed capacitance, what is the reactance of a 5-millihenry choke coil at a frequency of 1,000 kilocycles?

A. The reactance is 31,400 ohms.

D. To find the inductive reactance, use the formula, $X_L = 2\pi fL = 6.28 \times 1000 \times 10^3 \times 5 \times 10^{-3} = 31{,}400$ ohms.

Q. 3.321. What is meant by the term "radiation resistance"?

A. "Radiation resistance" is a fictitious quantity of resistance which, while not present physically in the antenna, is equivalent to a resistance which if inserted in the antenna would dissipate an amount of power equal to that radiated from the antenna.

D. In defining radiation resistance it is necessary to refer it to a particular point in the antenna. This point is usually taken at a current loop (maximum). The radiation resistance must be such that the square of the current times the radiation resistance will equal the power radiated. The grounded end is frequently used as the current reference point. Radiation resistance, $R_{rad} = \frac{\text{radiated power}}{I_{max}^2}$. To determine antenna or radiation resistance by the resistance substitution method, a known value of non-inductive resistance is placed in series with the antenna and antenna ammeter, and a shorting switch is connected across the resistance. All circuits should be correctly tuned and the driver power and output voltage should be maintained constant during the readings. The "antenna resistance" is found from the formula, $R_{rad} = \frac{I.}{I_1 = I_2} = R_1$, where R_1 is the known resistance, I_2 is the antenna current with R_1 in the circuit, I_1 is the antenna current with R_1 shorted out.

Q. 3.322. What is the value of total reactance in a series resonant circuit at the resonant frequency?

A. The total reactance is zero at the resonant frequency.

D. The definition of series resonance specifies that the inductive reactance and the capacitive reactance are equal. Since the inductance tends to cause a 90° lag of current and the capacitance a 90° lead of current the effect of the two reactances cancel, being equal and opposite, and the net impedance is purely resistive and contains no reactive component.

Q. 3.323. What is the value of reactance across the terminals of the capacitor of a parallel resonant circuit, at the resonant frequency, and assuming zero resistance in both legs of the circuit?

A. The value of reactance will be zero.

D. The assumption as stated in the question is that zero resistance appears in both legs of the circuit. Under this condition parallel resonance occurs when $X_L = X_C$. These are equal and opposite reactances and the total reactance will then be zero. The impedance measured across the combination will be infinite. Actually this is a theoretical condition since there is always appreciable resistance in the inductance leg of the parallel resonant circuit. In this case the net reactance will be capacitive. In order to have the line current in phase with the applied voltage, X_C must equal $X_L + \frac{R}{Q}$.

Q. 3.324. Given a series resonant circuit consisting of a resistance of 6.5 ohms, and equal inductive and capacitive reactance of 175 ohms, what is the voltage drop across the resistance, assuming the applied circuit potential is 260 volts?

A. The voltage drop across the resistance is 260 volts.

D. There is no need to make any calculations for the solution of this problem. The voltage drop across the two reactances at resonance is zero, and, therefore, the line voltage or 260 volts must appear across the resistance.

Q. 3.325. Given a series resonant circuit consisting of a resistance of 6.5 ohms, and equal inductive and capacitative reactances of 175 ohms, what is the voltage drop across the inductance when the applied circuit potential is 260 volts?

A. The voltage drop across the inductance is 7000 volts, assuming that the resistance is part of the inductance coil.

D. In a series resonant circuit the voltage drop across either reactive element equals Q times the applied voltage, where $Q = \frac{R}{X_L}$. For this problem $Q = \frac{175}{6.5} = 26.9$. The voltage across the inductance (or capacitance) equals $26.9 \times 260 = 7000$ volts.

Q. 3.326. Under what conditions will the voltage drop across a parallel-tuned circuit be a maximum?

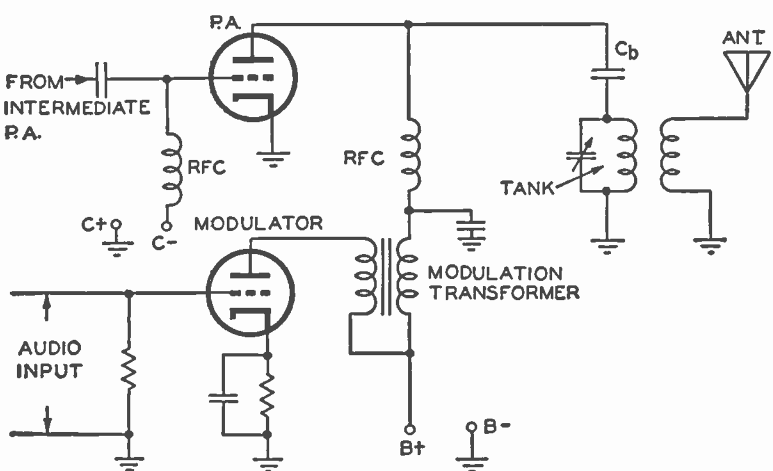


Fig. 3.327. Method of coupling to obtain plate modulation.

A. Assuming some resistance in series with the combination, the voltage drop across a parallel resonant circuit will be a maximum when the applied voltage is at the resonant frequency of the tuned circuit.

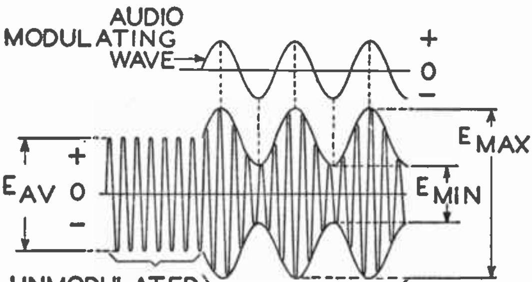
D. For a circuit of high Q (greater than 10) the line current will be minimum at approximately the resonant point. If the line current is minimum, the drop in the series resistor will also be minimum, thus permitting a maximum of the generator voltage to appear across the resonant circuit.

Q. 3.327. Draw a simple schematic diagram showing a method of coupling a modulator tube to a radio-frequency power-amplifier tube to produce plate modulation of the amplified radio-frequency energy.

A. See the figure.

D. See Questions 3.335 and 3.363.

Q. 3.328. Draw a diagram of a carrier-wave envelope when modulated 50 per cent by a sinusoidal wave. Indicate on the diagram the dimensions from which the percentage of modulation is determined.



$$\text{PERCENTAGE MODULATION} = \frac{E_{MAX} - E_{MIN}}{2\,E_{AV}} \times 100$$

Fig. 3.328. A 50-per-cent modulated wave.

A. See the figure.

D. Assume the carrier amplitude to be 100 volts unmodulated, the value of E_{max} to be 150 volts, and the value of E_{min} to be 50 volts. The percentage modulation is found according to the formula:

$$Mod. = \frac{E_{max} - E_{min}}{2\,E_{av}} \times 100 = \frac{150 - 50}{200} \times 100 = 50\%$$

For 100% modulation E_{max} would be 200 and E_{min} would be zero.

Q. 3.329. Draw a diagram of a microphone circuit complete with two stages of audio amplification.

A. See the figure for a circuit using a condenser microphone.

D. A "condenser microphone," as the name implies, acts as a condenser whose capacitance is varied according to the characteristics of the sound wave impressed upon its diaphragm. The diaphragm is a thin, tightly stretched metal disk which is in close proximity to a heavier fixed metal plate. The fixed plate acts as the second plate of a condenser, the dielectric being air. The air also serves as a damping medium. A d-c charging potential in the order of 200 volts is applied to the microphone through a high resistance. Any changes in capacitance cause charging and discharging currents to flow through this series resistance, thus developing the output voltage of the microphone. The output impedance of the microphone is extremely high and the output is very low, a combination which necessitates building a preamplifier right into the microphone case.

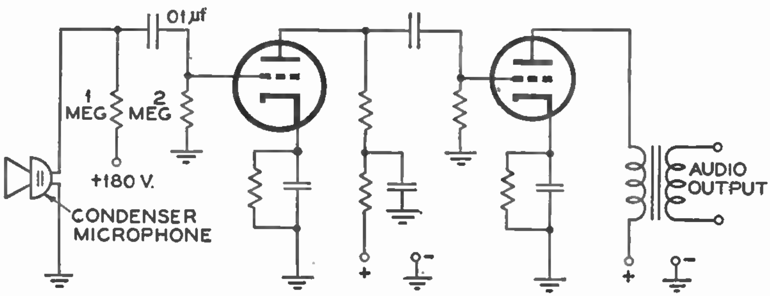


Fig. 3.329. A condenser microphone and two amplifier stages.

Q. 3.330. Draw a simple schematic diagram showing a Heising modulation system capable of producing 100 per cent modulation. Indicate power-supply polarity where necessary.

A. See Questions 6.438 and 6.439.

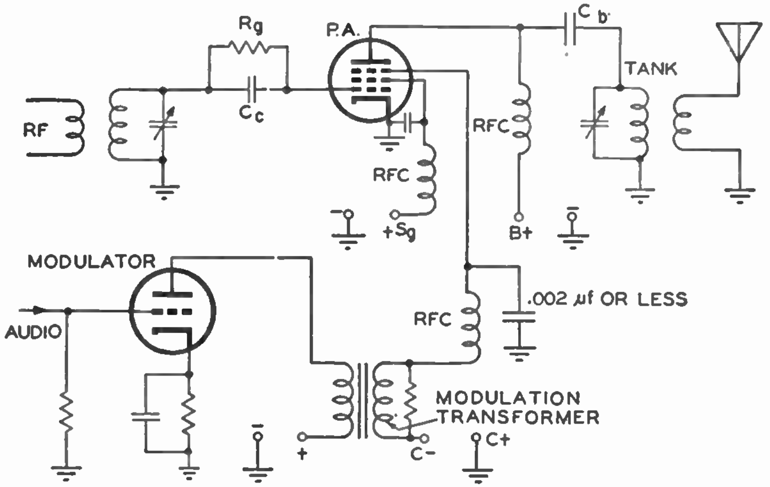


Fig. 3.331. Suppressor-grid modulation system.

Q. 3.331. Draw a simple schematic diagram showing a method of suppressor-grid modulation of a pentode-type vacuum tube.

A. See the figure.

D. See Question 3.335.

Q. 3.332. Draw a simple schematic diagram showing a method of coupling a modulator tube to a radio-frequency power-amplifier tube to produce grid modulation of the amplified radio-frequency energy.

A. See the figure.

D. See Question 3.335.

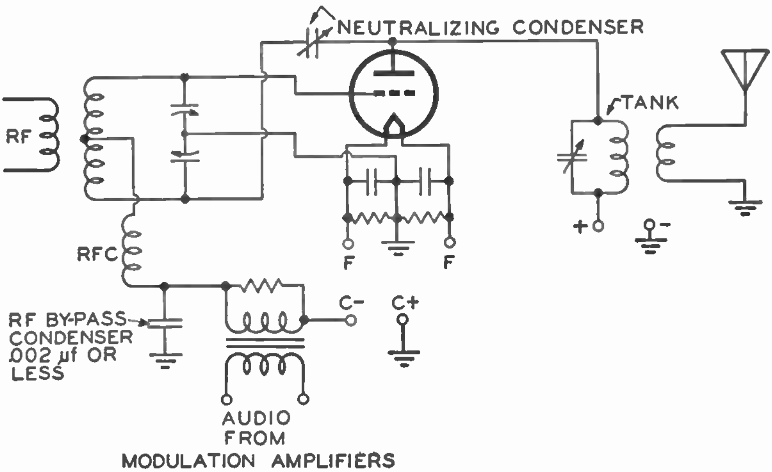


Fig. 3.332. Method of producing grid modulation.

Q. 3.333. What is meant by "frequency shift" or "dynamic instability" with reference to a modulated radio-frequency emission?

A. "Frequency shift" or "dynamic instability" refers to the instantaneous changes of oscillator frequency due to corresponding changes of plate and screen grid voltages of the oscillator tubes and is caused by improper regulation of the power supply.

D. If a common power supply were used for the oscillator, r-f amplifiers, and modulator stages, it would be difficult to prevent "dynamic instability," especially if the modulator was not operating strictly class A. Any changes in loading due to any cause, or any changes in modulator power requirements will create a change in power supply output voltage. This in turn may cause the oscillator frequency to shift, creating undesired frequency modulation. In general, an increase of oscillator plate voltage (with screen voltage constant) will cause the oscillator frequency to increase because of a decrease of tube input capacity. A proportional increase of screen voltage would have the opposite effect on the frequency, and this factor is taken advantage of in the electron-coupled oscillator to maintain frequency stability and reduce "dynamic instability." Dynamic instability can also be reduced by: (1) using an oscillator tank circuit with a high C/L ratio, (2) by light loading of the oscillator circuit, (3) by using a high value of grid leak, (4) by using separate power supplies for oscillator, modulator, and r-f amplifiers, or at least for the oscillator.

Q. 3.334. What is meant by "high-level" modulation?

A. "High-level" modulation is modulation of an r-f carrier produced in the plate circuit of the last radio stage of the system.

D. Compare Question 3.336. The above definition is taken from Federal Communications Commission's Rules and Regulations, Sec. 3.15.

Q. 3.335. What is meant by "grid modulation"? "Plate modulation"?

A. The term "grid modulation" indicates that the modulation component is impressed upon the carrier wave by introduction into any of the grid circuits of an r-f amplifier stage. See figure for Question 3.332.

The term "plate modulation" indicates that the modulation component is impressed upon the carrier wave by its introduction into the plate circuit of an r-f amplifier stage. See figures for Questions 3.327 and 3.363.

D. While "grid modulation" is a general term, it is usually interpreted to mean "control grid modulation." The other types of grid modulation are usually referred to by name, such as "suppressor grid modulation" and "screen grid modulation."

Q. 3.336. What is meant by "low-level" modulation?

A. "Low-level" modulation is modulation produced in an earlier stage than the final.

D. "Low-level" modulation occurs in r-f stages other than the final power amplifier, and because of this, the following stages must be linear (class B) amplifiers, in order not to distort the modulation component. The tank circuit used with such amplifiers must have a relatively low Q, so as not to attenuate the sideband frequencies. See Question 3.339. The definition given in the "Answer," above, is taken from Federal Communications Commission's Rules and Regulations, Section 3.15.

Q. 3.337. Describe the construction and characteristics of a "crystal" type microphone.

A. A "crystal" microphone depends for its operation upon the piezoelectric effect of a suitable crystalline material. Rochelle salts are most commonly used for this purpose in the crystal microphone. The crystal proper is made up of a number of crystal cells arranged so as to increase the sensitivity of the unit. One such unit consists of *two* crystal elements so arranged as to operate in phase when sound vibrations are present, but to generate out of phase potentials when subjected to shock or mechanical vibration. The entire crystal unit is impregnated in wax and enclosed in an airtight chamber. This enclosure, however, does not prevent the crystal from vibrating and thus generating emf's proportional to the sound wave components. The sound vibrations are transmitted to the crystal unit by means of a conical duralumin diaphragm either directly or by means of a resilient, intermediate member. The microphone has a flat frequency response over the entire audio range. It is lightweight, reasonably rugged, easily maintained, and requires no power supply. It has a high impedance output, is non-directional, and has no inherent background noise level. The microphone should be protected against excessive humidity, as Rochelle salts are soluble in water. The wax impregnation of the crystal element is, however, highly efficient in protecting the crystal against moisture.

Q. 3.338. Describe the construction and characteristics of a "carbon-button" type microphone.

A. The "carbon-button" microphone depends for its operation upon the characteristics of a pile of carbon granules when subjected to varying pressures. The carbon button proper consists of a small cup completely filled with very fine carbon granules. A tightly stretched duralumin diaphragm is attached to the carbon button (or buttons) in such a way that sound vibrations cause varying pressures upon the button. The resistance of the carbon button varies in proportion to the pressures upon it. A battery supply is connected in series with the button and a resistance (or transformer primary), so that variations in resistance will cause corresponding variations in the output current from the button. These varying currents will be proportional to the character of the sound waves producing them. The frequency response of a broadcast type is inferior to most other types of microphones, and is in the order of 70 to 6000 cycles. The carbon microphone is no longer in general use because, although it has very high sensitivity, it has a number of serious disadvantages. These are: (1) it is sensitive to vibration, (2) it cannot be handled while in use, (3) it generates a hissing sound in its output, (4) the carbon granules in the buttons are subject to "packing" (see Question 3.214), (5) it requires a battery power supply for operation. See Question 3.95 for circuit.

Q. 3.339. What might be the cause of variations in plate current of a class B type of modulator?

A. The average plate current of a class B modulator varies normally during modulation, when the modulation signal is not of a constant amplitude, sinusoidal voltage wave form.

D. With no input signal applied to the class B modulator grids, the plate current will be extremely small. (This is an advantage in portable or high power equipment where conservation of the power supply is essential.) The plate current will vary in direct proportion to the amplitude of the grid signal and since a modulating wave contains many harmonic frequencies, the shape and amplitude of the modulating signal is constantly changing. This in turn causes consequent variations of plate current. If the amplifier were operated class A, the plate current would remain substantially constant, with or without modulation.

Q. 3.340. What is the relationship between the average power output of the modulator and the modulated-amplifier plate-circuit input, under 100 per cent, sinusoidal, plate modulation?

A. The ratio is one to two.

D. Under 100% sinusoidal plate modulation conditions, the a-c power output of the modulator must equal ½ of the d-c power input to the modulated r-f amplifier. The modulator output supplies the power for the sidebands, while the d-c supply furnishes the power for the carrier wave. See Question 6.440 for a numerical example.

Q. 3.341. What would be the effect of a shorted turn in a class B modulation transformer? In a class A modulation transformer?

A. The immediate effects would be: distortion, and overheating with possible transformer burnout.

D. If a shorted turn existed in either type transformer, the transformer would overheat badly and almost invariably burn out. However, while it was still operating there would be considerable distortion present. This distortion would be caused by a change of the effective turns ratios and consequently, the load impedance. This impedance could change sufficiently, so that the modulator tube (or tubes) was no longer working into the correct load impedance. In a push-pull modulator it would be possible for one section of the primary winding to burn out, leaving one tube still operative. The output under this condition would be greatly distorted.

Q. 3.342. Why is a high percentage of modulation desirable?

A. The following are advantages of high percentage modulation:

(1) A higher signal to noise ratio at the receiver.

(2) Greater area coverage for a given carrier power.

(3) Greater useful transmitted power for a given carrier power.

(4) Higher plate efficiency of the modulated r-f amplifier.

(5) Less interference at the receiver from other stations operating on the same channel.

D. It should be realized that the only *useful* power contained in a modulated carrier wave is in the sidebands. At 100% modulation the sideband power represents only 33⅓% of the total radiated power. The remainder of the power, or 66⅔%, is in the carrier wave and is of no value in transmitting intelligence. If the percentage of modulation is reduced to 50%, the amount of power in the sidebands is reduced only about 11% of the *total* radiated power. (This corresponds to an increase of 12.5% over the original carrier power.) It may be seen from the above examples that it is important to keep the average percentage of modulation as high as may be practical for any particular transmitter.

Q. 3.343. What are some of the possible results of overmodulation?

A. Some results of overmodulation are:

(1) Distortion is produced in the modulation component of the radiated wave, causing distortion of the received signal.

(2) Generation of spurious harmonic frequencies.

(3) Adjacent channel interference due to extended sidebands.

D. When an r-f amplifier is modulated in excess of 100%, there are definite periods of time when the amplifier does not produce any output at all. This factor radically changes the original wavelength of the modulating signal. New frequencies are thus generated which were not present in the original modulating signal. Among these new frequencies are many harmonics, the number and intensity of which vary in proportion to the degree of overmodulation. These in effect create additional sideband frequencies which may extend far beyond the allotted bandwidth, and cause interference to adjacent channels. In addition to creating interference, the change in waveshape of the modulation component also causes distortion of the received signal, the magnitude of which increases with the degree of overmodulation.

Q. 3.344. What might cause frequency modulation in an amplitude modulated radiotelephone transmitter?

A. Frequency modulation of an amplitude modulated transmitter is due to "dynamic instability" of the oscillator and is generally due to poor regulation of the power supply. Varying loads cause power supply voltage changes which in turn vary the oscillator frequency.

D. See Question 3.333.

Q. 3.345. What percentage of antenna-current increase should be expected between unmodulated conditions and 100 per cent sinusoidal modulation?

A. The antenna current will increase by 22.5%.

D. The antenna current (rms) under sinusoidal modulation conditions is found by the formula, $I' = \sqrt{1 + \frac{m^2}{2}} \times I$, where m is the modulation factor as follows: For 100%, $m = 1$; for 50%, $m = .5$; for

30%, $m = .3$, etc. I is unmodulated antenna current; I' is modulated antenna current. Assume the unmodulated antenna current, I, to be 10 amperes. Then for 100% modulation, $I' = \sqrt{1 + \frac{1}{2}} \times 10 = 12.25$ amperes or an increase of 22.5%. In practical voice or music modulation (or other types), the modulating signal is usually a complex wave rather than a sinusoidal wave. Under these practical conditions the above formula cannot be relied upon to give any accurate indication of the modulation percentage. However, it will give a fairly reasonable approximation. See Question 6.441 for a numerical example.

Q. 3.346. What might be the cause of a decrease in antenna current of a high-level amplitude modulated radiotelephone transmitter, when modulation is applied?

A. This is called "downward modulation."

With *plate* modulation, "downward modulation" may be caused by any of the following:

(1) Insufficient bias at the modulated r-f amplifier.

(2) Insufficient excitation into the modulated r-f amplifier.

(3) Excessive overloading of the class C modulated r-f amplifier.

(4) Incorrect load impedance for the class C modulated r-f amplifier.

(5) Faulty or insufficient value of output capacity in the power supply filter for the modulated r-f amplifier.

(6) Poor regulation of a common power supply.

(7) Defective tube.

With *grid-bias* modulation, a downward "kick" may be caused by any of the following:

(1) Excessive r-f excitation to the grid of the modulated r-f amplifier.

(2) Insufficient operating bias on the grid of the modulated r-f amplifier.

(3) Distortion in the modulator or speech amplifier.

(4) Excessive resistance in the grid bias power supply.

(5) Faulty or insufficient output capacity in the plate power supply filter to the modulated r-f amplifier.

(6) Insufficient loading of the plate circuit of the modulated r-f amplifier.

(7) Too high plate circuit-efficiency of the modulated r-f amplifier under unmodulated conditions.

(8) Defective tube.

D. See Question 3.483.

Q. 3.347. Why is it necessary to use an oscillating detector for reception of an unmodulated carrier?

A. In order to provide a clear sharp indication of the unmodulated carrier. The presence of the carrier would be indicated, but indistinctly, by a hissing sound caused by increased tube noises, even if the receiver were not oscillating.

D. See Question 3.349.

Q. 3.348. What is the purpose of shielding in a multistage radio receiver?

A. In general, shielding of the various r-f and i-f components of a receiver prevents electromagnetic and electrostatic coupling between these elements and improves the overall stability of the receiver.

D. If these components were not shielded, there is a very serious possibility that feedback conditions might exist which would cause certain stages of the receiver to oscillate or become regenerative. In the event that oscillations took place, the output when receiving a station would probably contain a high frequency howl, as well as great distortion. If the receiver became regenerative, its bandpass would be restricted, causing sideband cutting and audio distortion. See Question 4.186.

Q. 3.349. Explain what circuit conditions are necessary in a regenerative receiver for maximum response to a modulated signal.

A. The regeneration control is first set so that the receiver oscillates. It is then backed off just beyond the point at which the receiver falls out of oscillation. The tuning condensers should be adjusted for maximum signal strength.

D. See Question 3.267. For an *un*modulated signal, the regeneration control should be advanced just beyond the point at which the receiver starts oscillating. In order to get a clear indication of the presence of an unmodulated carrier, it is necessary to "beat" it against another frequency and extract a high pitched audio note from the various beat frequencies. This additional "beat" frequency is provided by the receiver itself after it is put in an oscillating condition.

Q. 3.350. What feedback conditions must be satisfied in a regenerative detector for most stable operation of the detector circuit in an oscillating condition?

A. The feedback energy should be of sufficient magnitude and in the correct phase so that the oscillations will remain substantially constant over a wide tuning range.

D. For maximum stability the Q of the oscillating tank should be kept as high as possible. The tickler and antenna coils should not be too closely coupled, and the regeneration control should be set just above the point at which the circuit first oscillates. See Question 3.46. Compare also Question 3.52.

Q. 3.351. What are the advantages to be obtained from adding a tuned radio-frequency amplifier stage ahead of the first detector (converter) stage of a superheterodyne receiver?

A. The following advantages are obtained bv the use of a tuned radio frequency stage.

(1) Improved receiver sensitivity.

(2) Improved receiver selectivity.

(3) Greater image rejection.

(4) Decreases the required gain of the mixer and i-f amplifier, thus improving the receiver stability.

(5) Improves signal to noise ratio of the receiver.

(6) Reduces interference from signals at intermediate frequency.

(7) Reduces local oscillator radiation from the receiving antenna. (This is very important in television.)

D. Most of the receiver hiss is due to the noise generated in the mixer (also called first detector or converter stage) tube. By introducing gain before the mixer tube, the signal to noise ratio of the receiver is much improved. If the amplitude of the signal is raised before reaching the mixer tube, the usable sensitivity of the receiver can be increased. See also Question 6.551.

Q. 3.352. What feedback conditions must be satisfied in a regenerative detector in order to obtain sustained oscillations?

A. The feedback energy must be in the proper phase and of sufficient magnitude to overcome the grid circuit losses.

D. Grid circuit losses are caused by the following:

1. D-C resistance.
2. A-C resistance (skin effect).
3. Radiation.
4. Grid current.
5. Coupling losses.

See Question 3.350.

Q. 3.353. How is "automatic volume control" accomplished in a radio receiver?

A. By feeding back, into the control grids of the i-f and r-f amplifiers, a negative d-c bias which is proportional to the average magnitude of the received carrier wave.

D. The basis for efficient automatic volume control is the action of the variable-μ (remote cut-off) tube. This tube has a control grid which is so constructed, that changes of d-c grid bias cause corresponding variations in the tube's transconductance and thus control the gain of the i-f (and sometimes also r-f) amplifiers The transconductance decreases as the negative bias increases and vice versa. In the second detector, the modulated i-f signal is rectified in such a way that the average value of the detector audio output is negative with respect to ground. This is accomplished by grounding the cathode of the detector, and taking the output from the plate circuit. The average negative audio output is put through a long line constant R-C filter whose output is a pure, negative d-c voltage. This voltage is fed through suitable decoupling filters to the grids of the various i-f and r-f amplifiers involved, where it becomes all or part of the bias for these tubes. The output of the avc filter is a negative d-c voltage whose magnitude is proportional to the average strength of the incoming modulated carrier signal. An increase of incoming signal strength creates a larger negative bias on the various controlling grids, thereby reducing the overall gain of the receiver and providing a relatively constant output. A decrease of incoming signal strength results in a *less* negative bias, an increase in overall receiver gain, and again a relatively constant output. See Question 4.212 for diagram.

Q. 3.354. If a superheterodyne receiver is tuned to a desired signal at 1,000 kilocycles, and its conversion oscillator is operating at 1,300 kilocycles, what would be the frequency of an incoming signal which would possibly cause "image" reception?

A. The "image" frequency would be 1,600 kilocycles.

D. The "image" frequency in this case is found by adding twice the intermediate frequency to the incoming carrier frequency. The intermediate frequency is found by subtracting the incoming frequency of 1,000 kilocycles from the oscillator frequency of 1,300 kilocycles or 300 kilocycles. Thus the "image" frequency $= 2 \times 300 + 1{,}000 = 1{,}600$ kilocycles. Each signal would give a 300-kc beat from the mixer, and both would pass through the i-f amplifiers. See Question 3.265.

Q. 3.355. If a tube in the only radio-frequency stage of your receiver burned out, how could temporary repairs or modifications be made to permit operation of the receiver if no spare tube is available?

A. The tube should be removed from its socket and a small condenser (about 0.001 μf) connected between the control grid and plate connections of the removed tube.

An alternate method would be to connect the antenna to the control grid of the stage following the one which was burned out.

Q. 3.356. What are the characteristics of plate detection?

A. The grid is biased almost to cut-off so that the average audio plate current varies in proportion to the amplitude of the modulation component of the carrier wave. Detection takes place in the plate circuit.

D. See Question 3.131.

Q. 3.357. What is the purpose of a "radio-frequency" choke?

A. In general, an r-f choke acts as a low-pass filter which permits the passage of d-c and low frequency components but prevents the passage of radio frequencies.

D. Chokes are often used to prevent radio frequencies from entering the power supply. They are also used as coupling elements, to help maintain the Q of tank circuits, as in a crystal oscillator, and sometimes as tuning elements, as in a Pierce oscillator.

Q. 3.358. What would be the effect upon a radio receiver if the vacuum-tube plate potential were reversed in polarity?

A. The tubes could not conduct, and the receiver would be inoperative.

D. In order for the tubes to operate, the plate and screen grid potentials must be positive with respect to cathode. Obviously this condition could not be fulfilled if the polarity of the supply source were reversed.

Q. 3.359. Draw a simple schematic diagram of a system of coupling a single electron tube employed as a radio-frequency amplifier to a Hertz-type antenna.

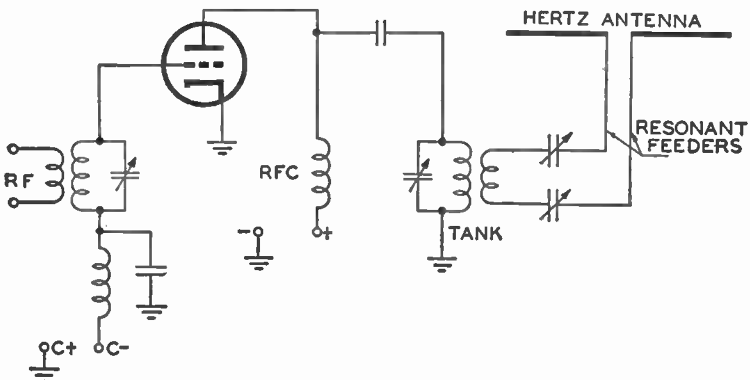


Fig. 3.359. Method of coupling an r-f amplifier to a Hertz antenna.

A. See the figure; see also Question 3.517.

Q. 3.360. Draw a simple schematic diagram indicating a link coupling system between a tuned-grid tuned-plate oscillator stage and a single electron tube, neutralized amplifier.

A. See the figure.

D. See Question 3.140.

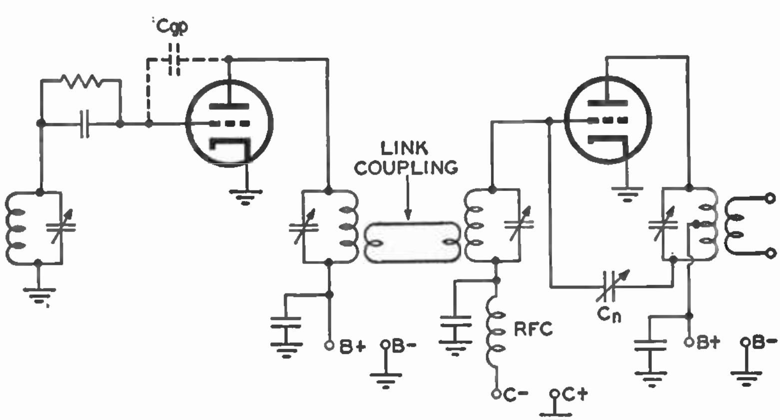


Fig. 3.360. Link coupling system.

Q. 3.361. Draw a simple schematic diagram of a push-pull, neutralized radio-frequency amplifier stage, coupled to a Marconi-type antenna system.

A. See the figure.

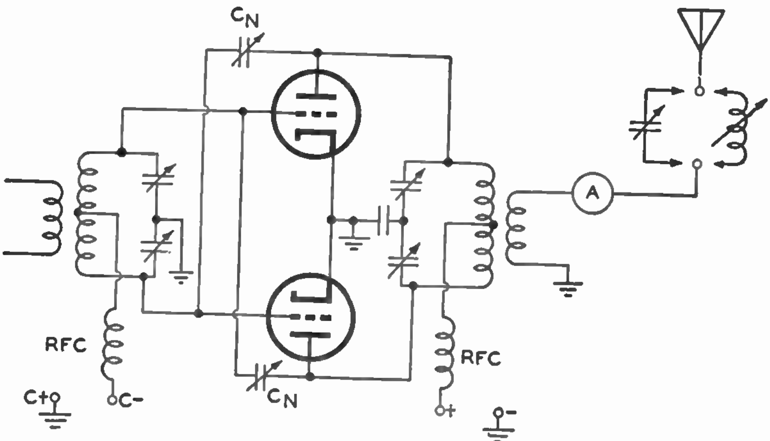


Fig. 3.361. Coupling of a push-pull stage to a Marconi antenna.

Q. 3.362. Draw a simple schematic diagram of a system of neutralizing the grid-plate capacitance of a single electron tube employed as a radio-frequency amplifier.

A. See Question 3.307.

Q. 3.363. Draw a simple schematic diagram showing the proper method of obtaining direct-current screen-grid voltage from the plate supply in the case of a plate-modulated pentode, class C amplifier.

A. See the figure.

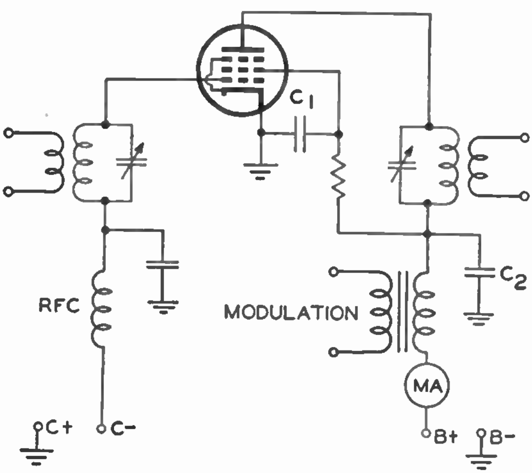


Fig. 3.363. A plate-modulated class C amplifier.

D. See Question 3.335.

Q. 3.364. What is the purpose of a "buffer" amplifier?

A. The purpose of a "buffer" amplifier is to prevent any tuning or load changes in the r-f amplifiers or antenna circuit from changing the frequency of the master oscillator of the transmitter.

D. In transmitters, the "buffer" amplifier is located between the master oscillator and the subsequent r-f amplifier stages. The "buffer" is usually operated class B by means of fixed bias (not grid-leak bias) and the grid signal swing is restricted so that grid current is not present. This prevents loading of the oscillator by the relatively low grid to cathode impedance which is present when grid current exists in the "buffer" stage. The "buffer" is often resistance coupled to the oscillator, and may be a tetrode or pentode rather than a triode to reduce capacity coupling from the oscillator to the succeeding r-f amplifiers. The plate tank circuit of the "buffer" has a low Q affording a wide bandpass characteristic, and this also helps to reduce reflected impedance changes back into the oscillator. The gain of the "buffer" amplifier is relatively low, making it possible usually to eliminate neutralizing circuits in this stage.

Q. 3.365. What are the characteristics of a "frequency doubler" stage?

A. The following are characteristic of a "frequency doubler" stage:

(1) Plate tank tuned to twice the grid circuit frequency.

(2) Does not have to be neutralized.

(3) Plate current pulse width of approximately 90°.

(4) Bias about 10 times cutoff. (Class C.)

(5) Large harmonic output in plate current pulse.

(6) Very large grid driving signal.

(7) Low plate efficiency compared to a straight class "C" amplifier.

D. See Questions 3.90 and 3.138.

Q. 3.366. What are the advantages of a master-oscillator power-amplifier type of transmitter as compared to a simple oscillator transmitter?

A. The major advantages are:

(1) Improved frequency stability of the oscillator.

(2) Greater power output.

(3) Greater rejection of oscillator harmonic output.

D. In the master-oscillator power-amplifier type of transmitter, the power amplifier also serves the function of a "buffer" stage. (See Question 3.364.) Thus any changes in antenna loading, which might simply be caused by the movement of the antenna in the wind, would not be reflected back into the oscillator to the degree which would exist in a simple oscillator transmitter. The oscillator frequency in the

"M.O.P.A." is more stable therefore, due to this isolating action. In the "M.O.P.A." there are more tuned circuits before the antenna, offering a greater degree of rejection to oscillator harmonics.

Q. 3.367. What are the differences between Colpitts and Hartley oscillators?

A. The basic difference between the Colpitts and Hartley oscillators is the method of adjusting the feedback. In both the Colpitts and Hartley oscillators, the tank circuit is effectively connected between the grid and plate of the vacuum tube. In both cases the amount of feedback is adjusted by varying the point at which the cathode is effectively tapped into the tank circuit. In the Hartley oscillator this is done by tapping into the coil proper, while in the Colpitts oscillator the tap is made by means of a capacitive voltage divider. This consists of two series condensers connected across the tuning inductance, with the cathode connected between the two. By varying the *ratio* between the two condensers, the feedback voltage may be varied. Once the feedback ratio is determined, the two condensers may be "ganged" together for tuning. See Questions 3.70 and 3.74 for diagrams.

D. Other differences are: (1) The Colpitts oscillator *must* be shunt fed, while the Hartley oscillator may be shunt or series fed. (2) In the Colpitts oscillator the grid leak resistance must be connected from grid to cathode, while in the Hartley oscillator it may alternatively be connected across the grid condenser. (3) The Colpitts oscillator seems to be preferred for use in the very low frequencies and the very high frequencies (ultraudion), while the Hartley oscillator is used between these two extremes.

Q. 3.368. What is the primary purpose of a grid-leak in a vacuum-tube transmitter?

A. When used in connection with a grid-leak biased tube, the purpose of the grid-leak resistance is to determine the value of the bias and to provide a d-c return from cathode to grid. The grid-leak resistance

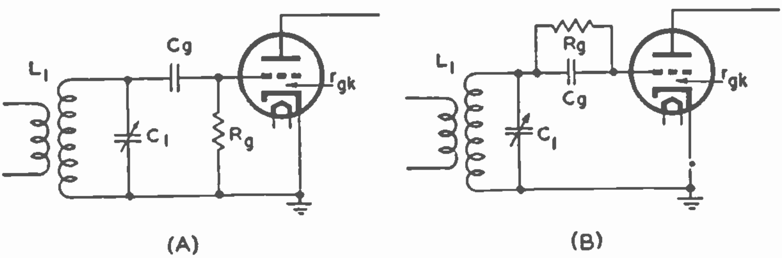


Fig. 3.368(A) and (B). The grid-leak resistor, R_g, may be connected as shown in (A) or (B).

also makes it possible for the bias to be self-adjusting to decreasing amplitudes of excitation voltage.

D. There are three main factors to be considered. These are (1) the value of grid-leak resistance, R, (2) the internal resistance of the tube between grid and cathode at the time grid current is flowing (r_{gk}), (3) the duration of time that grid current is flowing.

The grid-leak resistance may be connected directly from grid to cathode (part *A* of the figure) or in parallel with the grid condenser (part *B* of the figure) with the same bias being developed in each case. The value of bias varies almost directly with the value of grid-leak resistance in normal transmitter and receiver circuits, thus making the resistance value very critical. The value of grid condenser used is *not* critical, providing that with the grid-leak resistance in use, the time-constant ($R_g \times C_g$) is equal to at least one fifth of the time of one cycle ($t = \frac{1}{f}$) at the lowest operating frequency. Increasing the condenser above the capacity required for the stated minimum R_gC_g product will have very little effect upon the bias. Any small increase of bias which may result from increasing the condenser value is simply due to the improved filtering action of R_g and C_g.

Referring to part *A* of the figure, the approximate value of grid-to-cathode internal tube resistance is 1000 ohms (when grid is conducting). For practical purposes this value may be considered to be constant. It should be remembered at this point, that the only time grid current flows is when the grid is driven more positive than the cathode.

Let us first consider the case where R_g is, for example, 10 ohms (part C of the figure). R_g and r_{gk} form a parallel network (when grid current is flowing). However, 1000 ohms in parallel with 10 ohms still equals 10 ohms (practically) and therefore it does not matter whether or not the tube is connected as far as bias is concerned.

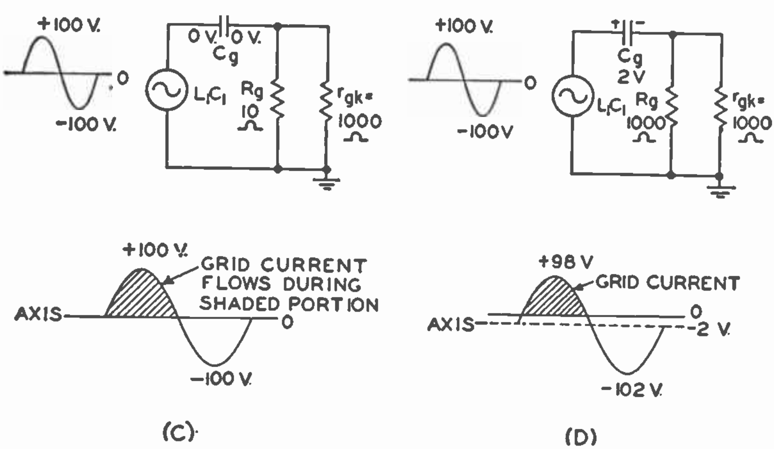


Fig. 3.368(C) and (D). Equivalent circuits of a grid-leak biased stage.

The amount of charge going into the condenser is practically equal to the amount of charge leaving the condenser, and since the original charge in the condenser was zero, the average voltage across the condenser is equal to zero. The bias voltage is at all times equal to the voltage across the condenser (and resistor) and likewise is zero. This condition is illustrated in part *C* of the figure.

If R_g is increased to 1000 ohms, operating conditions are now radically altered. When the grid is driven positive, and conducts, the effective charging resistance for C_g is equal to the parallel combination of R_g and r_{gk} or 500 ohms. When the grid ceases to be positive on the descending portion of the cycle, the condenser begins to discharge. The path of condenser discharge is only through R_g and does not involve the tube. The discharge resistance is equal to 1000 ohms, or is twice as great as the charging resistance. The condenser cannot possibly lose as much charge during the discharge period as was gained during the charge period, because the time constant of the discharge path (R_gC_g) is twice as great as the time constant of the charging path $\left(C_g \times \frac{R_g \times r_{gk}}{R_g \times r_{gk}}\right)$. If a definite value of bias is to be reached and maintained, a condition of equilibrium must be reached such that during any one excitation cycle (360°) the amount of charge entering the condenser (when the grid draws current) must be exactly equal to the amount of charge leaving the condenser during the remainder of the cycle. Since the amount of charge which can leave the condenser in any given time is fixed by the value of R_g, the amount of entering charge must somehow be adjusted to be equal to this discharge at the point of equilibrium (desired bias). This occurs automatically as shown in parts *C*, *D*, *E*, and *F* of the figure by decreasing the time during which grid current flows when the bias voltage is built up across the condenser. As shown in the figures, the bias set a new operating axis for the excitation signal so that grid cur-

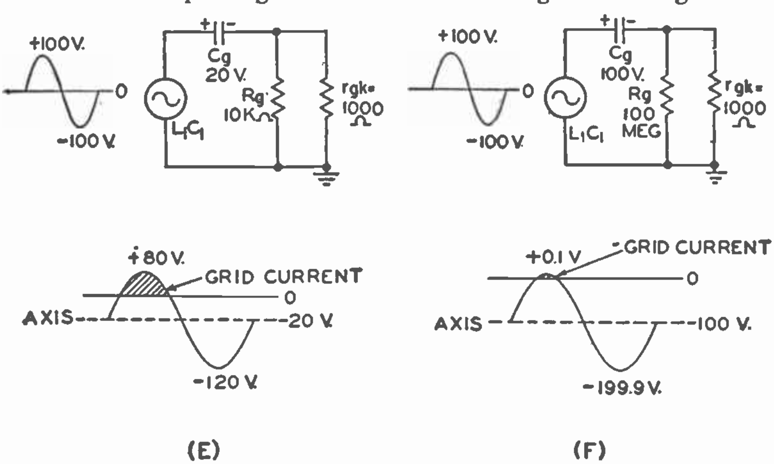


Fig. 3.368(E) and (F). Equivalent circuits of a grid-leak biased stage.

rent flows for less than 180°. Following the same line of reasoning, it is seen that as the grid-leak resistance is further increased, the amount of charge which can leak off is decreased, and again the angle, or duration, of grid-current flow is automatically adjusted by permitting the bias (condenser voltage) to increase until just enough grid current flows to replace whatever charge was lost during the discharge period.

If the grid-leak resistance is made extremely great, practically no charge will be able to leak off between cycles and the angle of grid current flow will become almost zero. In order for this condition to occur, the voltage across the condenser must rise until it is equal to the peak value of the excitation signal, where it now remains. The signal is now said to be "clamped" to the zero level. This condition is illustrated in part *F*.

As stated previously, the condenser value is not critical. The reason for this is that changing the capacity affects both the charging and discharging time constants equally, but changing the resistor affects only the discharging time constant.

(See also Question 3.484.)

Q. 3.369. By what means is feedback coupling obtained in a tuned-grid tuned-plate type of oscillator?

A. The feedback coupling unit in a tuned-grid tuned-plate oscillator is the plate to grid interelectrode capacitance of the tube.

D. See Question 3.69.

Q. 3.370. What may be the result of parasitic oscillations?

A. The following may result from parasitic oscillations:

(1) Generation of spurious frequencies (carrier).

(2) Generation of spurious sideband frequencies during modulation.

(3) Distortion of the modulated wave.

(4) Overheating of the amplifier tube.

(5) Reduced efficiency of the amplifier tube at the desired frequency or frequencies.

(6) Change of bias (grid leak).

D. See Question 3.372.

Q. 3.371. How may the production of harmonic energy by a vacuum-tube radio-frequency amplifier be minimized?

A. The *production* of harmonic energy may be minimized by the following methods:

1. Operating the amplifier tube with the proper bias and grid-excitation signal.
2. Use of push-pull circuits.
3. High *Q* plate tank circuit. (High *C* to *L* ratio.)

D. The *transfer* of harmonic energy may be minimized by the following methods:

1. Use of a Faraday screen between inductivity coupled circuits.
2. Use of a suitable low pass filter tuned to pass only the fundamental frequency.
3. Reduction of all forms of capacity coupling between stages.
4. Loose inductive coupling.

Q. 3.372. What is a definition of "parasitic oscillations"?

A. Parasitic oscillations are defined as, "either high or low frequency oscillations occuring in circuits other than the original tank circuits, and at frequencies other than the desired output frequencies."

D. Parasitic oscillations may be either high or low in frequency. High frequency parasitics are present in tuned circuits usually composed of tube and stray capacitance and lead inductance. Many times, this behaves as a tuned-grid tuned-plate oscillator. High frequency parasitic oscillations may be minimized by inserting small non-inductive resistors in series with plate and grid leads, and by making the plate leads considerably longer than the grid leads. Other methods are placing a wave trap in series with the grid, and placing small r-f chokes in series with the plate and grid leads. Low frequency parasitics are usually caused by having r-f chokes in both plate and grid circuits. These can be minimized by eliminating one of the two chokes, or by making the plate choke larger than the grid choke. Series plate and grid resistors may also help to eliminate low frequency parasitic oscillations. See Question 3.370.

Q. 3.373. What is the purpose of a Faraday screen between the final tank inductance of a transmitter and the antenna inductance?

A. The purpose of a "Faraday" screen (or shield) is to minimize the transfer of harmonic frequencies between two inductively coupled circuits due to the capacity between the two coils. The two coils in question are usually the plate tank circuit coil of the final r-f amplifier and the coupling coil to the antenna system.

D. In addition to inductive coupling between two coils, there also exists a degree of capacitive coupling due to the stray capacity existing between the two coils. The amount of capacity coupling increases as the two coils are brought closer together. This capacity coupling offers a relatively low impedance path for the transfer of harmonics, since the capacitive reactance decreases as the frequency is increased. One effective means of reducing harmonic transfer into the antenna circuit is to reduce the capacity between the two coupled coils. The method of accomplishing this is similar to the principle of a screen grid in a tetrode vacuum tube. A screen or shield which is grounded is placed between the two coils. Such a device is called a "Faraday" screen. It is made up of a flat plate constructed of separate parallel conductors insulated from each other at one end, but joined together physically and electrically at the other end. The conductors are insulated at one end so that no closed circuits will appear in the screen which would also cause magnetic shielding. The insertion of this grounded screen between the two coils greatly reduces the capacitance between the coils and so minimizes harmonic coupling due to the capacitance effect.

Q. 3.374. How may the distortion effects caused by class B operation of a radio-frequency amplifier be minimized?

A. The following methods may be used to minimize the distortion effects of a class B modulated radio frequency amplifier (linear amplifier):

(1) Confine operation to the linear portion of the tube characteristic.

(2) Maintain correct operating bias at all times. (Projected cut-off for class B; see Question 3.122.)

(3) Do not use grid-leak bias.

(4) Maintain proper tuning of plate and grid circuits.

D. See Question 3.107.

Q. 3.375. What is the effect of carrier shift in a plate modulated class C amplifier?

A. The following effects are caused by carrier shift in a plate modulated class C amplifier:

(1) Distortion of the modulated wave.

(2) Generation of spurious sideband frequencies.

(3) Adjacent channel interference caused by (2) above.

D. See Question 3.378.

Q. 3.376. What are some possible indications of a defective transmitting vacuum tube?

A. Some possible indications are:

(1) "Gas glow" within tube.

(2) Excessive plate color due to overheating.

(3) No light from filament.

(4) Insufficient or excessive plate current.

(5) Reduced output.

(6) Possible internal arcing.

(7) Fluctuating plate and/or grid current.

Q. 3.377. What would be possible indications that a vacuum tube in a transmitter has subnormal filament emission?

A. Some possible indications are:

(1) Reduced output.

(2) Reduced plate current.

(3) Distortion due to saturation.

(4) Weakened or no oscillations in an oscillator stage.

(5) Downward modulations if used as the modulated r-f amplifier.

Q. 3.378. What are possible causes of negative carrier shift in a linear radio-frequency amplifier?

A. The following may cause negative carrier shift:

1. Distorted modulating wave due to
(a) Improper bias of modulation amplifier.
(b) Overdriving of modulation amplifier.
(c) Poor regulation of modulator power supply.
(d) Defective tube or modulation transformer.
2. Overmodulation.
3. Incorrect load impedance presented to modulator tube by r-f amplifier.
4. Improper tuning of tank circuits.
5. Poor regulation of r-f amplifier power supply.
6. Insufficient r-f excitation (See Question 3.379.)

D. The term "negative carrier shift" does not denote a change of carrier frequency, although additional harmonic frequencies are produced. Carrier shift occurs when an unsymmetrical distortion of the modulation envelope is present. In "negative carrier shift," the negative portions of the modulation component become greater than the positive portions, resulting in a decrease of the average output power as evidenced by a decreased reading on the d-c plate milliameter of the final r-f amplifier. In "positive carrier shift" the positive portions of the modulation component become greater in amplitude than the negative portions, resulting in an increase of the average output power as evidenced by an increased reading on the d-c plate milliameter of the final r-f amplifier. See Question 3.384.

Q. 3.379. In a modulated class C radio-frequency amplifier, what is the effect of insufficient excitation?

A. Insufficient r-f excitation of a class C plate modulated amplifier may cause the following:
(1) Reduced amplifier efficiency.
(2) Reduced power output.
(3) Overmodulation with attendant distortion, harmonics, and carrier shift.

D. See also Question 3.378.

Q. 3.380. What is the purpose of a "dummy antenna"?

A. A "dummy antenna" is used in order to test the operation of a transmitter with a minimum of radiation.

D. A dummy antenna is made up of lumped constants, usually of resistance and capacitance which in a very small physical space approximates the actual performance of the original antenna, insofar as loading of the transmitter is concerned, but which is designed *not* to radiate energy. The use of such a dummy antenna enables the transmitter in question to be tested and adjusted while causing a minimum of interference due to radiation. The regular antenna is of course disconnected from the transmitter during such testing operations.

Q. 3.381. In a class C radio-frequency amplifier stage of a transmitter, if plate current continued to flow and radio-frequency energy is still present in the antenna circuit, what defect would be indicated?

A. Assuming the excitation to have been removed, the following conditions might be present:

(1) Improper neutralization.

(2) Insufficient bias to cut the tube off accompanied by improper neutralization.

(3) In a radio-telegraph transmitter, the blocking bias is not being applied when the key is up. (See Question 6.498.)

D. This might also be the result of high or low frequency parasitic oscillations. (See also Question 3.372.)

Q. 3.382. If the transmitter filament voltmeter should cease to operate, how may the approximately correct filament rheostat adjustment be found?

A. The approximately correct adjustment could be made by adjusting the filament voltage for normal plate and grid current readings assuming normal operation of the circuits.

D. A very rough adjustment could be made by adjusting the filaments to the normal brightness. If a suitable ammeter was available, it could be placed in series with the filament and the voltage adjusted until rated filament current was being drawn.

Q. 3.383. What are some possible causes of overheating vacuum-tube plates?

A. The following might cause overheating of a vacuum tube plate:

(1) Excessive screen grid voltage.

(2) Excessive plate voltage.

(3) Insufficient grid bias.

(4) Excessive load on an r-f amplifier.

(5) Detuning of plate tank of an r-f amplifier.

(6) Gassy tube.

(7) Excessive filament voltage.

(8) Improper neutralization and/or parasitic oscillations in an r-f amplifier.

(9) Emitting grid.

D. See also Question 3.469.

Q. 3.384. Should the plate current of a modulated class C amplifier stage vary or remain constant under modulation conditions? Why?

A. The d-c plate current should remain constant during modulation.

D. If no distortion (practically) occurs in the process of modulation, the amount of increase in class C plate current should be exactly the same as the amount of decrease and therefore the average change is zero. This applies as long as there is no overmodulation present or carrier shift. See Questions 3.378 and 3.482.

Q. 3.385. What is the effect of a swinging antenna upon the output of a simple oscillator?

A. The effect of a swinging antenna upon the output of a simple oscillator is to frequency-modulate the oscillator output.

D. Among other factors the resonant frequency of the simple oscillator will also depend upon the reactive (particularly capacitive) components of the antenna. As the antenna swings, its relative height above ground is changing and a change in capacitance of the antenna is reflected into the oscillator circuit. This in turn causes oscillator frequency changes at the rate of swinging of the antenna. The use of an amplifier between the oscillator and antenna would greatly reduce this effect.

Q. 3.386. What factors permit high conduction currents in a hot-cathode type of mercury-vapor rectifier tube?

A. In a mercury-vapor rectifier tube positive ions are produced which tend to neutralize the negative space charge and thus permit higher conduction currents to take place. Electrons which are removed from the positive ions, and the positive ions themselves, both contribute to the total plate current, moving in opposite directions.

D. See Questions 3.178 and 3.387.

Q. 3.387. List the principal advantages of a mercury-vapor rectifier over a high-vacuum-tube type of rectifier.

A. The primary advantages are:

(1) Low internal drop of 10 to 15 volts.

(2) Increased filament efficiency.

(3) Cooler operation.

(4) Greater efficiency and economy in high power systems.

D. See Question 3.179.

Q. 3.388. What effect does the resistance of the filter chokes have on the regulation of a power supply in which they are used?

A. The voltage regulation is best with low d-c resistance filter chokes.

D. See Question 3.180.

Q. 3.389. Describe the theory of current conduction and rectification by means of cold-cathode, gassy-diode vacuum tubes.

A. A typical cold-cathode gassy-diode rectifier tube consists of a large area cathode (which is coated with suitable emitting material such as barium and strontium), a small diameter rod-shaped pointed anode, and a starter anode. These elements are enclosed in an envelope containing a gas such as helium, acetylene, argon, or neon. The gas pressure is critical, for correct operation. Electron emission from the cathode is due to two major factors:

1. If the electrostatic field produced by the starter anode is sufficiently great, electrons will be pulled from the cathode coating by force of attraction.

2. Any gas is always in a state of partial ionization. The existing positive ions are accelerated by the cathode to starter-anode voltage so that they strike the cathode with sufficient force to aid in the emission of electrons. The rectifying action of such a tube makes use of the fact that the current which ionization causes to exist between two electrodes in a low-pressure gas is approximately proportional to the area of the cathode. If one electrode has a very large area (cathode) and the other electrode a very small area (anode), electrons will flow in the direction from cathode to anode. Conduction occurs on that half cycle which makes the anode positive with respect to the cathode.

D. See Question 6.337 for circuit diagrams.

Q. 3.390. Describe the principle of operation of a synchronous type of mechanical rectifier.

A. The usual type of synchronous rectifier is the synchronous vibrator. This consists of a "U" frame which is designed to permit the mounting of a coil with pole piece at the closed end. A vibrating reed and insulated side springs with contacts are mounted at the opposite end. The reed carries contacts mounted on either side in pairs, corresponding to the stationary side spring contacts. The vibrating reed is usually so connected as to keep it at ground potential. The "driver" coil is a high resistance winding which is placed in series with one-half of the center tapped primary of the transformer and the battery. Both primary and secondary windings of the transformer are center-tapped. The center tap of the primary is connected to the "hot" side of the d-c input line, while the center tap of the secondary is the take-off point for the positive high-voltage rectified d.c. The operation is as follows: All contact pairs are open normally and the starting of the reed movement depends upon the magnetic attraction of the "driver" coil. This movement is sufficient to cause the reed to make good electrical connection with a side spring contact which is connected to the same side of the transformer as the driver coil. This shorts the driver coil, destroys the magnetic field and releases the reed which now swings in the opposite direction beyond its original resting position. The reed now contacts the opposite side spring connections, and the driver-coil field pulls it back;

In this manner the reed sets up vibrations, usually designed to be 135 cycles per second. As the reed moves, the secondary side spring contacts alternately reverse the primary and secondary transformer connections so that the output is a uni-directional current (d.c.).

D. See Question 3.518 for diagram.

Q. 3.391. What might be the result of starting a motor too slowly, using a hand starter?

A. The motor and starting resistances would both overheat, and the starting resistances might burn out.

D. When a d-c motor is first starting, a very large armature current exists due to the lack of sufficient armature cemf. This large armature current exists only until the armature reaches sufficient speed so that the cemf becomes effective in limiting the current. If too long a time is taken in starting the motor with a hand starter, the large current value will overheat and possibly burn out the starting resistors which are only rated for intermittent operation. The starter handle should be held in each position only long enough to bring the motor speed up to the value which is normally present at that particular setting.

Q. 3.392. State the principal advantage of a third-brush generator for radio power supply in automobiles.

A. The third brush in a d-c generator improves the regulation of the generator.

D. In a three brush generator the field excitation is obtained from the third brush, which is usually movable within limits, between the other two brushes. Moving the third brush allows the charging rate of the battery to be adjusted. Since an automobile engine is usually run at widely varying speeds, the third brush is set so as to give the desired charging rate at the engine speed most often used. This system is now obsolete, and has been replaced by fixed brush generators employing current and voltage regulators which automatically provide the correct charging current depending upon the condition of charge of the battery. When the battery becomes fully charged, the charging current is automatically reduced to zero.

Q. 3.393. What materials should be used to clean the commutator of a motor or generator?

A. The commutator may be cleaned with a piece of very fine sandpaper or commutator polishing paste; never use emery.

D. A commutator polishing agent is available, which is applied with a clean cloth. The commutator is then polished while the machine is running.

Care should be taken in the handling of any rotating machinery, and especially in the handling of high voltage generators, in order to avoid injury and shock.

Q. 3.394. List three causes of sparking at the commutator of a direct-current motor.

A. See Question 3.168.

Q. 3.395. Why is it sometimes necessary to use a starting resistance when starting a direct-current motor?

A. To prevent excessive armature current while starting, due to insufficient armature cemf.

D. The amount of counter-emf induced into the armature is a direct function of the armature rotational velocity. When the armature is first starting the counter-emf is low and consequently the armature current will be high. See also Questions 3.172 and 3.391.

Q. 3.396. List the comparative advantages and disadvantages of motor-generator and transformer-rectifier power supplies.

A. The advantages of motor-generator power supplies are as follows:

(1) Simple output voltage control.

(2) Little filtering required, due to high ripple frequency.

(3) Very rugged in construction and will stand much abuse.

(4) Self-rectifying, requires no tubes.

(5) Can be operated from either a-c or d-c lines,

Disadvantages of motor-generator power supplies are:

(1) High initial cost.

(2) Difficult to repair.

(3) Subjected to bearing troubles and other difficulties attendant with rotating machinery.

(4) Equipment is noisy and causes vibration.

(5) Large bulk and weight.

(6) Requires comparatively frequent inspection and service, as to lubrication, brushes and commutator.

(7) Limited high voltage available.

(8) Causes radio frequency interference from brush sparking.

The advantages of transformer-rectifier power supplies are:

(1) Low initial cost.

(2) Practically unlimited high voltages available.

(3) Simple to repair and replace components, compared with motor-generator.

(4) Completely electronic—no moving parts to service.

(5) Quiet and practically vibrationless in operation.

(6) Clean.

(7) Can be built as an integral portion of transmitter.

(8) Usually lighter and smaller than equivalent motor-generator.

(9) Requires no inspection, except when trouble occurs.

Disadvantages of transformer-rectifier power supplies are:

(1) Voltage output not easily controlled.
(2) Requires large filter components.
(3) Tubes are fragile.
(4) Usually must be operated only from a-c lines.
(5) Tubes must occasionally be replaced.
(6) High voltage windings cannot stand much overload.

Q. 3.397. If the reluctance of an iron-cored choke is increased by increasing the air gap of the magnetic path, in what other way does this affect the properties of the choke?

A. Increasing the air gap will decrease the inductance of the choke and increase the d-c core saturation current rating.

D. See Questions 3.59, 3.62, and 3.398.

Q. 3.398. What is the effect upon a filter choke of a large value of direct-current flow?

A. The effect depends upon the original design of the choke. If it was designed to carry a large value of direct-current, there would be no adverse affects. However, if the normal rating of the choke was being exceeded, d-c core saturation would occur, the value of inductance would be reduced, and the choke might overheat.

D. See also Question 3.397.

Q. 3.399. What are the characteristics of a condenser-input filter system as compared to a choke-input system?

A. The primary comparative characteristics of a condenser input filter are:

(1) Higher d-c output voltage. (About 1.4 times rms value of secondary voltage under light loads.)
(2) Poorer voltage regulation.
(3) Higher peak surge currents.
(4) Not suitable for use with mercury vapor tubes.

D. See Question 3.401.

Q. 3.400. What is the principal function of the filter in a power supply?

A. The principal function of the filter is to remove the variations in amplitude of the rectifier output and provide a relatively unvarying d-c voltage for use in the various circuits.

D. See Question 3.488.

Q. 3.401. What are the characteristics of a choke-input filter system as compared to a condenser-input system?

A. The characteristics of a choke-input filter as compared with a condenser-input filter, are:

(1) Lower output voltage, about 90% of rms secondary voltage.
(2) Better voltage regulation.
(3) Lower peak current surges.
(4) More efficient utilization of tubes and transformers.

D. When a condenser input filter is used, the condenser charges to 1.414 times the rms value of the secondary voltage of the power transformer. Neglecting any drop in the d-c resistance of the choke, this will be the output d-c voltage with a light load. If the load increases, however, this voltage may drop to .9 of the rms secondary value or less. The choke input filter starts with a d-c voltage of .9 rms secondary voltage and will vary very much less, thus affording better regulation. See Question 3.399. If the rectifier has mercury-vapor tubes, a choke-input filter must be used, as otherwise the initial current may be high enough to damage the tube. At the first starting cycle of the rectifying voltage, the input condenser has no charge. This means that it is practically a short circuit for the initial current until it becomes charged. Thus there is nothing to limit the initial current except the impedance of the tube which is very low and the impedance of the high voltage secondary winding which is also very low. This means that the initial current value will be extremely high and may damage the tube.

Where the input condenser is removed and a choke input filter is used, the initial current will be very much lower. This is because, when the initial charging current flows, it must flow through the inductance of the choke oil. The sudden surge of current develops a high reactive drop across the choke coil which opposes the original secondary voltage and thus limits the current in the system to a safe value. Sometimes, in low current systems, a current limiting resistor may be used in series with the rectifier tube. This, however, has an adverse effect on the regulation.

Q. 3.402. What is the percentage regulation of a power supply with a no-load voltage output of 126.5 volts and a full-load voltage output of 115 volts?

A. The regulation is 10%.

D. See Question 3.410.

$$\frac{126.5 - 115}{115} = \frac{11.5}{115} = 0.1, \text{ or } 10\% \text{ regulation.}$$

Q. 3.403. What is the definition of "voltage regulation" as applied to power supplies?

A. The regulation of a source of power is the ratio of the change in voltage, between no load and full load, to the full load voltage output.

D. Regulation is usually expressed as a percentage according to the formula: Reg. $= \frac{E_{NL} - E_{FL}}{E_{FL}} \times 100$, where E_{NL} is the no-load voltage, and E_{FL} is the full-load voltage. For numerical examples, see Questions 3.402, 4.98, and 4.100.

Q. 3.404. May two condensers of 500 volts operating voltage, one an electrolytic and the other a paper condenser, be used successfully in series across a potential of 1,000 volts? Explain your answer.

A. Such an arrangement is not to be recommended except in emergencies.

D. When two condensers are connected in series, across d.c., the voltage across them divides in proportion to their leakage resistances. The leakage resistance of a good electrolytic condenser is in the order of a few megohms (often much less), while the leakage resistance of a good paper condenser may be in excess of 100 megohms. Thus, most of the voltage will appear across the paper condenser and it will probably break down. If such a connection should become necessary, it may be successfully accomplished by inserting in parallel with each condenser. a relatively low value of equalizing resistance (100,000 ohms or less). Of course, proper polarity of the electrolytic condenser must be observed. See Question 3.181.

Q. 3.405. What is the principal function of a swinging choke in a filter system?

A. The principal function of a swinging choke is to improve the regulation of the power supply under conditions of varying loads.

D. A swinging choke is one whose inductance varies inversely with the amount of d-c current flowing through it. The main reason for using a swinging choke is economy, as compared with the use of a conventional or smoothing choke. Where a varying load is present, less filtering is required at heavy loads. As the load decreases, it is necessary to have an increasing value of inductance if the choke is to continue to filter properly, otherwise the output voltage will rise sharply at low current values. A swinging choke may be chosen to fulfill these requirements much more economically than a smoothing choke which would have to be designed to present a constant maximum inductance under all load conditions. This would mean a large expensive choke. A swinging choke must be the one nearest the rectifier tube, and is generally followed by a smoothing choke in order to satisfy filtering conditions. A system like this is still considerably more economical than if two smoothing chokes had to be used. The inductance is made to vary by having a very small gap, such as the thickness of a piece of fish paper, inserted in the iron core.

Q. 3.406. What is the purpose of a bleeder resistor as used in connection with power supplies?

A. See Question 3.182.

Q. 3.407. What does a blue haze in the space between the filament and plate of a high-vacuum rectifier tube indicate?

A. A blue haze indicates the presence of gas in the tube.

D. The blue color is due to the ionization of free gas within the tube and is caused by electron bombardment. If the tube is operating under normal conditions, it should be replaced, as its peak inverse voltage rating is decreasing and it may soon become unsuitable as a rectifier under the existing conditions.

A blue color is a normal condition of operation in tubes such as mercury-vapor rectifier tubes and voltage regulator tubes. (See also Question 3.98.)

Q. 3.408. When condensers are connected in series in order that the total operating voltage of the series connection is adequate for the output voltage of a filter system, what is the purpose of placing resistors of high value in shunt with each individual condenser?

A. The purpose of these (equalizing) resistors is to insure the correct voltage distribution across the individual condensers.

D. See also Questions 3.101 and 3.404.

Q. 3.409. If a high-vacuum type, high-voltage rectifier tube should suddenly show severe internal sparking and then fail to operate, what elements of the rectifier-filter system should be checked for possible failure before installing a new rectifier tube?

A. The following should be checked:

(1) The filter condensers should be checked for leakage or short circuit.

(2) If these are good the choke or chokes should be checked for possible insulation breakdown.

(3) The rectifier tube itself should be checked for gas and shorts.

D. See Question 3.410.

Q. 3.410. If the plate, or plates, of a rectifier tube suddenly became red hot, what might be the cause and how could remedies be effected?

A. If the plate of a rectifier tube became red hot, it would be due to excessive current demand upon the tube.

D. The filter components should be checked as indicated in Question 3.102. If these are in good order the current demands of all the supplied circuits should be investigated. A screen or plate bypass condenser might be shorted. The coupling condenser to a high power tube might be shorted. In the case of an r-f power amplifier the plate tank might be mistuned or overloaded.

Q. 3.411. Draw a simple schematic diagram of a quartz-crystal-controlled oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.

A. See Question 3.73.

Q. 3.412. Draw a simple schematic diagram of a dynatron type of oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.

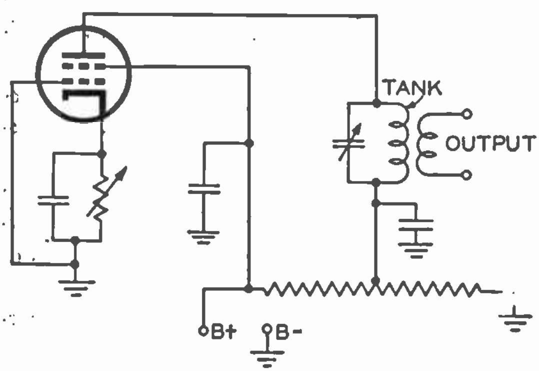


Fig. 3.412. A dynatron oscillator.

A. See the figure. Note that the tube is a tetrode and that the plate voltage is lower than the screen voltage.

D. See Questions 3.426 and 3.428.

Q. 3.413. Draw a simple schematic diagram of an electron-coupled oscillator, indicating the ciruit elements necessary to identify this form of oscillatory circuit.

A. See Question 3.76.

Q. 3.414. What does the expression "positive temperature coefficient" mean, as applied to a quartz crystal?

A. The expression means that the operating frequency of the crystal will increase as the temperature increases, and decrease as the temperature decreases. Such a characteristic is typical of a *Y*-cut crystal.

D. See Question 3.417.

Q. 3.415. Draw a simple schematic diagram of a crystal-controlled vacuum-tube oscillator using a pentode-type tube. Indicate power-supply polarity when necessary.

A. See Question 3.77.

Q. 3.416. What will result if a direct-current potential is applied between the two parallel surfaces of a quartz crystal?

A. The crystal plate will undergo a physical deformation.

D. The exact character of this deformation will depend upon the crystal cut and the magnitude of the d-c potential applied. It is conceivable that if sufficient d-c potential were applied, the crystal might actually crack under the strain of displacement. The phenomenon is known as the "piezo-electric effect."

Q. 3.417. What does the expression "negative temperature coefficient" mean, as applied to a quartz crystal?

A. The expression means that the operating frequency of the crystal will decrease as the temperature increases, and increase as the temperature decreases.

D. A standard crystal marking may be as follows: —50/10^6/C°/. This means that the crystal frequency will change at the rate of 50 cycles per megacycle, per degree change of temperature in centigrade. The negative sign indicates that the crystal has a negative temperature coefficient. For example, a 7 megacycle crystal has the following marking: —40/10^6/C°; find the operating frequency if the temperature increases 5°C. This is done simply as follows: $-40 \times 7 \times 5 = 1400$ cycles. The new frequency is 7,000,000 minus 1400 or 6,998,600 cycles. See Questions 3.414 and 3.418.

Q. 3.418. What does the expression "low temperature coefficient" mean, as applied to a quartz crystal?

A. "Low temperature coefficient" means that the crystal will undergo very small changes in its operating frequency with relatively large temperature variations.

D. See Questions 3.414 and 3.417.

Q. 3.419. What is the function of a quartz crystal in a radio transmitter?

A. The function of a quartz crystal in a radio transmitter is to provide a high degree of master oscillator frequency stability.

D. The quartz crystal, its holder capacitance and associated tube and stray capacitance actually form an equivalent tank circuit of very high Q. Etched crystals with plated electrodes, mounted in a vacuum, have been found to give Q's in the order of 500,000. This is exceptional, however, and ordinary crystal installations have a Q (unloaded) in the order of a thousand or more. Crystal oscillators are generally found in two forms. One is the tuned-plate variety, in which the crystal takes the place of the grid tank circuit (Question 3.73). The other type is the Pierce oscillator (equivalent to the "ultraudion"), in which the crystal is the sole tuned circuit in the oscillator (Question 6.413). In any event the very high Q of the crystal makes for excellent oscillator stability, especially when a constant temperature is maintained.

Q. 3.420. What may result if a high degree of coupling exists between the plate and grid circuits of a crystal-controlled oscillator?

A. The crystal might overheat and break.

D. In the conventional (tuned-plate—tuned-grid) crystal oscillator, discussed in Question 3.73, this means a relatively large value of grid to plate capacitance for the particular operating frequency. This in turn might cause excessive feedback into the crystal circuit, overheating and possibly cracking the crystal. The use of a tetrode or pentode greatly reduces this possibility because of the small value of grid to plate capacitance.

Q. 3.421. What is the purpose in maintaining the temperature of a quartz crystal as constant as possible?

A. To maintain a fixed frequency output from the crystal.

D. Many crystal cuts have temperature coefficients in varying degrees. (See Questions 3.414, 3.417, and 3.418.) Thus, if a very close tolerance in output frequency is to be maintained, it is essential that the crystal temperature be kept absolutely constant. This is done by enclosing the crystal assembly within a constant temperature "oven." See diagram, Q. 4.80.

Q. 3.422. Why is a separate source of plate power desirable for a crystal-oscillator stage in a radio transmitter?

A. To prevent "dynamic instability" of the crystal oscillator.

D. See Question 3.333. If a common power supply is used and its regulation is not excellent, any load changes occurring in the transmitter will cause plate and screen grid voltage changes at all tubes including the oscillator tube. Such supply voltage changes will cause shifts in the oscillator called "dynamic instability."

Q. 3.423. What are the principal advantages of crystal-control over tuned-circuit oscillators?

A. The principal advantages of crystal control are improved frequency stability and compactness of the crystal as compared to a conventional tuned circuit.

D. See Question 3.419. A serious disadvantage of crystal control is the difficulty of changing operating frequencies. This entails the use of a cumbersome crystal changing switch, or the actual plugging in of separate crystals. Small changes in the crystal operating frequency may be made by changing the pressure of the crystal holder or by having a small variable condenser across the crystal.

Q. 3.424. What is the approximate range of temperature coefficients to be encountered with X-cut quartz crystals?

A. The approximate range of temperature coefficients encountered with *X*-cut crystals is from 0 to —20 cycles per megacycle, per degree centigrade.

D. In order to achieve a low temperatur ecoefficient in a X-cut crystal, the "width" vibration is used, and the length in the direction of the *Z*-axis must be small compared to the width. When the bar is square and has sides that are .272 times the width along the mechanical, or *Y*-axis, the temperature coefficient will be zero.

Q. 3.425. Is it necessary or desirable that the surfaces of a quartz crystal be clean? If so, what cleaning agents may be used which will not adversely affect the operation of the crystal?

A. The crystal surfaces must be free of dirt or grease in order to operate properly. The faces of the crystal should not be touched with the fingers, and may be cleaned with soap and water or carbon tetrachloride.

D. Any greasy film upon the surfaces of a crystal will prevent good contact being made with the holder, and will interfere with the correct operation of the crystal.

Q. 3.426. List the characteristics of dynatron type of oscillator.

A. The characteristic of a dynatron oscillator are:

1. Good frequency stability. (But not as good as transitron oscillator.)
2. Poor efficiency.
3. Low output power.
4. Must use a tetrode tube.
5. Screen voltage higher than plate voltage.
6. Tank circuit connected between plate and cathode.

D. The use of the dynatron oscillator is becoming extremely restricted due to the lack of suitable tetrodes having the required secondary emission. The "transitron" oscillator is used instead, and has superior stability characteristics. (See also Questions 3.412 and 3.428.)

Q. 3.427. List the characteristics of an electron-coupled type of oscillator.

A. The characteristics of an electron-coupled oscillator are:

1. Buffer stage action because oscillator tank is isolated from the load.
2. Frequency multiplication obtainable in the plate circuit.
3. Frequency may be made independent of supply voltage variations.
4. Combination of oscillator and amplifier in only one tube.
5. Must use tetrode or pentode.
6. Excellent frequency stability.
7. Good efficiency.
8. Relatively large, stable output.

D. See Question 3.76.

Q. 3.428. Upon what characteristic of an electron tube does a dynatron type of oscillator depend?

A. The operation of a dynatron oscillator depends upon the negative resistance characteristic of a tetrode tube. (See the figure.)

D. If a conventional tetrode tube is operated with the plate voltage somewhat lower than the screen grid voltage, there will be a portion of the characteristic curve which will have a negative slope. Within this region any increase in plate voltage will be accompanied by an increase of plate current likewise, any decrease of plate voltage will be accompanied by an increase of plate current. In this operating region, the

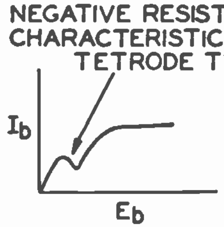


Fig. 3.428. I_b-E_b curve of a tetrode, showing the negative resistance characteristic.

plate to cathode resistance of the tube provides energy instead of requiring it. This ability to provide energy is called "negative resistance." If a tuned circuit of reasonably high Q is connected between the plate and cathode terminals of the tube continuous oscillations will be generated since the "negative resistance" is equivalent to feedback energy. "Negative resistance" differs from positive resistance in that it provides energy instead of dissipating it. The operation is briefly as follows: The tank circuit is shock-excited into oscillation either by the closing of the power supply switch or by random electron impulses within the tube. As the tank becomes more positive at the plate thus increasing the instantaneous plate voltage, the electron acceleration to the plate increases, and causes a considerably greater secondary emission which is picked up by the screen grid, thus increasing the screen grid current, but decreasing the plate current and providing negative resistance. As the plate side of the tank becomes more negative, the instantaneous plate voltage is decreased, the electron acceleration to the plate decreases, secondary emission from plate to screen decreases, and thus the plate current actually increases, again providing negative resistance. Since the negative resistance provides the necessary energy to overcome tank circuit losses, continuous oscillations are generated. See Questions 3.419 and 3.433.

Q. 3.429. What is a multivibrator and what are its uses?

A. A multivibrator is a form of relaxation oscillator which is rather unstable in the free running condition, but which may be completely stabilized by the application of suitable synchronizing voltages. It requires two tubes for its operation and has a frequency range extending approximately from 1 cycle per minute to 100,000 (or more) cycles per second.

Some uses for multivibrators are:

1. As frequency dividers.
2. As sawtooth generators.
3. As harmonic generators.
4. As square wave and pulse generators.
5. As a standard frequency source when synchronized by an external crystal oscillator.
6. Many specialized uses in radar and television circuits.

D. For schematic diagram, see Question 4.104. There are two general classifications of multivibrators. These are the *free running* or nondriven type, and the *driven* or "single-shot" type. The former type is capable of generating continuous oscillations, while the latter type requires a driving pulse to start the operation after which it will complete one full cycle and then stop and wait for the next driving pulse

Multivibrators are also classified as to the manner of feedback. These divisions generally speaking are: (1) plate coupling, where feedback is taken from the plate circuit of each tube and fed into the grid of the opposite tube, and (2) cathode coupling where feedback is provided by means of a common cathode resistor for both tubes and plate coupling for one tube. When used as a frequency divider, the free running frequency of the multivibrator is set so as to be slightly lower than a whole sub-multiple of the synchronizing frequency. A frequency division of 10:1 or so is usually considered to be the maximum obtainable with reliable stability of the multivibrator. For example an original source of 100,000 cycles could be used to synchronize a multivibrator operating at 10,000 cycles. Due to the very high harmonic content of the non-sinusoidal multivibrator output voltage, harmonics in the order of one hundred or more may be obtained. Thus if the 100,000 cycle synchronizing voltage was supplied by a very stable crystal oscillator, a series of standard harmonic frequencies would be available ranging from 10,000 cycles (fundamental) and increasing in steps of 10,000 cycles to possibly 1,000,000 cycles. A complete description of the operation of multivibrators is beyond the space limitations of this volume and so will not be attempted here. No definite simple formula may be given for the frequency of a multivibrator since there are too many variables. However, it can be said that the grid coupling elements (condenser and resistor) have the greatest effect upon the determination of the frequency. Increasing or decreasing the time-constant of this combination (Question 4.170) causes proportional increases or decreases of frequency.

Q. 3.430. If a frequency-meter, having an over-all error proportional to the frequency, is accurate to 10 cycles when set at 600 kilocycles, what is its error in cycles when set at 1,110 kilocycles?

A. The error will be 18.5 cycles.

D. Since it is stated that the error is proportional to the frequency, a ratio may be set up as follows: $\frac{10}{600} = \frac{X}{1{,}100}$; solving for X, $X = \frac{11{,}100}{600}$ or 18.5 *cycles.*

Q. 3.431. What precautions should be taken before using a heterodyne type of frequency meter?

A. The following precautions should be taken:

1. All operating potentials should be correct.
2. The equipment should be mechanically rigid.
3. The equipment should be permitted to heat up for about ½ hour before using.
4. Before using, the frequency meter should be calibrated by zero beating against a standard frequency crystal oscillator.

D. See Question 3.432.

Q. 3.432. What is the meaning of "zero beat" as used in connection with frequency-measuring equipment?

A. "Zero beat" occurs when two frequencies are being mixed together and have no difference frequency between them. To achieve this both frequencies must be the same.

D. In reference to a heterodyne frequency meter, zero beat would be used in two instances. The first use would be when calibrating. In this case the main dial is set to a calibrating point and a standard frequency is fed in which is mixed with the locally generated frequency. The calibration control is varied until both frequencies are exactly the same and the tone in the headphones disappears completely, thus achieving "zero beat."

The second use would be when determining the output frequency of a transmitter. Here the transmitter wave would be picked up and fed into the mixer of the frequency meter together with the locally generated signal. The frequency meter dial is turned until "zero beat" is accomplished in the headphones, whereupon the calibrated dial of the frequency meter may be read and the frequency of the transmitter determined. (See also Questions 3.431 and 4.166.)

Q. 3.433. What precautions should be observed in using an absorption-type frequency meter to measure the frequency of a self-excited oscillator? Explain your reasons.

A. The pickup coil of the absorption type frequency meter should be coupled as loosely as possible to the circuit under measurement in order to reduce errors in the readings.

D. An absorption type frequency meter consists basically of a tuned circuit in series with which is inserted a suitable indicating device such as a small light-bulb or thermocouple meter. For its operation it requires that a relatively large amount of energy be taken from the measured circuit. If the coupling between the frequency meter and circuit is excessive, an impedance will be coupled into the measured circuit, changing its basic operating frequency and introducing errors in the readings. See Questions 3.498 and 6.638.

Q. 3.434. If the first speech amplifier tube of a radio-telephone transmitter were overexcited, but the percentage modulation capabilities of the transmitter were not exceeded, what would be the effect upon the output of the transmitter?

A. The effect upon the transmitter would be to cause a distorted audio modulation component to be present in the radiated wave. New harmonic frequencies would be developed which might cause adjacent channel interference.

D. The effect would be the same as overdriving any audio amplifier. Clipping of the positive and negative peaks of the audio wave would occur, resulting in extreme distortion of the original wave, and the production of new harmonic frequencies.

Q. 3.435. What is the purpose of a pre-amplifier?

A. In general the purpose of any pre-amplifier is to increase the signal-to-noise ratio output from an amplifier.

D. At the same time that a pre-amplifier raises the signal to noise ratio it also increases the overall gain of the amplifier and thus its sensitivity. Pre-amplifiers may be found in both audio and r-f systems. In audio systems one example of the use of pre-amplifiers is found in broadcast studio operation. Here the output of each microphone is first fed into a pre-amplifier and the output of the pre-amplifier is connected to the studio mixer. This arrangement raises the signal level before mixing and thus overcomes to a large degree the inherent noise level of the mixer and connecting lines. In superheterodyne receivers, a tuned r-f pre-amplifier ahead of the first detector provides an increased signal level to the first detector which helps to override the noise generated in this stage.

Q. 3.436. What are the advantages of using two tubes in push-pull as compared with the use of the same tubes in parallel in an audio-frequency amplifier?

A. Advantages of push-pull operation are:
1. Cancellation of even harmonic distortion in the output.
2. Reduction of hum.
3. Reduction of regenerative feedback.
4. Elimination of d-c core saturation, in output transformer.
5. Elimination of cathode by-pass condenser.

D. 1. Even order harmonic currents flow out of phase in the output transformer and thus cancel. This does not apply to distortion created either before or after the push-pull stage.

2. Hum currents are out of phase in the output transformer and return circuits and, therefore, cancel.

3. There is no a-c signal current flowing through the plate supply and return circuits, and thus the tendency for regeneration in a multi-stage amplifier is reduced.

4. The d-c plate currents in the output transformer flow in opposite directions creating opposing magnetic fields which cancel. This enables the size of the iron core to be made much smaller for a given power rating.

5. The fundamental a-c signal components flow in opposite directions through the cathode resistor and cancel. Thus no by-passing is theoretically needed. However, a bypass condenser is often included to compensate for unbalance in the tubes and for heater to cathode leakage.

Q. 3.437. List four causes of distortion in a class A audio-frequency amplifier.

A. Distortion of a class A amplifier may be caused by the following:
1. Insufficient plate and screen potentials.

2. Incorrect grid bias.
3. Excessive amplitude of grid signal.
4. Leaky or shorted input coupling condenser.
5. Incorrect value of load impedance.
6. Defective tube.

D. See Questions 3.106, 3.133 and 3.135.

Q. 3.438. What is the purpose of bypass condensers connected across audio-frequency amplifier cathode-bias resistors?

A. The purpose of the cathode bypass condenser is to prevent variations of bias during excitation of the amplifier.

D. If no bypass condenser were across the cathode resistor, the amplifier would in general have improved performance but at a sacrifice in gain. Placing a condenser of suitable value across the cathode resistor prevents degenerative effects due to instantaneous bias changes on the cathode, which are in phase with the applied signal. This is due to the fact that the condenser charges very little on increasing plate currents and discharges very little on decreasing plate currents. This condition requires that the time constant in the cathode circuit be long with respect to the time of the lowest audio frequency desired to be passed through the amplifier without degeneration. A simple formula to calculate the value of cathode condenser is: $C_K = \frac{10{,}000{,}000}{2\pi f_1 R_k}$, where C_K is cathode condenser in microfarads, f_1 is the lowest frequency in cycles desired to be passed and R_K is the cathode bias resistance in ohms.

Q. 3.439. What are the advantages of using a resistor in series with the cathode of a class C radio-frequency amplifier tube to provide bias?

A. A cathode bias resistor in a class C r-f amplifier is used to provide protective bias in case the normal class C bias source fails.

D. This system is invariably used with fairly large tubes to protect such tubes against damage. If excitation is removed, in the case of grid leak bias, or if the bias supply fails, in the case of fixed bias, the plate current of the amplifier tube would immediately rise to large values. However, if a cathode resistor is present, the rising plate current automatically provides increased cathode bias and limits the maximum plate current to a safe value.

Q. 3.440. How may the generation of even harmonic energy in a radio-frequency amplifier stage be minimized?

A. The generation of even harmonic frequencies may be minimized by operating the amplifier class B or class A rather than class C, and by using negative feedback.

D. See Question 3.371.

Q. 3.441. What tests will determine if a radio-frequency power-amplifier stage is properly neutralized?

A. Two tests for neutralization may be made as follows:

1. (a) Remove the plate (and screen) voltage from the stage being tested, but keep filaments lit and grid excitation present. (See Question 4.129.)
   (b) If not already present, insert a d-c milliameter of suitable range into the grid circuit of the amplifier under test.
   (c) Vary the tuning of the plate tank circuit while observing the grid current meter.
   (d) If sharp variations of grid current are observed while so tuning, the stage is not properly neutralized.
   (e) Adjust neutralizing condenser until variations in grid current cease during plate tank tuning.

2. (a) This method requires the use of a suitable r-f indicator which may be a neon bulb, a small flashlight bulb with a loop of wire attached, a sensitive wavemeter, a sensitive thermocouple meter with a loop of wire attached, or any other suitable indicator.
   (b) Remove the plate (and screen) voltages from the stage being tested, but keep filaments lit and grid excitation present. (See Question 4.129.)
   (c) With any of the indicators mentioned above (a), test for the presence of oscillations in the plate tank while tuning the tank condenser through its range.
   (d) While performing the above (c), the grid circuit should be tuned for the maximum grid current, and the preceding plate circuit tuned for maximum drive, indicated by maximum grid current.
   (e) If oscillations are present in the plate tank circuit, adjust the neutralizing condenser until they vanish or are at a minimum.
   (f) After a minimum indication has been reached, the driver and grid tanks should be retuned for maximum grid current and the neutralizing procedure repeated.

(See also Question 3.448.)

Q. 3.442. Why is the plate-circuit efficiency of a radio-frequency amplifier tube operating as class C higher than that of the same tube operating as class B? If the statement above is false, explain your reasons for such a conclusion.

A. The above statement is correct. Class C efficiency is greater, because plate current exists in the tube only during that portion of the cycle when the instantaneous plate voltage is at a minimum, therefore the power consumed *in the tube* is low.

D. See Question 3.104.

Q. 3.443. Why does a class B audio-frequency amplifier stage require considerably greater driving power than a class A amplifier?

A. A class B audio amplifier stage usually operates with a value of grid input signal sufficient to drive the grid positive with respect to the cathode, on the positive peaks of the signal. Thus grid current exists for these positive peaks and appreciable power is dissipated in the grid circuit. The usual class A amplifier does not operate in the grid current region, and, therefore, requires an insignificant amount of grid driving power.

D. See Questions 3.107, 3.108, and 3.444.

Q. 3.444. Discuss the input circuit requirements for a class B audio-frequency amplifier grid circuit.

A. As with most power tubes, it is required that the input grid impedance be kept low, especially where grid current exists. A transformer is generally used to couple into the grid circuit of the push pull class B tubes. The turns ratio of this transformer must be correct so that the proper load impedance will be reflected back into the primary to the driver tube (or tubes). A well regulated power supply is needed to supply class B tubes because the average plate current varies in proportion to the grid signal.

D. See Question 3.443.

Q. 3.445. When a signal is impressed on the grid of a properly adjusted and operated class A audio-frequency amplifier, what change in average value of plate current will take place?

A. Under normal operating conditions the average plate current of a class A amplifier will remain constant.

D. See Questions 3.106, 3.109, and 3.133.

Q. 3.446. If the value of capacitance of a coupling condenser in a resistance-coupled audio amplifier is increased, what effect may be noted?

A. The low frequency response will be increased.

D. If the capacitance of a coupling condenser is increased and a frequency run is made on the amplifier, it will be noted that the low-frequency response has been increased. The coupling condenser and grid resistor form a voltage divider, the output of which is connected to the grid of the amplifier tube. Only the voltage appearing across the grid resistor is effective as grid signal for the tube. At high frequencies, the reactance of the coupling condenser is negligible and the total input voltage appears across the grid resistor. As the frequency decreases, the reactance of the coupling condenser increases and due to the voltage divider action, less voltage appears across the grid resistor. At some low frequency the reactance of the coupling condenser will be equal to the value of grid resistor and the voltage across the grid resistor will drop to .707 of the input voltage. This represents a drop of 3 db, generally not noticeable to the ear, and is commonly accepted as a design point. The frequency at which this amount of drop occurs can be reduced by increasing the time constant of the coupling circuit, which is done by raising the value of grid resistance or coupling condenser, or both. The low frequency response is inversely proportional to the time constant of the coupling circuit. Whether or not such an increase will be beneficial depends upon the original time constant of the coupling condenser and grid resistor combination. A simple means of determining the correct value of coupling condenser for any desired low frequency response is given by the formula: $C_c = \frac{1{,}000{,}000}{2f_1R_g}$, where C_c is the coupling condenser in microfarads, f_1 is lowest desired frequency in cycles, and R_g is the value of grid resistance in ohms. The maximum permissible value of grid resistance is usually given in the tube manual.

Q. 3.447. Why does a screen-grid tube normally require no neutralization when used as a radio-frequency amplifier?

A. A screen-grid tube has a very low value of grid-to-plate capacitance. This small capacitance offers a very high reactance to feedback currents at medium and low frequencies thus preventing oscillations from being sustained.

D. See Questions 3.101, 3.115, 3.279, and 3.12.

Q. 3.448. What instruments or devices may be used to adjust and determine that an amplifier stage is properly neutralized?

A. The following indicating devices may be used to determine correct neutralization:

1. A neon bulb.
2. A low-current flashlight bulb connected to a small loop of wire.
3. The amplifier grid current meter.
4. A sensitive wavemeter.
5. A sensitive thermocouple meter attached to a small loop of wire.
6. A thermocouple meter connected in series with the plate tank.

D. See Question 3.441.

Q. 3.449. What is meant by the term "unity coupling?"

A. "Unity coupling" is the theoretical maximum degree of coupling between two coils.

D. To achieve the condition of "unity coupling," it is necessary that all of the magnetic lines of force of the primary coil cut all the turns of the secondary coil, and that all of the magnetic lines of force of the secondary coil also cut the primary coil. In practice this situation is almost impossible to achieve. However, when an efficient iron core is used, it is possible to approach the condition of "unity coupling." The formula for coefficient of coupling is: $K = \frac{M}{\sqrt{L_1 L_2}}$, where K is equal to the coefficient of coupling with a maximum value of 1, M is the mutual inductance between the two coils, and L_1 and L_2 are the inductances of the primary and secondary coils.

Q. 3.450. Draw a diagram illustrating "capacitive" coupling between two tuned radio-frequency circuits.

A. See Question 3.84.

Q. 3.451. Draw a diagram illustrating "inductive" coupling between two tuned radio-frequency circuits.

A. See Question 3.85.

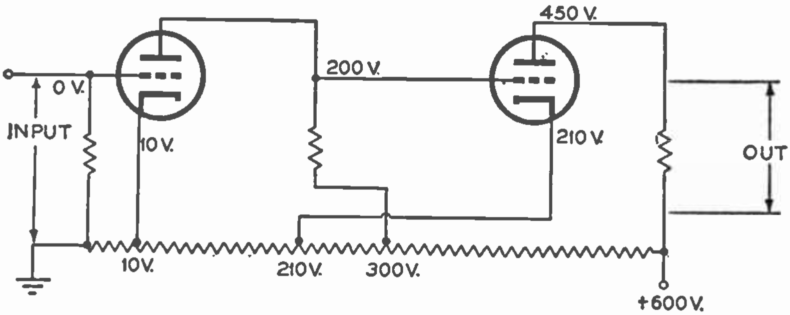


Fig. 3.452. A direct-coupled amplifier.

Q. 3.452. Draw a diagram illustrating "direct" or "Loftin-White" coupling between two stages of audio-frequency amplification.

A. See the figure.

D. The grid to cathode bias of each amplifier tube is shown as 10 volts. The plate supply voltage for the first tube is 290 volts, while for the second tube it is 390 volts. The low frequency response of this amplifier is perfect down to zero cycles. The frequency response is limited by the total shunt capacity to ground.

Q. 3.453. List four classes of stations which may be operated by a person holding a radiotelephone second-class license.

A. Any station while using type A-0, A-3, A-4, or A-5 emission except standard broadcast stations, international broadcast stations, or ship stations licensed to use power in excess of 100 watts and type A-3 emission for communication with costal telephone stations. Four classes of such permitted stations are as follows:

1. Relay broadcast stations.
2. Aeronautical stations.
3. ST broadcast stations.
4. General experimental stations.

(For emission types, see Question 3.462.)

Q. 3.454. May the holder of a radiotelephone second-class operator license adjust and service or supervise the adjustment and servicing of any class of police radio station?

A. Yes, as long as the police radio station does not use type A-1 or A-2 emission.

Q. 3.455. List four classes of stations, the equipment of which may be adjusted and serviced by the holder of a radio telephone second-class operator license.

A. Same as for Question 3.453.

Q. 3.456. If an operator is employed at more than one station, how may the requirements of the Commission's Rules and Regulations be met with respect to the posting of operator licenses?

A. The holder of a radiotelegraph or radiotelephone first- or second-class license who is employed as a service and maintenance operator at stations operated by holders of Restricted Operator Permits shall post at such stations his operator license or a verified statement from the Commission in lieu thereof.

Q. 3.457. Is it necessary that the original operator license be posted at an aeronautical station? An aircraft station? An airport station? A broadcast station? A ship station?

A. In all the above stations, the operator's license must be posted during the time that the operator is on duty. In the case of mobile stations either the original license or verification card must be kept in the operator's possession.

In cases where the holder of a restricted radiotelephone operator permit may act as operator on duty, the operator shall keep the permit (if of the card form, as distinguished from the diploma form) in his personal possession.

Q. 3.458. What is a "verification card" and under what circumstances may it be used?

A. The holder of an operator license who operates any station in which the posting of an operator license is not required, may, upon filing application in duplicate, accompanied by his license, obtain a "verification card." This card may be carried on the person of the operator in lieu of the original operator license, provided the license is readily accessible within a reasonable time for inspection upon demand by an authorized Government representative.

Q. 3.459. If a ship radiotelephone station is assigned the frequency of 2738 kilocycles and the maximum frequency tolerance is 0.02 percent, what are the highest and lowest frequencies within the tolerance limits.

A. The tolerance limits are between 2737.4524 kilocycles and 2738.5476 kilocycles.

D. The tolerance limits are found by first multiplying the original frequency by the tolerance. Thus, 2738 kilocycles $\times$ .0002 = 0.5476 kilocycles. The upper frequency limit equals 2738 + 0.5476 = 2738.5476 kilocycles. The lower frequency limit equals 2738 — 0.5476 = 2737.4524 kilocycles.

Q. 3.460. If an aircraft station is assigned the frequency of 3117.5 kilocycles and the maximum tolerance is 0.01 percent, what are the highest and lowest frequencies within the tolerance limits?

A. The tolerance limits are between 3117.18825 kilocycles and 3117.81175 kilocycles.

D. The tolerance limits are found by first multiplying the original frequency by the tolerance. Thus, 3117.5 $\times$ .0001 = 0.31175 kilocycles. The upper frequency limit equals 3117.5 + 0.31175 = 3117.81175 kilocycles. The lower frequency limit equals 3117.5 — 0.31175 = 3117.18825 kilocycles.

Q. 3.461. If a heterodyne frequency meter, having a calibrated range of 1000 to 5000 kilocycles, is used to measure the frequency of a transmitter operating on approximately 500 kilocycles by measurement of the second harmonic of this transmitter, and the indicated measurement was 1008 kilocycles, what is the actual frequency of the transmitter output?

A. The actual frequency is 504 kilocycles.

D. Since the second harmonic is 1008 kilocycles, the original frequency is found by dividing this number by two, or 504 kilocycles.

Q. 3.462. Define the following types of emission: A0, A1, A2, A3, A4, A5.

A. The emissions mentioned are amplitude-modulated in accordance with the following definitions:

Type A0. Waves, the successive oscillations of which are identical under fixed conditions. (Standard frequency transmission.)

Type A1. Telegraphy on pure continuous waves. A continuous wave which is keyed according to a telegraph code.

Type A2. Modulated telegraphy. A carrier wave modulated at one or more audible frequencies, the audible frequency or frequencies or their combination with the carrier wave being keyed according to a telegraph code.

Type A3. Telephony. Waves resulting from the modulation of a carrier wave by frequencies corresponding to the voice, to music, or to other sounds.

Type A4. Facsimile. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of a fixed image with a view to its reproduction in a permanent form.

Type A5. Television. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of fixed or moving objects.

D. According to the Federal Communications Commission Rules and Regulations, Part 2 (Rules Governing Frequency Allocations and Radio Treaty Matters; General Rules and Regulations), Amendment effective February 1, 1949, radiation is classified on the following basis:

(A) Types of modulation and emission are symbolized according to the following letters:

Amplitude Modulation	A
Frequency (or phase) modulation	F
Pulsed Emission	P

(B) Types of transmission are symbolized according to the following numbers:

Absence of any modulation intended to convey information	0
Telegraphy without the use of modulating audio frequency	1
Telegraphy by the keying of a modulating audio frequency or frequencies, or by the keying of the modulated emission (special case: an unkeyed modulated emission)	2
Telephony	3
Facsimile	4
Television	5
Composite transmissions and cases not covered by the above	9

(C) Supplementary characteristics are symbolized in accordance with the following letters:

Double sideband, full carrier	(none)
Single sideband, reduced carrier	a
Two independent sidebands, reduced carrier	b
Other emissions, reduced carrier	c
Pulse, amplitude modulated	d
Pulse, width modulated	e
Pulse, phase (or position) modulated	f

As an exception to the above principles, damped waves are symbolized in the Commission's Rules and Regulations as type B emission.

Some illustrative examples are given below, in addition to those included in the answer to the question.

F1 Telegraphy by frequency shift keying, without the use of modulating audio frequency.

F3 Telephony by FM (example: ordinary FM broadcast station)

P3e Telephony by width-modulated pulse.

It should be noted that operator licenses which have been issued for certain types of modulation under class A emission are, with the adoption of the above system of radiation classification, valid for the corresponding modulation types for class F and class P emission.

Q. 3.463. In the adjustment of a radio telephone transmitter, what precautions should be observed?

A. From the point of view of operation of the transmitter, it should be carefully determined that interference to other stations will not be caused.

D. Whenever possible, a dummy antenna should be used especially when major tuning adjustments or tests are being made. The operation of the transmitter should be confined in accordance with the terms of the station license. Radical tuning adjustments should be made under reduced power conditions, and care must be taken to insure that the transmitter frequency is maintained within proper tolerance ratings. Great care should be taken when undertaking adjustments or repairs *inside* of the transmitter, to insure that all high voltage condensers are fully discharged by a suitable grounding stick, before handling any of the equipment.

Q. 3.464. Explain the relation between the signal frequency, the oscillator frequency, and the image frequency in a superheterodyne receiver.

A. The difference between the signal frequency and the oscillator frequency is equal to the intermediate frequency. The image frequency is equal to the signal frequency,plus the intermediate frequency, or minus twice the intermediate frequency depending upon whether the oscillator frequency is above or below the signal frequency.

D. See Question 3.265.

Q. 3.465. What means are used to prevent interaction between the stages of a multistage audio-frequency amplifier?

A. The most effective means to prevent interaction is by the use of suitable *R-C* decoupling filters in the plate and screen grid circuits.

D. Another precaution is to locate the high gain stages apart from each other and properly shielded. The wiring arrangement may also be critical, to eliminate feedback.

Q. 3.466. For what period of time must a log containing distress entries be retained?

A. Logs containing communications incident to a disaster, or which include communications incident to or involved in an investigation by the Commission and concerning which the licensee has been notified, shall be retained by the licensee until specifically authorized in writing by the Commission to destroy them.

Q. 3.467. What effect, if any, does modulation have on the amplitude of the antenna current of an FM transmitter?

A. Modulation has no effect upon the amplitude of antenna current of an f-m transmitter.

D. Assuming that no amplitude modulation is also taking place, the output of an f-m transmitter should remain constant with or without modulation. The antenna current cannot change unless the power output varies, and thus remains at a fixed value. Modulation of an f-m wave varies the frequency and not the amplitude of the carrier wave.

Q. 3.468. Why is a high percentage of modulation desirable in amplitude modulated transmitters?

A. The following are advantages of high percentage modulation:

1. A higher signal to noise ratio at the receiver.
2. Greater area coverage for a given carrier power.
3. Greater useful transmitted power for a given carrier power.
4. Higher plate efficiency of the modulated r-f amplifier.
5. Less interference at the receiver from other stations operating on the same channel.

D. See Question 3.342.

Q. 3.469. How would loss of radio-frequency excitation affect a class C modulated amplifier when using grid leak bias only?

A. The bias depends upon the presence of an excitation signal and would therefore become zero. The plate current would then rise to a high value which might be excessive unless the tube is protected by cathode bias, or an overload relay.

D. If the tube in question were a small one such as a receiving type (6L6,6V6, etc.) there would probably be no burnouts, although if the power supply is normally working at its maximum capacity, the added load might conceivably damage the power transformer or the rectifier tube. In the event that a fairly large tube were being used, it would be customary to include a cathode bias network for safety. Then the larger the plate current tried to become, the more cathode bias would be developed, thus automatically limiting the plate current to a safe value.

Q. 3.470. What is the purpose of a center-tap connection on a filament transformer?

A. To prevent hum voltages from modulating the normal signal.

D. If the plate and grid returns were made to one side of the filament rather than the center, the filament voltage at the other side of the filament would vary at the rate of the supply frequency. This is equivalent to having the bias change at the supply frequency (usually 60 cycles) and thus the plate signal is modulated at supply frequency rate variations which becomes hum in the speaker. On the other hand, if the plate and grid returns are connected to the center tap, the voltage change on one side of the filament will be effectively cancelled out by an equal and opposite voltage change at the other side of the filament. Thus the bias remains substantially constant, and no hum will appear.

Q. 3.471. What would be the result of a short circuit of the plate radio-frequency choke coil in a radio-frequency amplifier?

A. In a shunt-fed amplifier, if the r-f choke shorted, then the plate tank circuit would be effectively shorted as far as r-f is concerned. The d-c plate current would increase considerably (possibly to excess) and no r-f output could be expected since the plate is now at r-f ground potential.

In a series fed amplifier a short circuit in the r-f choke would probably result in a decrease of amplifier efficiency due to the r-f dissipation in the power supply.

Q. 3.472. What are the advantages of push-pull operation compared to single tube operation in amplifiers?

A. Advantages of push-pull operation are:

1. Increased power output.
2. Cancellation of even harmonic distortion in the output.
3. Reduction of hum.
4. Reduction of regenerative feedback.
5. Elimination of d-c core saturation.
6. Elimination of cathode by-pass condenser.

D. The advantages are the same, as in the comparison with two tubes in parallel (Question 3.436) except that the power is proportionally greater for this case; a single tube can deliver only half the power delivered by two in parallel.

Q. 3.473. What class of amplifiers is appropriate to use in a radio-frequency doubler stage?

A. A class C amplifier is most efficient, with a bias approximately equal to 10 times cut-off.

D. See Questions 3.138 and 3.365.

Q. 3.474. What is the ratio of modulator power output to modulated amplifier plate power input for 100 percent amplitude modulation?

A. See Question 3.340.

Q. 3.475. Draw a diagram of a Hartley oscillator. A Colpitts oscillator.

A. For diagram of a Hartley oscillator see Question 3.70. For diagram of a Colpitts oscillator see Question 3.74.

Q. 3.476. Describe the construction and characteristics of (a) a beam power tube, (b) a thyratron tube, and (c) a battery charging rectifier tube.

A. (a) A beam power tube usually consists of a cathode, control grid, screen grid and plate, and in addition there are two so called "beam forming" plates on either side of the cathode. These plates are operated at cathode potential. The control grid and screen grid wires are aligned with each other so that the electron stream flows through them in "sheets." This reduces the screen grid current and thus increases the tube efficiency. These "sheets" diverge beyond the screen grid and cross the paths of other sheets thus forming an area of high electron density just short of the plate. This dense negatively charged area serves the same purpose as a suppressor grid, but permits more linear tube operation, with a reduction of third harmonic distortion. The "beam forming" plates confine the electrons to beams and also serve to prevent any stray secondary-emission electrons from approaching the screen grid from the sides of the tube.

(b) A "thyratron" is a mercury vapor or gas filled tube having special characteristics which make it adaptable for power or voltage control in electronic devices. The thyratron is a tube which may be found in either triode or tetrode form. However, the nature of the grid control is considerably different from the normal control as found in conventional amplifier tubes. In a thyratron, the grid is capable only of controlling the start of plate current. Once the current has started, the grid can neither stop it, nor alter its magnitude. The current can be stopped only by making the plate potential zero or negative for a short period of time. In the case of a tetrode thyratron the purpose of the screen grid is to reduce the control grid current which flows during periods of non-conduction. Uses of small thyratrons are as sawtooth generators in oscilloscopes and some television sets. In this case the control grid serves as a synchronizing device. The larger thyratrons are used for such functions as inverters and to fire ignitrons.

(c) A typical battery charging tube is the General Electric Tungar tube. It consists of a very heavy coiled filament of thoriated tungsten. which is mounted horizontally on two vertical supports, and a small graphite plate mounted above the filament. The bulb is first evacuated and then filled with argon gas to a pressure of 5 cm. of mercury. The filament is operated at a temperature considerably higher than that which could be used in an evacuated tube so that filament emission efficiency is extremely high. Cathode "evaporation" is negligible in the presence of an inert gas at the correct pressure, so that a very large increase in emission is achieved without an excessive increase of necessary heating energy. Tungar tubes are rated for very large currents, such as 5 and 10 amperes. Such a tube is simply a diode rectifier designed for low voltage, heavy-current operation.

Q. 3.477. What kind of vacuum tube responds to filament reactivation and how is reactivation accomplished?

A. It is usually considered that only thoriated tungsten filaments may be reactivated. This is not necessarily true as many oxide coated cathodes have been reactivated, especially during the period of civilian tube shortage due to the past war.

The method of reactivating a thoriated tungsten filament is as follows: The filament voltage is raised to about 3½ times normal and kept there for about 1 minute. It is then reduced to about 1½ times normal and held there for about 1 hour. This method is not recommended for tubes with normal filament voltages above 5 volts.

The following method of reactivating the cathodes of cathode ray tubes proved successful in at least 50% of the cases in which it was tried. A source of about 400 volts d.c. is connected in series with a milliameter between the intensity grid and the cathode, with the positive terminal going to the intensity grid. The filament voltage is then raised by about 50% and the milliameter is constantly observed. After some period of time sometimes as long as 5 minutes, the milliameter reading will be observed to be slowly and then rapidly increasing. When the reading reaches about 70 millamperes the supply voltage should be instantly disconnected. The intensity grid may become red momentarily, but this is of little consequence.

Q. 3.478. What is the purpose of a bleeder resistor in the filter of a high voltage d-c power supply?

A. See Question 3.182.

Q. 3.479. How much energy is consumed in 20 hours by a radio receiver rated at 60 watts?

A. 1200 watt-hours.

D. The answer is found by simply multiplying the wattage dissipation, by the number of hours of such dissipation. Thus: $60 \times 20 = 1200$ watt-hours.

Q. 3.480. How does the value of resistance in the grid leak of a regenerative type detector affect the sensitivity of the detector?

A. In general, an increase in sensitivity is obtained by increasing the value of grid leak resistance.

D. Increasing the value of grid leak resistance permits a higher *Q* to be developed in the grid tuned circuit, and thus a higher grid signal voltage. However, there is a definite limit to the maximum amount of grid resistance permissible for any given tube. This value is generally given in tube manuals. Possibly even more important, is the fact that the time constant of the grid resistor and condenser must not be made too long if "blocking" is to be avoided. Typical values are: 100 $\mu\mu f$ for the grid condenser and from 1 to 5 megohms for the grid resistor.

Q. 3.481. Compare the design and operating characteristics of class A, class B and class C amplifiers.

A. The characteristics of a class A amplifier are:

1. Low plate circuit, about 25% on the average.
2. Practically no grid driving power.
3. Plate current flows for 360° of each cycle.
4. Grid bias is adjusted to be well up on the linear portion of the tube characteristic.
5. Relatively low power output, compared to class C.
6. Practically no distortion of the output wave shape.

The most general use for a class A amplifier is as a voltage amplifier, although single ended power amplifiers which feed speakers must also be class A. The average plate efficiency for triodes is about 20%, while that of pentodes is about 30 to 35%. Unlike either class B or C, the average plate current and voltage remain constant regardless of the magnitude of the grid signal. The grid signal must be so confined that it does not cause grid current in its positive swing, or cut off the plate current in its negative swing. The power amplification ratio is high, since no grid current is drawn.

$$\textit{Power amplification ratio} = \frac{\textit{Power delivered to plate load}}{\textit{Power consumed in grid circuit.}}$$

The characteristics of a class B amplifier are:

1. Plate circuit efficiency, about 50 to 60%.
2. Used as linear r-f amplifiers in modulated stages.
3. Can be used for audio if push-pull circuit is used.
4. Grid current flows, so driver must supply power.
5. Plate current flows for slightly more than 180° of a cycle (projected cut-off).
6. Grid bias is set slightly above cut-off value.
7. Medium power output compared to class A and C.

Class B amplifiers are used in r-f circuits as buffer amplifiers, and linear modulated r-f amplifiers. In audio systems, very large power outputs may be obtained by using two class B tubes in push-pull. The distortion, however, is greater than for class A. When used in modulated r-f stages, the plate load must be a tank circuit in order to preserve the symmetry of the input wave shape. The average plate current and voltage varies with the magnitude of the grid signal, and the power output varies as the square of the grid voltage. The shape of the plate current pulse is about the same as the positive half of the grid signal.

The characteristics of the class C amplifier are:

1. High plate circuit efficiency, up to 85%.
2. Large grid driving power.
3. Plate current usually for about 120° in a cycle.

4. Grid bias usually about twice cut-off value.
5. Large power output in comparison to class A.
6. Great distortion of plate current wave shape.

In class C amplifiers the plate current is permitted to flow only during the time that the instantaneous value of plate voltage is at or near its minimum value. At all other times the tube is non-conducting. This permits a relatively small loss on the plate and high plate efficiency. However, in order that the above conditions be met, a large value of bias must be used, in some cases equal to 4 times cut-off value, but usually about twice cut-off value. Since grid current must flow at some time in each cycle, a large value of grid driving power must be available and appreciable power is consumed in the grid circuit. Although the plate current wave is a pulse and rich in harmonics, the plate voltage waveshape will be sinusoidal since the plate load will in most cases be a tank circuit with a reasonably high Q. An interesting feature is that the maximum positive value of grid voltage ($e_{c\ max}$), is approximately equal to the minimum value of the plate voltage ($e_{b\ min}$). Class C amplifiers may not be used in audio amplifiers due to the high distortion, but are commonly used for r-f amplification in transmitters; they are often applied to special circuits such as clippers and peakers. See Question 3.122 for discussion of proper bias points.

Q. 3.482. What are causes of downward fluctuation of antenna current at an amplitude modulated transmitter when the transmitter is modulated?

A. See Question 3.346; compare Question 3.483.

Q. 3.483. What may cause upward fluctuation of the antenna current at an amplitude modulated transmitter when the transmitter is modulated?

A. An upward rise of antenna current when a transmitter is amplitude modulated is a normal condition. However, an upward "kick" of current may occur which is not a normal condition.

D. With plate modulation an upward "kick" may be caused by any of the following:

(1) Parasitic oscillations in the modulated r-f amplifier.
(2) Overmodulation.
(3) Incomplete neutralization of the modulated r-f amplifier. With grid modulation an upward "kick" may be caused by any of the following:

(1) Overmodulation.
(2) Audio system distortion.
(3) Incomplete neutralization of the modulated r-f amplifier.
(4) Excessive grid bias in the modulated r-f amplifier.

Compare Question 3.346.

Q. 3.484. Explain how grid bias voltage is developed by the grid leak in an oscillator.

A. Grid leak bias is developed in an oscillator by the charging of the grid condenser from grid current and its discharging through the grid leak resistor. The average value of the condenser voltage is the bias.

D. Before the oscillator starts into operation there is no charge in the grid condenser and the initial bias is, therefore, zero. When the tank circuit starts oscillating the first cycle has a small amplitude which increases at a definite rate depending upon the Q until a maximum value is reached a number of cycles later. Since the initial bias was zero, the effect of the first positive swing of the tank circuit, on the grid, is to cause grid current to charge the grid condenser to some small value. In a like manner the grid condenser continues to charge to the increasing positive swings of the tank circuit until the condenser voltage is equal to some value of the steady state tank circuit positive swings, which depends upon the value of grid-leak resistance. The polarity of the charged condenser is such that it is negative at the grid side, and thus provides the bias potential. The maximum steady state bias depends upon a number of factors such as type of tube, effective Q of tank circuit, amount of feedback, and tube operating voltages. One method of calculating grid bias constants is given below, assuming that the average grid current is known, is given in a tube manual or can be found experimentally.

1. (a) For class C, $E_c = \dfrac{2E_b}{\mu}$ (for twice cut-off) where E_c is the d-c grid bias, E_b is the d-c plate voltage, and μ is the amplification factor of the tube.

(b) For class B, $E_c = \dfrac{E_b}{\mu}$ (At cut-off)

(c) For class A2, $E_c = \dfrac{.6E_b}{\mu}$.

2. $R_g = \dfrac{E_c}{I_g}$, where R_g is the grid resistance in ohms, and I_g is equal to the average d-c grid current in amperes.

3. $C_c = \dfrac{5000}{F_r \times R_g}$, where C_c is the grid condenser in microfarads, F_r is the lowest operating frequency in kilocycles, and R_g is the grid resistor in ohms. (For a complete discussion of grid-leak bias see Question 3.368. See also Questions 3.88 for diagram, and 3.122 for an explanation of proper bias value.)

Q. 3.485. Explain why radio-frequency chokes are sometimes placed in the power leads between a motor-generator power supply and a high powered radio transmitter.

A. Radio frequency chokes are used in this instance, to reduce r-f interference caused by commutator sparking, and also to reduce the effect of high voltage "kick-back" upon a high voltage generator.

D. See Questions 3.210 and 3.212.

Q. 3.486. What effect does inductive reactance in an a-c circuit have on the power factor of the circuit?

A. Inductive reactance in an a-c circuit has the effect of reducing the power factor of the circuit.

D. A purely resistive circuit has the maximum possible power factor, which is *one*. If inductance is added to such a circuit, the power factor will be reduced in proportion to the value of inductance. However, if some capacitance is also added, the power factor will be increased because the effect of the capacitive reactance will cancel the effect of a like amount of inductive reactance. If the two reactances are equal, the power factor will be *one;* if they are not equal, the power factor will be less than one. See Questions 3.34 and 4.173.

Q. 3.487. In which circuits of a radio station are three-phase circuits sometimes employed?

A. Three-phase circuits are often used in relatively high power transmitters to supply the power for plate and screen grid requirements for r-f amplifier and modulator tubes.

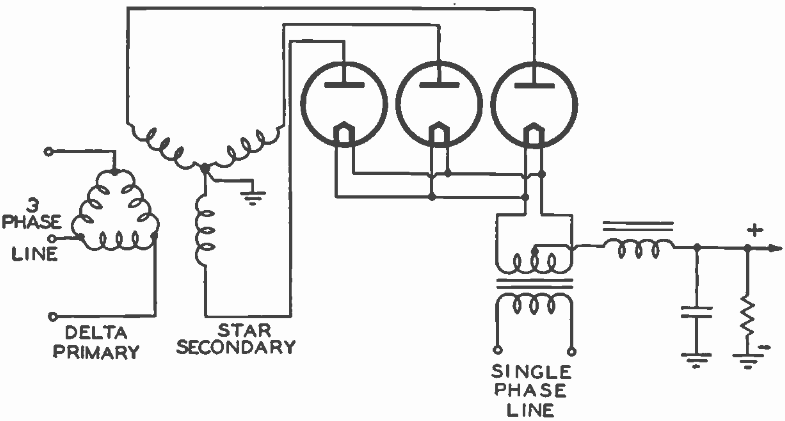


Fig. 3.487. A three-phase half-wave rectifier.

D. A typical three-phase half-wave rectifier circuit is given in the figure. The operation briefly is as follows. Each tube conducts for 120° of a cycle and switches to the next tube whose plate voltage becomes the highest of the three. Thus, in effect a sort of commutating action takes place among the three tubes. Since each tube is non-conducting about ⅔ of the time, smaller tubes can be used for a given job. A 3-phase system has a ripple frequency which is three times as great as a single phase rectifier. If the line frequency were 60 cycles, the ripple frequency would be 180 cycles for half wave and 360 cycles for full wave operation. This high ripple frequency makes it possible to reduce the size of the filter components.

Q. 3.488. Explain the operation of a vacuum tube rectifier power supply and filter.

A. The following description applies to a half wave rectifier system as illustrated in part "A" of the figure. The first problem to be considered is that of rectification, or changing alternating current into unidirectional (d-c) current. A rectifier tube is essentially a one-way path for electronic flow since its reverse (or inverse) current conduction is almost zero. The rectifier tube conducts only when its plate is positive with respect to cathode, and is a non-conductor when the plate is negative with respect to cathode. When an alternating voltage is applied to such a rectifier tube, its output consists of a series of current pulses, which are uni-directional in character. Due to the action

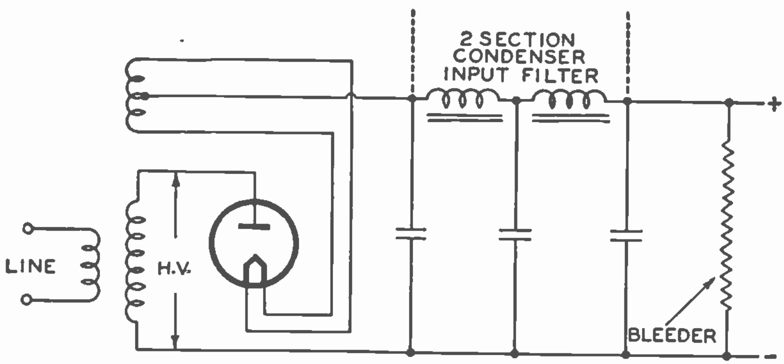


Fig. 3.488(A). A half-wave rectifier system.

of the filter, these pulses are considerably less than ½-cycle in width and are separated by spaces more than ½-cycle in width. The output of a rectifier tube must be filtered to a large degree in order to eliminate the fundamental and harmonic frequency components from the rectifier-filter system output. The usual method for accomplishing this is to insert a suitable *L-C* low pass filter in series with the rectifier output whose cut-off frequency is well below the line frequency The type shown in the figure is a two-section condenser-input "pi"-type filter. The input condenser of the filter charges up practically to the peak value of each positive alternation applied to the plate of the rectifier tube. The rectifier tube stops delivering current to the filter until the next positive alternation exceeds the potential of the input condenser. During this interval of time, the power is supplied by the input condenser, whose voltage drops in a linear manner due to the constant-current action of the first filter choke. The additional pi-section provides a greater degree of filtering than a single section could. The output condenser of the filter must be large enough to offer very little reactance at the lowest frequencies to be amplified, so as to reduce the possibilities of feedback through the medium of the common power supply impedance, and also to supply peak demands from the load.

A full-wave system is similar in operation, with the important exception that the ripple frequencies are twice those in the half-wave system. This makes it possible to effect economy in the filter components to provide the same degree of filtering. Such a filter is shown in part "B" of the figure; the rectifier tubes are so connected that both half cycles of the a-c voltage are used, instead of only one.

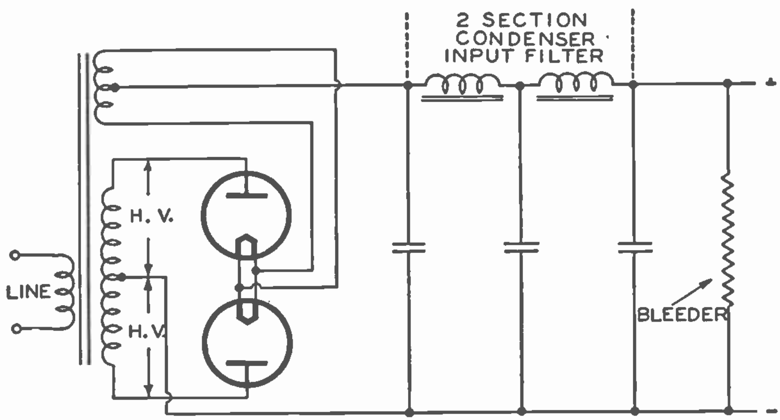


Fig. 3.488(B). A full-wave rectifier system.

See Question 4.90 for bridge rectifiers; and Question 4.180 for voltage-doubling rectifiers.

Q. 3.489. **What are the merits of a frequency-modulation communication system compared to the merits of an amplitude-modulation communication system?**

A. The following are advantages of a frequency-modulation system:

1. Reduced noise output from the f-m receiver.
2. Reduced interference in output of receiver from atmospheric conditions, ignition noises and electrical appliances.
3. Reduction of interference between stations on the same or adjacent channels.
4. Reduction of fading effects at the output of the receiver.
5. Less power required for a given power output of the transmitter.

The merits of an AM system are:

1. Simpler circuits at transmitter and receiver.
2. Simpler alignment of transmitter and receiver circuits.
3. Greater stability of circuits due to the lower broadcast frequencies generally used.
4. Narrow bandwidth making use of lower frequencies feasible.
5. Less critical antenna requirements at lower broadcast frequencies.

Discussion of FM systems (The portion of the answer dealing with AM systems is largly self-explanatory):

1. *Receiver noise*: The receiver proper generates its own noises. These noises are created by tubes and resistors as well as by other causes. The majority of tube noises are generated by the mixer tube. Noises of this nature take the form of a continuous hissing sound and are generally not heard on less sensitive broadcast receivers. For equal signal-to-noise ratio from the receiver an amplitude-modulated wave would have to be 15 times as strong as a FM wave.
2. *Reduced interference from ignition, etc.*: This is undoubtedly the outstanding feature of FM. See Question 3.247.
3. *Reduced station interference*: When two AM stations are being received simultaneously, it is necessary that a ratio of signal strengths of about 100:1 exist in order that only one station shall be heard. FM receivers encounter no such difficulty, since a ratio of approximately 2:1 will insure that only the stronger station will be heard. Adjacent FM stations are separated by guard bands, further reducing the possibility of adjacent channel interference.
4. *Reduction of fading*: This is partially due to the use of high frequencies (88-108 megacycles), at which practically no ionospheric reflections take place, and partially due to the limiting action of the receiver. AVC circuits also help to reduce fading effects.
5. See Question 4.232.

Q. 3.490. What is meant by horizontal and vertical polarization of a radio wave?

A. A radio wave is said to be "polarized" according to the direction of the plane of its electrostatic field.

D. The physical positioning of an antenna with respect to the earth determines the polarization of the emitted wave. An antenna which is positioned vertically with respect to the earth radiates a wave which is vertically polarized, while a horizontal antenna radiates a horizontally polarized wave. If the antennas are located close to the ground, vertically polarized waves will provide a stronger signal close to the earth than do horizontally polarized waves. If the transmitting and receiving antennas are more than one wavelength above the earth, there is little difference in signal strength between the two types of polarization. If the transmitting antenna is located at least several wavelengths above ground, horizontally polarized waves will result in the greatest signal strength close to the earth.

Q. 3.491. How should a transmitting antenna be designed if a vertically polarized wave is to be radiated and how should the receiving antenna be designed for best performance in receiving the ground wave from this transmitting antenna?

A. Both the transmitting and receiving antennas should be positioned vertically with respect to the earth.

D. See Question 3.490.

Q. 3.492. Draw a block diagram of a frequency modulation receiver and explain its principle of operation.

A. For diagram of a frequency modulation receiver, see the figure. It will be noted that basically, an FM receiver is a conventional superheterodyne. The important differences lie in the method of detection, reduction of sensitivity to amplitude modulation, and de-emphasis.

D. A stage discussion of a typical FM receiver follows:

1. *Radio-frequency amplifier*: As in a conventional superheterodyne, the main functions of the r-f amplifier are to improve the signal to noise ratio of the receiver, increase receiver sensitivity and selectivity, and to improve image frequency rejection. The input impedance

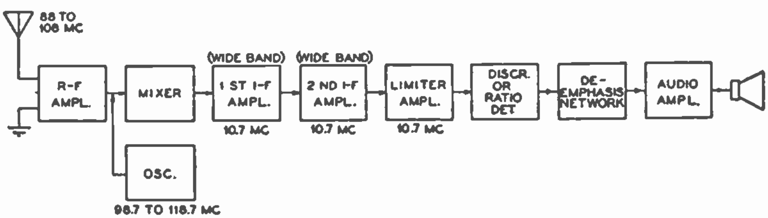


Fig. 3.492. Block diagram of an FM receiver.

to the receiver has been standardized at 300 ohms, which affords an excellent match to a 300 ohm transmission line and a folded dipole. The bandpass characteristic of the r-f amplifier exceeds that of the conventional broadcast receiver by about 15 times, having a required bandpass of about 150 kilocycles.

2. *Oscillator stage*: Three types of oscillators are in the most general use today for FM receivers. These are, the conventional Hartley, the electron-coupled Hartley, and the tuned-grid tickler feedback (Armstrong) types. Oscillator stability is an important consideration because of the high frequencies involved. Methods of improving oscillator stability are: rigid mechanical mountings, use of ceramics rather than phenolics for insulation, use of a small added negative temperature coefficient condenser across the tank circuit, and the use of Invar and Nilvar wire for oils.

3. *Mixer stage*: As in a conventional superheterodyne receiver, the mixer serves to combine the incoming r-f carrier wave with the oscillator wave in a non-linear fashion, so as to produce the desired intermediate frequency. The usual table model type of FM receiver in-

corporates a pentagrid converter such as the Type 6BE6 for both os- for oscillator and mixer. A more desirable system incorporates separate tubes for oscillator and mixer. One such system makes use of a 6BE6 tube in an electron-coupled Hartley oscillator circuit, and a 6BA6 tube as a mixer.

4. *Intermediate-frequency amplifier*: The two most important functions of an i-f amplifier are: to produce most of the signal gain in the receiver, and to provide selectivity capable of rejecting adjacent channel interference. In FM receivers, the intermediate frequency has been standardized at 10.7 megacycles. The bandpass curve of an f-m intermediate frequency amplifier is such that the required 150 kilocycle bandwidth is provided at —6db (.5 of max.). The lack of a flat response is unimportant here, and is compensated for by the limiting action. The average gain of such an i-f amplifier is generally not more than 60.

5. *Limiter stage*: (if used). The function of a limiter stage (or stages) is to remove amplitude variations from the signal and thus provide most of the noise reduction qualities of an FM system. A limiter is usually identifiable by its use of grid-leak bias, and very low plate and screen grid supply voltages. The limiter tube (invariably a pentode with sharp cut-off characteristics) must be easily saturated and driven beyond cut-off by a certain specified minimum value of grid signal swing, usually about 1 or 2 volts. It is this "limiting" action which removes most of the noise pulses. The limiter has a very low gain, in the order of 5. See also Question 4.233.

6. *Frequency-modulation detector*: There are two general types of f-m detectors in use today. These are the conventional discriminator and the relatively new ratio detector. Both of these types transform the deviations of frequency into audio-frequency variations of amplitude. The discriminator responds to amplitude variations and must be preceded by one or more limiters. The ratio detector rejects amplitude variations to a great extent but is sometimes preceded by a limiter type of i-f amplifier in order to improve noise rejection. Both types of detectors are followed by a de-emphasis network. (See Questions 4.222 and 4.223.)

7. *Audio amplifier*: The audio amplifier is conventional except that in the better quality FM receivers, the frequency response is extended to about 15,000 cycles to take advantage of the improved audio frequency range.

Q. 3.493. Draw a block diagram of a frequency modulated transmitter and indicate the center frequency of the master oscillator and the center frequency radiated by the antenna.

A. See the figures. *A* is an NBC transmitter, *B* an Armstrong, and *C* a General Electric.

Q. 3.494. In a frequency modulation radio communication system what is the meaning of modulation index? Of deviation ratio? What values of deviation ratio are used in radio communication systems?

A. The "modulation index" is the ratio of the amount of frequency

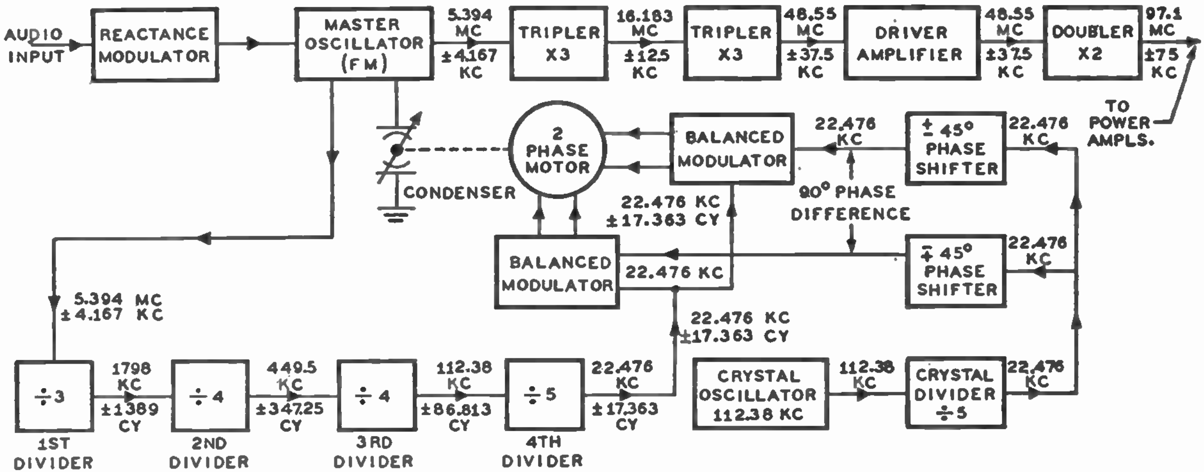


Fig. 3.493(A). Block diagram of the NBC FM transmitter.

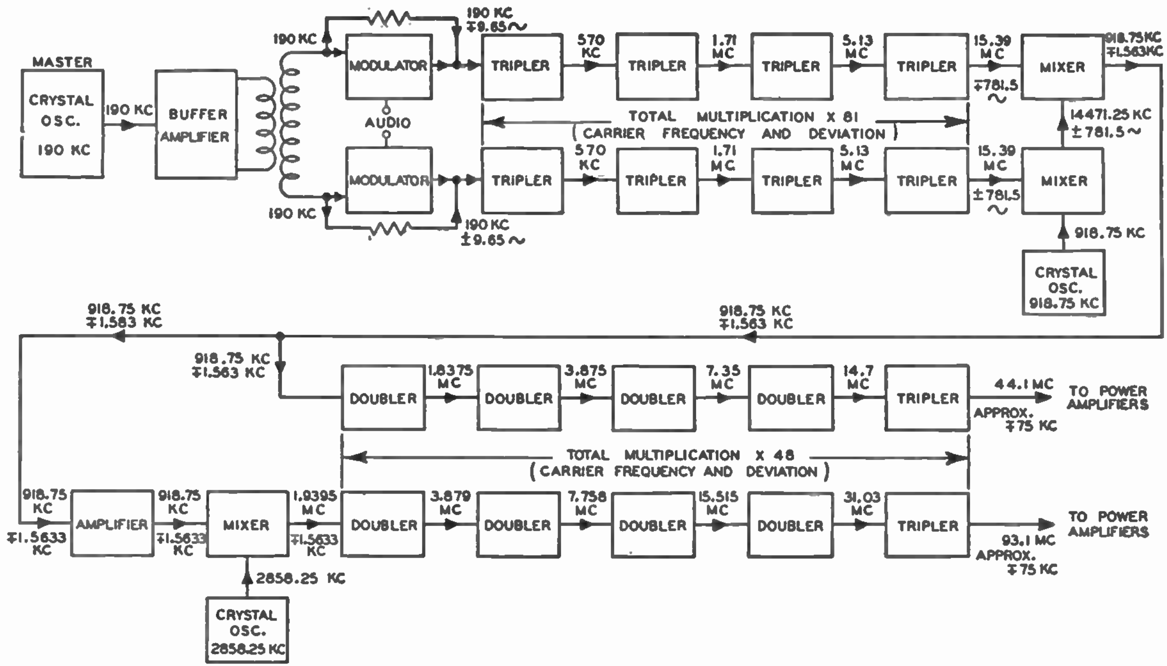


Fig. 3.493(B). Block diagram of the Armstrong FM transmitter.

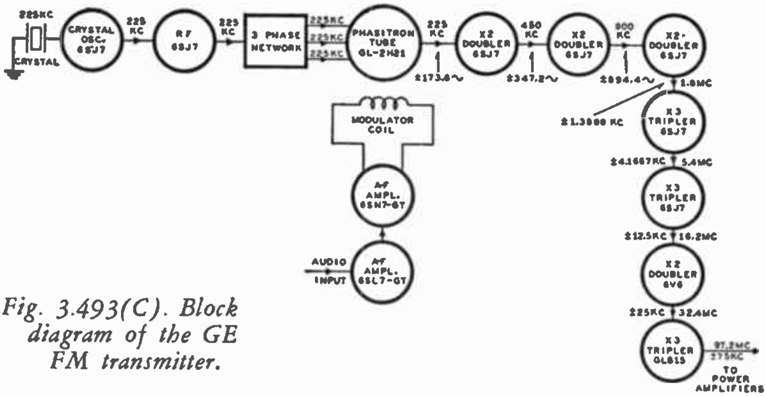


Fig. 3.493(C). Block diagram of the GE FM transmitter.

deviation, to the audio modulating frequency causing the deviation. "Deviation ratio" is the ratio of the maximum permissible frequency deviation to the maximum permissible audio modulating frequency.

D. For a standard FM broadcast station the maximum permissible deviation is 75 kilocycles above or below the average; while the maximum permissible audio modulating frequency is equal to 15 kilocycles. Therefore the "deviation ratio" (or modulation index) for a standard FM station is equal to $\frac{75}{15}$ or 5. The FM sound carrier of a television transmitter has a maximum deviation of plus or minus 25 kilocycles. The "deviation ratio" in this case is $\frac{25}{15} = 1.667$.

Q. 3.495. Why is narrow band frequency modulation rather than wide band frequency modulation used in radio communication systems?

A. The advantage of narrow band over wide band frequency modulation in radio communication systems is the increase of readable transmission distance.

D. In a radio communication system the primary object of the system is the transfer of intelligence by voice. A high signal to noise ratio is desirable in voice reception, but an increase of this ratio above a certain definite value will not improve the readability of the received signal. For carrier wave strengths below a certain minimum value, a low-deviation system will produce a greater signal to noise ratio, than a high deviation system will produce a greater signal to noise ratio, than a high deviation system. The optimum frequency deviation for an FM system which is designed to obtain maximum distance for complete readability corresponds to a deviation ratio of *one*. Since voice frequencies are not generally of importance above 4000 cycles, a deviation ratio of one means that the peak deviation frequency will be equal to 4000 cycles. In general however, narrow band modulation is considered to be present if the peak deviation frequency is not greater than about 15 to 20 kilocycles.

Further advantages of narrow band FM are the possibility of increasing the number of stations operating within a given frequency range, and the increased gain possible in narrow band FM receivers for a given number of r-f stages.

Q. 3.496. What is the purpose of a squelch circuit in a radio communication receiver?

A. The purpose of a "squelch" circuit is to render a receiver inoperative during the periods when no carrier wave is present.

D. Most receivers have a high output noise level in the absence of a carrier wave. This noise will be accentuated in receivers using AVC, since there is maximum gain in the absence of a carrier wave. Such noises can be very detrimental to reception, especially when several receivers are operating simultaneously on different listening frequencies. There are various squelch systems and one typical system operates as follows: When a carrier signal is being received, a rectifier diode which is coupled to the last i-f amplifier, conducts strongly and provides a high negative voltage which is sufficient to cut off a "squelch" amplifier. Under this condition the normal bias is applied to the first audio amplifier tube. If there is no carrier wave present, the negative "squelch" amplifier bias will not be developed by the diode. The "squelch" amplifier will now conduct heavily and provide a bias to the cathode of the first audio amplifier which is sufficient to cut off this tube. A disadvantage of "squelch" systems is that very weak signals cannot be heard. In this case a switch may be provided to make the "squelch" circuit inoperative.

Q. 3.497. Discuss methods whereby interference to a radio receiver can be reduced.

A. This problem is divided into two general classifications:

1. Interference due to static noises. The following methods may be employed to reduce the effect upon the receiver of such noises:

a. Insertion of a power line filter in series with the receiver supply cord close to the outlet.

b. Electrostatic shielding between primary and secondary windings in the power transformer.

c. Suitable filtering applied to the source of such noises whenever possible. (Motors, neon lights, etc.)

d. Use of horizontally polarized antennas if possible.

e. Use of shielded or well balanced transmission lines.

f. Use of suitable noise limiters in receiver.

g. Use of crystal filter in receiver if possible.

h. Use of highly directional antennas if practical.

i. Complete shielding of entire receiver.

2. Interference due to undesired carrier waves. The following methods may be employed to reduce this type of interference:

a. Use of series or parallel resonant wave trap in antenna circuit.

b. Use of parallel resonant wavetrap in cathode of first stage of receiver, and, if necessary, in some succeeding stages also.

c. Use of tuned r-f amplifier ahead of mixer stage.

d. Use of highly directional antennas if practical.

e. Complete shielding of receiver.

Q. 3.498. Draw a diagram of an absorption type wave meter and explain its principle of operation.

A. For a diagram of a simple absorption type wavemeter, see the figure.

D. In general a wavemeter is a resonant circuit which is tuned by a variable condenser. A calibrated dial is provided on which is indicated the resonant frequency of the wave meter in terms of condenser settings. A suitable r-f indicator is connected in series or parallel with the wavemeter tuned circuit to indicate resonance. When a series connected indicator is used, the indicator may be a sensitive flashlight bulb or thermocouple meter. A better (but more complex) arrangement is the use of a diode-type vacuum tube voltmeter connected across a portion of the tuned circuit. (Instead of a diode tube, one of the recently developed, small cartridge type of crystal detector could be used.) The advantage of this type of indicator is that it consumes very little power and thus permits a higher value of Q to be developed in the wavemeter circuit. This is important because the accuracy with which

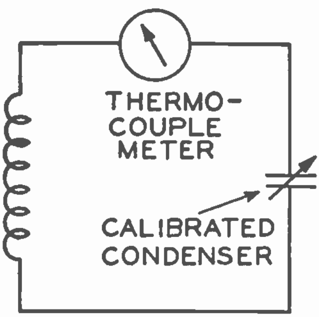


Fig. 3.498. An absorption type wavemeter.

readings can be made depends upon the Q. As discussed in Question 3.433, a disadvantage of absorption type wavemeters in general is the reflected impedance they cause to appear in the measured circuit, which changes the tuning of the measured circuit and reduces the accuracy of readings.

Q. 3.499. Draw a diagram of an ohmmeter and explain its principle of operation.

A. For diagrams, see the figure.

D. The basic ohmmeter consists of a milliammeter or microammeter connected in series with a battery and a zero adjusting resistance. Before using the ohmmeter, the two test leads are shorted together and the zero adjustment is set so that the meter reads full scale. This is equivalent to zero ohms, which will appear at the right side of the scale.

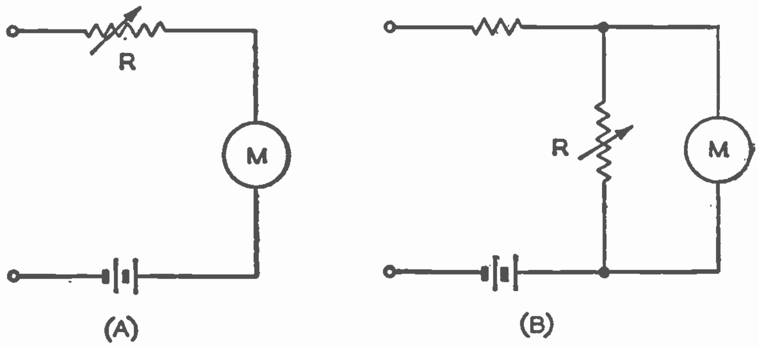


Fig. 3.499(A) and (B). Two simple ohmmeters.

When a resistance is inserted between the two test leads, the meter will read less than full scale by an amount which depends upon the resistance being measured, and the scale may be calibrated directly in ohms. It will be noted that an ohmmeter scale is not linear but has widely spaced divisions at the right side of the scale, and very narrow spaced divisions at the left side (high resistance end) of the scale. This is due to the fact that the current through the ohmmeter is inversely proportional to the resistance in the circuit.

Q. 3.500. Discuss Lecher wires, their properties and uses.

A. Lecher wires (or lines) is a term which is often applied to lengths of parallel two-wire transmission line which are used as resonant lines for the purpose of making high frequency wavelength measurements.

D. Lecher wires are generally at least one wavelength long and may be as much as 5 wavelengths long. The input end may be closed and inductively coupled, or open and capacitively coupled to the r-f generator or amplifier. A shorting bar is usually provided which is adjustable over a considerable length of line. Lecher lines may be used to measure wavelengths by determining the distance between the positions of current or voltage maximum (or minimum) points by a suitable indicating instrument. Such indicators may consist of a thermocouple meter connected to a loop of wire, or a neon bulb. The indicator is moved down the line and the distance between two current or voltage maximum points (or minimum points) is measured. The wavelength is equal to twice the distance between the two indications. The line must possess standing waves in order to obtain measurements and so should never be terminated in its own characteristic impedance.

Q. 3.501. If a 0–1 d-c milliammeter is to be converted into a voltmeter with full scale calibration 100 volts, what value of series resistance should be connected in series with the milliammeter?

A. The series resistance should equal 100,000 ohms, minus the meter resistance which is usually small enough to neglect in this case.

D. The value of series resistance can be found from the formula,

$$R = \frac{E \text{ (full scale)}}{I \text{ (full scale)}} = \frac{100}{.0001} = 100{,}000 \text{ ohms.}$$

(See also Question 3.194.)

Q. 3.502. What are waveguides? Cavity resonators?

A. Waveguides are a form of transmission line which consist of a hollow rectangular or circular pipe. There is no inside conductor as with a coaxial line. Cavity resonators are a form of resonant tank circuit which consists of a hollow metal cylinder closed on all sides. These can be considered to be a small section of a waveguide.

D. Some advantages of hollow waveguides are as follows:

1. Lowest losses of any conventional transmission line at the frequencies for which they are practical.
2. A hollow waveguide can transmit higher power than a coaxial line of the same size.
3. A hollow waveguide is more rugged than a coaxial line because there is no inner conductor or supports.
4. Simpler construction than a coaxial line.
5. Complete shielding.

Some disadvantages of hollow waveguides are:

1. The minimum size is proportional to the wavelength used. For a rectangular guide the height must be approximately ½ wavelength or more.
2. Because of the size, waveguides are not extensively used below about 3000 megacycles (10 cm.). For 10 meter waves the pipe would have to be 25 feet wide.
3. Installation and operation of hollow waveguides is considerably more difficult than for other types of lines. Cavity resonators have the advantage of very high Q and selectivity, but are limited for use at low frequencies due to the required size. Thus at 1 megacycle the cavity would have to be about 100 feet wide, but at 1000 megacycles, the size is only a few inches. Energy is coupled into and out of cavity resonators by means of magnetic or electrostatic "probes."

Q. 3.503. What is the purpose of a diversity antenna receiving system?

A. The purpose of a diversity antenna receiving system is to minimize the fading effects of a received signal in a receiver.

D. It has been determined that signals which are induced in antennas spaced 5 to 10 wavelengths apart will fade in and out independently of each other. Thus if three or more such antennas are connected to separate receivers with a combined output, the chances are very small that the received signal will ever fade out completely. The AVC voltages developed by the three receivers are added and the combined voltage is used to control the gain of three receivers simultaneously. In this manner the channel receiving the strongest signal at any instant is the one which is contributing most to the output, the other two being relatively inoperative at that instant.

Q. 3.504. Why are insulators sometimes placed in antenna guy wires?

A. Insulators are placed in guy wires in order to reduce the efficiency of the guy wires in acting as unwanted radiators and reflectors of radio frequency energy, and to reduce r-f losses in these wires.

D. The guy wires should be broken up into lengths of such dimensions that they will not resonate at the fundamental or harmonics thereof of the transmitted frequency. It is considered common practice to insert an insulator near the top of each guy wire, and then cut each section of wire between the insulators so as to be non-resonant. The insulators should preferably be of the so called "egg" type which operate under compression, so that the guy wire will not separate even if an insulator breaks.

Q. 3.505. Discuss the construction and operation of dynamotors.

A. A dynamotor is a combination motor and generator which utilizes a common field winding (or permanent field magnets). The two armatures (motor and generator) are mounted on a single shaft and require only two bearings. The motor is generally run by battery power, but may also be run from a-c or d-c lines, depending upon design requirements. The output from the generator is d-c. Typical output values are 200 volts at 50 ma., 300 volts at 200 ma., and 600 volts at 300 ma.

D. Dynamotors are used extensively in aircraft and other portable installations to supply plate and screen grid power. A dynamotor has a higher efficiency than a motor-generator set, but its output voltage cannot be readily varied, and its regulation (Question 3.403) is poor.

Q. 3.506. Discuss the cause and prevention of interference to radio receivers installed in motor vehicles.

A. Interference to radio receivers in motor vehicles comes primarily from the following sources:

1. Generator brush sparking.
2. Opening and closing of breaker points.
3. Spark gap between rotor and distributor contacts.
4. Spark gap in spark plugs.
5. Static charges built up in tires and tubes while vehicle is moving.
6. Incorrect gap settings of spark plugs and breaker points.
7. Momentary interference from switches, such as dome switch, ignition switch, and heater switch and rheostat.

D. Most modern vehicles are completely bonded and so this is usually not a problem for servicemen. It is not practical to shield the ignition wires in the ordinary type of motor vehicle, but this is generally unnecessary. The following methods may be employed to minimize interference:

1. Use a by-pass condenser across the generator output. (Usually provided by vehicle manufacturer.)
2. Have breaker points and spark plugs cleaned and correctly gapped.
3. Use anti-static springs in hub of wheels, and conducting power inside of tire tubes.
4. By-pass all switches and long connecting wires.
5. Shield antenna transmission line.
6. Locate antenna well away from ignition system.
7. Use suppressor resistors if necessary at all spark plugs and distributor rotor connection. Some plugs (such as "Auto-Lite") have built in suppressors.
8. A condenser is normally across the distributor breaker points, and will take care of interference at this point. The value is somewhat critical and should not be varied.

Q. 3.507. Explain the process of neutralizing a triode radio-frequency amplifier.

A. See Question 3.441.

Q. 3.508. A relay with a coil resistance of 500 ohms is designed to operate when 0.2 ampere flows through the coil. What value of resistance must be connected in series with the coil if operation is to be made from a 110 volt d-c line?

A. A series resistance of 50 ohms is needed.

D. The normal working voltage of the relay coil equals $.2 \times 500 = 100$ volts. Ten volts at .2 ampere must be dropped in the series resistor, $R = \frac{10}{.2} = 50$ ohms.

Q. 3.509. What value of resistance should be connected in series with a 6-volt battery that is to be charged at a 3-ampere rate from a 115-volt d-c line?

A. A series resistance of 36.33 ohms is required.

D. The resistance should drop the difference between 115 and 6 volts or 109 volts. Thus the resistance equals $\frac{109}{3} = 36.33$ *ohms.*

(Compare Question 6.312.)

Q. 3.510. What may cause self-oscillation in an audio amplifier?

A. Self-oscillation may be caused by the following:
1. Open grid resistor (when amplifier draws grid current).
2. Coupling circuit time constant too long (when amplifier draws grid current).
3. Output power supply filter condenser too small, or defective.
4. Decoupling filter(s) defective.

D. Self-oscillation is an oscillation which is generally of the relaxation type when coupling elements are involved. If the output impedance of the power supply is relatively large and decoupling filters are not used, it represents a common impedance coupling element between the various amplifier stages and thus affords a means for feedback to sustain oscillations. See Question 6.261.

Q. 3.511. Why are pairs of wires carrying a-c heater currents in audio amplifiers twisted together?

A. To reduce hum voltage radiation and pickup by the various amplifier circuits.

D. When the two wires are twisted together in close proximity, the hum radiation is largely cancelled. The reason for this is that the two wires are carrying currents in opposite directions and thus the magnetic fields will oppose and cancel out to a large degree.

Q. 3.512. Draw a block diagram of a superheterodyne receiver capable of receiving amplitude modulated signals and indicate the frequencies present in the various stages when the receiver is tuned to 2450 kilocycles. What is the frequency of a station that might cause image interference to the receiver when tuned to 2450 kilocycles?

A. See the figure.

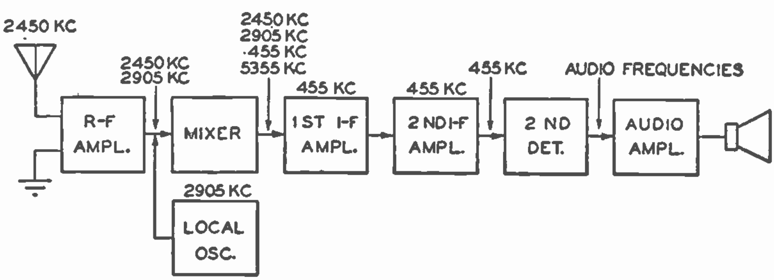


Fig. 3.512. Block diagram of a superheterodyne AM receiver.

The image frequency is equal to the incoming signal plus twice the intermediate frequency, or $2450+(2\times 455)=3360$ kilocycles.

See also Question 6.534.

Q. 3.513. Show by a diagram how to connect a wave trap in the antenna circuit of a radio receiver to attenuate an interfering signal.

A. See the figure. *A* is a parallel resonant wave trap in the antenna circuit, to present a high impedance to the unwanted signal. *B* is a series resonant trap, to by-pass the unwanted signal. *C* is a parallel resonant trap in the cathode circuit of an r-f amplifier; it causes high degeneration and loss of amplification at the unwanted frequency.

D. See Question 3.271.

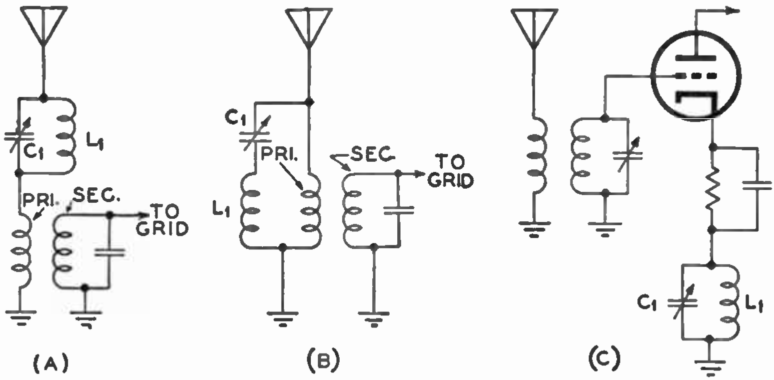


Fig. 3.513. Three possible methods of connecting a wave trap to a receiver.

Q. 3.514. Draw a diagram of a tuned radio-frequency type radio receiver.

A. See the figure.

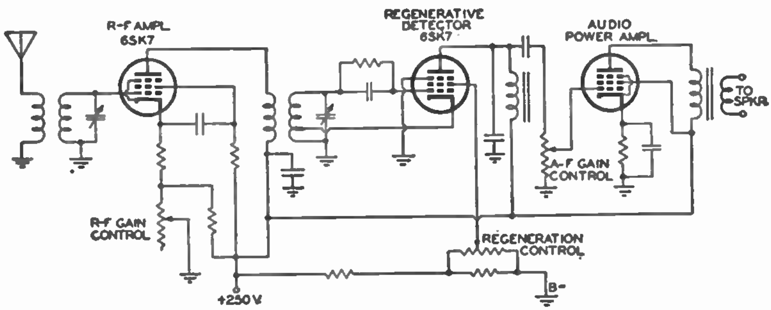


Fig. 3.514. A trf receiver.

D. See Question 6.536 for a block diagram.

Q. 3.515. What would be the effects of connecting 110 volts at 25 cycles to the primary of a transformer rated at 110 volts and 60 cycles?

A. The transformer would overheat and would possibly burn out.

D. The primary current of a transformer, without a load, is equal to the applied voltage divided by the impedance of the primary. This impedance is mostly the inductive reactance of the primary. If the line frequency is lowered to 25 cycles the primary impedance will be reduced to about .42 of the value at 60 cycles. The primary current will rise proportionately to about 2.4 times the value at 60 cycles. This increased current will cause overloading of the primary winding. At a lower frequency and the same voltage, a greater amount of flux is necessary to induce the required counter-emf. Since transformers are designed to operate, normally, just short of the saturation point, the increased flux would oversaturate the core by far, causing heavy hysteresis losses and consequent overheating. To produce the increased flux, a much higher current must be taken from the line, resulting in additional heating in the form of copper (I^2R) losses in the primary winding.

Q. 3.516. Draw a diagram of a one-tube audio oscillator using an iron core choke.

A. See the figure.

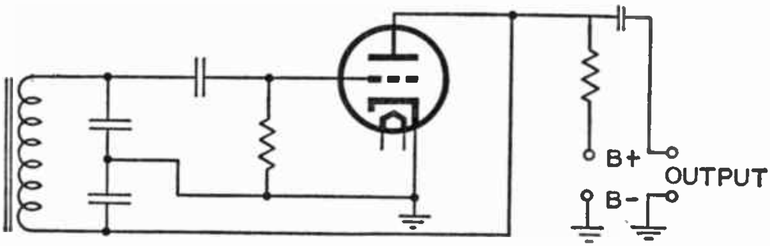


Fig. 3.516. A one-tube audio oscillator.

D. The Colpitts circuit is used, since it is assumed that it may not be possible to tap the coil at a point suitable for a Hartley oscillator.

Q. 3.517. Show by a diagram how a two-wire radio-frequency transmission line may be connected to feed a Hertz antenna.

A. See the figure; see also Question 3.359.

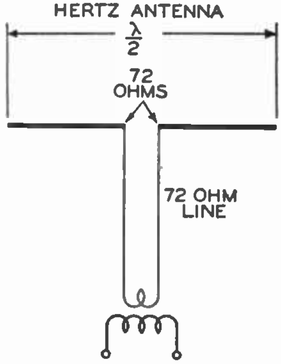
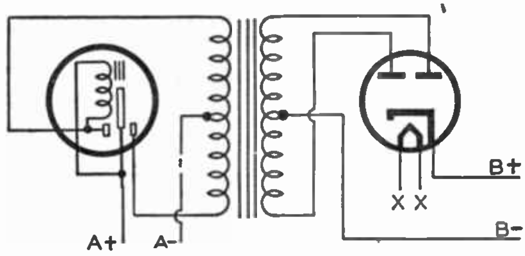


Fig. 3.517. A two-wire line connected to a Hertz antenna.

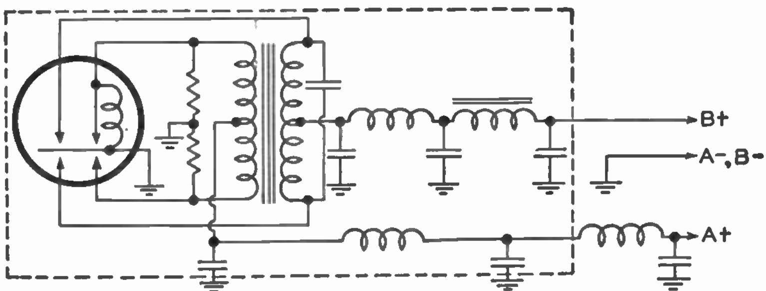
Q. 3.518. Draw a diagram of a synchronous vibrator power supply. A non-synchronous vibrator power supply.

A. See the figure.

D. See Question 3.390.



(A)



(B)

Fig. 3.518 (A). A non-synchronous vibrator power supply. (B) A synchronous power supply.

Q. 3.519. In accordance with the commission's Rules and Regulations what is the primary standard for r-f measurements of radio stations in the various services? (Sec. 2.1)

A. The primary standard of frequency for radio-frequency measurements shall be the national standard of frequency maintained by the National Bureau of Standards, Washington, D.C. The operating frequency of all radio stations will be determined by comparison with this standard or the standard signals of station WWV of the National Bureau of Standards.

Q. 3.520. What is meant by carrier frequency? Carrier wave? (Sec. 2.1)

A. 1. The frequency of the carrier.

2. Carrier wave may be defined as "the output of a transmitter when the modulating wave is made zero."

Q. 3.521. Define land station, base station, mobile station, experimental station, domestic fixed service, public correspondence, facsimile, fixed service, industrial radio services, industrial, scientific, and medi-

cal equipment, land transportation radio services, public safety radio service, and citizens' radio service. (Sec. 2.1)

A. *Base Station* (FB). A land station in the land mobile service carrying on a service with land mobile stations.

Carrier frequency. The frequency of the carrier.

Citizens' radio service. A radio communication service of fixed, land, or mobile stations, or combinations thereof, intended for use by citizens of the United States for private or personal radiocommunication (including radio signalling, control of objects by radio, and other purposes).

Common carrier fixed station (FXC). A fixed station open to public correspondence.

Developmental fixed station (FXJ). A fixed station operated for the express purpose of developing equipment or a technique solely for use only in that portion of the nongovernment fixed service which has been specifically allocated the authorized frequency of the developmental fixed station.

Domestic fixed service. A fixed service intended for the transmission of information between points, all of which lie within the 48 states and the District of Columbia, except for the domestic haul of international traffic.

Domestic fixed public service. A fixed service, the stations of which are open to public correspondence, for radiocommunication between points all of which lie within: (a) the 48 states and the District of Columbia, or (b) within a single territory or possession of the United States.

Domestic public radiocommunication services. The land mobile and domestic fixed public services the stations of which are wide open to public correspondence.

Experimental station (EX). A station utilizing Hertzian waves in experiments with a view to the development of science or technique. This definition does not include amateur stations.

Facsimile. A system of telecommunication for the transmission of fixed images with a view to their reception in a permanent form.

Fixed service. A service of radiocommunication between specified fixed points.

Industrial radio services. Any service of radiocommunication essential to, operated by, and for the sole use of, those enterprises which for purposes of safety or other necessity require radiocommunication in order to function efficiently, the radio transmitting facilities of which are defined as fixed, land, or mobile stations.

Industrial, scientific, and medical equipment. Radio transmitting equipment or other devices employing Hertzian waves for industrial, scientific, or medical purposes, including the transfer of energy by radio, and which are not intended to be used for radiocommunication.

Land station (FL). A station in the mobile service not intended for operation while in motion.

Land transportation radio services. Any service of radiocommunication operated by, and for the sole use of certain land transportation carriers, the radio transmitting facilities of which are defined as fixed, land, or mobile stations.

Localizer Station (RLL). A radio navigation land station in the aeronautical radio navigation service which provides signals for the lateral guidance of aircraft with respect to a runway center line.

Marine radio beacon station (RLM). A radio navigation land station, the emissions of which are intended to enable a ship station to determine its bearing or its direction in relation to the marine radio beacon station.

Mobile station (MO). A station in a mobile service intended to be used while in motion or during halts at unspecified points.

Public correspondence. Any telecommunication which the offices and stations, by reason of their being at the disposal of the public, must accept for transmission.

Public safety radio service. Any service of radiocommunication essential to either the discharge of nonfederal governmental functions relating to public safety responsibilities or the alleviation of an emergency endangering life or property, the radio transmitting facilities of which are defined as fixed, land, or mobile stations.

Q. 3.522. What are the frequency ranges included in the following frequency subdivisions: MF (medium frequency), HF (high frequency), VHF (very high frequency), UHF (ultra high frequency), and SHF (super high frequency)? (Sec. 2.102)

A. MF—300 to 3,000 kc
HF—3,000 to 30,000 kc
VHF—30,000 kc to 300 Mc
UHF—300 to 3,000 Mc
SHF—3,000 to 30,000 Mc.

Q. 3.523. Explain what is meant by the following types of emission: FO, F1, F2, F3, F4, and PO emission? (Sec. 2.201)

A. See Question 3.462.

Q. 3.524. What are the requirements for posting of operator license for (1) the operator performing duties other than, or in addition to,

service or maintenance at two or more stations and (2) the operator performing service or maintenance duties at one or more stations? (Sec. 13.74)

A. Posting Requirements for Operators.

1. Performing duties other than, or in addition to, service or maintenance, at two or more stations. The holder of any class of radio operator license or permit of the diploma form (as distinguished from the card form) who performs any radio operating duties, as contrasted with but not necessarily exclusive of service or maintenance duties, at two or more stations at which posting of his license or permit is required shall post at one such station his operator license or permit and shall post at all other such stations a duly issued verified statement.

2. Performing service or maintenance duties at one or more stations. The holder of a radiotelephone or radiotelegraph first- or second-class radio operator license who performs, or supervises, and is responsible for service or maintenance work on any transmitter of any station for which a station license is required, shall post his license at the transmitter involved whenever the transmitter is in actual operation while service or maintenance work is being performed: provided, that in lieu of posting his license, he may have on his person either his license or a verification card: and provided further, that if he performs operating duties in addition to service or maintenance duties he shall, in lieu of complying with the foregoing provisions of this subsection, comply with the posting requirements applicable to persons performing such operating duties, as set forth in subsection 13.74 (a) above, and in the Rules and Regulations applicable to each service.

Q. 3.525. If service or maintenance logs are required to be kept at a radio station, what entries are required to be entered in the log? (Sec. 13.75)

A. 1. Pertinent details of all service and maintenance work performed by him or under his supervision.

2. His name and address, and

3. The class, serial number, and expiration date of his license, provided that the responsible operator shall not be subject to requirements 2. and 3. above, of this section in relation to a station, or stations of one license at a single location, at which he is regularly employed as an operator on a full-time basis and at which his license is posted properly.

Q. 3.526. In communication services such as the Public Safety Radio Services, (1) what percentage of modulation is normally required when

amplitude modulation is used for radiotelephony and (2) what maximum frequency deviation arising from modulation is permitted when phase or frequency modulation is used for radiotelephony? (Sec. 10.105)

A. 1. Not less than 70 per cent or more the 100 per cent on peaks.
2. The total frequency swing shall not exceed 75 per cent of the frequency separation bandwidth.

Q. 3.527. In communication services such as the Public Safety Radio Services how often should 1. transmitter frequencies be measured, 2. transmitter power be measured, and 3. percentage of modulation be measured? What entries relative to technical measurements are required to be entered in station records? (Sec. 10.108)

A. 1. (a) When the transmitter is initially installed;
(b) When any change is made in the transmitter which may affect the carrier frequency or the stability thereof;
(c) At intervals not to exceed six months, for transmitters employing crystal-controlled oscillators;
(d) At intervals not to exceed one month, for transmitters not employing crystal-controlled oscillators.
2. (a) When the transmitter is initially installed;
(b) When any change is made in the transmitter which may increase the transmitter power input;
(c) At intervals not to exceed six months.
3. (a) When the transmitter is initially installed;
(b) When any change is made in the transmitter which may affect the modulation characteristics;
(c) At intervals not to exceed six months.
Any measurements taken under parts 1, 2, or 3 (above) should be entered in the station records.

Q. 3.528. Describe the physical structure of two types of transistor and explain how they operate as an amplifier.

A. The two general types of transistors are called "point-contact" and "junction" types. The point-contact type will be discussed first. An enlarged cross-sectional view of this transistor and its associated circuit as a simple amplifier is shown in part (A) of the figure. The point contact transistor consists of a single pellet of *N*-type germanium with two catwhisker contacts. The catwhiskers are known as the "emitter" and the "collector" and are spaced a few thousandths of an inch apart on the surface of the germanium. The "base" which is the third connection, makes area contact with the germanium. The germanium pellet is very small, being no larger than the head of a pin. Note in the figure that the emitter and collector have so-called *P*-type areas around the emitter and collector.

The meaning of *N*-type and *P*-type will now be discussed. Transistors are known as semi-conductor devices. This indicates that the germanium

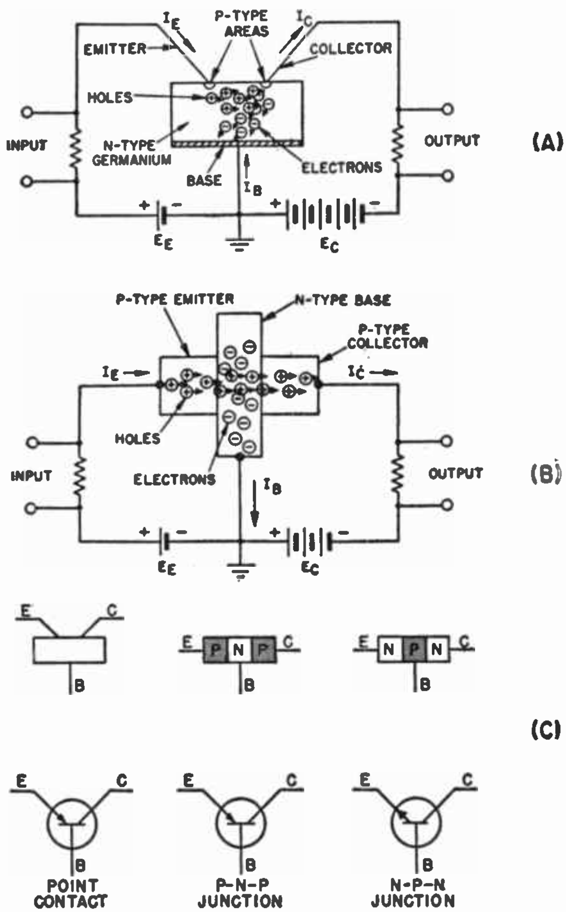


Fig. 3.528. Cross-sectional views of (A) point-contact and (B) junction transistors along with physical and symbolic representations. Courtesy CBS-Hytron.

from which they are made is neither a pure insulator nor a pure conductor. The electrical characteristics of a semi-conductor may be controlled precisely by regulating the amount of impurities it contains. If the atoms of the impurity have more electrons in their outer orbit than the pure semi-conductor, there results an excess of electrons and an

N-type (negative carrier) semi-conductor is formed. If, on the other hand, the atoms of the impurity have fewer electrons in their outer orbit than does the pure semi-conductor, a deficiency of electrons results and a *P*-type (positive carrier) of semi-conductor is formed. In this latter case, we may consider that an excess of *positive* charges (or "holes") is present. It must be considered that an electric current is produced by an effective movement of positive charges as well as the more conventionally considered movement of negative charges (electrons).

The conception of transistor operation is simplified by comparing its components to the elements of a conventional triode vacuum tube. The emitter, functionally, corresponds to the cathode; the collector to the plate; and the base, to the grid. Note in the figure that the polarity of the voltage applied to the collector is negative and therefore opposite to that ordinarily applied to the plate of a vacuum tube.

Because of the positive bias applied to the emitter, electrons are attracted to the emitter circuit. This action produces "holes" (positive charges) in the region of the emitter. The holes are attracted by the negative voltage of the collector and travel to the region of the collector. The resultant *positive* charge thus produced, allows electrons to pass more easily from the collector (which is negative) into the germanium (positive region). Some of the electrons coming in from the collector combine with holes, tending to neutralize their charge. However, the majority of the electrons travel through the germanium to the base.

The presence of the positively charged holes in the region of the collector produces an effective *increase in base current*. Because the electrons have greater mobility than the holes, a greater number of electrons enter the germanium under the influence of a lesser number of holes. From this fact stems the factor of current amplification in a transistor in that a change of emitter current causes a *larger* change in collector current. For the conditions given in part (A) of the figure, the current amplification factor is defined as the ratio of the change in collector current to the change in emitter current, for a constant collector voltage. Current amplification factors in the order of two or three are not uncommon for a point-contact transistor. Another feature is its high frequency capability, operating easily up to 10 megacycles, while special units have operated as high as 300 megacycles. The point-contact transistor is recommended for use in r-f oscillators and amplifiers, i-f amplifiers and switching circuits.

The junction transistor differs from the point-contact type both in principle of operation and in its physical construction. The junction transistor is made with wafer-type construction, the complete transistor consisting of three wafers. The wafers may be arranged in positive-negative-positive sequence in the *P-N-P* type, or in negative-positive-negative sequence in the *N-P-N* type. The middle layer, or wafer, of the junction transistor is called the base. On either side of the base are found the very much smaller emitter and collector wafers. As in the point-contact transistor, the emitter corresponds to the cathode of a vacuum tube, the base to the control grid, and the collector, to the plate.

An enlarged cross-sectional view of a *P-N-P* junction transistor with grounded base circuit is shown in part (B) of the figure. This view illustrates the internal operation of the unit. The *P-N-P* transistor utilizes "holes" (which may for simplicity be considered as positive charges) for conduction.

In the case of the *P-N-P* junction transistor, any voltage or current variations in the input (emitter) circuit cause corresponding variations in the number of holes in the base. Any variations in the supply of holes from the emitter can vary the number of holes traveling through the base and to the collector element. It is found that any change in emitter current produces a substantially equal change in collector current; however, the emitter circuit has *low* impedance, while the collector circuit has *high* impedance. If the currents in the two circuits are substantially equal, it follows that the voltage (or power) variations in the collector circuit will be greater than the variations in the emitter circuit. It is by virtue of this effect that amplification is obtained in the *P-N-P* junction transistor.

Important characteristics of the junction transistor are: high power gain, low input power requirements and a low noise factor. These transistors are particularly adaptable for operation in oscillator and amplifier circuits in the low-frequency ranges.

For the convenience of the reader, part (C) of the figure shows the generalized physical structure and the corresponding schematic diagram for the point contact, the *P-N-P* and the *N-P-N* transistors.

Q. 3.529. Draw a simple schematic circuit diagram of a two stage audio amplifier using transistors.

A. See the figure.

D. See Question 3.528.

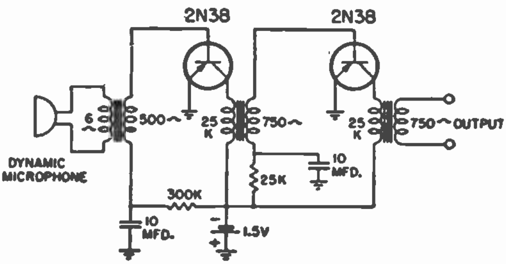


Fig. 3.529. Simple schematic diagram of a two-stage audio preamplifier using transistors (P-N-P junction type). Courtesy CBS-Hytron.

Q. 3.530. Describe briefly the construction and purpose of a wave guide. What precautions should be taken in the installation and maintenance of a wave guide to insure proper operation?

A. See Question 3.502 for construction and purpose. See Questions 8.27, 8.28, 8.29 and 8.33 for precautions in installation and maintenance.

Q. 3.531. Describe the physical structure of a multianode magnetron and explain how it operates.

A. See Questions 6.179 and 8.43.

Q. 3.532. Describe the physical structure of a klystron tube and explain how it operates as an oscillator.

A. See Question 8.48.

Q. 3.533. Describe three methods for reducing the radio frequency harmonic emission of a radiotelephone transmitter.

A. See Question 3.371.

Q. 3.534. A ship radiotelephone transmitter operates on 2738 kilocycles. At a certain point distant from the transmitter the 2738 kilocycle signal has a measured field of 147 millivolts per meter. The second-harmonic field at the same point is measured as 405 microvolts per meter. To the nearest whole unit in decibels, how much has the harmonic emission been attenuated below the 2738 kilocycle fundamental?

A. The harmonic emission has been attenuated by 51 decibels.

D. The number of decibels representing the ratio of two voltages is given by the expression $db = 20 \log \frac{E_1}{E_2}$ where E_1 is one of the voltages (conveniently, the larger of the two) and E_2 is the other voltage. Thus, in this case

$$db = 20 \log \frac{0.147 \text{ volts per meter}}{.000405 \text{ volts per meter}}$$

$$db = 20 \log 363$$

$\log 363 = 2.56$, therefore $db = 20 \times 2.56$, or 51.20 decibels.

To the nearest whole unit, the harmonic emission has been attenuated by 51 decibels.

Note: If a table of decibels versus voltage (or current) ratios is available, it is only necessary to find the number of decibels corresponding to the voltage ratio of 363. This, of course, will be 51 decibels.

ELEMENT IV

ADVANCED RADIOTELEPHONE

Q. 4.01. A parallel circuit is made up of five branches, three of the branches being pure resistances of 7, 11, and 14 ohms, respectively. The fourth branch has an inductive reactance value of 500 ohms. The fifth branch has a capacitive reactance of 900 ohms. What is the total impedance of the network? If a voltage is impressed across the parallel network, which branch will dissipate the greatest amount of heat?

Answer. The total impedance is 3.275 ohms. The greatest amount of heat is dissipated by the 7 ohm resistor.

Discussion. The impedance of a parallel circuit is equal to the applied voltage divided by the total current, or

$$Z_T = \frac{E_A}{I_T}$$

$$I_T = \sqrt{I_R^2 + (I_L - I_C)^2}$$

Step 1: Assume a voltage of 1000 (E_A)
Step 2: Find the total resistance

$$R_T = \frac{1}{1/7+1/11+1/14} = \frac{1}{22/154+14/154+11/154} = \frac{1}{47/154} = \frac{154}{47}$$

$= 3.275$ *ohms*

Step 3: Find $I_R = \frac{E_A}{R_T} = \frac{1000}{3.275} = 305$ *amp.*

Step 4: Find $I_L = \frac{E_A}{X_L} = \frac{1000}{500} = 2$ *amp.*

Step 5: Find $I_C = \frac{E_A}{X_C} = \frac{1000}{900} = 1.11$ *amp.*

Step 6: Find $I_T = \sqrt{305^2 + (2 - 1.11)^2} = 305$ *amp.*

Step 7: Find $Z_T = \frac{1000}{305} = 3.275$ *ohms.* (Ans.)

No calculations are required to prove the second answer. Since the reactances are not said to have any resistance associated with them, it must be assumed that they are "pure" reactances and thus dissipate no power. So the two reactances can be immediately neglected for this particular part of the problem. We now have left, three parallel resistances of 7, 11, and 14 ohms. The smaller resistance (in a parallel circuit) always dissipates the most heat, which in this case is the 7-ohm resistance.

Q. 4.02. What is the reactance of a condenser at the frequency of 1200 kilocycles if its reactance is 300 ohms at 680 kilocycles?

A. The reactance at 1200 kilocycles is 170 ohms.

D. This problem can be solved in two ways.

Solution #1

Step 1: Find the value of capacitance.

$X_C = \frac{1}{2\pi fC}$, therefore $C = \frac{1}{2\pi fX_C}$. Substituting known values,

$$C = \frac{10^{12}}{6.28 \times (680 \times 10^3) \times 300} = 781 \ \mu\mu f.$$

Step 2: Find the new reactance at 1200 kc. $X_c = \frac{1}{2\pi fC}$.

$$X_C = \frac{1}{6.28 \times (1200 \times 10^3) \times 781 \times 10^{-12}} = 170 \ \textit{ohms}.$$

Solution #2

The reactances are *inversely* proportional to frequency, so a ratio may be set up as: $\frac{X_{C1}}{X_{C2}} = \frac{f_2}{f_1}$, $\frac{300}{X_{C2}} = \frac{1200}{680}$.

$$1200 \ X_{C2} = 300 \times 680; \ X_{C2} = 170 \ \textit{ohms}.$$

Q. 4.03. If the mutual inductance between two coils is 0.1 henry, and the coils have inductances of 0.2 and 0.8 henry, respectively, what is the coefficient of coupling?

A. The coefficient of coupling is .25.

D. The coefficient of coupling may be found from the formula,

$$K = \frac{M}{\sqrt{L_1 L_2}} = \frac{.1}{\sqrt{.2 \times .8}} = \frac{.1}{.4} = .25.$$

Q. 4.04. If, in a given alternating-current series circuit, the resistance, inductive reactance, and capacitive reactances are of equal magnitude of 11 ohms, and the frequency is reduced to 0.411 of its value at resonance, what is the resultant impedance of the circuit at the new frequency.

A. The impedance at the new frequency is 24.8 ohms.

D. The capacitive reactance varies in inverse proportion to the frequency, and the new capacitive reactance therefore equals, $\frac{11}{.411}$ $= 26.7$ ohms. The inductive reactance varies in direct proportion to the frequency, and the new inductive reactance therefore equals, $11 \times .411 = 4.52$. The total impedance $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{11^2 + (4.52 - 26.7)^2} = 24.8$ ohms.

Q. 4.05. If an alternating current of 5 amperes flows in a series circuit composed of 12 ohms resistance, 15 ohms inductive reactance, and 40 ohms capacitive reactance, what is the voltage across the circuit?

A. The total voltage across the circuit is 138.5 volts.

D. Step 1: Find the voltage across the individual components.

$E_R = IR = 5 \times 12 = 60V \angle 0°$

$E_L = IX_L = 5 \times 15 = 75V \angle 90°$

$E_C = IX_C = 5 \times 40 = 200V \angle -90°$

Step 2: Find the vector sum of all the voltages. Since the voltages across L and C are in opposition they may be subtracted as:

$$200 - 75 = 125V \angle -90°$$

$$E_T = \sqrt{E_R^2 + E_X^2} = \sqrt{3600 + 15{,}625} = 138.5 \ volts$$

Q. 4.06. A series circuit contains resistance, inductive reactance, capacitive reactance. The resistance is 7 ohms, the inductive reactance is 8 ohms, and the capacitive reactance is unknown. What value must this condenser have in order that the total circuit impedance be 13 ohms?

A. The capacitive reactance is 18.96 ohms.

D. Using the conventional impedance formula $Z = \sqrt{R^2 + X^2}$ and solving for X, we get $X = \sqrt{Z^2 - R^2} = \sqrt{169 - 49} = \pm 10.96$ *ohms*, which is the total reactance. However, it is not known whether the total reactance is capacitive (—) or inductive (+) and this must be determined by trial and error.

(1) Assume the total reactance is + (inductive); $X = X_L - X_C$, $10.96 = 8 - X_C, X_C = -2.96$ *ohms*. This is an impossible answer.

(2) Assume the total reactance is — (capacitive); $-X = X_L - X_C$, $-10.96 = 8 - X_C, X_C = 18.96$ *ohms*.

Q. 4.07. What is the total reactance of two inductances connected in series with zero mutual inductance?

A. The total reactance is the sum of the two reactances.

D. If the mutual coupling is zero there is no exchange of magnetic fields between the two coils. The total inductance is equal to the sum of the two individual inductances, and, therefore, the total reactance is found simply by adding the two individual reactances.

Q. 4.08. If an alternating voltage of 115 volts is connected across a parallel circuit made up of a resistance of 30 ohms, an inductive reactance of 17 ohms, and a capacitive reactance of 19 ohms, what is the total circuit current drain from the source?

A. The total current drain equals 3.91 amperes.

D. The total current (I_T) equals the vector sum of all the branch currents of $\sqrt{I_R^2 + (I_C - I_L)^2}$.

Step 1: Find the current in the resistance: $I_R = \frac{E_A}{R} = \frac{115}{30} 3.84$ amp. $\angle 0°$.

Step 2: Find the current in the inductance: $I_L = \frac{E_A}{X_L} = \frac{115}{17}$ $= 6.77$ amp. $\angle -90°$

Step 3: Find the current in the capacitance: $I_C = \frac{E_A}{X_C} = \frac{115}{19}$ $= 6.05$ amp. $\angle 90°$

Step 4: Find the total current: $I_T = \sqrt{3.84^2 + (6.05 - 6.77)^2} = \sqrt{15.27} = 3.91$ *amperes.*

Q. 4.09. When two coils, of equal inductance, are connected in series, with unity coefficient of coupling and their fields in phase, what is the total inductance of the two coils?

A. The total inductance of the two coils is equal to four times the inductance of either coil.

D. The total inductance of two coils may be found from the formula $L_T = L_1 + L_2 \pm 2M$, where $M = k\sqrt{L_1 L_2}$ and k is the coefficient of coupling. Since both inductances are equal, and the coefficient of coupling is 1, $M = 1\sqrt{L^2} = L$; thus $L_T = L_1 + L_2 + 2L = 4L$.

Q. 4.10. If a power transformer has a primary voltage of 4,400 volts and a secondary voltage of 220 volts, and the transformer has an efficiency of 98 per cent when delivering 23 amperes of secondary current, what is the value of primary current?

A. The primary current is 1.173 amperes.

D. If the transformer were 100% efficient, the secondary volt-amperes would be (220 volts $\times$ 23 amp.) $\times \frac{100}{98}$, to draw the same primary current. Since, for 100% efficiency, the primary and secondary volt-amperes are equal, this value is divided by 4,400 to obtain primary amperes $\frac{220 \times 23}{4400} \times \frac{100}{98} = 1.173$ amperes.

Q. 4.11. Three single-phase transformers, each with a ratio of 220 to 2,200 volts are connected across a 220-volt three-phase line, primaries in delta. If the secondaries are connected in Y, what is the secondary line voltage?

A. The secondary line voltage is 3810 volts.

D. In a delta *Y*-connected three-phase system, the secondary line voltage may be found from the formula, $E_s = E_p \times$ turns ratio $\times \sqrt{3}$. Substitution: $E_s = 220 \times 10 \times 1.732 = 3810$ *volts.* (See also Questions 3.496 and 4.14.)

Q. 4.12. What factors determine the core losses in a transformer?

A. Transformer core losses are determined by two important factors:

1. Hysteresis losses.
2. Eddy current losses.

D. Definitions for these terms will be found in Question 6.602. If a magnetic field is established in air, it will be found that under normal conditions all of the energy stored in the magnetic field will be returned to the circuit upon the collapse of the field. If the field is established in iron or steel, however, only a part of the energy will be returned to the circuit, the remainder appearing as heat in the iron or steel. This heat loss is partly due to the effect of hysteresis. According to the molecular theory of magnetism, the molecules in a magnetic material are haphazardly arranged when the material is unmagnetized. When a magnetizing force is applied, these tiny magnets turn and become aligned with the magnetic field. Their motion is resisted by a force which is called molecular friction. The work done in overcoming this friction is the hysteresis energy loss, which appears as heat. This loss is given by the equation: $P = Kf(B_{max})^{1.6}$ watts, where K is a constant of the magnetic material, f is the frequency in cycles per second, and B_{max} is the maximum flux density in the material.

Eddy current losses are due to the presence of circulating currents throughout the core material. The current in any path is directly proportional to the emf induced in it, and inversely proportional to the resistance of the path. The heat produced is proportional to the square of the induced current. Eddy current losses can be reduced by building the core out of thin laminations individually insulated, and by using material having high specific resistivity. Eddy current losses are proportional to the square of the maximum flux density, the square of the thickness of laminations, and the square of the frequency. This loss is unaffected by d-c core saturation. See Question 4.13 for copper losses.

Q. 4.13. What circuit constants determine the "copper" losses of a transformer?

A. The "copper losses" of a transformer are determined by the effective resistance of the primary and secondary windings, and the current through each winding.

D. At power frequencies the copper losses may be found by determining the d-c resistance of each winding and multiplying this value by the square of the current in the winding. At radio frequencies, "skin effect" must be taken into account, as the effective resistance may be much greater than the d-c resistance alone. At radio frequencies, therefore, the copper loss is found by, $P = I^2 \times R_{eff}$ watts. See Question 4.12 for core losses.

Q. 4.14. Draw a schematic wiring diagram of a three-phase transformer with delta-connected primary and Y-connected secondary.

A. See the figure.

D. See Questions 3.487 and 4.165.

Q. 4.15. What factor(s) determine the ratio of impedances which a given transformer can match?

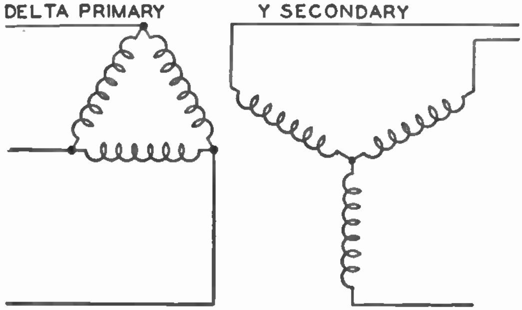


Fig. 4.14. A three-phase transformer.

A. The impedance ratio which a transformer can match is a function of the transformer *turns* ratio.

D. A basic (approximate) formula relating impedance ratio and turns ratio is:

$$\frac{N_p}{N_s}=\sqrt{\frac{Z_p}{Z_s}}, \qquad \text{or} \quad \left(\frac{N_p}{N_s}\right)^2=\frac{Z_p}{Z_s}, \text{ where}$$

N_p is the number of turns in the primary
N_s is the number of turns in the secondary
Z_p is the primary impedance
Z_s is the secondary impedance

This means, for example, that if 5400 ohms were connected to the secondary of a 1:3 step-up transformer, the apparent impedance, measured at the primary, would be $5400\times\left(\frac{1}{3}\right)^2$ ohms, or 600 ohms.

Q. 4.16. If a transformer, having a turns ratio of 10:1, working into a load impedance of 2,000 ohms and out of a circuit having an impedance of 15 ohms, what value of resistance may be connected across the load to effect an impedance match?

A. A resistance of 6000 ohms should be connected across the load.

D. An impedance of 15 ohms is connected across the primary of the transformer, and, therefore, the reflected impedance into the secondary may be found from: $Z_s = Z_p \times (\textit{turns ratio})^2$, $Z_s = 15 \times 10^2 = 1500$ *ohms*. In order to effect a correct impedance match therefore, the secondary load impedance must be 1500 ohms. However, in the problem it is given as 2000 ohms and a resistance must be paralleled across 2000 ohms to bring the total secondary impedance down to 1500 ohms. This is done as follows: $R_t=\frac{R_1R_2}{R_1+R_2}$ where R_1 is the existing secondary impedance (2000 ohms) and R_2 is the unknown paralleling resistance.

$$1500=\frac{2000\times R_2}{2000+R_2};\quad R_2=\frac{2000\times1500}{2000-1500}=\frac{3,000,000}{500}=600\ \textit{ohms}.$$

Q. 4.17. In a class C radio-frequency power amplifier what ratio

of load impedance to dynamic plate impedance will give the greatest plate efficiency?

A. There is no definite ratio for maximum plate efficiency.

D. The load impedance is chosen approximately as follows: The minimum value of instantaneous plate voltage is made equal to the maximum positive grid voltage in such a manner that the desired plate dissipation is obtained. From this value, the angle of plate current flow can be determined, and the plate current value may be found. Knowing the plate current, a plate load impedance can then be chosen which will produce the necessary plate voltage swing. This is the value of plate load impedance for maximum plate efficiency.

Q. 4.18. If a lamp, rated at 100 watts and 115 volts, is connected in series with an inductive reactance of 355 ohms and a capacitive reactance of 130 ohms across a voltage of 220 volts, what is the current value through the lamp?

A. The lamp current is 0.842 ampere.

D. Since this is a series circuit, the lamp current will be the same as the line current.

Step 1: Find the lamp resistance (R_L). $R_L = \frac{E^2}{W} = \frac{(115)^2}{100}$ $= 132.25$ *ohms.*

Step 2: Find the total series impedance (Z_T).

$Z_T = \sqrt{R^2+(X_L-X_C)^2} = \sqrt{(132.25)^2+(355-130)^2} = 261.5$ *ohms.*

Step 3: Find the line (and lamp) current (I_T).

$$I_T = \frac{E_A}{Z_T} = \frac{220}{261.5} = 0.842 \text{ amp.}$$

Q. 4.19. If an alternating-current series circuit has a resistance of 12 ohms, an inductive reactance and capacitive reactance, each of 7 ohms, at the resonant frequency, what will be the total impedance at twice the resonant frequency?

A. The total impedance at twice the resonant frequency will be 15.95 ohms.

D. The impedance is found from the formula $Z_T = \sqrt{R^2+(X_L-X_C)^2}$. The resistance will remain constant regardless of frequency. However, the inductive reactance varies directly with the frequency and will be double at twice the original frequency, or $2\times7=14$ ohms. The capacitive reactance varies inversely with the frequency and will be one half, at twice the original frequency or $\frac{7}{2} = 3.5$ ohms. Substituting the new values: $Z_T = \sqrt{(12)^2+(14-3.5)^2} = \sqrt{254} = 15.95$ *ohms.*

Q. 4.20. In a parallel circuit composed of an inductance of 150 microhenrys and a capacitance of 160 micromicrofarads, what is the resonant frequency?

A. The resonant frequency is 1027 kilocycles.

D. Since there is no resistance given in the parallel resonant circuit, the simple (pure reactance) formula may be used.

$$F_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{6.28\sqrt{150\times10^{-6}\times160\times10^{-12}}} = \frac{1}{6.28\sqrt{2.4\times10^{-14}}}$$

$$= \frac{.1592\times10^{7}}{1.55} = 1027 \text{ kc.}$$

If there is appreciable resistance in the coil, then for parallel resonance the value of $X_C = X_L + \frac{R_{eff}}{Q}$, or $F_r = \frac{1}{2\pi\sqrt{LC}} \times \sqrt{1 - \frac{1}{Q^2}}$.

Q. 4.21. What value of capacitance must be shunted across a coil having an inductance of 56 microhenrys in order that the circuit resonate at 5,000 kilocycles?

A. The shunting capacity must be 18.1 micromicrofarads.

D. It must be assumed that the resistance in the circuit is negligible since none is given in the problem. Then from the single (pure reactance—no resistance) formula, $C = \frac{10^{12}}{4\pi^2 f^2 L}$ micromicrofarads

$$= \frac{1}{(39.5)\times(25\times10^{12})\times(56\times10^{-6})} = 18.1 \textit{ micromicrofarads.}$$

Q. 4.22. Why should impedances be matched in speech-input equipment?

A. Impedances should be matched in speech-input equipment in order that maximum transfer of power may take place and to preserve the proper frequency response of the equipment.

D. A mismatch of impedances might also introduce distortion in the case of amplifiers. In short transmission lines, impedance matching is not too important. However, if the line is long and standing waves are present (due to mismatch), the input impedance of the line may change radically and this change will be reflected into the circuit through the matching transformer. This in turn may cause distortion and incorrect frequency response characteristisc.

In amplifiers, an impedance match is usually not desirable. For minimum distortion, triode amplifiers require a load impedance several times greater than the plate resistance; while screen-grid amplifiers require a load only a small fraction of the plate resistance. For example, a 6V6 power amplifier tube, with a plate impedance of 52,000 ohms, requires a load resistance of only 5000 ohms or less than 1/10 of the plate impedance.

Where distortion is not a factor however, a 1-to-1 impedance match is desirable for maximum power transfer between circuits.

Q. 4.23. What are the purposes of H or T pad attenuators?

A. The purpose of *H* or *T* pad attenuators is to permit a desired amount of attenuation to take place and at the same time to maintain proper impedance matching of input and output circuits.

D. A "volume control" of the potentiometer variety is also an attenuator, but the impedance of the potentiometer is changed whenever the arm is moved. Thus a potentiometer is usually used only in circuits where the power level is negligible and impedance matching is not an important factor. Another disadvantage of such a volume control is the fact that the frequency response of the system varies with changes in the control setting. Both of the above mentioned disadvantages can be eliminated by the use of a suitable "pad" which maintains a correct impedance match regardless of its attenuation setting (within limitations), and thus does not affect the frequency response characteristics of the circuit.

Q. 4.24. Why are grounded center-tap transformers frequently used to terminate program lines?

A. Grounded center-tap transformers are used to terminate program wire lines in order to reduce the effects of "crosstalk" and noise pickup in the lines.

D. Lines which are used to carry programs are almost always standard telephone lines. Thus a great number of such lines are usually in close proximity for a considerable distance, and the possibility of "crosstalk" occurring becomes important. "Crosstalk" may be due either to capacitive or inductive coupling between lines and results when a signal from one line is picked up by another line, producing undesired interference. Such crosstalk is effectively eliminated by using balanced lines and circuits and by restricting the input power level in telephone lines to a maximum of about 6 milliwatts (0 db). Balancing of the lines also serves to cancel out the effects of any noise or other stray pickup in the lines. By having currents of equal amplitudes flow in opposite directions through a grounded center-tapped transformer winding, any such undesired pickup will be cancelled.

Q. 4.25. What is the purpose of a "line pad"?

A. The primary purpose of a line pad is to isolate the line amplifier from the effects of changing line impedances.

D. To illustrate the isolating properties of a line pad take as an example a 6db, 600-ohm *T*-pad. This consists of two series arms of 200 ohms each and a shunt arm of 800 ohms. If the line should open completely, the impedance presented to the input of the amplifier would equal 1000 ohms. On the other hand, if the line were short circuited, it would equal 360 ohms. Thus a relatively constant impedance is always presented to the line amplifier. The line pad also serves the function of attenuator to limit the input power to the line to a maximum of about 6 milliwatts or less as desired.

Q. 4.26. Why are electrostatic shields used between windings in coupling transformers?

A. To eliminate capacitive coupling between windings.

D. If the coupling between coils is made to be completely inductive, the transfer of line noises between primary and secondary will be reduced to a minimum. In r-f transformers, electrostatic shields will reduce the transfer of undesired harmonic frequencies between windings.

Q. 4.27. Why is it preferable to isolate the direct current from the primary winding of an audio transformer working out of a single vacuum tube?

A. It is preferable to isolate the direct current from the primary in order to reduce d-c core saturation.

D. Isolating the direct current from the primary winding enables a transformer to be used, which has a relatively small core area. This makes possible a saving in the price, size, and weight of a transformer. If the core becomes even partially saturated, the inductance of the primary will be reduced, attenuating the low-frequency response of the amplifier. The reflected impedance into the primary might also be changed. This effectively changes the tube load impedance and may cause distortion.

Q. 4.28. Why are pre-amplifiers sometimes used ahead of mixing systems?

A. Pre-amplifiers are used ahead of mixing systems to improve the signal-to-noise ratio at the output of the mixer.

D. All mixers have a certain inherent noise level. The output of most microphones is extremely low, in the order of —55 V.U. (volume units), so that if the microphone output were fed directly into the mixer the signal-to-noise ratio would be poor. Pre-amplifiers are therefore connected immediately following each microphone, and the output of each pre-amplifier is then fed to the mixer, thus raising the signal-to-noise ratio considerably.

Q. 4.29. What is the purpose of a variable attenuator in a speech-input system?

A. Variable attenuators in a speech-input system are used for the purpose of adjusting the signal level to a desired amplitude.

D. It may be that several signals are at entirely different levels and thus must be adjusted to a more or less common level before being further amplified. In a studio mixer, the various attenuation controls must be set so that the signal level output will always be kept between certain desired limits.

Q. 4.30. In a low-level amplifier using degenerative feedback, at a nominal mid-frequency, what is the phase relationship between the feedback voltage and the input voltage?

A. The feedback voltage is 180° out of phase with the input voltage.

D. In degenerative feedback (or negative feedback) the feedback voltage must be in opposition to the input voltage. Certain advantages are obtained by the use of degenerative feedback as outlined in Question 4.33.

Q. 4.31. Under what circumstances will the gain-per-stage be equal to the voltage amplification factor of the vacuum tube employed?

A. The gain-per-stage of a voltage amplifier will be equal to the voltage amplification factor of the tube when the ratio of load impedance to dynamic plate impedance is infinite.

D. The voltage amplification factor of a tube equals, $\mu \times E_s$, where E_s is the input grid signal voltage. Since every tube has an internal impedance some of the output voltage is "lost" in the tube impedance and is not available in the plate load. From a practical standpoint the load resistance should be relatively high with respect to the internal tube impedance (in triodes) if maximum gain is to be achieved. The mid-frequency gain may be calculated from the formula, $G_{mid} = g_m \times R_{eq}$, where g_m is the tube transconductance, and R_{eq} is the resultant parallel impedance of the internal tube impedance, the plate load resistance and the grid resistance of the following stage. This applies only to an R-C coupled amplifier.)

Q. 4.32. Why is a high-level amplifier, feeding a program transmission line, generally isolated from the line by means of a pad?

A. A "line" pad is used to isolate the amplifier from the line, to prevent overloading of the line and to provide impedance matching.

D. (See Question 4.25.) A further benefit of a line pad is the isolation of the line shunt capacitance from the amplifier, thereby improving the high frequency amplifier response.

Q. 4.33. What is the purpose of deliberately introduced degenerative feedback in audio amplifiers?

A. The results of degenerative feedback in audio amplifiers are:

1. Greater stability of amplifier characteristics.
2. Reduction of harmonic distortion.
3. Reduction of phase distortion.
4. Improvement of frequency response linearity.
5. Reduction of amplifier gain.
6. Reduction of noise output.
7. Reduction of effective r_p with negative voltage feedback.
8. Increase of effective r_p with negative current feedback.

D. The gain of an amplifier with negative feedback may be determined from the formula, $a' = \frac{a}{1 + Ba}$ where a' is the gain with feedback, B is the fraction of the total output voltage fed back in opposition to the input signal voltage E_s, a is the gain without feedback. The low-frequency response will be affected according to the formula, $F_1' = \frac{F_1}{1 + Ba}$, where F_1' is the new low-frequency response without feedback. The high-frequency response will be affected according to the formula, $F_2' = F_2 (1 + Ba)$.

Q. 4.34. What unit has been adopted by leading program transmission organizations as a volume unit and to what power is this unit equivalent?

A. The unit which has recently been adopted is called the "Volume Unit" (VU). The reference level, (0 VU) is 1 milliwatt in 600 ohms.

D. The other common standard reference is 0db = 6 milliwatts in 500 ohms. The "volume unit" is measured on a db scale. A VU-meter is very highly damped and thus indicates a dynamic or average reading. In broadcast studios, 0 VU often indicates 100% modulation. See Question 3.38.

Q. 4.35. What is the purpose of a line equalizer?

A. The purpose of a line equalizer is to make the response characteristics of a transmission line independent of frequency within the desired range (transmission band), which is usually between 40 and 10,000 cycles.

D. If a transmission line has appreciable length, the line capacitance will cause the high frequencies to be attenuated. The line, therefore, produces frequency distortion of programs passing through it. To eliminate frequency distortion, the line is equalized at the studio by means of a highpass filter, shown in Question 4.36, which attenuates the low frequencies to the same degree that the line capacitance attenuates the high frequencies. The equalizer should have an attenuation characteristic curve which is exactly the same as the line response curve in order to produce a "flat" corrected response of line and equalizer. It is generally unnecessary to equalize a short line because of the relatively low line capacitance. The total shunting line capacitance is proportional to the line length and if the line is short the capacity is relatively low. The high frequency response of a line may be improved if the line is terminated in an impedance which is low compared to the surge impedance of the line. Standing waves are produced due to the mismatch, but are not important in a short line due to the negligible phase shift which is introduced.

Q. 4.36. Draw a diagram of an equalizer circuit most commonly used for equalizing wire-line circuits.

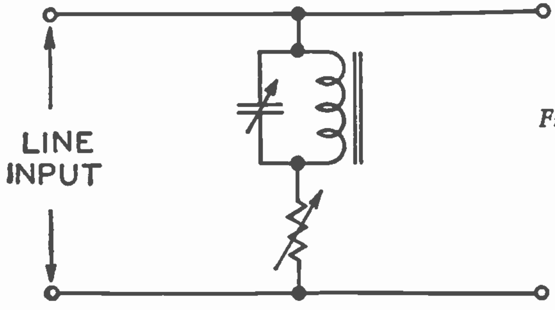


Fig. 4.36. An equalizer circuit for a transmission line.

A. See the figure.

D. See Question 4.35.

Q. 4.37. What type of microphone employs a coil of wire, attached to a diaphragm, which moves in a magnetic field as a result of the impinging of sound waves?

A. This describes a "dynamic" microphone.

D. A "dynamic" or "moving coil" type of microphone is somewhat similar in construction to a small permanent magnet dynamic speaker. The diaphragm is of the unstretched, non-rigid type and has a number of circular corrugations. These corrugations give the diaphragm a great amount of flexibility and excellent low frequency response. Attached to the diaphragm is a circular coil constructed of a large number of thin aluminum turns held together and insulated by a varnish. The coil, which moves with the diaphragm, passes between the poles of a strong permanent magnet, with very small clearance. When the diaphragm is actuated by sound waves, the coil moves in the magnetic field of the permanent magnet, and has induced into it a voltage corresponding to the sound variations.

The microphone has a low impedance output (25 to 50 ohms) and may be connected through long shielded cables to a distant amplifier. It is rugged, dependable, requires no power supply, and very little maintenance. The frequency response of those commonly available is approximately from 20 to 9,000 cycles.

Q. 4.38. What is the most serious disadvantage of using carbon microphones with high-fidelity amplifiers?

A. A carbon microphone has a high inherent noise level (hissing) and a relatively poor frequency response.

D. See Questions 3.216 and 3.338.

Q. 4.39. Why are the diaphragms of certain types of microphones stretched?

A. The diaphragms of certain microphones are stretched in order to raise the lowest natural resonant frequency of the diaphragm above a certain desired high frequency and thus obtain a relatively flat frequency response.

D. Stretching a microphone diaphragm has certain disadvantages, one of the most important being a great reduction in sensitivity. For example, a carbon microphone with an unstretched diaphragm may have an output of 0 VU, while one with a stretched diaphragm may have an output of only —45 VU.

Q. 4.40. Draw a simple schematic diagram of a grid-bias modulation system, including the modulated radio-frequency stage.

A. See Question 3.332.

Q. 4.41. Draw a simple schematic diagram of a class B audio high-level modulation system, including the modulated radio-frequency stage.

A. See the figure.

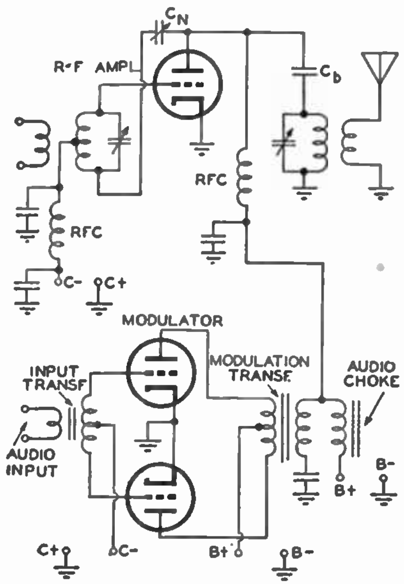


Fig. 4.41. A class B high-level modulation system, including the modulated stage.

D. See Question 6.438, which also includes a schematic diagram of a circuit in which there is no modulation transformer.

Q. 4.42. Draw a simple sketch of the trapezoidal pattern on a cathode-ray oscilloscope screen indicating low per cent modulation without distortion.

A. See the figure showing several trapezoidal pattern indications.

D. The percentage of modulation may be calculated from:

$$\% = \frac{B - A}{B + A} \times 100.$$

Q. 4.43. During 100 per cent modulation, what percentage of the average output power is in the sidebands?

A. The power in the sidebands for 100% modulation equals 33⅓ per cent of the total output power.

D. The above statement may be proven by the following reasoning: For sinusoidal single tone modulation the total power output may be

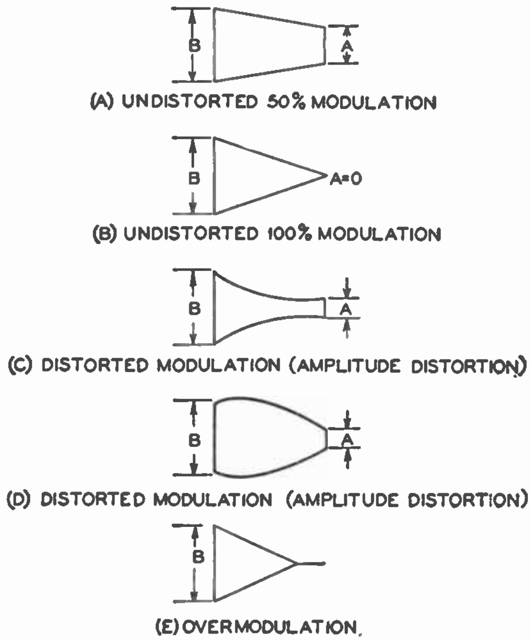


Fig. 4.42. Possible trapezoidal patterns.

found from the relationship, $P_{mod.} = \quad 1 + \frac{m^2}{2} \quad \times P_{unmod.}$ Assume that the carrier power is 100 watts. Then for 100% modulation, $P_{mod.} = (1 + \frac{1}{2}^2) \times 100 = 150$ *watts*. Of this total, 50 watts of power is in the sidebands, so the percentage of sideband power $= \frac{50}{150} \times 100 =$ $33\frac{1}{3}\%$.

Q. 4.44. Draw a schematic diagram of test equipment which may be used to detect carrier-shift of a radiotelephone transmitter output.

A. See the figure.

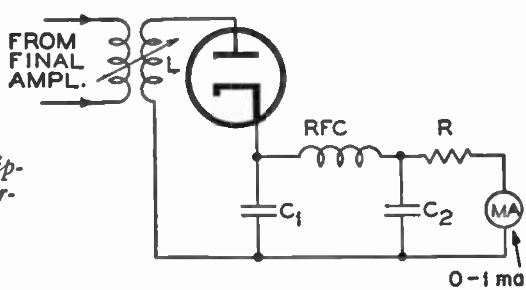


Fig. 4.44. Test equipment to detect carrier shift.

D. The inductance *L* is coupled to the transmitter stage it is desired to monitor and the degree of coupling is adjusted until ½-scale reading is obtained and on the 0—1 ma. meter. The transmitter is now modulated and the meter observed. If no carrier shift or overmodulation exists the needle will remain stationary. If the meter reading increases there is positive carrier shift present, and if it decreases there is negative carrier shift present.

Q. 4.45. What are the advantages and disadvantages of class B modulators?

A. Class B modulators generally have greater efficiency but more distortion than class A modulators.

D. Advantages of class B modulators are:

(1) Greater power output for a given type of tube.
(2) Greater plate efficiency.
(3) Lower average power consumption.
(4) Smaller tubes can be used for a given output power.

Disadvantages of class B modulators are:

(1) Plate supply must have excellent regulation.
(2) Grid bias supply must be low impedance and have good regulation.
(3) Grid circuit requires considerable *driving* power.
(4) Must use two tubes in push-pull circuit.
(5) More distortion than Class A.

Q. 4.46. Why is frequency modulation undesirable in the standard broadcast band?

A. A frequency modulation system is undesirable in the standard broadcast band due to the small number of f-m stations which could be accommodated, and because of the difficulty in designing the necessary broad-band circuits at broadcast frequencies.

D. The channel width allotted to a standard f-m broadcast station is 200 kilocycles. The standard broadcast band is only about 1000 kilocycles wide and so could accommodate only five f-m stations, but almost 100 a-m stations. To design wide-band r-f amplifiers for broadcast band receivers would necessitate low-gain stages. Thus an additional number of stages would be needed, making for poor economy in both transmission and reception.

Q. 4.47. What is meant by "low-level" modulation?

A. See Question 3.336.

Q. 4.48. If a pre-amplifier, having a 600-ohm output, is connected to a microphone so that the power output is —40 db, and assuming the mixer system to have a loss of 10 db, what must be the voltage amplification necessary in the line amplifier in order to feed +10 db into the transmitter line?

A. The voltage amplification must be 1000 times.

D. The input to the line amplifier equals —40 db + (—10 db) = —50 db. It is assumed that the 600 ohm impedance is maintained throughout the system. Therefore, if the output to the transmitter line is to be +10 db, the amplifier voltage gain must be +60 db. The voltage ratio equivalent to 60 db is found from: $N = 20 \log \frac{E_1}{E_2}$ $60 = 20 \log \frac{E_1}{E_2}$, $3 = \log \frac{E_1}{E_2}$. Since the logarithms are to the base 10, $10^3 = \frac{E_1}{E_2} = 1{,}000$. Voltage amplification required is 1000:1.

Q. 4.49. If the power output of a modulator is decreased from 1,000 watts to 10 watts, how is the power reduction expressed in decibels?

A. The power loss = 20 db.

D. The db formula for a power ratio is (N being number of *db*);

$$N = 10 \log \frac{P_1}{P_2} = 10 \log \frac{1000}{10} = 10 \log 100 = 10 \times 2 = 20 \text{ db.}$$

Q. 4.50. In a modulated amplifier, under what circumstances will the plate current vary, as read on a direct-current meter?

A. D-c plate current variations during modulation will occur during conditions of overmodulation or carrier shift, or both.

D. See Questions 3.375, 3.378, 3.379, and 3.384.

Q. 4.51. What would cause downward deflection of the antenna current ammeter of a transmitter when modulation is applied?

A. For a complete answer and discussion, see Question 3.346.

Q. 4.52. If tests indicate that the positive modulation peaks are greater than the negative peaks in a transmitter employing a class B audio modulator, what steps should be taken to determine the cause?

A. This indicates that carrier shift or overmodulation is present and checks should be made as indicated in the questions listed in the discussion below. The audio drive should be checked for overmodulation.

D. (See references mentioned in Question 4.50 and 4.51.) In a class B push-pull stage, the tubes and amplifier should be checked for balance.

Q. 4.53. In a properly adjusted grid-bias modulated radio-frequency amplifier, under what circumstances will the plate current vary, as read on a direct-current meter?

A. The plate current may vary with excessive audio drive

D. See references in Questions 4.50 and 4.51.

Q. 4.54. What percentage increase in average output power is obtained under 100 per cent sinusoidal modulation as compared with average unmodulated carrier power?

A. The increase of average power output is 50%.

D. The increase of average power output is found from the formula:

$$\% \text{ increase} = \frac{m^2}{2} \times 100, \text{ at } 100\% \text{ sinusoidal modulation then,}$$

$$\% \text{ increase} = \frac{(1)^2}{2} \times 100 = 50\%. \text{ (Compare Question 4.43.)}$$

Q. 4.55. In a class C radio-frequency amplifier stage feeding an antenna system, if there is a positive shift in carrier amplitude under modulation conditions what may be the trouble?

A. The following are causes of positive carrier shift:

1. High or low frequency parasitic oscillations.
2. Excessive audio drive.
3. Incorrect tuning of final amplifier.
4. Incorrect neutralization.

D. For references, See Questions 4.50 and and 4.51.

Q. 4.56. Name four causes of distortion in a modulated-amplifier stage output.

A. Such distortion is generally caused by overmodulation, carrier shift, parasitic oscillations, improper neutralization, excessive r-f drive or improper tuning of final tank circuits.

D. See Questions 4.50 and 4.51 for references.

Q. 4.57. If you decrease the percentage of modulation from 100 per cent to 50 per cent by what percentage have you decreased the power in the sidebands?

A. The power in the sidebands will be decreased by 75%.

D. The power in the sidebands may be found from the following formula (assuming sinusoidal modulation),

$$P_{sb} = \frac{m^2}{2} \times P_{\text{carrier}}.$$

Assume a carrier of 100 watts.

$$\text{For } 100\% \text{ modulation, } P_{sb} = \frac{(1)^2}{2} \times 100 = 50 \textit{ watts.}$$

$$\text{For } 50\% \text{ modulation } P_{sb} = \frac{(0.5)^2}{2} \times 100 = 12.5 \textit{ watts.}$$

Since 12.5 is only ¼ of the original 50 watts, it follows that a reduction of ¾, or 75%, has occurred.

Q. 4.58. If a certain audio-frequency amplifier has an overall gain of 40 db and the output is 6 watts, what is the input?

A. The input power is 0.6 milliwatt.

D. The input power is found by dividing the output power by the ratio represented by 40 db.

$$N = 10 \log \frac{P_1}{P_2} \text{ db, } 40 = 10 \log \frac{P_1}{P_2}, \log^{-1} \frac{40}{10} = \frac{P_2}{P_1} 10{,}000{:}1.$$

$$\text{The input power} = \frac{6}{10{,}000} = 0.6 \textit{ milliwatt.}$$

Q. 4.59. If the field intensity of 25 millivolts per meter develops 2.7 volts in a certain antenna, what is its effective height?

A. The effective height of the antenna is 108 meters or 354 feet.

D. The total developed voltage in the antenna is 2.7 volts. In each meter of the antenna there is developed .025 volt. The total effective height of the antenna is $\frac{2.7}{.025}$ or 108 meters. To convert meters into feet, multiply by 3.28; $108 \times 3.28 = 354$ *feet.*

Q. 4.60. Draw a schematic diagram of a final amplifier with capacity coupling to the antenna which will discriminate against the transfer of harmonics.

A. See the figure.

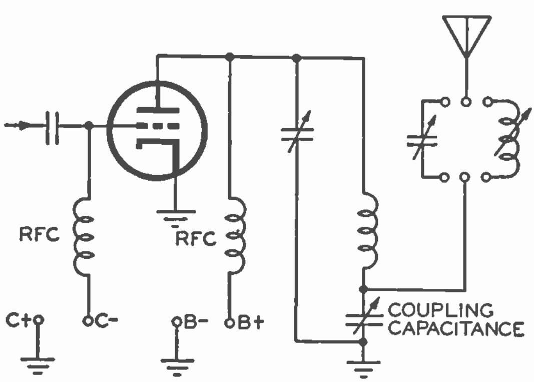


Fig. 4.60. Capacity coupling which will discriminate against harmonics.

Q. 4.61. In what units is the field intensity of a broadcast station normally measured?

A. Field intensity is measured generally in terms of microvolts per meter, or millivolts per meter.

D. A common method of measuring field intensity utilizes a sensitive receiver, a standard signal generator and a loop antenna. The loop is connected to the receiver and oriented to give maximum reception. The receiver gain is adjusted to give a convenient reading on a microammeter which is inserted in the second detector circuit. The loop is now rotated so that no signal is received and a voltage from the signal generator is introduced in series with the loop. The signal generator is adjusted to the same frequency as the incoming signal and the generator output is varied until the receiver output indication is the same as it was when receiving the incoming signal. The signal generator output voltage is now measured with a suitable vacuum tube voltmeter and this reading, in conjunction with the effective antenna height (given in calibration data with the receiver), is the equivalent field strength indication. See Question 4.273.

Q. 4.62. Draw a simple schematic diagram showing a method of coupling the radio-frequency output of the final power-amplifier stage of a transmitter to a two-wire transmission line, with a method of suppression of second- and third-harmonic energy.

A. See the figure.

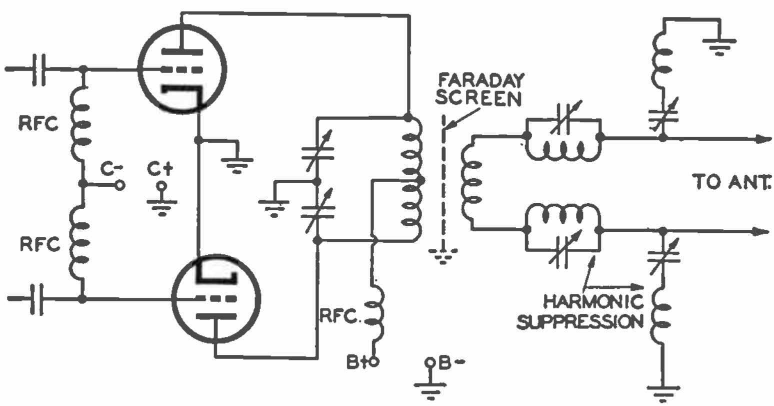


Fig. 4.62. R-f output of a transmitter may be coupled to a transmission line in this manner, utilizing the Faraday screen to suppress the second and third harmonics.

D. See Question 3.373 for discussion of the Faraday shield to reduce electrostatic coupling. The tuned-filter network tends to suppress any harmonic currents in the antenna circuit.

Q. 4.63. An antenna is being fed by a properly terminated two-wire transmission line. The current in the line at the input end is 3 amperes. The surge impedance of the line is 500 ohms. How much power is being supplied to the line?

A. The power supplied to the line is 4500 watts.

D. Since it is stated that the line is correctly terminated, it can be assumed that the line is non-resonant (infinite) and, therefore, the input impedance of the line equals the surge impedance, $Z_{in} = Z_{out}$. The power supplied to the line $= I^2 \times Z_{out} = (3)^2 \times 500 = 4500$ *watts.*

Q. 4.64. If the daytime transmission-line current of a 10-kilowatt transmitter is 12 amperes, and the transmitter is required to reduce to 5 kilowatts at sunset, what is the new value of transmission-line current?

A. The new transmission line current is 8.48 amperes.

D. The power is proportional to the square of the current.

$$\frac{P_1}{P_2} = \frac{I_1^2}{I_2^2};\ I_2 = I_1\sqrt{\frac{P_2}{P_1}} = 12\sqrt{\frac{5}{10}} = 12 \times 0.707 = 8.48\ amp.$$

Q. 4.65. If the antenna current of a station is 9.7 amperes for 5 kilowatts, what is the current necessary for a power of 1 kilowatt?

A. The new antenna current is 4.33 amperes.

D. Power is proportional to the square of the current.

$$\frac{W_1}{W_2} = \frac{I_1^2}{I_2^2};\ \frac{1}{5} = \frac{(I_1)^2}{(9.7)^2};\ I_1 = \frac{9.7}{\sqrt{5}} = 4.33\ amperes.$$

Q. 4.66. What is the antenna current when a transmitter is delivering 900 watts into an antenna having a resistance of 16 ohms?

A. The antenna current is 7.5 amperes.

D. The current is found from the power formula:

$$I_{ant} = \sqrt{\frac{W}{R}} = \sqrt{\frac{900}{16}} = \sqrt{56.25} = 7.5\ amperes.$$

Q. 4.67. If the day input power to a certain broadcast station antenna having a resistance of 20 ohms is 2,000 watts, what would be the night input power if the antenna current were cut in half?

A. The nighttime input power would be 500 watts.

D. Power is proportional to the square of the current. $\frac{P_{night}}{2000} = \frac{(\frac{1}{2}I)^2}{(I)^2}$

$$P_{night} = 2000\,(\tfrac{1}{2})^2 = \frac{2000}{4} = 500\ watts.$$

Q. 4.68. The direct-current input power to the final-amplifier stage is exactly 1,500 volts and 700 milliamperes. The antenna resistance is 8.2 ohms and the antenna current is 9 amperes. What is the plate efficiency of the final amplifier?

A. The plate efficiency of the final amplifier is 63.25%.

D. Plate efficiency equals the output power divided by the input power multiplied by 100.

Step 1: Find the input power

$P_{in} = E_b \times I_b = 1500 \times .7 = 1050$ *watts.*

Step 2: Find the output power

$P_{out} = I_{ant}^2 \times Z_{ant} = (9)^2 \times 8.2 = 664.2$ *watts.*

Step 3: Find the plate efficiency

$$P.E. = \frac{P_{out}}{P_{in}} \times 100\% = \frac{664.2}{1050} \times 100 = 63.25\%.$$

Q. 4.69. If the power output of a broadcast station is quadrupled, what effect will this have upon the field intensity at a given point?

A. The field intensity will be doubled.

D. It is stated that the power output is quadrupled, but the field intensity is a measure of voltage which varies as the square root of power, $E = \sqrt{W \times Z}$. The field intensity will change therefore as the square root of 4, or 2, which is double the original field intensity.

Q. 4.70. The ammeter connected at the base of a Marconi antenna has a certain reading. If this reading is increased 2.77 times, what is the increase in output power?

A. The increase in output power will be by 7.67 times.

D. Power varies as the square of the current as, $P = I_{ant}^2 \times Z_{ant}$. If the current increases 2.77 times the power increases as the square of this number or $(2.77)^2 = 7.67$ *times.*

Q. 4.71. If the power output of a broadcast station has been increased so that the field intensity at a given point is doubled, what increase has taken place in the antenna current?

A. The antenna current has doubled.

D. Field intensity is a measure of voltage and is directly proportional to antenna current. Therefore, if the field intensity is doubled, the antenna current is also doubled.

Q. 4.72. If a transmitter is modulated 100 per cent by a sinusoidal tone, what percentage increase in antenna current will occur?

A. The antenna current will increase by 22.5 %.

D. The antenna current increase in percent for sinusoidal modulation may be found from the formula,

$$I_{increase} = \left(\sqrt{1 + \frac{m^2}{2}} - 1\right) \times 100$$

$$= (\sqrt{1.5} - 1) \times 100 = (.225)100 = 22.5\%$$

See Question 3.345 for a fuller discussion.

Q. 4.73. What is the ratio between the currents at the opposite ends of a transmission line, ¼ wavelength long, and terminated in an impedance equal to its surge impedance?

A. The ratio of the currents is 1 to 1.

D. Since the line is terminated in its own surge impedance, it becomes non-resonant (infinite). Therefore, there are no standing waves on the line and the current remains the same all along the line. The above statements are made on the assumption that the terminating impedance is purely resistive.

Q. 4.74. The power input to a 72-ohm concentric transmission line is 5,000 watts. What is the rms voltage between the inner conductor and the sheath?

A. The rms voltage is 600 volts.

D. It is assumed that the line is non-resonant. The power formula is applied as,

$E = \sqrt{W \times R} = \sqrt{5000 \times 72} = \sqrt{360{,}000} = 600$ volts rms. The peak value $= 600 \times 1.414 = 848.4$ *volts.*

Q. 4.75. A long transmission line delivers 10 kilowatts into an antenna; at the transmitter end the line current is 5 amperes and at the coupling house it is 4.8 amperes. Assuming the line to be properly terminated and the losses in the coupling system negligible, what is the power lost in the line?

A. The power lost in the line is 875 watts.

D. Step 1: Find the line impedance

$$Z_L = \frac{W}{I_L^2} = \frac{10{,}000}{(4.8)^2} = \frac{10{,}000}{23.04} = 435 \text{ ohms.}$$

This is also the input antenna impedance since the line is properly terminated.

Step 2: Find the input power to theline

$$P_{in} = I_L^2 \times Z_L = (5)^2 \times 435 = 10{,}875 \text{ watts.}$$

Step 3: Find the power loss in the line, $P_{in} - P_{out}$, or

$$10{,}875 - 10{,}000 = 875 \text{ watts.}$$

Q. 4.76. The power input to a 72-ohm concentric line is 5,000 watts. What is the current flowing in it?

A. The line current is 8.33 amperes, rms.

D. It is assumed that the line is properly terminated. The line current is found by using the power formula,

$$I_L = \sqrt{\frac{W}{Z_L}} = \sqrt{\frac{5000}{72}} = \sqrt{69.4} = 8.33 \text{ amperes.}$$

This current, multiplied by the voltage found in Question 4.74 (using the rms value), is: $8.33 \times 600 = 5000$ watts, as it must, since $W = EI$ in a resistive circuit (assumed for these problems).

Q. 4.77. What is the primary reason for terminating a transmission line in an impedance equal to the characteristic impedance of the line?

A. The primary reason for terminating a transmission line in a resistive impedance equal to its own characteristic impedance is to prevent line reflections and standing waves.

D. When an original (incident) voltage and current wave travel towards the end of a transmission line upon leaving the generator, they are in the same phase. If, upon reaching the end of the line these waves encounter a resistive termination equal to the characteristic impedance of the line, all of the incident energy will be absorbed by the termination. Under this condition, no line reflections can occur, and there will be no standing waves on the line. The line is now described variously as a non-resonant line, a "flat" line or an infinite line. The most important characteristics of an "infinite" line are:

1. The voltage and current are in phase throughout the entire length of the line.
2. No reflections can take place, and, therefore, "standing waves" cannot exist.
3. The ratio of the voltage to the current (characteristic impedance) is constant along the entire length of the line.
4. The line input impedance is equal to the characteristic impedance.
5. The line operates with minimum loss.

Q. 4.78. If a vertical antenna is 405 feet high and is operated at 1250 kilocycles, what is its physical height, expressed in wavelengths? (1 meter = 3.28 feet.)

A. The physical height is .5143 wavelength. (Slightly greater than ½-wavelength.)

D. Step 1: Change antenna height in feet, into meters. One meter equals 3.28 feet $\frac{405}{3.28} = 123.44$ *meters.*

Step 2: Change kilocycles into wavelength in meters

$$\text{Wavelength} = \frac{300{,}000}{f \text{ (in kc)}} = \frac{300{,}000}{1250} = 240 \textit{ meters.}$$

Step 3: Compare the two measurements in meters. (One wavelength = 240 meters) $\frac{123.44}{240} = .5143$ wavelength.

Q. 4.79. What must be the height of a vertical radiator ½ wavelength high if the operating frequency is 1100 kilocycles?

A. The effective height must be 136.35 meters.

D. The wavelength in meters of 1100 kilocycles is first found as,

$$\text{wavelength} = \frac{300{,}000}{1100} = 272.7 \textit{ meters.}$$

This is a full wavelength, and ½ wavelength $= \frac{272.7}{P_{out}} = 136.35$ *meters* or 447.228 *feet.* The physical height will be somewhat less due to the decreased velocity of propagation and the "end" effect.

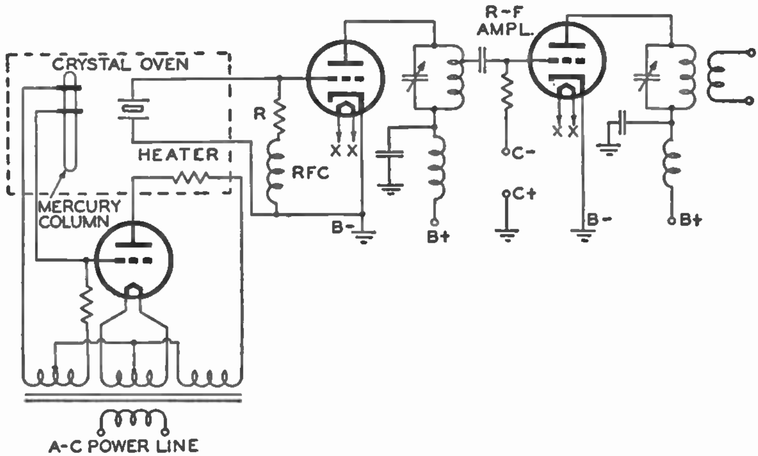


Fig. 4.80. A crystal oscillator.

Q. 4.80. Draw a diagram of a crystal oscillator.

A. See the figure, for an oscillator, with one stage of radio frequency amplification, and crystal temperature control. For other diagrams see Questions 3.73, 3.77, and 6.413.

D. See Questions 3.419, 3.421, 3.422, and 3.433.

Q. 4.81. Draw a diagram of a class B push-pull linear amplifier using triode tubes. Include a complete antenna coupling circuit and

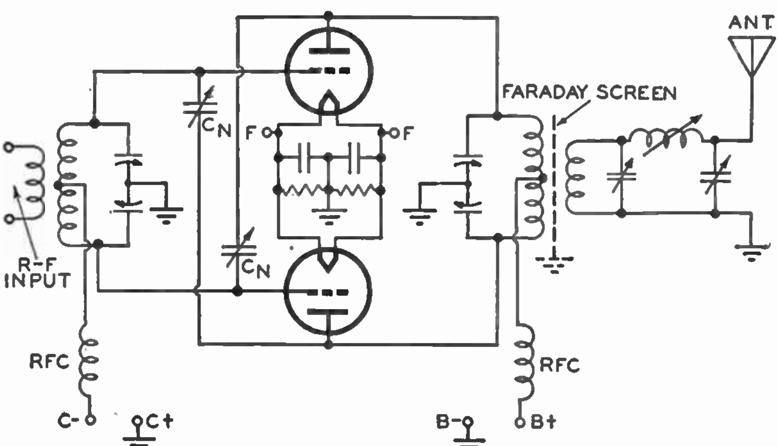


Fig. 4.81. Class B push-pull amplifier.

antenna circuit. Indicate points at which the various voltages will be connected.

A. See the figure.

Q. 4.82. Draw a diagram of a complete class B modulation system, including the modulated radio-frequency amplifier stage. Indicate points where the various voltages will be connected.

A. See Question 4.41.

Q. 4.83. A certain transmitter has an output of 100 watts. The efficiency of the final, modulated-amplifier stage is 50 per cent. Assuming that the modulator has an efficiency of 66 per cent, what plate input to the modulator is necessary for 100 per cent modulation of this transmitter? Assume that the modulator output is sinusoidal.

A. The plate input power to the modulator must be 151.5 watts.

D. The reasoning behind this answer is as follows: The unmodulated carrier output is 100 watts and the efficiency of the final stage is 50%. The d-c input power to the final stage, $P_{in} = \frac{P_{out}}{Eff.} = \frac{100}{.5} =$ 200 *watts*. For 100% modulation the a-c power supplied by the modulator must be equal to 50% of the d-c power to the r-f amplifier of $200 \times 50\% = 100$ *watts*. The modulator efficiency is 66% so the input power to the modulator $P_{in} = \frac{P_{out}}{Eff.} = \frac{100}{.66} = 151.5$ *watts*.

Q. 4.84. If an oscillatory circuit consists of two identical tubes, the grids of which are connected in push-pull and the plates in parallel, what relationship will hold between the input and output frequencies?

A. The output frequency should be an even harmonic of the input frequency.

D. This type of circuit is called a "push-push" doubler. Due to the push-pull grid connection and parallel plate connection, the plate tank receives two pulses of plate current for each cycle of the input frequency. A "push-pull" circuit is more suitable for multiplication of odd harmonics, since there is a tendency for cancellation of even harmonic frequencies in the plate tank.

Q. 4.85. What undesirable effects result from overmodulation of a broadcast transmitter?

A. Some results of overmodulation are:

(1) Distortion is produced in the modulation component of the radiated wave, causing distortion of the received signal.

(2) Generation of spurious harmonic frequencies.

(3) Adjacent channel interference due to extended sidebands.

D. See Question 3.343.

Q. 4.86. What do variations in the final amplifier plate current of a transmitter employing low level modulation usually indicate?

A. Plate current variations in the final stage indicate the presence of some type of distortion such as overmodulation or carrier shift. This might be caused by audio overdrive, excessive r-f excitation or improper tank circuit tuning.

D. See Questions 3.346 and 3.378.

Q. 4.87. If, upon tuning the plate circuit of a triode radio-frequency amplifier, the grid current undergoes variations, what defect is indicated?

A. The usual cause would be improper neutralization. It might also be caused by excessive r-f excitation or incorrect grid bias.

D. See Question 3.307.

Q. 4.88. A 50-kilowatt transmitter employs 6 tubes in push-pull parallel in the final class B linear stage, operating with a 50-kilowatt output and an efficiency of 33 per cent. Assuming that all of the heat radiation is transferred to the water-cooling system, what amount of power must be dissipated from each tube?

A. Each tube must dissipate 16.919 kilowatts.

D. Step 1: Find the total input power

$$P_{in} = \frac{P_{out}}{Eff.} = \frac{50{,}000}{.33} = 151{,}515 \textit{ watts.}$$

Step 2: Find the total dissipated power (6 tubes)

$$P_{diss.} = P_{in} - P_{out} = 151{,}515 - 50{,}000 = 101{,}515 \textit{ watts.}$$

Step 3: Find the power dissipated in one tube, $\frac{101{,}515}{6} = 16{,}919$ *watts.*

Q. 4.89. What is the value of voltage drop across the elements of a mercury-vapor rectifier tube under normal conducting conditions?

A. The voltage drop is in the order of 15 volts.

D. See Questions 3.178 and 3.179.

Q. 4.90. Draw a diagram of a bridge rectifier giving full-wave rectification without a center-tapped transformer. Indicate polarity of output terminals.

A. See the figure.

Q. 4.91. Draw a diagram of a rectifier system supplying two plate voltages, one approximately twice the other and using one high-voltage transformer with a single center-tapped secondary, and such filament supplies as may be necessary.

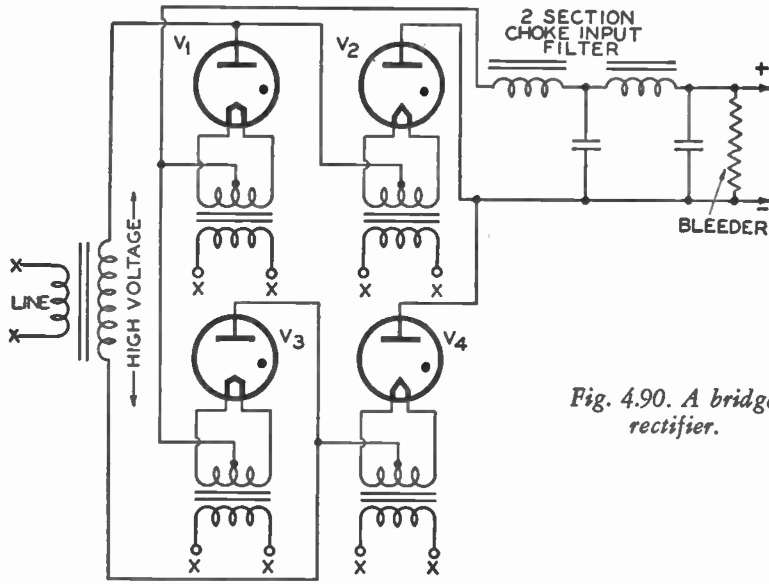


Fig. 4.90. A bridge rectifier.

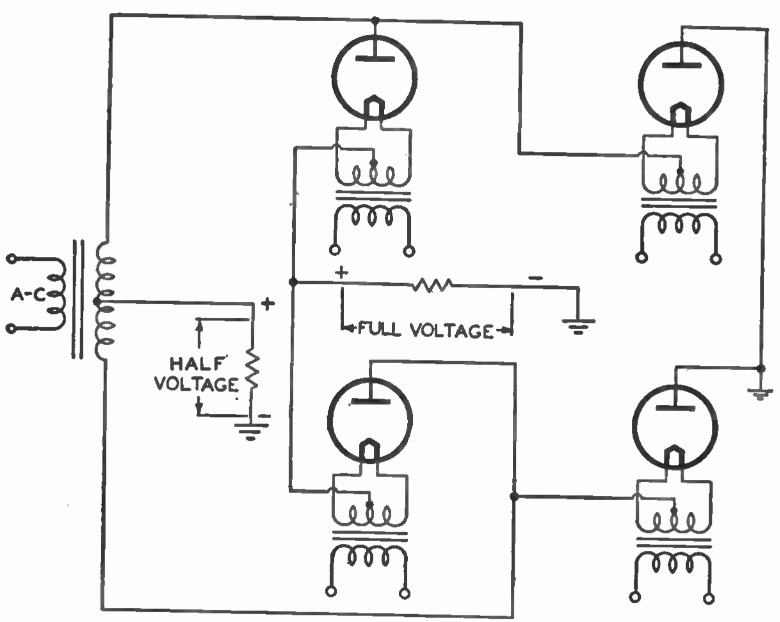


Fig. 4.91. Two plate voltages, one approximately twice the other, may be obtained from a rectifier system like this.

A. See the figure.

Q. 4.92. What is meant by "arc back" or "flash-back" in a rectifier tube?

A. "Arc back" or "flash-back" is the condition in a rectifier tube where electrons flow in the reverse direction from plate to cathode. This is dependent upon the "inverse peak voltage" rating of the rectifier tube.

D. See Question 4.93.

Q. 4.93. What is meant by the "inverse peak voltage" rating of a rectifier tube?

A. "Inverse peak voltage" rating of a rectifier tube is the maximum safe peak voltage which can be applied in the reverse direction without causing "arc back" or "flash back."

D. See Questions 4.92, 4.99, and 6.134. Question 6.351 gives a numerical example.

Q. 4.94. How may a condenser be added to a choke-input filter system to increase the full load-voltage?

A. A condenser may be added to the input side of the choke.

D. This would not necessarily increase the load-voltage output except under reasonably light loading conditions. The filter would now become a condenser-input system which is not usually practical if the rectifier tube is a mercury vapor type. The voltage regulation of the supply would be poorer with condenser-input. (See also Questions 3.397 and 3.399.)

Q. 4.95. Why is it not advisable to operate a filter reactance in excess of its rated current value?

A. This type of operation might saturate the core and reduce the inductance of the choke. This in turn would impair the filtering action of the choke.

D. See Question 3.398.

Q. 4.96. What is a low-pass filter? A high-pass filter?

A. (a) A low-pass filter is, in general, a coupling device which is designed to pass without undue attenuation all frequencies below a certain critical value called the cut-off frequency. The filter should reject all frequencies above the cut-off value.

(b) A high-pass filter is, in general, a coupling device which is designed to pass without undue attenuation all frequencies above a certain critical value called the cut-off frequency. The filter should reject all frequencies below the cut-off value.

D. Some basic equations to be used in the design of filters are given below.

1. Low-pass filter

$$L = \frac{R_{eff.}}{\pi f_c}, \quad C = \frac{1}{\pi f_c R_{eff.}}$$

2. High-pass filter.

$$L = \frac{R_{eff.}}{4\pi f_c}, \quad C = \frac{1}{4\pi f_c R_{eff.}}$$

where $R_{eff.}$ is the terminating impedance, and f_c is the design cut-off frequency. See the figure for Question 4.97.

Q. 4.97. Draw a diagram of a simple low-pass filter.

A. Several types of filters are shown in the figure, including low-pass and high-pass.

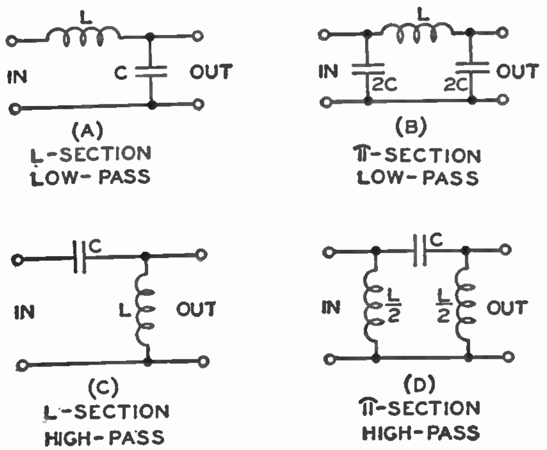


Fig. 4.97. Several types of low-pass filters.

D. See Question 4.96.

Q. 4.98. If a power supply has a regulation of 11 per cent when the output voltage at full load is 240 volts, what is the output voltage at no load?

A. The no load output voltage is 266.4 volts.

D. By the definition of regulation (Question 3.410) the increase is 11% of 240 volts, or 26.4 volts. The no-load voltage is 240 + 26.4 = 266.4 volts.

Q. 4.99. How is the inverse-peak voltage, to which the tubes of a full-wave rectifier will be subject, determined from the known secondary voltages of the power transformer? Explain.

A. In a full wave rectifier the inverse-peak voltage across the non-conducting tube equals the peak-to-peak a-c voltage, or the rms value of the entire secondary winding times 1.414, less the drop in the conducting tube and the d-c drop in the half of the transformer which is conducting.

D. In a half-wave rectifier system the inverse peak voltage is simply equal to the rms secondary voltage times 1.414.

Q. 4.100. If a power supply has an output voltage of 140 volts at no load and the regulation at full load is 15 per cent, what is the output voltage at full load?

A. The output voltage under full load conditions is 121.7 volts.

D. Use the formula for regulation, Question 3.403, $Reg. = \frac{E_{NL} - E_{FL}}{E_{FL}}$ transposing and solving E_{FL} we have

$$E_{FL} = \frac{E_{NL}}{Reg. + 1} = \frac{140}{1.15} = 121.7 \text{ volts.}$$

Q. 4.101. Why is a time-delay relay arranged to apply the high voltage to the anodes of mercury-vapor rectifier tubes some time after the application of filament voltages?

A. The purpose of the time delay is to permit the tube to reach its proper operating temperature before being placed in operation. The tube may otherwise be damaged.

D. The time delay permits the tube to reach its correct operating temperature and also to vaporize any mercury which may have been deposited upon the filament. (See also Question 4.102.)

Q. 4.102. Why is it important to maintain the operating temperature of mercury-vapor tubes within specified limits?

A. It is important to operate a mercury-vapor tube within specified temperature limits in order to realize maximum tube life and efficiency.

D. Mercury-vapor tubes are built with an excess of liquid mercury to maintain a saturated condition of the vapor. The temperature of this vapor determines the pressure in the tube. If the pressure (or temperature) is too low, ionization is incomplete and the space charge is not sufficiently neutralized. Under these conditions the tube drop becomes excessive. With a high voltage drop, the ion velocities become very great, and bombard the cathode with enough energy to damage it. The minimum temperature at which the condensed mercury may be operated without causing disintegration of the cathode is about 20°C. If the operating temperature is excessive, an increase of vapor pressure will occur which will decrease the inverse peak voltage and may cause "flash-back." The maximum operating temperature is usually in the order of 75°C. (See Question 4.101.)

Q. 4.103. If a frequency-doubler stage has an input frequency of 1000 kilocycles, and the plate inductance is 60 microhenrys, what value of plate capacitance is necessary for resonance, neglecting stray capacitances?

A. The value of plate capacitance should be 105.4 micromicrofarads.

D. Since this is a frequency doubler and the input frequency is 1000 kilocycles, the output (plate circuit) frequency must be 2000 kilocycles. The value of inductance is given, so the value of capacitance may be computed from the formula,

$$C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{39.4 \times (2 \times 10^6)^2 \times 60 \times 10^{-6}} = 105.4\ \mu\mu f.$$

Q. 4.104. Draw a simple schematic diagram of a multivibrator oscillatory circuit.

A. See the figure.

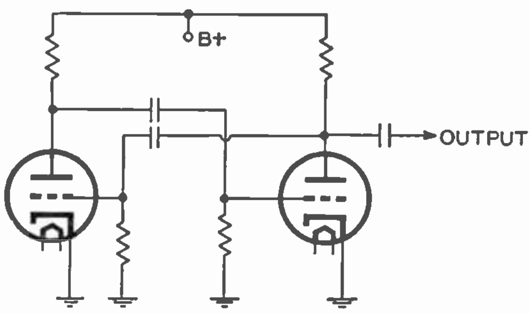


Fig. 4.104. A simple multivibrator circuit.

D. See Question 3.436.

Q. 4.105. What precautions should be taken to insure that a crystal oscillator will function at one frequency only?

A. The following precautions should be taken:

1. Use a well regulated (preferably separate) power supply.
2. Use a pentode rather than a triode tube.
3. Use a crystal cut which has a low temperature coefficient.
4. Maintain as nearly as practicable a constant crystal temperature.
5. Keep feed back to crystal as low as practical, to avoid vibration of crystal in undesired "modes."
6. Use a buffer amplifier following the crystal oscillator.
7. Have all parts rigidly mounted and well shielded.
8. If necessary, use temperature compensating devices, such as a small negative temperature coefficient condenser.

9. Keep crystal and holder bright and clean and maintain proper spring pressure.

10. "Shock-mount" the entire oscillator.

D. See Questions 3.414 through 3.425 inclusive.

Q. 4.106. What are the advantages of mercury thermostats as compared with bimetallic thermostats?

A. In general, mercury thermostats will provide better and more reliable operation than bimetallic thermostats.

D. In a mercury thermostat the entire unit is enclosed in an evacuated container. Because of the lack of air, ionization and oxidation difficulties are practically eliminated. This insures long life and good electrical contacting at all times. The thermostat operates by virtue of the expansion and contraction of a column of mercury with changes of temperature. Hermetically sealed bimetallic thermostats are available, which do not have the disadvantages of the open type.

Q. 4.107. A 600-kilocycle X-cut crystal, calibrated at 50 degrees centigrade, and having a temperature coefficient of —20 parts per million per degree, will oscillate at what frequency when its temperature is 60 degrees centigrade?

A. The crystal will oscillate at 599,880 cycles.

D. This crystal should be designated as follows: $-20/10^6/C°$. This means that the crystal frequency will decrease by 20 cycles for every megacycle of the crystal and for every degree centigrade increase of temperature. Substituting, we have, $-20 \times .6 \times 10 = -120$ cycles. The new operating frequency is $600{,}000 - 120 = 599{,}880$ cycles.

Q. 4.108. Why are quartz crystals usually operated in temperature-controlled ovens?

A. To maintain the maximum possible oscillator stability.

D. See Questions 3.421 and 4.105.

Q. 4.109. What is the device called which is used to derive a standard frequency of 10 kilocycles from a standard-frequency oscillator operating on 100 kilocycles?

A. This device is usually in the form of a *multivibrator* oscillator.

D. See Question 3.429 for complete discussion and Question 4.104 for diagram.

Q. 4.110. What procedure should be adopted if it is found necessary to replace a tube in a heterodyne frequency meter?

A. Changing a tube, particularly one employed in a tuned circuit will change the interelectrode capacities, and require that the instrument be checked for calibration against a standard frequency generator.

D. See Questions 3.431 and 3.432.

Q. 4.111. If a frequency of 500 cycles is beat with a frequency of 550 kilocycles, what will be the resultant frequencies?

A. The resultant frequencies will be 500 cycles, 550 kilocycles, 550.5 kilocycles and 549.5 kilocycles, and in addition many harmonic frequencies, if they are mixed in a non-linear system.

D. When two frequencies are "beat" together in a non-linear circuit the following important frequencies are present:

1. The two original frequencies.
2. The sum of the two frequencies.
3. The difference between the two frequencies.
4. Various harmonics.

Q. 4.112. In what part of a broadcast-station system are phase monitors sometimes found? What is the function of this instrument?

A. A "phase monitor" may be found in the antenna system where a directional array requires the use of two or more radiating elements.

D. Where a directional antenna system consists of two or more driven elements, the correct radiation pattern from this system depends upon the phase relationship between the currents in the various elements. Some stations require a different radiation pattern at night than in the daytime to reduce interference to other stations. In order to determine the relative phases, "sampling" transmission lines are excited from small untuned loops on each element and connected into the phase monitor. The "sampling" lines often have provision to dehumidify the atmosphere within the lines, or may be filled with an inert gas under pressure. This precaution is necessary because the humidity might change the readings of phase measurements. One commercially available phase monitor also utilizes expanded-scale r-f milliammeters to indicate the true relative amplitudes of the currents in each tower. A 360-degree scale is provided which measures the phase displacement of each tower current in the proper 90° quadrant. Leading phase angles are shown in red and lagging angles in black. The phase monitor requires an r-f power input from about ⅕ to 4 watts per element. It has an input impedance of about 65 ohms making it adaptable to transmission lines of widely different impedances.

Q. 4.113. If a broadcast station receives a frequency-measurement report indicating that the station frequency was 45 cycles low at a certain time, and the transmitter log for the same time shows the measured frequency to be 5 cycles high, what is the error in the station-frequency monitor?

A. The error is 50 cycles.

D. The frequency monitor is reading too high and its total error is the sum of the two errors: $45 + 5 = 50$ *cycles*. If the monitor had read 5 cycles low, the total monitor error would have been: $45 - 5 = 40$ *cycles*.

Q. 4.114. If a heterodyne-frequency meter, having a straight-line relation between frequency and dial reading, has a dial reading of 31.7 for frequency of 1390 kilocycles, and a dial reading of 44.5 for a frequency of 1400 kilocycles, what is the frequency of the ninth harmonic of the frequency corresponding to a scale reading of 41.2?

A. The frequency of the 9th harmonic corresponding to a scale reading of 41.2 is 12,576.8 kilocycles.

D. Since the dial-frequency relationship is linear we can find the amount of frequency change per 1/10 of a dial division.

Step 1: The difference between the two dial readings given, is 44.5 —31.7 = 12.8 divisions. The difference between the two given frequencies in cycles is, 1,400,000 — 1,390,000 = 10,000 cycles.

Step 2: Divide the frequency by the number of dial divisions

$$\frac{10{,}000}{12.8} = 781.3 \textit{ cycles per division.}$$

Step 3: Find the number of divisions between 44.5 and 41.2 = 3.3 *divisions.*

Step 4: Multiply the answer in step 3 by the answer in step 2 or 3.3 × 781.3 = 2578.28 *cycles* which represents the *change* of frequency between the readings of 44.5 and 41.2.

Step 5: Find the actual frequency at the reading of 41.2 or 1,400,000 — 2578.29 = 1,397,421.7 *cycles.*

Step 6: Find the 9th harmonic of the frequency found in step 5 or 9 × 1,397,421.7 = 12,576,795.3 cycles or 12,576.8 *kilocycles.*

Q. 4.115. What is the reason why certain broadcast-station frequency monitors must receive their energy from an unmodulated stage of the transmitter?

A. In order to obtain the maximum possible accuracy of frequency measurement.

D. This would be particularly true if the frequency monitor were of the heterodyne type. In the process of modulation many harmonic frequencies are produced. Some of these harmonics might conceivably beat against harmonics of the frequency meter oscillator and produce entirely erroneous zero beat points. It is important, therefore, to obtain the energy for measuring from an unmodulated r-f stage.

Q. 4.116. In what part of a broadcast-station system are "limiting" devices usually employed? What are their functions?

A. Limiting devices are employed at the transmitter end of a broadcast station where the audio program is received. The purpose of such devices is to prevent overmodulation and consequent distortion and interference.

D. Peak limiting amplifiers are often used in modern broadcast transmitters. The purpose of such amplifiers is to prevent overmodulation of the transmitter which would cause distortion and adjacent channel interference on high intensity peaks. In peak limiting, the amplifier is controlled by rectifving a portion of the output signal to secure a component of direct-voltage which is proportional to the peaks. This direct component may then be used to control the bias of a remote cut-off pentode in a manner similar to avc action. The gain of a peak limiter is quickly reduced on peaks and then smoothly restored, whenever the instantaneous peak amplitude of the signal exceeds a pre-determined value.

Q. 4.117. What are the results of using an audio-peak limiter?

A. The use of an audio-peak limiter permits a higher average percentage of modulation to be achieved without the difficulties of overmodulation. Such limiters prevent the carrier from being put off the air following intensified peaks which might operate the overload relays.

D. See Question 4.116.

Q. 4.118. How is the load on a modulator, which modulates the plate circuit of a class C radio-frequency stage, determined?

A. The load on a modulator is equal to the d-c plate impedance of the class C modulated r-f amplifier.

D. The d-c plate impedance of an amplifier tube (R_p) equals $\frac{E_b}{I_b}$, where E_b is the d-c plate voltage, and I_b is the d-c plate current.

Q. 4.119. Given a class C amplifier with a plate voltage of 1,000 volts and a plate current of 150 milliamperes which is to be modulated by a class A amplifier with a plate voltage of 2,000 volts, plate current of 200 milliamperes, and a plate impedance of 15,000 ohms. What is the proper turns ratio for the coupling transformer?

A. The approximate turns ratio is 2.12 to 1.

D. A class A amplifier triode tube of moderate amplification factor should have as a load impedance, a value approximately equal to twice the a-c internal plate impedance of the tube. Under this condition the amplifier may achieve maximum power output with tolerable distortion (about 5%). Thus in this problem the load impedance should be 15,000 $\times$ 2 = 30,000 ohms. As shown in the preceding question (4.118), the load upon the modulator tube $= \frac{E_b}{I_b} = \frac{1000}{150} \times 10^3 = 6{,}667$ *ohms*. Since these two impedances are widely different they must be matched by the modulation transformer. The approximate turns ratio of this transformer equals $\sqrt{\frac{Z_1}{Z_2}} = \sqrt{\frac{30{,}000}{6{,}667}} = \sqrt{4.5} = 2.12{:}1$.

Q. 4.120. Indicate, by a simple diagram, the shunt-fed plate circuit of a radio-frequency amplifier.

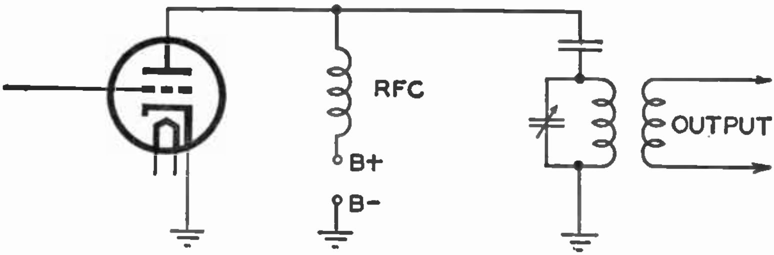


Fig. 4.120. An r-f amplifier with shunt-fed plate circuit.

A. See the figure.
D. See also Question 4.121.

Q. 4.121. Indicate, by a simple diagram, the series-fed circuit in a radio-frequency amplifier.
A. See the figure.
D. See also Question 4.120.

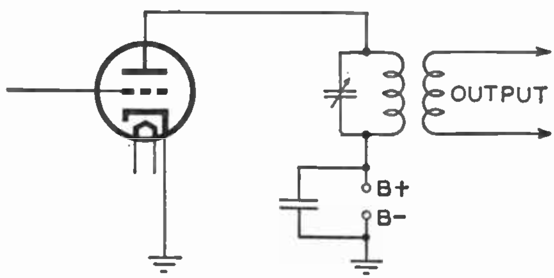


Fig. 4.121. An r-f amplifier with series-fed plate circuit.

Q. 4.122. With respect to the unmodulated values, doubling the excitation voltage of a class B "linear" radio-frequency amplifier will result in what increase in radio-frequency power output?

A. The power output will be quadrupled.

D. Assuming that the amplifier is operated only on the linear portion of its characteristic, the output current will be directly proportional to the grid voltage. Thus if the grid excitation doubles, the plate current also doubles and since the power varies as to the square of the current the power increases by four times.

Q. 4.123. What may be the cause of a decrease in antenna current during modulation of a class B linear radio-frequency amplifier?

A. See Question 3.346.

Q. 4.124. In adjusting the plate-tank circuit of a radio-frequency amplifier, should minimum or maximum plate current indicate resonance?

A. Minimum plate current reading indicates resonance.

D. In a class C amplifier the only time plate current is allowed to exist is during the interval the instantaneous plate voltage is approaching its minimum positive value. It is this minimum plate voltage which determines the magnitude of the plate current. When the tank circuit is at resonance the alternating plate voltage swing is at its maximum amplitude and thus when the tube conducts, it does so at minimum instantaneous plate voltage and consequently minimum plate current.

Q. 4.125. What is the formula for determining the db loss or gain in a circuit?

A. The db power ratio in a circuit is expressed by:

$$N = 10 \log \frac{P_1}{P_2} \ db.$$

If the impedance is the same at the two points of measurement, and the voltages or currents are given, then

$$N = 20 \log \frac{E_1}{E_2} \ db, \text{ or } = 20 \log \frac{I_1}{I_2} \ db.$$

D. See Question 3.38.

Q. 4.126. What will occur if one tube is removed from a push-pull class A audio-frequency amplifier stage?

A. The other tube will not have the correct load impedance and distortion will result. The second harmonic component will reappear, the hum level may increase, and the power output will be reduced. In class AB or B the distortion will be excessive.

D. See Question 3.436.

Q. 4.127. What is the stage amplification obtained with a single triode operating with the following constants: plate voltage 250, plate current 20 milliamperes, plate impedance 5,000 ohms, load impedance 10,000 ohms, grid bias 4.5 volts, amplification factor 24?

A. The stage gain, neglecting any coupling circuit, is 16.

D. The stage gain may be computed from,

$$A = \frac{\mu \times R_L}{R_L + r_p} = \frac{24 \times 10{,}000}{10{,}000 + 5000} = \frac{240{,}000}{15{,}000} = 16.$$

Q. 4.128. Under what circumstances is neutralization of a triode radio-frequency amplifier not required?

A. Neutralization of a triode r-f amplifier is not required when the amplifier is used as a frequency multiplier, has a very low gain, or is used as a grounded-grid amplifier.

D. See Questions 3.307 and 4.185.

Q. 4.129. Why is it necessary or advisable to remove the plate voltage from the tube being neutralized?

A. The plate voltage should be removed in order to make the amplifier inoperative.

D. If the amplifier were in the process of being neutralized and the plate voltage were not removed, it would be extremely difficult to determine when neutralization had taken place, since with grid-excitation present there would always be r-f in the plate tank circuit. The danger of self-oscillations damaging the tube before neutralization is completed is another important factor.

Q. 4.130. Under what conditions may a standard broadcast station be operated at a power lower than specified in the station license?

A. The licensee of a broadcast station shall maintain the operating power of the station within the prescribed limits of the licensed power at all times, except that in an emergency, when, due to causes beyond the control of the licensee, it becomes impossible to operate with the full licensed power, the station may be operated at reduced power for a period of not to exceed 10 days, provided that the Commission and the engineer in charge shall be notified in writing immediately after the emergency develops.

Q. 4.131. When the transmitter of a standard broadcast station is operated at 85 per cent modulation, what is the maximum permissible combined audio-harmonic output?

A. When the transmitter is operated with 85 per cent modulation, not over 10 per cent combined audio-frequency harmonics shall be generated by the transmitter.

Q. 4.132. How frequently must the auxiliary transmitter of a regular broadcast station be tested?

A. "The auxiliary transmitter shall be tested at least once each week to determine that it is in proper operating condition and that it is adjusted to the proper frequency, except that in case of operation in accordance with paragraph (c) of this section during any week, the test in that week may be omitted provided the operation under paragraph (c) is satisfactory. A record shall be kept of the time and result of each test operating under paragraph (c). Tests shall be conducted between midnight and 9 A.M., local standard time."

D. See Question 4.133 for text of paragraph (c), here referred to.

Q. 4.133. For what purpose is an auxiliary transmitter maintained?

A. The regulations state: (c) The auxiliary transmitter shall be maintained so that it may be put into immediate operation at any time for the following purposes:

(1) The transmission of the regular programs upon the failure of the main transmitter.

(2) The transmission of regular programs during maintenance or modification work on the main transmitter, necessitating discontinuance of its operation for a period not to exceed five days.

(3) Upon request by a duly authorized representative of the Commission.

D. See Questions 4.132 and 4.157.

Q. 4.134. If the plate ammeter in the last stage of a broadcast transmitter burned out, what should be done?

A. No instrument indicating the plate current or plate voltage of the last radio stage, the antenna current, or the transmission-line current shall be changed or replaced without written authority of the Commission, except by instruments of the same make, type, maximum scale reading, and accuracy. Requests for authority to change an instrument may be made by letter or telegram giving the manufacturer's name, type number, serial number, and full-scale reading of the proposed instrument and the values of current or voltage the instrument will be employed to indicate. Requests for temporary authority to operate without an instrument or with a substitute instrument may be made by letter or telegram stating the necessity therefor and the period involved.

Q. 4.135. The currents in the elements of a directive broadcast antenna must be held to what percentage of their licensed value?

A. Five per cent.

Q. 4.136. What are the permissible tolerances of power of a standard broadcast station?

A. Each station shall be operated at all times as near to the authorized power as practicable. However, in order to provide for variations in the power supply or other factors affecting the operating power which would necessitate continual adjustment to keep the operating power exactly the same as the authorized power, the operating power may be permitted to vary from 5 per cent above to 10 per cent below the authorized power for periods of short duration.

Q. 4.137. What are meant by "equipment," "program," and "service" tests where these are mentioned in the Rules and Regulations of the Commission?

A. *Equipment test.* Upon completion of construction of a radio station in exact accordance with the terms of the construction permit, the technical provisions of the application therefor and the rules and regulations governing the class of station concerned and prior to filing of application for license, the permittee is authorized to test the equipment for a period not to exceed 10 days, subject to the Commission's approval.

Service or *program test.* When construction and equipment tests are completed in exact accordance with the terms of the construction permit the technical provisions of the application therefor, and the rules and regulations governing the class of station concerned, and after an application for station license has been filed with the Commission showing the transmitter to be in satisfactory operating condition, the permittee is authorized to conduct service or program tests in exact accordance with the terms of the construction permit for a period not to exceed 30 days.

Q. 4.138. At broadcast stations using the direct method of computing output power, at what point in the antenna system must the antenna current be measured?

A. The antenna current must be measured at the point where the antenna resistance is determined. This is usually a maximum-current point.

D. See Questions 3.226 and 3.321. For the indirect method of measurement, see Questions 4.142 and 4.154.

Q. 4.139. For what purpose may a standard broadcast station which is licensed to operate daytime or specified hours operate during the experimental period without specific authorization?

A. The hours between midnight and local sunrise cover the experimental period of a standard broadcast station and these hours may be used for testing purposes for proper maintenance of the station but not for regular broadcasting; the tests must be conducted without causing interference to the regular service of other stations which maintain regular schedules during these hours. See Question 4.145.

Q. 4.140. What is the last audio-frequency amplifier stage which modulates the radio-frequency stage termed?

A. This stage is called the *modulator.*

Q. 4.141. How frequently must a remote-reading ammeter be checked against a regular antenna ammeter?

A. Calibration shall be checked against the regular meter at least once a week.

Q. 4.142. What factors enter into the determination of power of a broadcast station which employs the indirect method of measurement?

A. In accordance with the following formula the factors are the total plate current and plate voltage of the last radio stage and the proper factor, *F*, according to the type of modulation used. (The proper efficiency factor, is obtained from the table issued by the F.C.C)

$$Operating\ power = E_p \times I_p \times F$$

D. Examples of the use of the efficiency factor, *F*, are: for stations employing plate modulation in the last radio stage *F* ranges from 0.70 to 0.80; for stations of all powers using low-level modulation it ranges from 0.35 to 0.65; for stations of all powers employing grid modulation in the last radio stage it ranges from 0.25 to 0.35. For the direct method of measurement, see Questions 4.138 and 4.154.

Q. 4.143. What is the power that is actually transmitted by a standard broadcast station termed?

A. "Operating power" means the power that is actually supplied to radio station antenna.

Q. 4.144. Are the antenna current, plate current, etc., as used in the Rules and Regulations of the Commission with reference to radiotelephone transmitters modulated or unmodulated values?

A. These are *unmodulated* values.

D. Since modulation conditions are variable and since measurements should be made on a uniform basis, it is reasonable to select a condition of non-modulation for all measurements.

Q. 4.145. With reference to broadcast stations, what is meant by the "experimental period"?

A. The experimental period means that time between 12 midnight and local sunrise when tests may be conducted for the proper maintenance of a station, providing no interference is caused to the regular service of other stations and compliance is made with the Commission's rule in Section 3.72.

D. The rule referred to in Section 3.72, reads as follows: The licensee of each standard broadcast station shall operate or refrain from operating its station during the experimental period as directed by the Commission in order to facilitate frequency measurement or for the determination of interference. (Stations involved in the after-midnight frequency monitoring programs are notified of their operating and silent schedule.) See Question 4.139.

Q. 4.146. What percentage of modulation capability is required of a standard broadcast station?

A. 85 per cent.

D. The operating percentage of modulation of all stations shall be maintained as high as possible consistent with good quality of transmission and good broadcast practice and in no case less than 85 per cent on peaks of frequent recurrence during any selection which is normally transmitted at the highest level of the program under consideration.

Q. 4.147. Define the maximum rated carrier power of a broadcast station transmitter.

A. "Maximum rated carrier power" is the maximum power at which the transmitter can be operated satisfactorily and is determined by the design of the transmitter and the type and number of vacuum tubes used in the last radio stage.

Q. 4.148. Define the plate input power of a broadcast station transmitter.

A. The plate input power is the product of the plate d-c voltage and the total plate direct current of the last radio stage with no modulation.

Q. 4.149. Define "high-level" and "low-level" modulation.

A. See Questions 3.334 and 3.336.

Q. 4.150. What is the frequency tolerance for a standard broadcast station?

A. The tolerance is plus or minus 20 cycles.

Q. 4.151. What is the frequency tolerance allowed an international broadcast station?

A. .005 per cent.

Q. 4.152. What is the required full-scale accuracy required in the ammeters and voltmeters associated with the final radio stage of a broadcast transmitter?

A. Two per cent.

Q. 4.153. If a broadcast transmitter employs seven tubes of a particular type, how many spare tubes of the same type are required to be kept on hand in accordance with F.C.C. regulations?

A. 3 spare tubes.

D. The requirements regarding spare tubes are covered in the F.C.C. Standards of Good Engineering Practice, as follows: A spare tube of every type employed in the transmitter and frequency and modulation monitors shall be kept on hand. When more than one tube of any type is employed, the following table determines the number of spares of that type required:

Number of each type employed	*Spares required*
1 or 2	1
3 to 5	2
6 to 8	3
9 or more	4

Q. 4.154. Describe the various methods by which a broadcast station may compute its operating power, and state the conditions under which each method may be employed.

A. The direct and indirect measurements of operating power are applied as follows:

DIRECT MEASUREMENT OF OPERATING POWER.

How determined: The antenna input power determined by direct measurement is the square of the antenna current times the antenna resistance at the point where the current is measured and at the operating frequency.

Conditions governing use: Direct measurement of the antenna input power will be accepted as the operating power of the station provided the data on the antenna resistance measurements are submitted under oath giving detailed description of the method used and the date taken. The antenna current shall be measured by an ammeter of accepted accuracy. These data must be submitted to and approved by the Commission before any licensee will be authorized to operate by this method of power determination. The antenna ammeter shall not be changed to one of different type, maximum reading, or accuracy without the authority of the Commission. If any change is made in the antenna system, or any change made which may affect the antenna system, the method of determining operating power shall be changed immediately to the indirect method.

INDIRECT MEASUREMENT OF OPERATING POWER.

How determined: The operating power determined by indirect measurement from the plate input power of the last radio stage is the product of the plate voltage (E_p), the total plate current of the last radio stage (I_p), and the proper factor (F) according to the type of modulation used, or

$$\text{Operating power} = E_p \times I_p \times F$$

Examples of the range of the efficiency factor, F, are: for stations employing plate modulation in the last radio stage F ranges from 0.70 to 0.80; for stations of all powers using low-level modulation it ranges from 0.35 to 0.65; for stations of all powers employing grid modulation in the last radio stage it ranges from 0.25 to 0.35. (Tables of the efficiency factor F are given in F.C.C. Rules and Regulations, Section 3.52.)

Conditions governing use: The indirect measurement is used only on a temporary basis in an emergency where the licensee antenna has been damaged or destroyed by storm or other cause beyond control of the licensee or pending completion of authorized changes in the antenna system.

D. A third method of determination may be used, but at present only for ship, coastal harbor, or marine relay stations; this method permits the use of field intensity measurements, according to prescribed methods, to determine the power.

Q. 4.155. What portion of the scale of an antenna ammeter having a square law scale is considered as having acceptable accuracy for use at a broadcast station?

A. The portion from one-third to full scale, that is, the upper two-thirds of the scale.

D. No scale division above one-third full scale reading (in amperes) shall be greater than one-thirtieth of the full-scale reading. (Example: An ammeter having a full-scale reading of 6 amperes is acceptable for reading currents from 2 to 6 amperes, provided no scale division between 2 and 6 amperes is greater than one-thirtieth of 6 amperes, or 0.2 ampere.)

Q. 4.156. Define: "amplifier gain," "percentage deviation," "stage amplification," and "percentage of modulation." Explain how each is determined.

A. (a) "Amplifier gain" may be expressed as the ratio of the output voltage (or power) to the input voltage (or power). The ratio is often expressed in decibels.

(b) "Percentage deviation" refers to the amount of frequency change from the original carrier frequency or other standard frequency expressed in percentage.

(c) "Stage amplification" refers to the gain of a single amplifier tube stage and is measured from the grid of the stage to the grid of the following stage.

(d) "Percentage of modulation" (amplitude modulation) is the ratio of ½ of the difference between the maximum and minimum amplitudes of the modulated wave, to the carrier amplitude, expressed as a percentage.

Q. 4.157. Define an auxiliary broadcast transmitter and state the conditions under which it may be used.

A. The term "auxiliary transmitter" means a transmitter maintained only for transmitting the regular programs of a station in case of failure of the main transmitter. The auxiliary transmitter shall be maintained so that it may be put into immediate operation at any time for the following purposes:

(1) The transmission of the regular programs upon the failure of the main transmitter.

(2) The transmission of regular programs during maintenance or modification work on the main transmitter, necessitating discontinuance of its operation for a period not to exceed 5 days.

(3) Upon request by a duly authorized representative of the Commission.

D. See Questions 4.132 and 4.133.

Q. 4.158. What is the purpose of using a frequency standard or service independent of the transmitter-frequency monitor or control?

A. This is the ruling of the F.C.C. regarding many stations. An independent source of standard frequency is necessary to insure that the transmitter frequency is being maintained within the required tolerance and to serve as a check on the accuracy of the station monitor.

Q. 4.159. Discuss the characteristics of a modulated class C amplifier.

A. The following are characteristics of a class modulated amplifier:

1. Needs large value of driving power.
2. Operates at high efficiency, in the order of 60% or greater.
3. Grid bias is usually about twice cut-off.
4. Plate current r-f pulses are in the order of 120°.
5. Very little distortion of the modulation envelope in the output

if operated correctly.

6. Large power output for a given size of tube.

D. See Question 3.104.

Q. 4.160. What is the purpose of neutralizing a radio-frequency amplifier stage?

A. The purpose is to prevent self sustaining oscillations from occurring in an r-f amplifier.

D. See Question 3.307.

Q. 4.161. When the authorized nighttime power of a standard broadcast station is different from the daytime power and the operating power is determined by the "indirect" method, which of the efficiency factors established by the F.C.C. rules is used?

A. The efficiency factor for the maximum rated carrier power is used.

D. In computing operating power by indirect measurement the above factors shall apply in all cases and no distinction will be recognized owing to the operating power being less than the maximum rated carrier power.

Q. 4.162. Describe the technique used in frequency measurements employing a 100-kilocycle oscillator, a 10-kilocycle multivibrator, a heterodyne-frequency meter of known accuracy, a suitable receiver, and standard-frequency transmission.

A. The method of frequency measurement utilizing a receiver, heterodyne frequency meter of known accuracy and an unknown frequency is as follows: The receiver is first tuned to the unknown frequency and the heterodyne frequency meter is adjusted until a zero beat is obtained in the receiver. This reading on the frequency meter in kilocycles or megacycles is then noted and is designated as f_1. The frequency meter dial is now adjusted to the next lower reading where another zero beat is obtained. This frequency is designated as f_2. The order of the harmonic being utilized in the frequency meter can now be determined from the formula, $H = \frac{f_2}{f_1 - f_2}$. Knowing the order of the harmonic, the unknown frequency of (f_x) can be determined from the formula, $f_x = H \times f_1$.

D. The standard frequency emission (5 mc) may be used to check the accuracy of the heterodyne frequency meter by beating various harmonics of the frequency meter against the standard emission in the receiver. The dial calibration can then be readjusted if necessary. If a secondary standard such as a stable 100 kilocycle crystal oscillator is available, is may be used to synchronize a 10 kilocycle multivibrator. The waveform of the multivibrator is such that harmonics of 10 kilocycles in the hundreds are available. These harmonics provide convenient check points each 10 kilocycles. Harmonics up to 30 megacycles may be obtained from the 100 kilocycle crystal. The identification of 100 kilocycle points is sometimes difficult to determine, but may be checked by the harmonic method previously described. Another method of identifying 100 kilocycle points more easily would be to provide an accurate signal of 1000 kilocycles. It is then relatively easy to identify a signal to the nearest megacycle on practically any receiver and the intermediate 100 kilocycle and 10 kilocycle points can then be identified. The primary frequency standard emissions from station WWV are on frequencies of 2.5 megacycles (from 7 P.M. to 9 A.M. EST only), 5 megacycles, 10 megacycles, and 15 megacycles. The accuracy of all frequencies is better than 1 part in 10,000,000.

Q. 4.163. What is the power specified in the instrument of authorization for a standard broadcast station called?

A. This is called the "licensed power" or "authorized power."

Q. 4.164. What is the effect of 10,000-cycle modulation of a standard broadcast station on adjacent channel reception?

A. This will produce sideband frequencies equal to the carrier frequency of the adjacent channel. This may produce heterodyning and other interference with the adjacent channel.

D. Where harmful interference occurs, the modulation frequency is limited to 7500 cycles by the F.C.C.

Q. 4.165. What system of connections for a three-phase, three transformer bank will provide maximum secondary voltage?

A. A delta-*Y* connection will provide maximum secondary voltage.

D. See Question 4.14.

Q. 4.166. Draw a diagram and describe the electrical characteristics of an electron-coupled oscillator circuit.

A. See Question 3.76 for diagram and discussion.

Q. 4.167. In frequency measurements using the heterodyne "zero beat" method, what is the best ratio of signal emf to calibrated heterodyne oscillator emf?

A. The best ratio is 1:1.

D. In order to produce the strongest beat frequencies it is necessary to produce an effective condition of 100% modulation. This condition can be obtained only if the signal emf and the heterodyne oscillator emf are of equal amplitude.

Q. 4.168. What is meant by the "Q" of a radio-frequency inductance coil?

A. The Q of a coil is the ratio of the energy stored to the energy dissipated in the coil over a period of one cycle.

D. The energy storage is within the field of the pure inductance (no resistance) of the coil while the energy losses are due to a so-called resistance, made up of several parts. This small resistance is designated *effective resistance.*

1. The d-c resistance of the coil.
2. The a-c resistance of the coil (skin effect).
3. Dielectric losses in the wire insulation and coil form.
4. Core losses.
5. Radiation from the coil (if an appreciable part of a wavelength long).

$$Q = \frac{X_L}{R_{effective}}$$

Sometimes eddy current losses in nearby bodies, such as a coil shield, are included if desired, since the effect on circuit performance is the same as any other loss.

Q. 4.169. What effect does a loading resistance have on a tuned radio-frequency circuit?

A. A loading resistance has the effect of broadening the frequency response characteristic of a tuned circuit by reducing the Q.

D. A loading resistance is usually placed in shunt with the tuned circuit for the purpose of increasing the band-width response of the circuit. Since this reduces the parallel impedance of the tuned circuit, a proportional reduction in gain takes place. This device is often used in television i-f amplifiers to obtain the necessary band-pass. A simple formula to determine the value of loading resistance is, $R = X_r \dfrac{f_r}{2\Delta f}$ where $2\Delta f$ is the desired band width, f_r is the resonant frequency, X_r is the reactance of L at the resonant frequency. See Question 4.168 for discussion of Q. See also Question 6.98.

Q. 4.170. What is meant by the "time constant" of a resistance-capacitance circuit?

A. The "time constant" of an R-C circuit is defined as the length of time (in seconds) which is required for a condenser to attain a voltage across its terminals which is equal to 63.2% of the applied voltage.

D. The "time constant" may also be defined as the time required for a condenser to discharge 63.2% of the original charge in the condenser. (The remaining charge at the end of one "time constant" is therefore 36.8%.) In each succeeding time constant, the charge in the condenser will again change (charge or discharge) by 63.2%. For all practical purposes a condenser may be considered to be fully charged or discharged in 5 "time constants." The "time constant" $T = R \times C$ seconds where R is the resistance in ohms and C is the capacitance in farads. If R is in ohms and C is in microfarads, then T is in microseconds. The voltage across a condenser under charge, at any instant may be found from the formula, $E_c = E_A \left(1 - \epsilon^{\frac{-t}{RC}}\right)$ where E_c is the voltage across the condenser, E_A is the applied voltage, $\epsilon = 2.718$, t is the elapsed time, RC equals one time constant.

Q. 4.171. A potential of 110 volts is applied to a series circuit containing an inductive reactance of 25 ohms, a capacitive reactance of 10 ohms and a resistance of 15 ohms. What is the phase relationship between the applied voltage and the current flowing in this circuit?

A. The current will lag the applied voltage by 45°.

D. Since this is a series circuit the effect of the two reactances is subtractive. Thus the 10 ohms of capacitive reactance is subtracted from the 25 ohms of inductive reactance, leaving a net value of 15 ohms inductance reactance ($X = X_L - X_C$). The angle is found as follows: $\theta = \tan^{-1}\frac{X}{R} = \tan^{-1}\frac{15}{15} = \tan^{-1} 1 = 45$ *degrees* (lagging, because the inductive reactance is greater than the capacitive, as discussed in Question 3.486).

Q. 4.172. What does the term "power factor" mean in reference to electric power circuits?

A. "Power factor" is the ratio of the resistance to the impedance in a circuit. It is also the ratio of the true power to the apparent power ($E \times I$) of a circuit.

D. See Questions 3.34 and 3.311.

Q. 4.173. What is the predominant ripple frequency in the output of a single-phase full wave rectifier when the primary source of power is 110 volts at 60 cycles?

A. The predominant ripple frequency is 120 cycles.

D. The fundamental ripple frequencies for various combinations are listed below, for 60-cycle line frequency.

½-wave single-phase	=	60 cycles
Full wave single-phase	=	120 cycles
½-wave two-phase	=	60 cycles
Full wave two-phase	=	240 cycles
½-wave three-phase	=	180 cycles
Full wave three-phase	=	360 cycles

Q. 4.174. When mercury-vapor tubes are connected in parallel in a rectifier system, why are small resistors sometimes placed in series with the plate leads of the tubes?

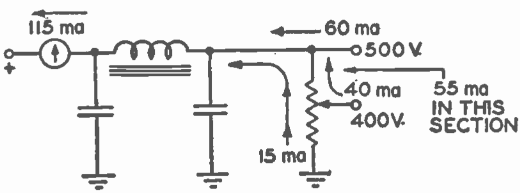
A. Small resistors are used to insure that both tubes will ionize and carry the load.

D. The operating characteristic curve of a mercury-vapor rectifier tube is so steep that any slight difference in the characteristics of two tubes would cause a very large difference in the currents taken by each tube. The tube with the smaller voltage drop would take almost the entire load current. This difficulty can be overcome by connecting a small resistor in series with each tube before connecting them in parallel.

Q. 4.175. A rectifier-filter power supply is designed to furnish 500 volts at 60 milliamperes to one circuit and 400 volts at 40 milliamperes to another circuit. The bleeder current in the voltage divider is to be 15 milliamperes. What value of resistance should be placed between the 500- and 400-volt taps of the voltage divider?

A. The value of resistance should be 1818.2 ohms.

Fig. 4.175. A rectifier-filter system which can supply 500 volts at 60 milliamperes and 400 volts at 40 milliamperes to another circuit.



D. Refer to the diagram. It will be seen that two currents are present in the 400 to 500 volt section. These are the bleeder current of 15 ma. plus the 400 volt load current of 40 ma. or a total of 55 milliamperes. The value of resistance is found by Ohm's Law.

$$R = \frac{E}{I} = \frac{100}{.055} = 1818.2 \text{ ohms.}$$

The power rating is found as follows: $E \times I = 5.5$ watts actual dissipation. Use a 10-watt resistor, for safety-factor.

Q. 4.176. What is the approximate speed of a 220-volt, 60-cycle, 4-pole, 3-phase induction motor?

A. The approximate speed is 1800 rpm.

D. The synchronous speed of the induction motor is, $\frac{120f}{N}$, where f is the power line frequency in cycles per second, and N is the number of poles. Substituting, *Sync. speed* $= \frac{120 \times 60}{4} = 1800$ rpm. The actual running speed of an induction motor must always be slightly less than the synchronous speed, so that the emf generated in the rotor circuit will be exactly the correct amount to supply enough current to produce a propelling torque which is equal to the resisting torque of the load and rotor losses combined. This difference in speed, expressed as a fraction, is called the *slip*. For the motor in question, a reasonable value of slip will be .0277 or 2.77 percent and the actual running speed is found by: $RPM_{run} = RPM_{sync} \times (1—slip) = 1800\ (1—0.0277) = 1800 \times 0.9723 = 1750\ RPM.$

Q. 4.177. Draw a diagram of a shunt wound DC motor.

A. See Question 3.172.

Q. 4.178. Draw a diagram of a voltage doubling power supply using two half wave rectifiers.

A. See the figure.

D. CASCADE DOUBLER, FIGURE-GROUP A. During the first negative half cycle, condenser C_1 charges through diode V_1 to approximately the peak value, E, of the transformer secondary voltage (Figure A′). As soon as the negative peak has gone by and the wave starts in the positive direction, condenser C_1 begins to charge C_2 through V_2 (Figure A″). When the wave reaches its positive peak, the voltage across the transformer secondary in series with the voltage across C_1 (totalling $2\ E$) charges C_2 to approximately double the peak secondary voltage. This doubler is a half-wave device.

CONVENTIONAL DOUBLER, FIGURE-GROUP B. For simplicity of explanation it is assumed that the circuit has been in operation for some time and that we are considering a positive-going half-cycle (Figure B′). C_2 has been previously charged through V_2 and the transformer secondary to approximately the peak value of secondary voltage. As soon as the transformer voltage starts in the positive direction, C_2 begins to discharge through V_1 into the load and filter. When the transformer reaches its maximum positive value, it adds its voltage to that of C_2 and charges the filter condenser (not shown) to approximately double the peak secondary voltage. During this same positive-going half-cycle, condenser C_1 is being recharged to the peak secondary voltage through V_1 and the transformer secondary.

As soon as the wave starts in the negative direction (Figure B″), condenser C_1 begins discharging through V_2 into the load (and filter, not shown); when the transformer reaches its maximum negative value, its voltage is added in series to that of C_1 charging the filter condenser (not shown) to approximately double the peak secondary voltage. During this same negative-going half-cycle, C_2 is being recharged to the peak secondary voltage through V_2 and the transformer secondary. This completes one cycle of full-wave operation.

Q. 4.179. Why is degenerative feedback sometimes used in an audio amplifier?

A. The results of degenerative feedback in audio amplifiers are:

1. Greater stability of amplifier characteristics.
2. Reduction of harmonic distortion.
3. Reduction of phase distortion.
4. Improvement of frequency response linearity.

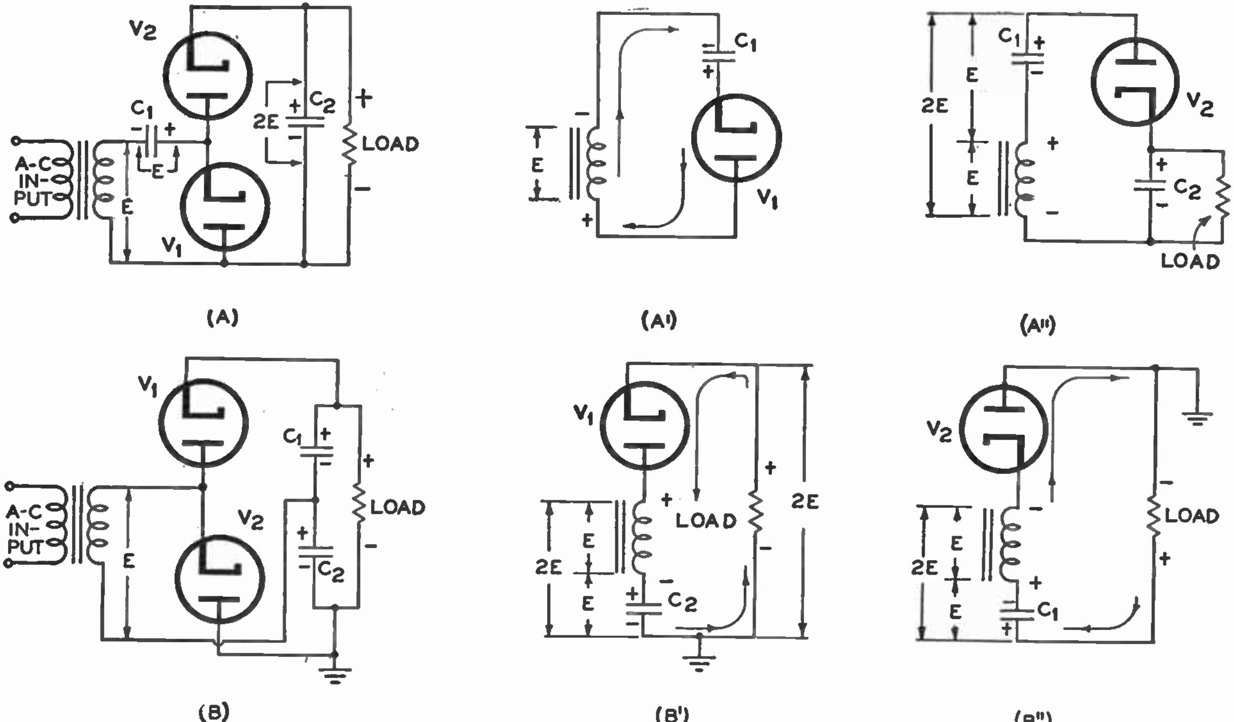


Fig. 4.178. Group A shows a cascade doubler. Group B shows a conventional doubler circuit.

5. Reduction of amplifier gain.
6. Reduction of noise output.
7. Reduction of effective r_p with negative voltage feedback.
8. Increase of effective r_p with negative current feedback.

D. See Question 4.33.

Q. 4.180. What determines the fundamental operating frequency range of a multivibrator oscillator?

A. The fundamental operating frequency is determined by many factors but mostly by the grid coupling constants to each tube. (Resistance and capacity.)

D. See Question 3.429.

Q. 4.181. Draw a diagram of an audio amplifier with inverse feedback.

A. See the figure.

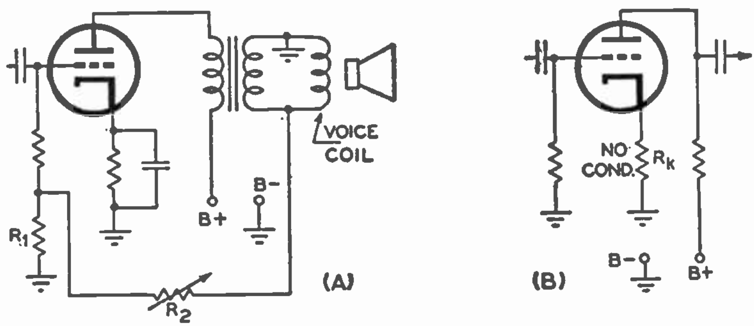


Fig. 4.181. An audio amplifier utilizing inverse feedback.

Q. 4.182. What is the meaning of "mutual conductance," and "amplication factor" in reference to vacuum tubes?

A. Transconductance (G_m) (or mutual conductance) of a tube expresses the effectiveness of the grid in causing changes of plate current. It is sometimes referred to as a figure of merit of a tube. "Amplification factor" (mu or μ) is the theoretical voltage gain of a tube, and is the ratio of a small change in plate voltage to give a certain small change in plate current, to a change in grid voltage which would cause the same change of plate current.

D. TRANSCONDUCTANCE. Of the various expressions used in describing the characteristics of a tube, perhaps the one which most completely expresses its operation is transconductance. Transconductance is the ratio of the small change in plate current *caused* by a small change in grid voltage with the plate voltage held constant or $G_m = \frac{\Delta i_b}{\Delta e_c}$, $|e_b|$. Transconductance is most commonly measured in micromhos as shown in the following example. Assume the plate current of a tube changes 2 milliamperes for a one volt change in grid voltage. The transconductance is: $G_m = \frac{.002 \text{ a.}}{1\text{v.}} = .002$ mho, or 2000 μmho.

Another way of expressing G_m is $G_m = \frac{\mu}{r_p}$.

AMPLIFICATION FACTOR. The actual voltage gain of an amplifier tube can never be equal to the amplification factor because the drop across the plate impedance of the tube must be subtracted from the total available output signal. This amounts to a voltage divider with r_p in series with the plate load resistance. The only output voltage available is that across the plate load resistance. This means that in order for the voltage gain to be equal to the amplification factor, the load resistance must be infinitely large. The formula for amplification factor is $\mu = \frac{e_b}{e_c}$, $|i_p|$.

PLATE RESISTANCE. The plate impedance or plate resistance of a vacuum tube is a function of the physical and electrical properties of the tube, and is the ratio between a small change of plate current to the change in plate voltage producing it, with the grid voltage held constant. If normal operating voltages are applied to a tube a certain definite value of plate current will flow. If the plate voltage is divided by the plate current the result is called the d-c plate resistance. Thus $R_p = \frac{E_b}{I_b}$. While this value is of some limited use, such as in regulated power supplies, a more general term is needed which more accurately states the operating characteristics of a tube. This more general term is r_p or plate impedance. It represents the impedance offered by the cathode-to-plate path within a tube to a varying voltage. Thus $r_p = \frac{\Delta e_b}{\Delta i_b}$, $|e_c|$ where Δ means "a small change of" r_p is the plate impedance in ohms, e_b and i_b are the instantaneous values of plate voltage and current, and e_c is the instantaneous value of grid voltage, which is here held constant, as indicated by the parallel vertical lines enclosing e_c. The plate impedance may be considered to be the internal resistance of an equivalent a-c generator.

Q. 4.183. What is the purpose of a screen grid in a vacuum tube?

A. See Question 3.115.

Q. 4.184. What is meant by secondary emission in a vacuum tube?

A. "Secondary emission" is the emission of electrons from a material, which is due to the impact of high velocity electrons upon the surface. The original electrons are called primary electrons.

D. See Question 3.102.

Q. 4.185. Why are grounded grid amplifiers sometimes used at very high frequencies?

A. Grounded grid amplifiers are sometimes used at very high frequencies because it is often possible to utilize triode tubes without the necessity for neutralization.

D. (See Question 4.189 for diagram.) In the grounded-grid amplifier the feedback capacitance is not the plate-grid capacitance, but is the much smaller plate-cathode capacitance. This smaller capacitance is less likely to cause oscillations, even at extremely high frequencies when special triodes (Lighthouse type) are used.

Q. 4.186. What material is used in shields to prevent stray magnetic fields in the vicinity of radio-frequency circuits?

A. A good conductor such as aluminum, copper, or brass should be used.

D. The material used must be a good conductor. Magnetic shielding action is as follows: due to the the r-f current flowing through the coil a magnetic field is set up which expands and contracts about the coil. This field cuts the metal shield, which actually represents a short circuited turn. The field induces a voltage into the shield which causes a current to flow in it. This current is comparatively large, due to the low resistance of the shield. The current produces a magnetic field which is in such a direction as to oppose the original field of the coil. It is this opposing field which prevents the original field from passing through the shielding. Since some of the original field is cancelled, the inductance (and hence the inductive reactance) of the coil is reduced. The I^2R dissipated by the shield represents a power loss from the coil and therefore an increase in the effective resistance of the coil. The Q of the coil is thus decreased, since Q is the ratio of energy stored to energy dissipated during one cycle. If the diameter of the shield is made large with respect to the coil the losses are not too serious.

The higher the resistance of the material used, the less effective it is. It is well to note than any actual shield, not having perfect conductivity, will absorb energy, and should not be placed too close to coils carrying r-f currents. See Question 3.348.

Q. 4.187. For maximum stability, should the tuned circuit of a crystal oscillator be tuned to exact crystal frequency?

A. The tuned circuit should be tuned somewhat above(capacitance decreased) the exact crystal frequency.

D. If the tuned circuit is adjusted to the exact dip point on the plate milliammeter, it is possible that slight load changes may thro wthe circuit out or oscillation since it is very critical at this point. After finding the dip, the tuning capacitance should decrease slightly to improve the operating stability of the crystal oscillator.

Q. 4.188. What is the principal advantage of a class C amplifier?

A. The principal advantage of a class C amplifier lies in its high plate efficiency. This may be in the order of 85 to 90 per cent in some cases. Such amplifiers are not suitable for audio amplification.

D. See Questions 3.104, 3.105, and 3.137.

Q. 4.189. Draw a diagram of a grounded grid amplifier.

A. See the figure.

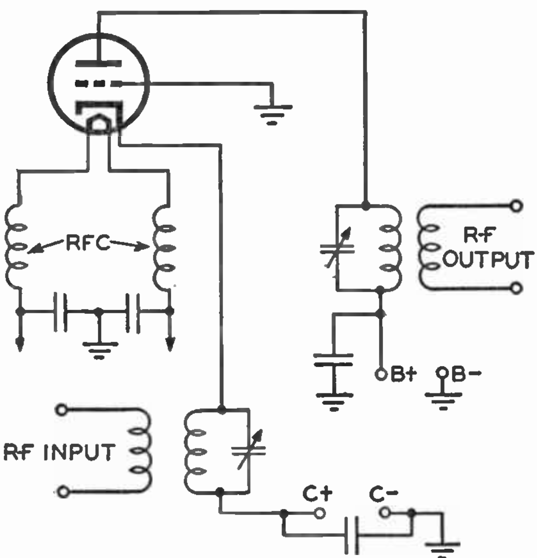


Fig. 4.189. A grounded grid amplifier.

D. See Question 4.185.

Q. 4.190. A current-squared meter has a scale divided into 50 equal divisions. When 45 milliamperes flow through the meter the deflection is 45 divisions. What is the current flowing through the meter when the scale deflecton is 25 divisions?

A. The current at 25 divisions is 33.53 milliamperes.

D. The scale is linear, but the deflection of the needle is proportional to the *square* of the measured current. We may set up a ratio as follows:

$$\frac{D_a}{D_b}=\frac{Ia^2}{I_b^2} \quad \frac{25}{45}=\frac{I_a^2}{45^2}, \quad I_a^2=\frac{25\times(45)^2}{45}, \quad I_a=\sqrt{1{,}125}=33.53 \quad ma.$$

Q. 4.191. What is the ohms per volt of a voltmeter constructed of a 0-1 DC milliammeter and a suitable resistor which makes the full scale reading of the meter 500 volts?

A. 1000 ohms per volt.

D. The meter sensitivity rating which is here given in ohms per volt, is completely independent of the size of the multiplier resistor or of the amount of voltage which is to be read. The sensitivity of the meter is determined by the physical properties of the meter itself, such as, size and strength of magnet, tension of springs, number of turns of wire on moving coil, etc. To calculate ohms per volt rating of meter, merely take the reciprocal of the full scale current reading. For the example in question the ohms per volt rating equals $\frac{1}{.001} = 1000$ ohms per volt. For a meter with full scale current of 200 microamperes, ohms per volt equals $\frac{1}{200 \times 10^{-6}} = 5000$ ohms per volt. For a meter with full scale current of 50 microamperes, ohms per volt equals $\frac{1}{50 \times 10^{-6}} = 20{,}000$ ohms per volt. If it were desired to calculate the value of series multiplier resistor in the original problem to read 500 volts full scale, this could be done with reasonable accuracy from the formula $R_m = \frac{E_{fs}}{I_{fs}}$ where R_m equals the value of series multiplier resistor; E_{fs} equals full scale voltage reading; I_{fs} equals full scale current rating of the meter. The value of resistor needed for the 500 volt scale then would be $R_m = \frac{500}{.001} = 500{,}000$ ohms. While this method does not take into consideration the resistance of the meter, the error incurred is very small. (See Questions 3.194 and 3.195.)

Q. 4.192. What is the power output of an audio amplifier if the voltage across the load resistance of 500 ohms is 40 volts?

A. The power output is 3.2 watts.

D. The power output may be found from the power formula,

$$P = \frac{E^2}{R} = \frac{40^2}{500} = 3.2 \textit{ watts.}$$

Q. 4.193. What type of meter is suitable for measuring peak a-c voltage?

A. For sine wave voltages any standard rms reading voltmeter may be used if the scale reading is multiplied by the factor 1.414. The frequency of the measured voltage must be within the operating range of the meter. Peak-reading vacuum tube voltmeters are available. In this type the grid bias is adjusted to be appreciably greater than cut-off bias and the rectified current is determined primarily by the peaks of the positive cycles. The "slide-back" type of vacuum tube voltmeter may also be used to measure peak voltages.

Q. 4.194. What type of meter is suitable for measuring the AVC voltage in a standard broadcast receiver?

A. Any standard voltmeter may be used providing it has a high sensitivity. At least a 20,000 ohms-per-volt meter should be used.

D. When a meter is used to measure AVC voltage, it places a load across the AVC system which was not previously there. This tends to reduce the AVC voltage and therefore to give erroneous readings. It is preferable to use a vacuum tube voltmeter for these measurements to insure the greatest accuracy.

Q. 4.195. What type of meter is suitable for measuring radio-frequency currents?

A. The most common type is the thermocouple meter. A hot-wire meter may also be used.

D. See Questions 3.183 and 3.188.

Q. 4.196. What type of voltmeter absorbs no power from the circuit under test?

A. The vacuum tube voltmeter.

D. Strictly speaking, all voltmeters absorb *some* power from the circuit under test; however a triode type vacuum tube voltmeter may absorb an entirely insignificant amount of power.

Q. 4.197. What type of voltmeter is appropriate to measure peak AC voltages?

A. See Question 4.193 for answer and discussion.

Q. 4.198. If the spacing of the conductors in a two-wire radio-frequency transmission line is doubled, what change takes place in the surge impedance of the line?

A. The surge impedance will be increased.

D. The formula to calculate the surge impedance of a two wire line in air is $Z_o = 276 \log\frac{b}{a}$; where Z_o equals the surge impedance of the line; b is the spacing center to center between the two wires; and a is the radius of one conductor. If the spacing is doubled, then of course b is doubled and the ratio $\frac{b}{a}$ is also doubled, or now becomes $\frac{2b}{a}$.

$$Z_{o[1]} = 276 \log\left(\frac{b}{a}\right) \; ; \; Z_{o[2]} = 276 \log\left(\frac{2b}{a}\right)$$

$$\frac{Z_{o[2]}}{Z_{o[1]}} = \frac{276 \log\left(\frac{2b}{a}\right)}{276 \log\left(\frac{b}{a}\right)} = \frac{\log\left(\frac{b}{a}\right) + \log 2}{\log\left(\frac{b}{a}\right)} = 1 + \frac{\log 2}{\log\left(\frac{b}{a}\right)}$$

If $b = 2$ inches, and $a = 1/8$ inch, the increase when b is doubled will be

$$\frac{\log 2}{\log 16} = \frac{0.30}{1.20} = 0.25 = 25\% \text{ increase.}$$

For this example the original impedance $Z_{o[1]} = 276 \log 16 = 332$ ohms. The new impedance, $Z_{o[2]} = 276 \log 32 = 415$ ohms.

The ratio is $\frac{415}{332} = 1.25$, a 25% increase. See Questions 4.199 and 6.502.

Q. 4.199. If the conductors in a two-wire radio-frequency transmission line are replaced by larger conductors, how is the surge impedance affected, assuming no change in the center-to-center spacing of the conductor?

A. The surge impedance will be decreased.

D. The surge impedance may be calculated from the approximate formula $Z_o = \sqrt{\frac{I}{C}}$, where L is the inductance of the two lines per unit length, and C is the capacitance between the two wires for the same unit length. Assuming no change in center to center spacing, two things happen if the diameter of the conductors is increased. First, the effective inductance is reduced. This is true because the two wires are carrying current in opposite directions and the closer their surfaces become, the greater field cancellation takes place, reducing the effective inductance. Second, the capacitance is increased due to the greater surface area represented by the two wires and also because the spacing is reduced. The effects of decreasing the inductance and increasing the capacitance cause the surge impedance to be decreased.

A more practical formula to calculate the surge impedance of a two wire line in air is $Z_o = 276 \log \frac{b}{a}$; where Z_o equals the surge impedance of the line, b equals the spacing center to center between the two wires, and a equals the *radius* of one conductor. Any increase in the radius a will result in a decrease of Z_o. See Questions 4.198 and 6.502.

Q. 4.200. Why is an inert gas sometimes placed within concentric radio-frequency transmission cables?

A. This is done to prevent arcing within the cables.

D. Certain types of coaxial cables are evacuated then filled with an inert gas under pressure and sealed. The reason for this is to prevent moisture from accumulating within the cable. Such moisture would reduce the normal voltage breakdown rating as well as cause increased losses within the cable. Another method sometimes used, is to continuously pump dry air under pressure through the concentric cable.

Q. 4.201. What is the direction of maximum radiation from two vertical antennas spaced 180 degrees and having equal currents in phase?

A. Maximum radiation will take place along a line perpendicular to the plane of the two antennas.

D. See the figure. The two vertical antennas are spaced 180 degrees

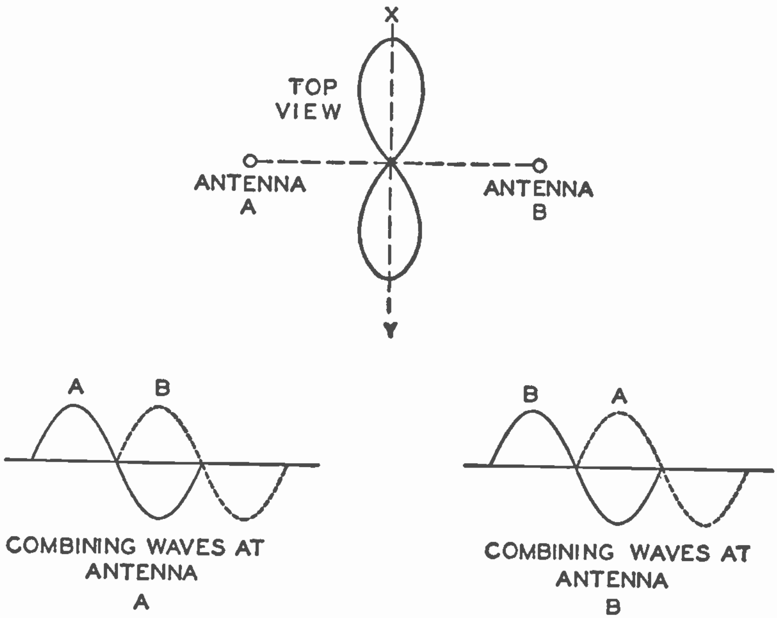


Fig. 4.201. The combining action of two waves coming from vertical antennas spaced 180 degrees apart.

apart. This is also equivalent in time to one half cycle of the exciting r.f., or in distance, one half wavelength. That is to say, in the interval of time required for a radio wave to traverse the distance from antenna *A* to antenna *B*, the sine wave will have completed one half or 180 degrees of a cycle. As shown in the diagram, the currents to each antenna are of equal magnitude and are in phase. Let us assume first that the wave has left antenna *A* and is proceeding toward antenna *B*. This motion takes place along a straight line. By the time this wave arrives at antenna *B*, 180 degrees later, the exciting current for antenna *B* has changed by 180 degrees and the wave now radiated by antenna *B* is exactly 180 degrees out of phase with the wave that has just arrived from antenna *A*. Thus the two waves completely cancel in the direction leading away from antenna *B*. A similar action takes place in the direction from antenna *B* to antenna *A*. That is, by the time the original wave from antenna *B* arrives at antenna *A*, the exciting current of antenna *A* has changed by 180 degrees and again the two radiated waves will cancel out in the direction leading away from antenna *A*. Thus it is seen that the radiation along a line connecting the two antennas will always be zero. On the other hand, if we take two points such as X and *Y*, it may be seen that the two radiated waves must always arrive together at these points in phase and so are additive. This causes maximum radiation to take place in the direction *XY*.

Q. 4.202. Explain the properties of a quarter-wave section of a radio-frequency transmission line.

A. A quarter-wave section of a transmission line with standing waves acts as an impedance inverter.

D. If a quarter-wave section is terminated in a resistance equal to its characteristic impedance, it acts as any non-resonant line. However, if the termination is not as described above, standing waves will appear on the line and the generator end will see an impedance which is the exact opposite of the impedance across the load end. For example, if the load impedance is a short circuit (0 ohms) the impedance as seen by the generator is theoretically infinite, and this type of quarter-wave line is often used as a parallel-resonant tank circuit. If the load impedance is an open circuit (∞ ohms), the impedance as seen by the generator is theoretically 0 ohms and this type line may be used as a series resonant circuit. If the line is greater than one quarter-wave-length long by an exact number of odd quarter wavelengths, the above mentioned effects will hold true. There are many uses for quarter-wave sections, both open circuited and short circuited. A few uses are as follows:

1. As metallic insulators (shorted section) a transmission line may be supported physically by connecting it to the open ends, since the impedence here is extremely high. The shorted end may be grounded if desired.

2. As filters or suppressors of even or odd harmonics. A shorted quarterwave section may be connected directly at the open end, across a transmission line. It then serves as an efficient suppressor of even harmonics since it is a short circuit at these (even) harmonics. An open quarter-wave section may be placed in series with one wire of transmission line to serve as a suppressor of odd harmonics.

3. As impedance matching devices. For example an open circuited quarter-wave section of characteristic impedance Z_o may be used to match two impedances Z_{in} and Z_{out} if $Z_o = \sqrt{Z_{in} \times Z_{out}}$. See Question 6.502.

Q. 4.203. How does the field strength of a standard broadcast station vary with distance from the antenna?

A. The field strength of a standard broadcast station varies inversely as the distance from the antenna.

D. The field strength is a measure of the magnitude of the voltage (not power) in millivolts or microvolts per meter. The power would vary as the square of the voltage or inversely as the square of the distance. The value of field strength at moderate distances from the transmitter is found from the formula, $E = \frac{188\,hI}{\lambda r}$ millivolts per meter, where

h = effective antenna height in meters.
I = antenna current in amperes.
λ = operating wavelength in meters.
r = distance from antenna in meters.

Q. 4.204. What pattern on a cathode-ray oscilloscope indicates over-modulation of a standard broadcast station?

A. See Question 4.42.

Q. 4.205. What is a Doherty amplifier?

A. A Doherty amplifier is a high efficiency linear amplifier which has an average efficiency ranging between 60 and 65% as compared to 30 and 35% efficiency for a conventional class B linear amplifier.

D. (See the figure for simplified diagram.) The Doherty amplifier

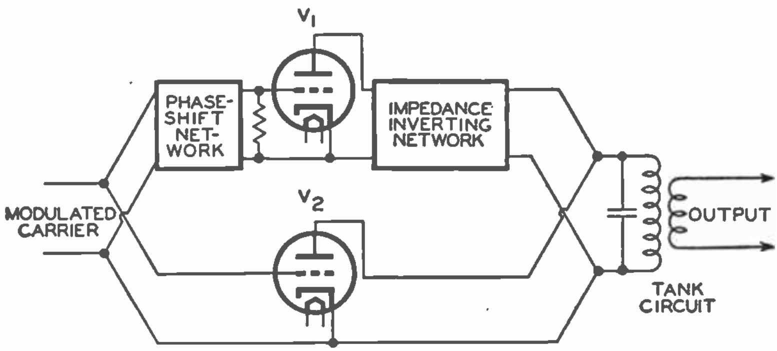


Fig. 4.205. A simplified diagram of a Doherty amplifier.

uses two tubes. The first tube, V_1, operates as a conventional class B amplifier except that it is designed to operate at maximum efficiency when the grid excitation is the unmodulated carrier. With this excitation the tube just begins to saturate when the load impedance is equal to twice the normal impedance that would be used to develop full output. The second tube, V_2, is operated with a bias and grid excitation voltage such that when the peak of modulation is reached (exciting voltage equals twice carrier voltage) it develops an output equal to twice the carrier power. When the exciting voltage is the unmodulated carrier, the output of the second tube is reduced to zero. When the amplitude of excitation voltage does not exceed carrier level, the second tube is completely inoperative, but the first tube functions as a conventional linear amplifier. The first tube, therefore, operates as a linear amplifier for those portions of the modulation cycle which do not exceed carrier level, while the second tube operates as a class C amplifier on those portions of the modulation cycle which do exceed carrier level. At the peak of a modulated wave each tube carries one half of the total output power. Phase-shifting and impedance-inverting networks are used in connection with the first tube to maintain the proper conditions during the full modulation cycle.

Q. 4.206. Why do some standard broadcast stations use top-loaded antennas?

A. A "top-loaded" antenna is sometimes used when it is not practical to construct a simple antenna of the required height due to purposes of economy, or in the case where commercial airways pass nearby.

D. Broadcast antenna towers are sometimes provided with top loading. This is often in the form of a spider, ring, or any other equivalent arrangement which provides a lumped capacity at the top of the tower. This lumped capacity may be connected directly to the top of the tower or insulated from the tower and connected to it by a coil. The use of top loading permits the same field distribution to be obtained as with a vertical antenna of somewhat greater height. This makes it possible in an antenna of given height to produce an increased concentration of energy along the horizontal plane, and a reduction of radiation at large vertical angles.

Q. 4.207. How may a standard broadcast antenna ammeter be protected from lighting?

A. A shorting switch should be connected across the ammeter and closed during electrical storms.

D. If the meter is shielded in a metal case, the case should be directly grounded.

Q. 4.208. What is the ratio of unmodulated carrier power to instantaneous peak power, at 100 percent modulation at a standard broadcast station?

A. The instantaneous peak power under modulation conditions rises to 4 times the unmodulated peak carrier power.

D. When a carrier is modulated to 100% the current (and voltage) vary between twice the original unmodulated value and zero. Since power varies as the square of the current or voltage, the peak power will be increased to 4 times the original carrier power.

Q. 4.209. What effect do broken ground conductors have on a standard broadcast antenna?

A. In general, broken ground conductors will decrease the efficiency of the antenna system; the antenna resistance may be varied and the radiation pattern changed.

D. The most important losses in an antenna system occur in the conductors, insulation, antenna tuning inductance and in the ground. The largest of these losses usually occurs in the ground. The ground acts as the second plate of a condenser with the antenna acting as the other plate and the air as the dielectric. The charging currents for this condenser must return through the earth to the ground point at the transmitter proper. Since the earth is generally a poor conductor, other means must be found to return these currents to the transmitter ground point. One method often used is to bury wires near the surface of the earth to provide a good conducting path to the transmitter ground point. The system usually consists of a large number of radial wires with a good earth termination for each wire. Such wires are generally more than a half-wavelength long. It has been determined that the longer such wires are made, the stronger the ground signals will be for a given power input.

Q. 4.210. What may cause unsymmetrical modulation of a standard broadcast transmitter?

A. The following may cause unsymmetrical modulation of a standard broadcast transmitter:

1. Faulty or insufficient value of output capacity in the power supply filter.
2. Insufficient bias at the modulated amplifier.
3. Incorrect load impedance for the class C modulated r-f amplifier.
4. Insufficient grid excitation of the modulated r-f amplifier.
5. Tube with low emission.
6. Distortion in the modulator.
7. Improper tuning of tank circuits.

D. See Questions 3.346 and 3.378.

Q. 4.211. If the two towers of a 950-kilocycle directional antenna are separated by 120 electrical degrees, what is the tower separation in feet?

A. The tower separation is 345.27 feet.

D. Step 1: Convert the frequency to wavelength in meters.

$$\text{Wavelength} = \frac{300{,}000}{f\text{ (kc)}} = \frac{300{,}000}{950} = 315.799 \textit{ meters.}$$

Step 2: The tower separation is ⅓ wavelength $\left(\frac{120°}{360°}\right)$ or $\frac{315.799}{3}$ $= 105.266$ *meters.*

Step 3: Find the tower separation in feet. $105.266 \times 3.28 = 345.27$ *feet.*

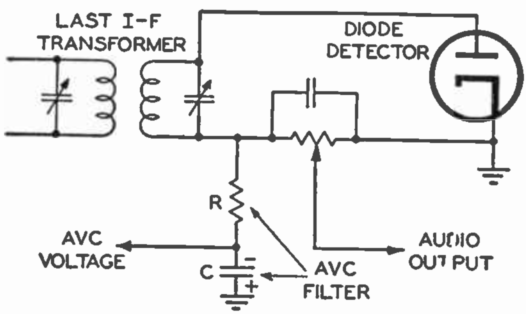


Fig. 4.212. Automatic volume control circuit in a standard broadcast receiver.

Q. 4.212. Draw a diagram showing how automatic volume control is accomplished in a standard broadcast receiver.

A. See the figure. (For complete receiver diagram, see Question 6.587.)

D. See Question 3.353.

Q. 4.213. What is the required full scale accuracy of the plate ammeter and plate voltmeter of the final radio stage of a standard broadcast transmitter?

A. The required full scale accuracy is 2 percent.

Q. 4.214. What is the maximum carrier shift permissible at a standard broadcast station?

A. The maximum permissible carrier shift is plus or minus 20 cycles.

Q. 4.215. In accordance with the Commission's Standards of Good Engineering Practice, what determines the maximum permissible full scale reading of indicating instruments required in the last radio stage of a standard broadcast transmitter?

A. According to the Commission's standards, the maximum permissible full-scale reading shall not be in excess of 5 times the normal minimum indication.

D. Other requirements of these instruments are:

1. A scale length of at least 40 divisions.
2. A scale length not less than 2.3 inches.
3. A full scale accuracy of 2% or better.

Q. 4.216. When an X- or a Y-cut crystal is employed in the automatic frequency control equipment at a standard broadcast station, what is the maximum permitted temperature variation at the crystal from the normal operating temperature?

A. The maximum permissible temperature variation is plus or minus 0.1 degree Centigrade at 1000 kilocycles.

D. This temperature variation should maintain the carrier frequency within plus or minus 20 cycles (Question 4.214).

Q. 4.217. What is the purpose of a discriminator in an FM broadcast receiver?

A. A discriminator in an f-m receiver is the circuit which changes the variations in frequency of the f-m wave into a conventional audio output wave which is capable of being amplified by a standard audio amplifier.

D. The discriminator has the same relative function in an f-m receiver as the second detector of a superheterodyne a-m receiver. In order to detect an f-m wave it is necessary to utilize a device whose d-c output voltage increases when the carrier deviates in one direction and decreases when the carrier deviates in the other direction. An f-m wave from a broadcast station deviates in exact accordance with the audio modulating signal, so that the variations of d-c from the output of the discriminator will be a reproduction of the original modulating signal. The conventional type of discriminator does not reject a-m and must be preceded by one or more limiter stages for noise suppression. A newer circuit, the "Ratio Detector" discriminates against a-m to a large degree but is sometimes preceded by a special i-f amplifier, described in Question 4.233, to improve the output signal to noise ratio.

Q. 4.218. Explain why high gain antennas are used at FM broadcast stations.

A. High-gain antennas are used at f-m broadcast stations in order to concentrate the radiated energy within low vertical angles.

D. At the frequencies used for f-m broadcasting (88 to 108 megacycles), there is no useful sky wave, and the ground wave is attenuated very rapidly as it travels outward from the transmitting antenna. Most of the useful transmission is confined to practically line of sight directions. Due to the high frequencies and the correspondingly small antenna elements it becomes entirely practical to construct directional high-gain antennas of reasonable dimensions. The radiation pattern for an f-m station usually must be such, that it is non-directional in all azimuth (compass) directions but discriminates against radiation in the vertical plane. Any energy which is radiated into the sky is obviously wasted. It is the function of the high-gain f-m antenna to concentrate all of the radiated energy within low vertical angles to achieve the maximum efficiency of the output energy from the antenna. The most common f-m broadcasting antennas in use at the present time are the turnstile antenna, the circular antenna, the Pylon antenna and the square loop antenna.

Q. 4.219. What is the frequency swing of an FM broadcast transmitter when modulated 60 percent?

A. The frequency swing is plus and minus 44 kilocycles.

D. For a standard f-m broadcast station, 100% modulation corresponds to a deviation of plus and minus 75 kilocycles, At 60% modulation, therefore, the frequency is ± 75 kc. $\times$ 0.6 = ± 45 *kilocycles.*

Q. 4.220. An FM broadcast transmitter is modulated 50 percent by a 7000-cycle test tone. When the frequency of the test tone is changed to 5000 cycles and the percentage of modulation is unchanged, what is the transmitter frequency swing?

A. The transmitter frequency swing is ± 37.5 kilocycles.

D. Since 100% modulation is considered to be ± 75 *kilocycles,* 50% modulation is half that amount or ±37.5 *kilocycles,* In f.m., the frequency swing is not dependent upon the modulating frequency.

Q. 4.221. What is a common method of obtaining frequency modulation in an FM broadcast transmitter?

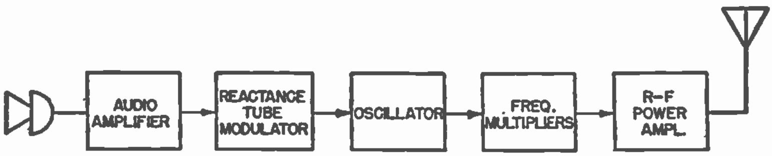


Fig. 4.221(A). A simplified block diagram of a reactance tube modulated f-m transmitter.

A. One common method makes use of a reactance tube modulator which changes the frequency of the master oscillator in accordance with the amplitude of the modulation voltage.

D. Part A of the figure shows a simplified block diagram of a reactance tube modulated f-m transmitter. Frequency multipliers are needed in this system since the reactance tube is not capable of providing sufficient modulation directly. Another benefit derived from the use of frequency multiplication is the operation of the master oscillator at a comparatively low frequency. This makes it possible to obtain better frequency stability. The theory of operation of the reactance tube modulator arises from the fact than an ordinary vacuum tube may be caused to act as either an inductive or capacitive reactance. Furthermore the magnitude of reactance may be caused to vary in direct relationship to the speech or music which originates at the microphone. If the reactance tube is connected to the tank circuit of an oscillator, it is then possible to cause the frequency of the oscillator to vary in accordance with the modulation signal. There are several variations of the reactance tube, but only one type will be explained here. The remaining types are basically similar in operation. A basic diagram of a capacitive reactance tube modulator is shown in Part B of the figure. The oscillator tank circuit is made up of L and C which determines the normal frequency of the tank circuit according to the formula $f = \frac{1}{2\pi\sqrt{LC}}$. This formula shows that an increase of either L or C will cause a decrease of frequency, and that a decrease of L or C will cause an increase of frequency. The reactance tube V_1 is effectively in parallel with the tank, since C_b can be considered to be a short circuit at tank frequency. If a capacitance as represented by V_1 is placed across the tank and caused to vary at an audio rate, then the total tuning capacitance which is made up of C plus V_1 will cause the oscillator frequency to vary at the same audio rate. If it can be shown that the a-c plate current of V_1 leads the a-c plate voltage by 90 degrees, then

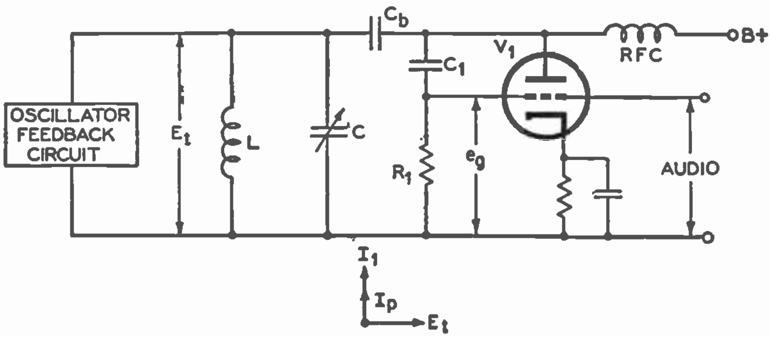


Fig. 4.221(B). A capacitive reactance tube modulator.

V_1 represents a capacitive reactance. The a-c tank voltage is designated as E_t. It will be seen that E_t is also the a-c plate voltage of V_1, since it is effectively applied between plate and cathode. (C_b is effectively a short.) In the vector diagram, E_t is used as the reference. Due to the applied voltage E_t, a current I_1 is caused to flow through the series circuit C_1—R_1. These are so proportioned that the reactance of C_1 is made to be many times greater than the resistance R_1. Since the two are in series and the reactance predominates, we may consider C_1—R_1 to be a capacitive circuit. Therefore, the current I_1 will lead E_t by 90 degrees. Remember that this current I_1 flows through both C_1 and R_1 in the same phase. The grid signal of V_1 is the voltage which is developed across R_1, or in other words the *IR* drop across R_1. However, this *IR* drop is in the same phase as I_1, which is leading the a-c plate voltage of V_1 by 90 degrees. Thus, as shown in the vector diagram, the a-c grid voltage is leading the a-c plate voltage by 90 degrees. apparent then that the a-c plate current also leads the a-c plate voltage by 90 degrees. Thus the tube appears to be a capacitive reactance in parallel with the oscillator tank circuit. The magnitude of this reactance is a function of the amount of a-c plate current which flows. We can say that $X_c = \frac{E_T}{I_p}$. Thus if the a-c plate current should increase (which would happen on the positive swing of an audio wave applied to the grid), the X_c of V_1 would correspondingly decrease and this would be equivalent to an increase of shunt capacitance across the tank, since $X_c = \frac{1}{2\pi fC}$ and therefore $C = \frac{1}{2\pi fX_c}$. That is a decrease of capacitive reactance is equivalent to an actual increase of capacitance. Since this capacitance is added in parallel with the tank capacitance, it would cause the oscillator frequency to decrease. Therefore, the amount of frequency decrease would depend upon the amplitude of the positive swing of audio grid signal. The greater the amplitude of audio grid signal, the greater would be the effective increase of capacitance and the greater the decrease in frequency. On the other hand let us take the negative swing of the audio cycle acting upon the grid of V_1. This would cause a decrease in a-c plate current and therefore X_c of V_1 would appear larger. This is equivalent to a decrease in the shunting capacitance and to an increase of oscillator frequency. It should be remembered that the *rate* at which the oscillator frequency changes is a function of the audio frequency only and not of its amplitude. The *amplitude* of the audio determines only the amount of frequency change or deviation. See also Question 4.237.

Q. 4.222. What is meant by pre-emphasis in an FM broadcast transmitter?

A. Pre-emphasis is the process whereby the higher audio frequencies in the modulating stages of an f-m transmitter are over-amplified with respect to their value, and in relation to the lower audio frequencies.

D. See Part (A) of the figure. It has been found that the noises which are most irritating to the listener are those which are concentrated in the upper end of the audio frequency spectrum. It is also true that these high audio frequencies represent very little energy as compared to the low frequencies. Thus it is possible in the audio stages of an f-m transmitter to over-amplify the high audio frequencies without much danger of overmodulating the transmitter. In this case overmodulation would mean a deviation in excess of ±75 kilocycles. Since there are guard bands of ±25 kilocycles in each f-m channel, occasional overmodulation would not be too serious. A practical circuit to produce pre-emphasis is shown in Part (A) of the figure. The important part of this circuit is the parallel network $R_1 - C_1$ which is in series with resistor R_g. $R_1 - C_1$ is in effect a high pass filter. At low frequencies where C_1 is practically an open circuit, we have a voltage divider made up of R_1 and R_g. Only a small portion of the input appears across R_g at low frequencies. As the frequency increases however, the impedance of the parallel network becomes less, and more of the input signal appears across R_g. Example: At 60 cycles, the reac-

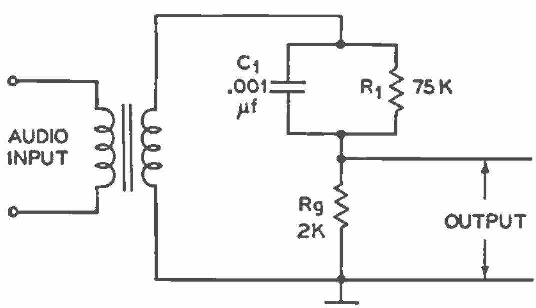


Fig. 4.222(A). A standard pre-emphasis network.

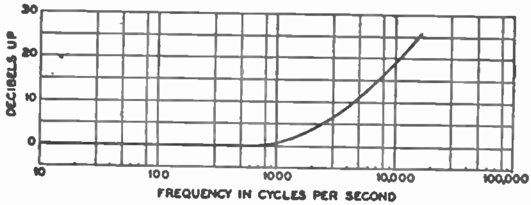


Fig. 4.222(B). A standard pre-emphasis chart.

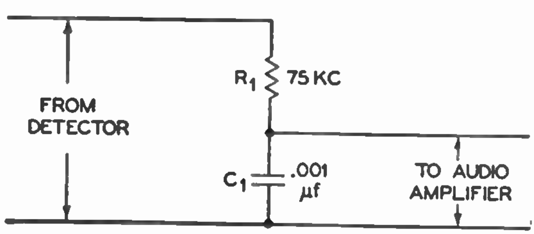
tance of C_1 is 2,670,000 ohms and the parallel combination of $R_1 - C_1$ is then 75,000 ohms. The amount of signal now appearing on the grid is, $e_g = E_s \frac{R_g}{R_1 + R_g} = E_s \times \frac{2000}{77,000} = E_s \times 2.56\%$.

At 15,000 cycles the reactance of C_1 is about 10,000 ohms. The parallel impedance of R_1—C_1 is now about 8800 ohms, and the signal voltage which appears on the grid is $e_g = E_s \times \frac{2000}{10,800} = E_s \times 18.5\%$. This means that 15,000 cycles will be amplified about 7 times more than 60 cycles. The time constant for a pre-emphasis network such as $R_1 - C_1$ is standardized by the F.C.C. at 75 microseconds, = 0.001 (μf) $\times$ 75,000 (ohms). A standard pre-emphasis chart is shown in Part (B) of the figure, and it should be noted here that the gain remains substantially constant until about 500 cycles. From then on it continues to rise until a maximum of 17 db is reached at 15,000 cycles. (Ratio of 17 db is 7:1 approx.) The fact that the higher audio frequencies are thus over emphasized makes it possible to override much of the high frequency noises which are picked up en route to and within the receiver. However, in order to obtain the full benefits of this system and regain the correct tonal values a de-emphasis network must be incorporated into the f-m receiver. See Question 4.223.

Q. 4.223. **What is the purpose of a de-emphasis circuit in an f-m broadcast receiver?**

A. See the figure. The purpose of a de-emphasis circuit is to restore the over-amplified high frequencies (see Question 4.224) to their correct value, and at the same time to greatly reduce the high frequency noise output of the receiver.

Fig. 4.223. A de-emphasis circuit.



D. Actually the de-emphasis circuit is the exact opposite in its characteristics to the pre-emphasis circuit. Where the pre-emphasis circuit amplifies high frequencies, the de-emphasis circuit attenuates them. For example the gain at 15,000 cycles is over amplified about 7 times by pre-emphasis. In the receiver it is attenuated by the same factor of 7, thus returning the 15,000 cycle tone to its correct amplitude in comparison with low frequencies. Where the pre-emphasis circuit was a high pass filter, the de-emphasis circuit is a low pass filter. A simple de-emphasis circuit is shown in the figure. This network is usually found between the f-m detector and the first audio amplifier. The time constant of a de-emphasis circuit is also 75 microseconds. It will be noted that the de-emphasis circuit works on the principle of a voltage divider with only that portion of the audio developed across C_1, being transmitted to the audio amplifier. At high frequencies the reactance of C_1 will be low and not much signal will be developed across C_1. For example at 16,000 cycles the reactance of C_1 is about 10,000 ohms. The series impedance of C_1 and R_1 equals

$$\sqrt{R^2+X_{c1}^2} = \sqrt{75{,}000^2+10{,}000^2}=75{,}700 \text{ ohms.}$$

The amount of voltage developed across C_1 is

$$E_{c1} = E_s \times \frac{X_{c1}}{\sqrt{R^2+X_{c1}^2}} = E_s \times \frac{10{,}000}{75{,}700} = E_s \times 13.2\%.$$

At 60 cycles the reactance of C_1 is 2,654,000 ohms and the series impedance of C_1 and R_1 equals $\sqrt{R^2+X_{c1}^2} = \sqrt{75{,}000^2+2{,}654{,}000^2}$ $=2{,}655{,}000$. The amount of voltage developed across C_1 is $E_{c1} = E_s \times$ $\frac{X_{c1}}{\sqrt{R_2 \times X_{c1}^2}} = E_s \times \frac{2{,}654{,}000}{2{,}655{,}000} = E_s \times 100\%$ which is approximately 7 times more signal than for 16,000 cycles. Thus it is seen that the de-emphasis circuit works in exactly the opposite manner to the pre-emphasis circuit. It must be remembered that at the same time the high frequencies are attenuated, all high frequency noises are also attenuated by the same degree, and it is here that the greatest noise reduction takes place. It should also be borne in mind that while the high frequencies are being attenuated, they are simply being returned to their normal value and are not being suppressed in any way. After leaving the de-emphasis circuit, the audio signal is fed into a standard audio amplifier.

Q. 4.224. An FM broadcast transmitter operating on 98.1 megacycles has a reactance tube-modulated oscillator operating on a frequency of 4905 kilocycles. What is the oscillator frequency swing when the transmitter is modulated 100 percent by a 2500-cycle tone?

A. The frequency swing of the oscillator would be from 4901.25 kilocycles to 4908.75 kilocycles, or ±3.75 kilocycles.

D. Since the transmitted frequency is 98.1 megacycles and the oscillator frequency is 4905 kilocycles, this indicates that a frequency multiplication of 20 times is being used, $\frac{98.1}{4.905} = 20$.

At 100% modulation, regardless of the audio tone, the deviation will always be plus and minus 75 kilocycles. This means that the transmitted frequency will swing between 98.025 megacycles and 98.175 megacycles. However, since this swing was achieved by a multiplication of 20, the oscillator proper will only deviate $\frac{75}{20} = 3.75$ kilocycles. Thus, the oscillator frequency will be 4905 kilocycles plus and minus 3.75 kilocycles at 100% modulation.

Q. 4.225. What characteristic of an audio tone determines the percentage of modulation of an FM broadcast transmitter?

A. The percentage of modulation of an f-m station is primarily determined by the amplitude of the audio tone.

D. For a standard f-m broadcast station, 100% modulation is obtained for a modulation tone which causes a deviation of plus and minus 75 kilocycles. For any given audio tone, an increase of amplitude causes a proportional increase in the amount of frequency deviation. (See also Questions 4.221 and 4.226.)

Q. 4.226. What determines the rate of frequency swing of an FM broadcast transmitter?

A. The rate of frequency swing of an f-m broadcast station depends upon the tone frequency of the modulating signal.

D. The rate at which the carrier deviates (swings) is a direct function of the audio frequency. Thus for an audio frequency of 10,000 cycles the carrier will deviate (or swing) at the rate of 10,000 times per second. (See Question 4.225.)

Q. 4.227. How wide a frequency band must the intermediate frequency amplifier of an FM broadcast receiver pass?

A. The i-f amplifier must pass a frequency band of 150 kilocycles

D. Since the deviation at 100% modulation is equal to ±75 kilocycles, it might be expected that the overall bandpass should be flat for at least 150 kilocycles to insure equal gain at all modulation frequencies. Actually this is not the case as the response at ±75 kc is reduced by a voltage ratio of about 2:1 (—6db), while the response at plus and minus 100 kilocycles is reduced by a voltage ratio of about 5:1 (—14 db). This is done to increase the gain of the i-f amplifier and to improve its selectivity. The distortion resulting from this procedure will not be apparent if the response is not narrowed too much, and if associated circuits are designed properly.

Q. 4.228. An FM broadcast transmitter is modulated 40 percent by a 5000-cycle test tone. When the percentage of modulation is doubled, what is the frequency swing of the transmitter?

A. The frequency swing is plus and minus 60 kilocycles.

D. The original modulation percentage was 40 percent, so doubling this gives a value of 80 percent modulation. At 100% modulation the frequency swing is ±75 kilocycles, so at 80% modulation the swing equals ±75 × .8 = ±60 *kilocycles.*

Q. 4.229. If an FM transmitter employs one doubler, one tripler and one quadrupler, what is the carrier frequency swing when the oscillator frequency swing is 2 kilocycles?

A. The carrier frequency swing is 48 kilocycles.

D. The total frequency multiplication is 2×3×4 = 24 times. The carrier frequency swing, therefore, equals the oscillator frequency swing times the total frequency multiplication, or 24×2 *kilocycles* = 48 *kilocycles.*

Q. 4.230. What is the purpose of a "reactance tube" in an FM broadcast transmitter?

A. A reactance tube in an FM transmitter is generally used for the the purpose of producing frequency modulation of the master oscillator. In some transmitters it is also used as a frequency stabilizing device.

D. See Question 4.223 for basic discussion of the reactance tube.

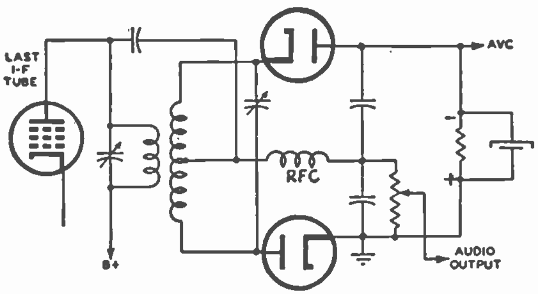


Fig. 4.231. A ratio detector circuit.

Q. 4.231. What is a ratio detector?

A. The "radio detector" is a type of f-m demodulator (detector) which may be used without a preceding limiter stage.

D. The conventional (Foster-Seeley) discriminator must be preceded by one or more limiter stages if any noise rejection is to be accomplished, since the discriminator responds to amplitude variations. A newer type of f-m detector, now widely used, is the ratio detector. This circuit is very insensitive to amplitude variations present in its input circuit. The name is derived from the fact that the output of the ratio detector is proportional only to the ratio of the input i-f voltages and not to their amplitude. (See also Questions 4.217 and 4.236.)

Q. 4.232. How does the amount of audio power required to modulate a 1000-watt FM broadcast transmitter compare with the amount of audio power required to modulate a 1000-watt standard broadcast transmitter to the same percentage of modulation?

A. The audio power required to modulate a 1000-watt f-m transmitter is very small compared to the audio power required to modulate a 1000-watt a-m transmitter.

D. In order to modulate an a-m transmitter 100% with an input power of 1000 watts, the modulator must furnish 500 watts of audio power. On the other hand, the audio power required to modulate an f-m transmitter is very small since generally only voltage amplification is required to operate the modulator. See Question 4.221 for frequency modulation, 3.327 and 3.328 for amplitude modulation.

Q. 4.233. What is the purpose of a limiter stage in an FM broadcast receiver?

A. The purpose of a limiter stage is to remove the amplitude variations from the intermediate frequency signal before it is detected in the discriminator.

D. Since most noises are amplitude modulated, they can be removed by a special i-f amplifier called a limiter stage, whose output amplitude is relatively independent of input amplitude for most operating conditions. A limiter tube is easily saturated and driven below cut-off by a certain minimum value of grid swing (about .5 to 2 volts).

The limiter tube must be of the sharp cut-off type and operate with low plate and screen grid voltages in the order of 50 to 75 volts. Bias for this stage is obtained by a grid leak and condenser network in the grid circuit. (See Question 4.238 for diagram.) Some receivers use two limiters in cascade to improve the sensitivity of limiting action. In this case the first limiter is grid leak biased, and the second usually operates at zero bias.

Q. 4.234. If the transmission line current of an FM broadcast transmitter is 8.5 amperes without modulation, what is the transmission line current when the percentage of modulation is 90 percent?

A. The transmission line current is still 8.5 amperes.

D. Since the power output remains substantially constant with or without modulation there should be no change of transmission line current. See also Question 3.467.

Q. 4.235. An FM broadcast transmitter has 370 watts plate power input to the last radio-frequency stage and an antenna field gain of 1.3.

The efficiency of the last radio-frequency stage is 65 percent and the efficiency of the antenna transmission line is 75 percent. What is the effective radiated power?

A. 304.8338 watts.

D. The d-c plate power input to the last r-f stage is given at 370 watts. The efficiency of this stage is given as 65%. This means that only 65% of 370 watts or 240.5 watts is available to the transmission line as r-f power. The remaining 35% or 129.5 watts is dissipated in the form of heat on the plate of the last r-f stage. If, of the 240.5 watts of r-f power fed to the transmission line, only 75% reaches the antenna (or 180.375 watts), the remaining 25% or 60.125 watts is dissipated on the line. The antenna has a field gain over a simple dipole of 1.3 (see Questions 4.218 and 4.273) so the effective radiated power is then 180.375 times 1.3^2 or 304.8338 watts. Note: Antenna field gain is a measure of voltage. This value must be squared in order to find the power gain.

Q. 4.236. Draw a diagram of an FM broadcast receiver detector circuit.

A. See the figure for a discriminator circuit. See also Question 4.234.

D. See Question 4.241.

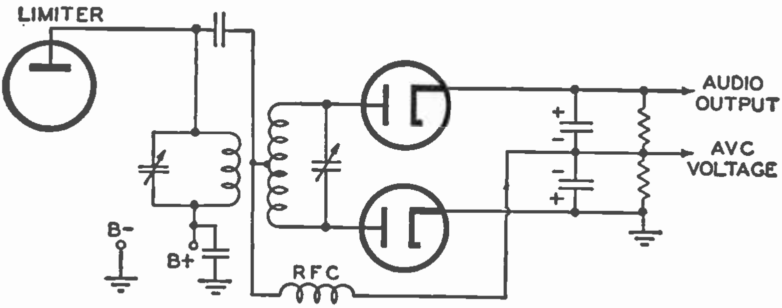


Fig. 4.236. A discriminator detector.

Q. 4.237. Draw a diagram of a means of modulation of an FM broadcast station.

A. See the figure.

D. See Question 4.221.

Q. 4.238. Draw a diagram of a limiter stage in an FM broadcast receiver.

A. See the figure.

D. This figure, as far as the circuit goes, should immediately precede the figure for Question 4.236.

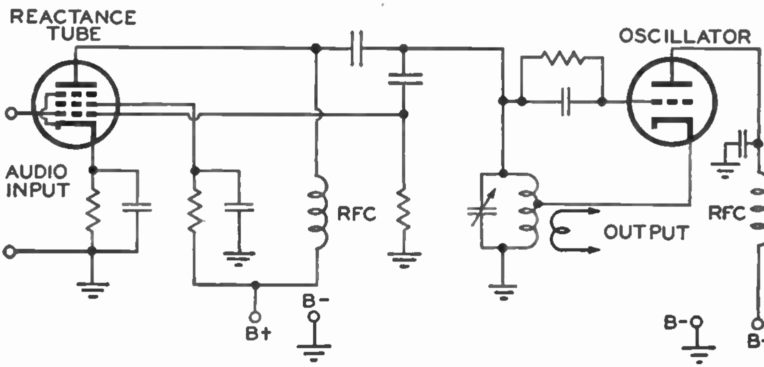


Fig. 4.237. Means of modulating an f-m transmitter.

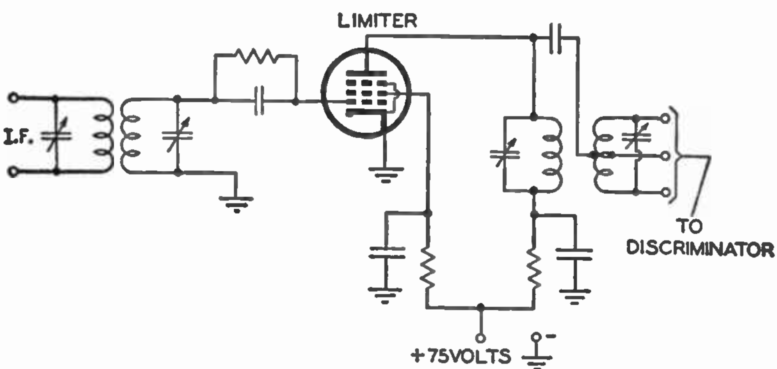


Fig. 4.238. A limiter stage in an f-m receiver.

Q. 4.239. How is the operating power of an FM broadcast station determined?

A. The operating power of an f-m broadcast station equals $E_b \times I_b \times F$, where E_b is the d-c plate voltage of the final amplifier, I_b is the d-c plate current of the final amplifier, F is an efficiency factor determined by the manufacturer, and is in the order of 60—65%. This is the so called indirect method of determining operating power.

Q. 4.240. If an FM broadcast station uses a total of 5 tubes of a given type at the transmitter, what is the minimum number of spare tubes of this type required at the transmitter?

A. The minimum required number of spare tubes is 2.

D. See Question 4.153.

Q. 4.241. What is the required frequency range of the indicating device on the frequency monitor at an FM broadcast station?

A. The range of the indicating device on a frequency-modulation frequency monitor shall be at least from 2000 cycles below to 2000 cycles above the assigned center frequency.

Q. 4.242. What is the audio frequency range that an FM broadcast station is required to be capable of transmitting?

A. The required audio frequency range is from 50 to 15,000 cycles per second.

D. This is in contrast to the limit of 5000 cycles per second for an a-m broadcast station.

Q. 4.243. How wide is an FM broadcast channel?

A. One f-m channel is 200 kilocycles wide.

D. Of the allotted 200 kiloycles, 150 kilocycles is to be used for the actual transmission, while a guard band of 25 kilocycles is established on either end of each channel. The f-m broadcast channels are allotted frequencies from 88 to 108 megacycles. The first f-m channel has a center frequency of 107.9 megacycles.

Q. 4.244. What frequency swing is defined as 100 percent modulation for an FM broadcast station?

A. 100% modulation corresponds to a frequency swing of plus and minus 75 kilocycles.

D. The stated value is a matter of legal definition, as, theoretically, any other frequency swing could have been taken as a base. This is to be distinguished from amplitude modulation, where 100% represents modulation to the full depth of the carrier, which is a natural, rather than arbitrary, base. See the discussion for Question 4.253. Also see Questions 4.220, 4.224, and 4.225.

Q. 4.245. What is the tolerance in operating power of FM broadcast stations?

A. The operating power tolerance is plus 5 percent or minus 10 percent of the rated operating power of an f-m broadcast station.

Q. 4.246. What is the meaning of the term "Center Frequency" in reference to FM broadcasting?

A. The "Center Frequency" is the unmodulated carrier frequency of an f-m broadcast station.

D. The "Center Frequency" of the f-m broadcast station may be thought of as being analogous to the unmodulated carrier frequency of an a-m transmitter. It is the frequency about which the deviation changes occur.

Q. 4.247. Exclusive of monitors, what indicating instruments are required in the transmitting system at an FM broadcast station?

A. An f-m broadcast transmitter shall be equipped with suitable indicating instruments of acceptable accuracy to measure (1) the direct plate voltage and current of the last radio stage, and (2) the main transmission line radio frequency current or voltage.

D. Recording instruments may be employed in addition to the indicating instruments to record the transmission line current or voltage and the direct place current and/or direct plate voltage of the last radio stage, provided that they do not affect the operation of the circuits or accuracy of the indicating instruments. If the records are to be used in any proceeding before the Commission as representative of operation, the accuracy must be the equivalent of the indicating instruments and the calibration shall be checked at such intervals as to insure the retention of accuracy.

Q. 4.248. What is the required accuracy of instruments indicating the plate current and the plate voltage of the last radio stage or the transmission line current or voltage at an FM broadcast station?

A. The required accuracy is not less than 2% of the full-scale reading.

Q. 4.249. What is the frequency tolerance of an FM broadcast station?

A. The frequency tolerance is ±2000 cycles from the assigned center frequency.

D. At 100 megacycles this corresponds to a tolerance of .002 percent.

Q. 4.250. What is the meaning of the term "frequency swing" in reference to FM broadcast stations?

A. This term usually denotes the difference between maximum and minimum frequencies, or twice the deviation from the center frequency, during modulation. Some writers use the term "frequency swing" to denote the deviation.

D. See Questions 4.224, 4.244, and 4.246.

Q. 4.251. Why is a scanning technique known as "interlacing" used in television broadcasting?

A. Interlaced scanning is used in order to eliminate flicker from the television picture.

D. One of the very important factors in transmitting a television signal is the number of complete pictures sent each second. In motion picture practice it is common to show 24 frames or pictures per second to give the illusion of smooth and continuous motion. However, due to the action of a shutter, each frame is shown twice; being blanked out for a short period of time and then shown again. Thus to the eye it appears that there are 48 pictures per second while in reality there are only 24. This optical illusion is necessary in order to eliminate flicker from the picture. Flicker refers to a change of light intensity and not to motion. Reference is made to electric light bulbs operated from a 25 cycle power source. A very noticeable and objectionable flicker may be readily observed by watching the bulbs. On the other hand, bulbs operating from a 60 cycle source apparently have no flicker at all. To eliminate flicker, the repetition rate should be in excess of 40 pictures per second. A system similar to motion picture practice is used in television and this is called interlaced scanning. The frame or picture repetition rate in television has been standardized at 30 per second. This rate is not sufficient to eliminate flicker. Each frame, therefore, has been split into two parts called fields. Thus there are 60 fields per second. Instead of scanning all of the lines which make up a picture, in sequence, every other line is scanned first. This makes up one field. Then, the alternate lines are scanned completing the second field and one frame. In this way, the illusion of 60 pictures per second is gained and the appearance of flicker is eliminated.

Q. 4.252. Does the video transmitter at a television broadcast station employ frequency or amplitude modulation?

A. The video transmitter employs amplitude modulation.

D. Most video transmitters use grid modulation. This is necessary because the wide band width required (about 5.25 megacycles) makes it necessary to use very low values of plate load impedances. To produce enough power in these low impedances for plate modulation, would require extremely high currents which would be impractical. Grid modulation requires much less driving power and is, therefore, more practical.

Q. 4.253. Does the sound transmitter at a television broadcast station employ frequency or amplitude modulation?

A. The sound transmitter employs frequency modulation.

D. In a television sound transmitter, 100% modulation corresponds to ±25 kilocycles rather than ±75 kilocycles as in a standard f-m broadcast station. See Question 4.244.

Q. 4.254. What is a monitor picture tube at a television broadcast station?

A. A monitor picture tube is a cathode-ray tube which may be connected so as to show a complete television picture.

D. In general there are two types of monitor picture tubes. On one type the actual picture to be transmitted may be scrutinized for any faults of a technical nature or in lighting. There are a number of such monitors at various points. For example there may be one monitor for each camera in the studio, plus a separate monitor on the outgoing studio line. There may be such a monitor at the film transmitting studio, at the synchronizing signal generator and at the transmitter proper at the output of the video line amplifier.

The other type of monitor more closely resembles a cathode-ray oscilloscope. On this monitor may be viewed the various horizontal and vertical synchronizing and blanking pulses. The percentage of modulation may be checked on such a monitor, and in addition the relative amplitude of the synchronizing pulses may be checked. Such monitors may be found at the synchronizing signal generator at the film transmitting studio and at the output of the video line amplifier at the transmitter. In both cases, additional monitor picture tubes may be installed as desired.

Q. 4.255. Describe scanning as used by television broadcast stations. Describe the manner in which the scanning beam moves across the picture in the receiver.

A. A frame is a complete picture containing all of the necessary picture elements. There are a total of 525 horizontal sweep cycles or *lines* in one frame and, therefore, a total of 525 × 30 = 15,750 lines per second. Of the 525 lines per frame there are 262.5 lines in each field of which about 242.5 lines contain picture information and about 20 lines do not. These 20 lines are blanked out during the vertical retrace interval. At the transmitter and receiver, the scanning process may be broken down into four distinct periods. These may be referred to as (1) the odd line field trace period, (2) the odd line field retrace period, (3) the even line field trace period, (4) the even line field retrace period. The permissible time allowed for each operation is approximately as follows: (1) For the even line field trace period during which picture information is being transmitted, about 15,417 microseconds or 242.5 horizontal sweep cycles, (2) for the even line field retrace period during which no picture information is transmitted, about 1250 microseconds or 20 horizontal sweep cycles. This period is also known as the vertical blanking interval. The even line field trace and retrace periods have the same time allowances and the same number of horizontal sweep cycles as the odd line field trace and retrace periods. Each trace and retrace period constitutes a complete field. There are 60 of these fields (odd and even) per second. An odd line field plus an even line field equals one *frame* of which there are 30 per second.

D. The actual scanning process takes place as follows: A narrow beam of electrons is produced and directed upon an image plate in a camera tube or a fluorescent screen in a kinescope (receiving) cathode ray tube. Due to the presence of various synchronizing pulses, the beam at the camera tube and the beam at the kinescope tube are locked in step with each other and may be considered to be covering the same basic areas of the picture in question, simultaneously. The electron beam is acted upon by electromagnetic coils or electrostatic plates in such a manner that it is caused to move relatively slowly from left to right (trace), during which time picture information is present, and then moves quickly from right to left (retrace) in which time no picture information is present, as the beam is blanked out. During the left to right movement (in 53.34 microseconds) the beam also is moving slightly downwards so that when the retrace takes place (in 10.16 microseconds) the beam returns at the left hand side of the screen slightly below its original starting position. The distance below is equal to the width of two lines, since every other line is skipped in interlaced scanning. In a similar manner the beam moves across horizontally and downward until the entire picture area has been covered in about 242.5 lines. At this point (beginning of vertical blanking interval) the screen is blanked out and the beam returns horizontally and upwards in about 3 to 5 lines until it reaches the top of the picture. This completes one field. The downward scanning process is now resumed but the beam is now so positioned that it falls into the empty line spaces previously left in the preceding field. About 242.5 lines are again completed in the downward direction until the beam reaches the bottom of the picture. At this time the picture is again blanked out and the beam moves horizontally and upwards in about 3 to 5 lines until it reaches the top. This completes another field and one *frame*. This sequence of events is repeated at the frame repetition rate of 30 cycles per second.

Q. 4.256. What is a mosaic plate in a television camera?

A. A mosaic plate is that part of the Iconoscope camera tube upon which the picture to be televised is focused. Certain electrical changes take place on the plate so that an "electrical image" is formed on the plate which corresponds to the actual image. This "electrical image" is then scanned by an electron beam and the information it contains is successively transferred in the form of electrical impulses to a series of amplifiers.

D. The mosaic plate consists of a mica plate (about .001 inch thick). One side of this plate is coated with a very fine silver oxide powder and the plate is then baked in an oven. During the baking process the silver oxide powder is reduced to pure silver globules each less than .001 inch in diameter. Each globule is insulated from other globules by the mica. The silver globules are caused to be photosensitive by introducing cesium vapor into the tube and then passing glow discharge through the tube in an oxygen atmosphere. Some pure cesium is formed upon the silver globules and causes them to be photosensitive. The opposite side of the mosaic plate is coated with a thin layer of collodial graphite. This layer serves as the electrode through which the signal is transferred by capacity effect, to the external circuit during the scanning process. This type of image plate has the property of storage and will retain the image in electrical form for some time after the optical image has been removed.

Q. 4.257. What is the purpose of synchronizing pulses in a television broadcast signal?

A. In general, the purpose of synchronizing pulses is to maintain the correct scanning pattern and to synchronize or lock-in the action of the receiving tube (Kinescope) scanning beam with that of the camera tube scanning beam.

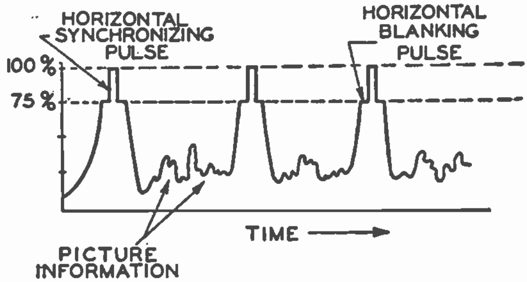


Fig. 4.257. The video signal, including the synchronizing pulses.

D. There are two types of synchronizing pulses, the amplitude of each type being confined to the region between 75% and 100% of maximum carrier amplitude. The upper tip of the synchronizing pulses is at an amplitude corresponding to 100% and the base of the pulses is at an an amplitude corresponding to 75%. The horizontal pulses are rectangular in shape and extend above the top of the horizontal blanking pulses (see the figure). They have a width equal to about 5.08 microseconds. There is one horizontal synchronizing pulse for each horizontal line, or 525 per frame and 15,750 per second. The horizontal synchronizing pulse normally occurs at the time when the electron beam has progressed to the extreme right hand edge of the picture. The pulse acts upon a horizontal multivibrator or blocking oscillator type of sweep generator in such a way as to initiate the start of the horizontal retrace.

The vertical synchronizing pulse is somewhat more complicated being formed from 6 vertical serrated pulses which are electronically added in an integrating circuit to form a single pulse. There is one complete vertical synchronizing pulse for every field or 2 per frame and 60 per second. The vertical pulse acts upon a vertical multivibrator or blocking oscillator type of sweep generator in such a way as to initiate the starting of the electron beam to return to the top of the picture from the extreme lower part. (See also Question 4.255.)

Q. 4.258. What is the effective radiated power of a television broadcast station if the output of the transmitter is 1000 watts, antenna transmission line loss is 50 watts and the antenna power gain is 3?

A. The effective radiated power is 2850 watts.

D. Since the transmitter output is 1000 watts and the line loss is 50 watts, the power delivered to the antenna is $1000 - 50 = 950$ watts. The antenna power gain is 3 so the effective radiated power = $950 \times 3 = 2850$ *watts.*

Q. 4.259. Besides the camera signal, what other signals and pulses are included in a complete television broadcast signal?

A. The following signals and pulses are included:

1. Horizontal synchronizing pulses. (525 per frame, 15,750 per second.

2. Horizontal blanking pulses, (525 per frame, 15,750 per second).
3. Vertical synchronizing pulses, (1 per field).
4. Vertical blanking pulses, (1 per field).
5. Equalizing pulses, (12 per field, 6 on either side of each vertical synchronizing pulse).
6. F-m sound carrier frequency and sidebands.
7. Video carrier frequency.

D. See Questions 4.257, 4.260, and 4.261.

Q. 4.260. What are synchronizing pulses in a television broadcasting and receiving system?

A. These are short duration rectangular pulses which are used to control the synchronism of both the transmitting and receiving scanning generators.

D. See Question 4.257.

Q. 4.261. What are blanking pulses in a television broadcasting and receiving system?

A. Blanking pulses are rectangular pulses of short duration used to extinguish the electron beam during the retrace periods.

D. See the figure for Question 4.257. Blanking pulses of negative polarity when applied to the intensity grid of the electron gun at both the transmitting and receiving cathode ray equipment. At the end of each horizontal line just before the retrace is initiated, the horizontal blanking pulse extinguishes the electron beam so that it returns to the left side of the picture unnoticed. The horizontal blanking pulse width is 10.16 microseconds, and there are 525 per frame or one for each horizontal synchronizing pulse. When the scanning beam reaches the extreme bottom of the picture and just prior to the vertical retracing, the vertical blanking interval pulse causes the electron beam to be extinguished so that the lines moving upward will not be seen. The duration of the vertical blanking interval pulse is about 1250 microseconds and there are 60 per second.

Q. 4.262. For what purpose is a voltage of sawtooth wave form used in a television broadcast receiver?

A. To produce the desired scanning pattern of the Kinescope screen.

D. A voltage (or current) of sawtooth wave form is provided by the horizontal and vertical sawtooth generators in the receiver and synchronized by the incoming horizontal and vertical synchronizing pulses. These sawtooth waveforms are applied to the horizontal and vertical deflection plates (or coils) for the purpose of producing a linear scanning pattern upon the Kinescope screen. (See also Questions 4.255 and 4.257.)

Q. 4.263. In television broadcasting, what is the meaning of the term "aspect ratio"?

A. The "aspect ratio" is the ratio of the width to height of a television frame, as determined by the camera tube.

D. See Question 4.270.

Q. 4.264. How many frames per second do television broadcast stations transmit?

A. There are 30 complete pictures or frames per second.

D. See Questions 4.225 and 4.257.

Q. 4.265. In television broadcasting, why is the field frequency made equal to the frequency of the commercial power supply?

A. To prevent any hum or ripple voltages from causing shadows or bands to *move* vertically across the screen, and to improve vertical synchronism.

D. Most receivers in this country must be operated from 60 cycle power mains. Sinc erectifier filter systems are never perfect in their action, there always exist in the rectifier output a small 60 or 120 cycle ripple voltage. This ripple voltage is applied together with the d-c output voltage to the scanning and synchronizing circuits as well as to the the video circuits. If the field frequency is 60 cycles, any small amount of ripple will remain stationary on the Kinescope screen and will not normally be noticeable. However, if the power frequency is 60 cycles and the field frequency was for instance, 48 cycles, then any ripple content would be very noticeable due to its continuous motion upon the screen. It is also a fact that vertical synchronism is much more reliable when the field frequency is made equal to the power-line frequency. In areas where 25 cycle power prevails, it would probably be necessary to employ additional filtering in the power supply to avoid the above mentioned difficulties.

Q. 4.266. If the cathode ray tube in a television receiver is replaced by a larger tube such that the size of the picture is changed from 8 by 6 inches to 16 by 12 inches, what change if any is made in the number of scanning lines per frame?

A. There will be no change.

D. The number of lines per frame is standardized in this country as 525. Increasing the physical size of the picture does not increase the number of frame lines, but merely increases the physical spacing between picture elements. That no changes are necessary may be borne out from the fact that certain television receivers originally designed with a 10" Kinescope are sometimes adapted to take a 21" or 24" Kinescope with no basic circuit changes needed.

Q. 4.267. If a television broadcast station transmits the video signals in channel No. 6 (82 to 88 Megacycles), what is the center frequency of the aural transmitter?

A. The center frequency of the f-m (aural) transmitter is 87.75 megacycles.

D. The center frequency of the aural transmitter is always .25 megacycle below the upper limit of the channel. The nominal center frequency, or carrier, of the video transmitter is always 1.25 megacycles above the lower limit of the channel. (See also Question 4.274.)

Q. 4.268. What is the field frequency of a television broadcast transmitter?

A. The field frequency is standardized at 60 cycles per second.

D. See Questions 4.251, 4.255, and 4.265.

Q. 4.269. How is the operating power of the aural transmitter of a television broadcast station determined?

A. The operating power is determined by the indirect method, as
$Operating\ power = E_b \times I_b \times Efficiency$, where
E_b = plate voltage of the final amplifier
I_b = plate current of the final amplifier
Efficiency = efficiency of the final amplifier, specified by the manufacturer. (See also Questions 4.301 and 4.156.)

Q. 4.270. Numerically, what is the aspect ratio of a picture as transmitted by a television broadcast station?

A. The aspect ratio is 4 to 3.

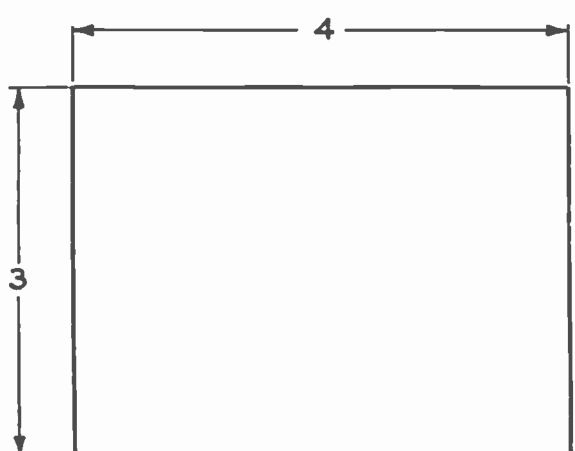


Fig. 4.270. The aspect ratio of the television picture is always 4 to 3.

D. The aspect ratio refers to the ratio of the width to height of a television picture. As shown in the figure, the width is always made 4/3 as great as the height of the picture. This value is chosen to be the same as used in motion picture practice. The advantage of doing this is that it permits the televising of standard motion picture film without wasting any of the area occupied by the scanning pattern. Originally this ratio was chosen in motion picture theaters as being the best geometry of the viewing screen which would give the most satisfactory results from the audience point of view. (See also Question 4.263.)

Q. 4.271. What is meant by vestigial sideband transmission of a television broadcast station?

A. In television "vestigial sideband transmission" means that the entire upper video sideband is transmitted but only a part of the lower video sideband.

D. In the video transmitter a large part (2.75 megacycles) of the lower sideband is suppressed. The reason for so doing is to save space on the channels and allow more television stations to exist within a given frequency range. This is permissible since only one set of sidebands is needed to transmit all of the video information. The entire lower sideband cannot be readily eliminated due to the difficulty in building suitable filters and the introduction of undesirable phase shift distortion into the picture. The partial elimination of the lower sideband is shown clearly in the figure of Question 4.274.

Q. 4.272. What is the frequency tolerance of television broadcast transmitters?

A. For the video carrier it is ±1 kc; for the sound carrier it is ±4 kc. If the sound carrier frequency is so controlled that it will drift with the video carrier, the tolerance is ±5 kc.

Q. 4.273. What is meant by antenna field gain of television broadcast antenna?

A. "Antenna field gain" is the ratio of the voltage induced into a receiving antenna under two separate transmitting conditons. The first condition is when a relatively complex transmitting antenna system is used and the second case is when a simple dipole transmitting antenna is used.

D. The ratio is usually taken with respect to a dipole antenna as a reference value. The actual power output of the transmitting antenna is not increased to produce a field gain. Rather the available energy is concentrated or focused in the desired directions. According to a definition of the F.C.C., "antenna field gain" is defined as the "ratio of the effective free space field intensity, produced at one mile in the horizontal plane and expressed in millivolts per meter or one kilowatt antenna input power, to 137.6 microvolts per meter." The figure of 137.6 microvolts per meter is the figure used to represent an average value of field strength, at a point one mile from the antenna, which would be produced by one kilowatt radiated from a simple dipole at the mean height of the antenna being measured. (See Question 4.61.)

Q. 4.274. How wide is a television broadcast channel?

A. 6 megacycles.

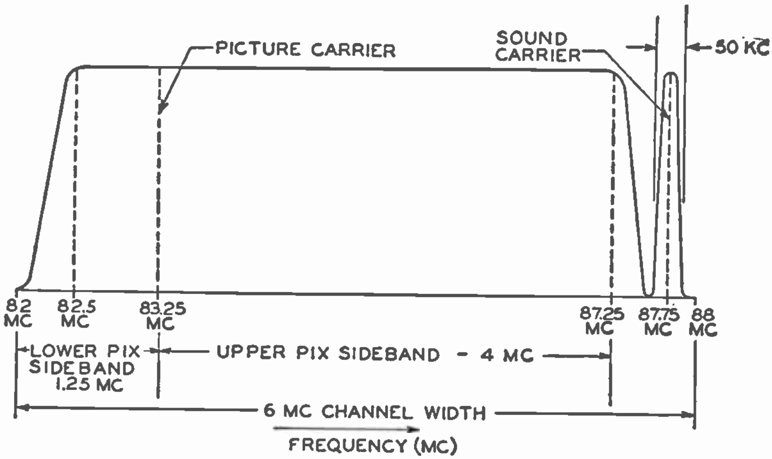


Fig. 4.274. The over-all response curve of a television channel.

D. See the figure. Each television channel is 6 megacycles wide. Within this range there are two carrier waves, their corresponding sidebands, and guard bands on each side of the sound carrier. The picture carrier, which is amplitude modulated, is always 1.25 megacycles above the lowest end of the channel. In the figure, the picture carrier is 83.25 megacycles. The upper sideband of the picture carrier extends for 4 megacycles or to 87.25 megacycles. However, part of the lower picture sideband is suppressed and as shown, the lower sideband only extends 1.25 megacycles. This system of partial sideband suppression is known as vestigial sideband transmission (Question 4.274). Its purpose is to reduce the bandwidth of the channel. The picture content does not suffer since only one sideband is actually needed in transmission. The sound carrier is always found .25 megacycles below the upper end of the channel. In this case the sound carrier frequency is 87.75 megacycles. With 100% modulation, the sidebands of the sound carrier, which is f-m, extend to ±25 kilocycles. (See Question 4.253 and 4.256.) Accordingly, the sound bandwidth extends from 87.725 megacycles to 87.775 megacycles. This leaves a guard band above the upper f-m sideband of 225 kilocycles, and a guard band on the lower side of the f-m sideband of 475 kilocycles. This distribution of frequencies is the same for all TV channels.

TABLE OF TELEVISION CHANNELS

Channel No.	*Frequency in Mc.*
2	54 to 60
3	60 to 66
4	66 to 72
5	76 to 82
6	82 to 88
7	174 to 180
8	180 to 186
9	186 to 192
10	192 to 198
11	198 to 204
12	204 to 210
13	210 to 216
UHF	470 to 890

Q. 4.275. If standard broadcast emissions are classified as A3 emissions, what is the classification of television broadcast video emissions?

A. Television broadcast video emissions are classified as type A5.

D. See Question 3.462.

Q. 4.276. What is the range of audio frequencies that the aural transmitter of a television broadcast station is required to be capable of transmitting?

A. The required audio range is from 50 to 15,000 cycles. This is the same as for a standard f-m broadcast station.

Q. 4.277. What is meant by one hundred percent modulation of the aural transmitter at a television broadcast station?

A. 100% modulation is achieved with a frequency swing of ±25 kilocycles.

D. See Questions 4.253 and 4.254.

Q. 4.278. What is the frequency tolerance for a broadcast STL station? (R & R 4.561)

A. The frequency tolerance is ± .005 percent of the assigned frequency.

Q. 4.279. What are the radio operator requirements of the person on duty at an experimental television broadcast station?

A. One or more radio operators holding radiotelephone first-class or radiotelephone second-class operator licenses shall be on duty at the place where the transmitting apparatus of any experimental television broadcast station is located and in actual charge of its operation. The licensed operator on duty and in charge of a broadcast transmitter may, at the discretion of the licensee, be employed for other duties or for the operation of another station or stations in accordance with the class of operator's license which he holds and the rules and regulations governing such stations. However, such duties shall in no wise interfere with the operation of the broadcast transmitter.

Q. 4.280. What type of antenna is required at a broadcast STL station? (R & R 4.536)

A. Each broadcast STL or FM Intercity Relay station is required to employ a directional antenna. Considering one kilowatt of radiated power as a standard for comparative purposes, such antenna shall provide a free space field intensity at one mile of not less than 435 microvolts per meter in the main lobe of radiation toward the receiver and not more than 20 percent of the maximum value in any azimuth 30 degrees or more off the line to the receiver. Where more than one antenna is authorized for use with a single station, the radiation pattern of each shall be in accordance with the foregoing requirement.

Q. 4.281. What is the frequency tolerance of a non-commercial educational FM broadcast station?

A. Frequency tolerance. (a) The center frequency of each noncommercial educational FM broadcast station licensed for transmitter power output of 10 watts or less shall be maintained within 3,000 cycles of the assigned center frequency.

(b) The center frequency of each noncommercial educational FM broadcast station licensed for transmitter power output above 10 watts shall be maintained within 2,000 cycles of the assigned center frequency.

Q. 4.282. What are the licensed operator requirements for a TV broadcast station? An FM broadcast station? A 5-kw night-time directional standard broadcast station? (R & R 3.165, 3.265, 3.661)

A. 1. The licensed operator requirements for a TV broadcast station are:

(a) One or more radio operators holding a valid radiotelephone first-class operator license, except as provided below, shall be in actual charge of the transmitting apparatus and shall be on duty either at the transmitter location or remote control point.

(b) A station which is authorized for non-directional operation with power of 10 kilowatts or less may be operated by persons holding commercial radio operator license of any class, except an aircraft radiotelephone operator authorization or a temporary limited radiotelegraph second-class operator license, when the equipment is so designed that the stability of the frequency is maintained by the transmitter itself within the limits of tolerance specified, and none of the operations, except those specified in subparagraphs (1) through (4) of this paragraph, necessary to be performed during the course of normal operation may cause off-frequency operation or result in any unauthorized radiation. Adjustments of transmitting equipment by such operators, except when under the immediate supervision of a radiotelephone first-class operator, shall be limited to the following:

(1) Those necessary to commence or terminate transmitter emissions as a routine matter.

(2) Those external adjustments that may be required as a result of variations of primary power supply.

(3) Those external adjustments which may be necessary to insure modulation within the limits required.

(4) Those adjustments necessary to effect any change in operating power which may be required by the station's instrument of authorization.

Should the transmitting apparatus be observed to be operating in a manner inconsistent with the station's instrument of authorization and none of the above adjustments are effective in bringing it into proper operation, a person holding other than a radiotelephone first-class operator license and not acting under the immediate supervision of radiotelephone first-class operator, shall be required to terminate the station's emissions.

(c) The licensee of a station which is operated by one or more operators holding other than a radiotelephone first-class operator license shall have one or more operators holding a radiotelephone first-class operator license in regular full-time employment at the station whose primary duties shall be to effect and insure the proper functioning of the transmitting equipment.

2. The licensed operator requirements for an FM broadcast station are:

(a) One or more radio operators holding a valid radiotelephone first-class operator license, except as provided in this section shall be in actual charge of the transmitting apparatus and shall be on duty either at the transmitter location or remote control point.

(b) A station which is authorized with transmitter power output of 10 kilowatts or less may be operated by persons holding commercial radio operator license of any class, except on aircraft radiotelephone operator authorization or a temporary limited radiotelegraph second-class operator license when the equipment is so designed that the stability of the frequency is maintained by the transmitter itself within the limits of tolerance specified and none of the operations, except those specified in subparagraphs (1), (2) and (3) of this paragraph, necessary to be performed during the course of normal operation may cause off-frequency operation or result in any unauthorized radiation. Adjustments of transmitting equipment by such operators, except when under the immediate supervision of a radiotelephone first-class operator shall be limited to the following:

(1) Those necessary to commence or terminate emissions as a routine matter.

(2) Those external adjustments that may be required as a result of variations of primary power supply.

(3) Those external adjustments which may be necessary to insure modulation within the limits required.

Should the transmitting apparatus be observed to be operating in a manner inconsistent with the station's instrument of authorization and none of the above adjustments are effective in bringing it into proper operation, a person holding other than a radiotelephone first-class operator license and not acting under the immediate supervision of a radiotelephone first-class operator, shall be required to terminate the station's emissions.

(c) The licensee of a station which is operated by one or more operators holding other than a radiotelephone first-class operator license shall have one or more operators holding a radiotelephone first-class operator license in regular full-time employment at the station whose primary duties shall be to effect and insure the proper functioning of the transmitting equipment.

3. The licensed operator requirements for a 5 kilowatt night-time directional standard broadcast station are:

One or more licensed radio-telephone first-class operators shall be on duty at the place where the transmitting apparatus of each station is located and in actual charge thereof whenever it is being operated. The original license (or FCC Form 759) of each station operator shall be posted at the place where he is on duty. The licensed operator on duty and in charge of a television broadcast transmitter may, at the discretion of the licensee, be employed for other duties or for the operation of another station or stations in accordance with the class of operator's license which he holds and by the rules and regulations governing such stations. However, such duties shall in nowise interfere with the operation of the broadcast transmitter.

Q. 4.283. Under what conditions may a standard broadcast station be operated by remote control? (R & R 3.66)

A. A station which is authorized for non-directional operation with power of 10 kilowatts or less may, upon prior authorization from the Commission, be operated by remote control at the point(s) which shall be specified in the station license. An application for authorization to operate by remote control may be made as a part of an application for construction permit or license, or modification thereof by specifying the proposed remote control point(s). Operation by remote control shall be subject to the following conditions:

(a) The equipment at the operating and transmitting positions shall be so installed and protected that it is not accessible to or capable of operation by persons other than those duly authorized by the licensee.

(b) The control circuits from the operating position to the transmitter shall provide positive on and off control and shall be such that open circuits, short circuits, grounds or other line faults will not actuate the transmitter and any fault causing loss of such control will automatically place the transmitter in an inoperative condition.

(c) Control and monitoring equipment shall be installed so as to allow the licensed operator either at the remote control point or at the transmitter, to perform all of the functions in a manner required by the Commission's rules and standards.

Q. 4.284. Within what limits is the operating power of a TV aural or visual transmitter required to be maintained? (R & R 3.689)

A. The operating power of the visual transmitter shall be maintained as near as practicable to the authorized operating power and shall not exceed the limits of 10 percent above and 20 percent below the authorized power except in emergencies.

The operating power of the aural transmitter follows the same restrictions as outlined above for the visual transmitter.

Q. 4.285. Describe the composition of the chrominance subcarrier used in the authorized system of color television.

A. The chrominance subcarrier has a frequency of 3.579545 megacycles. This subcarrier contains information relative to color only, that is to the saturation and hue of a color. Information pertaining to saturation is impressed upon the subcarrier by means of amplitude modulation. Information pertaining to the hue of a color is impressed upon the subcarrier by means of phase modulation. Brightness (and fine detail) information in a color picture is not transmitted on the subcarrier, but is sent by the conventional monochrome TV methods.

Q. 4.286. Describe the procedure and adjustment necessary to couple properly a typical VHF visual transmitter to its load circuits.

A. The following discussion of coupling a VHF visual transmitter to its load circuits is based upon a transmitter (RCA) employing grid modulation of the final power r-f amplifiers. Because of the method of modulation used, stages prior to the final need not be broadbanded since they are producing only the carrier frequency to be used.

Power amplifier *preliminary* loading is accomplished as follows:

1. Terminate the transmission line with a dummy load. (Power delivered to the dummy load is indicated by an accompanying wattmeter.)

2. The loading control should be set to provide light loading at the start. It is desired to approach the desired final loading through a series

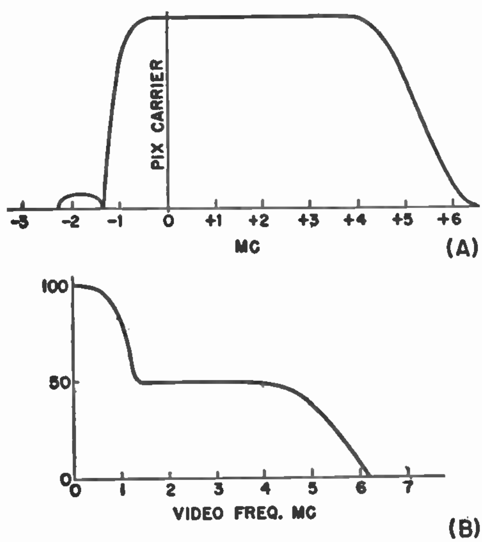


Fig. 4.286. (A) Frequency response output and (B) detected output of sideband filter of visual transmitter.

of small adjustments. These must be carefully made to assure high-quality picture transmission since they affect the overall frequency response and the linearity of modulation. Correct loading causes the frequency characteristic of the power amplifier to broaden so that it will transmit sideband components up to four megacycles.

3. With video gain control set to *zero* and normal r-f excitation applied, tune the power amplifier plate control for a dip on its plate current meter.

4. Rotate antenna tuning dial for resonance. This may be indicated by a dip in screen current of the final power amplifier.

5. Increase the coupling with the loading control in small steps, each time repeating steps 3 and 4 until the readings specified by the manufacturer are noted. For a typical RCA transmitter, the readings may be:

a. P.a. plate voltage ....1000 volts
b. P.a. plate current ....0.65 amperes
c. Bias ....57 volts
d. Power output ....300 watts

6. Couple power output of visual transmitter into the vestigial sideband filter and retouch power amplifier plate and antenna tuning controls as in 3 and 4 above.

7. The final broadband characteristic can now be obtained. A video sweep generator is connected to the video amplifier circuits and a scope and detector connected to the output of the sideband filter. The frequency response output of the sideband filter is shown in part (A) of the figure while the detected output as observed on a scope is given in part (B). The waveform of part (B) is the final desired one.

Roughly, the three power amplifier adjustments will have the following effects on the response curve.

a. Power amplifier plate control tilts the curve so that either high- or low-frequency end of curve may be overpeaked. In tuning, the high-frequency end should be favored.

b. Antenna tuning control has much the same effect as the power amplifier plate control.

c. Output coupling control changes the power output and the band width. If power output is too low and bandwidth too broad, coupling should be reduced and plate and antenna tuning controls readjusted for flattest frequency response and maximum power output. If the bandwidth is found to be too narrow, increase the coupling slightly and readjust plate and antenna tuning controls.

Q. 4.287. Draw a block diagram of a typical monochrome television transmitter indicating the function of each part.

A. A block diagram of a typical monochrome TV transmitter (visual portion) is given in the figure. For block diagrams of typical FM sound transmitters, see Question 3.493. However, remember in TV sound, the maximum deviation is ± 25 kilocycles and the sound carrier frequencies are those associated with each TV channel. See also Question 4.274 for table of channels and discussion of TV channel distribution.

D. The block diagram shown is that of a low-level modulated monochrome visual TV transmitter, based on the G.E. TT-10-A transmitter. Although not shown here, visual transmitters also may employ medium-level or high-level modulation.

The first block shown in the figure is a crystal oscillator operating at one-twelfth of the desired picture carrier frequency. For example, the picture carrier for channel 2 is 55.25 megacycles. In this case the crystal oscillator would operate at one-twelfth of this frequency, or 4.6 (approximately) megacycles. This is done to insure good crystal oscillator stability. Following the crystal oscillator is a series of frequency multipliers

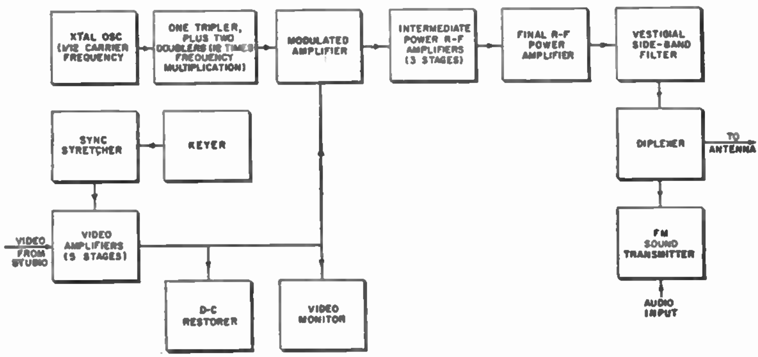


Fig. 4.287. Block diagram of a typical monochrome TV transmitter using low-level modulation.

consisting of one tripler and two doublers providing a total frequency multiplication of 12 times. Thus, the output of the multipliers is at actual picture carrier frequency and is then applied to the modulated amplifier stage. The modulated amplifier also receives an input consisting of the composite video signal including sync and blanking pulses The video signal is provided at about 25 volts peak-to-peak level by a five-stage video amplifier. This amplifier receives its input from the studio cameras, relay equipment, or from a line amplifier. D-c restorers are provided to reinsert the d-c component of the signal before application to the modulated amplifier.

In addition, a video monitor is employed to afford continuous monitoring of the composite video signal. Such factors as proper sync level, and white and black levels may be observed on the monitor. Synchronizing and blanking pulses as well as equalizing pulses are generated and keyed in at the appropriate times by the Keyer unit. The sync stretcher controls the amplitude of the sync pulses to compensate for compression or variations in amplitude.

The output of the modulated amplifier is a low-level r-f monochrome TV signal. This is brought up to the desired transmitting strength by three stages of intermediate r-f power amplification and then by the final r-f power amplifier.

Note that the output of the final r-f power amplifier is fed through a vestigial sideband filter and a diplexer before being applied to the transmitting antenna. The use of the vestigial (partial) filter assures that the undesired portion of the *lower picture sidebands* will be attenuated in accordance with the FCC requirements. This attenuation must be at least 20 db at a point 1.25 megacycles below the visual carrier to prevent interference with the next lower TV channel.

The diplexer is a device employed for the purpose of supplying both the visual and aural modulated carriers to the same transmitting antenna without crosstalk. Electrically, the diplexer is a circuit with the aural and visual transmitters connected across opposite arms of the bridge, thus preventing cross talk from occurring between the two sources.

Note: See also Questions 4.251 through 4.277.

Q. 4.288. Describe the scanning process employed in connection with color TV broadcast transmission.

A. This scanning process is identical with that employed in monochrome TV as described fully in Question 4.258.

D. A minor difference in scanning rates exists when transmitting a color program. This helps to reduce beat interference on the picture tube. In color transmission, the vertical rate is actually 59.94 cps instead of 60 cps and the horizontal rate is 15,734.264 cps instead of 15,750 cps. The difference between these frequencies is so slight that monochrome receiver circuits are not affected.

Q. 4.289. Under what conditions should the indicating instruments of a TV visual transmitter be read in order to determine operating power?

A. The operating power of the visual transmitter shall be determined at the output terminal of the vestigial sideband filter, if such filter is used; otherwise, at the transmitter output terminal. The average power shall be measured while operating into a dummy load of substantially zero reactance and a resistance equal to the transmission line surge impedance, while transmitting a standard black television picture. The peak power shall be the power obtained by this method, multiplied by the factor 1.68.

Q. 4.290. In a transmitted monochrome television signal what is the relationship between peak carrier level and the blanking level? (R & R 3.682)

A. The blanking level shall be transmitted at 75 ± 2.5 percent of the peak carrier level.

D. See Q. 4.257.

Q. 4.291. Draw a simple schematic diagram of a T-type coupling network suitable for coupling a coaxial line to a standard broadcast antenna. Include means for harmonic attenuation.

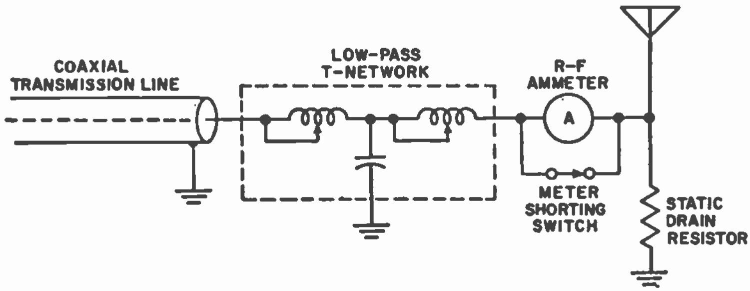


Fig. 4.291. Simple schematic of a low-pass T-type coupling network between a coaxial line and a broadcast antenna.

A. See the figure.

D. The T-type network shown in the figure is a low-pass type. As in any low-pass filter, it discriminates against frequencies above its desired pass band. Therefore, this network discriminates against harmonic frequencies. The T-network is adjusted to provide a correct impedance match between the coaxial transmission line and the broadcast antenna.

ELEMENT V

RADIOTELEGRAPH OPERATING PRACTICE

Question 5.01. List three classes of stations which may not be operated by the holder of a radiotelegraph third-class operator permit. (Sec. 13.61.)

Answer. 1. The permit is not valid for the operation of any of the various classes of broadcast stations other than remote pickup and ST broadcast station.

2. The permit is not valid for the operation of a ship station licensed to use type A-3 emission for communication with coastal telephone stations.

3. The license is not valid for the operation of a radiotelegraph station on board a vessel required by treaty or statute to be equipped with a radio installation.

4. The license is not valid for the operation of any ship telegraph, coastal telegraph, or marine-relay station open to public correspondence.

Q. 5.02. Is the holder of a radiotelegraph third-class operator permit authorized to make technical adjustments to a radiotelephone transmitter? To a radiotelegraph transmitter? (Sec. 13.61)

A. The holder may make technical adjustments to a transmitter only in the presence of an operator holding a first- or second-class license, either telephone or telegraph.

Q. 5.03. Where should the operator on duty at a manually operated radiotelegraph station normally post his operator license or permit? (Sec. 13.6)

A. The operator license shall be posted conspicuously at the station where the operator is employed.

Q. 5.04. What are the requirements for station identification at radiotelegraph stations in the Public Safety Radio Services? (Sec. 10.152)

A. Every station in the public safety radio service, except those classes of stations covered by other station identification requirements of the Commission, shall transmit its call letters at the end of each transmission: Provided, however, That transmission of the call letters at the end of each transmission is not required during periods of communication requiring continuous, frequent, or extended use of the transmitting apparatus if, during such periods and in connection with such use, the call letters are transmitted at intervals of not more than 15 minutes.

Q. 5.05. What is the radiotelegraph distress signal? Urgency signal? Safety signal?

A. (1) In radiotelegraphy, the distress signal shall consist of the group ...— — —... transmitted as one signal, in which the dashes must be emphasized so as to be distinguished clearly from the dots. (2) The urgency signal shall consist of the group XXX transmitted three times, with the letters of each group, as well as the consecutive groups, well separated; it shall be sent before the call. (3) In radiotelegraphy, the safety signal shall consist of the group TTT, transmitted three times, with the letters of each group, as well as the consecutive groups, well separated. This signal shall be followed by the word DE and three transmissions of the call signal of the station sending it. It announces that this station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings.

Q. 5.06. The speed of radiotelegraph code transmission in cases of distress, urgency or safety must not, in general, exceed what speed?

A. The speed of telegraph transmission in cases of distress, urgency, or safety must not normally exceed 16 words a minute.

Q. 5.07. What radiotelegraph signal is generally used in a call "to all stations"?

A. Two types of call signal "to all stations" are recognized:

1. The call CQ followed by the letter K (general call to all stations in the mobile service with request for reply).
2. The call CQ not followed by the letter K (general call to all stations without request for reply).

Q. 5.08. What is meant by the following radiotelegraph operating signals: R, $\overline{\text{AS}}$, $\overline{\text{IMI}}$, C, $\overline{\text{BT}}$, K; $\overline{\text{AR}}$; $\overline{\text{VA}}$; DE?

A. R means "Receiving you"; $\overline{AS}$ means "Wait"; $\overline{IMI}$ means "Question mark", or request for repetition of a transmission not understood; C means "Yes"; $\overline{BT}$ means "Double hyphen"; K means "Invitation to transmit"; $\overline{AR}$ means "Cross, or end of telegraph or transmission"; $\overline{VA}$ means "End of work"; DE means "From".

Q. 5.09. If a radiotelegraph operator makes an error in transmitting message text how does he indicate that an error has been made?

A. He sends the error signal consisting of a series of dots as follows: . . . .

Q. 5.10. When testing a radiotelegraph transmitter what signals are generally transmitted?

A. A series of V's with the call sign of the transmitting station sent at frequent intervals.

Q. 5.11. In order to avoid confusion in transmitting numbers involving a fraction, how should such numbers be transmitted? Give an example of such a number showing how it should be transmitted.

A. In order to avoid confusion, the hyphen, or dash, signal (— . . . . —) is transmitted between the whole number and the fraction.

D. Two examples follow:

1. Instead of 1 1/16, transmit 1 — . . . . — 1/16 in order not to have it read 11/6.

2. Instead of ½ 4, transmit ½ — . . . . — 4 in order not to have it read 1/24.

Note: The signal for the hyphen or dash is — . . . . —

Q. 5.12. What is meant by the preamble in a radiotelegraph message? What information is usually given in the preamble?

A. The preamble is sent before the chargeable words. See Question 6.726 (a) for complete example of preamble.

Q. 5.13. In addition to the preamble what parts does a radiotelegraph message contain?

A. The message also contains the address, text, and the signature. (See also Question 6.726.)

Q. 5.14. What is meant by a service prefix or indicator in a radiotelegraph message?

A. A service prefix or indicator is a code designation made up of from 2 to 4 letters as the first part of the preamble. It contains directions for handling and other information as shown in Question 6.724.

Q. 5.15. What does "word count" or "check" mean in a radio telegraph message?

A. This indicates the number of paid-for words contained in a message. If the number of actual words differs from the paid-for words, a fraction is used, as 17/14. The first figure indicates the number of paid-for words; the second figure indicates the number of actual words. (See also Question 6.725.)

Q. 5.16. At what time, or times, does the serial numbering of radio radio messages begin? Does the period of numbering vary in some services?

A. Serial numbers begin at 0000 GMT daily. A new series of numbers is used for each station. Some foreign stations number messages in a single unbroken series, without regard to date or station worked.

Q. 5.17. Code or cipher groups are often used in radiotelegraph messages for what purpose?

A. Code or cipher language radiotelegraph messages may be sent for security reasons.

D. In code language, the message is often sent in groups of 4 or 5 numbers or letters which may be decoded by the recipient. Cipher language is composed of figures, words, names or combinations of letters of no apparent meaning, but which can be deciphered by the recipient.

Q. 5.18. Immediately following the transmission of a radiotelegraph message containing figures or odd symbols why are such figures sometimes collated?

A. Such figures are collated (repeated back) for verification of accuracy in sending the figures or odd symbols.

Q. 5.19. If receiving conditions are bad and you desire that the transmitting station send each word or group twice to facilitate reception, what operating signal would be appropriate to use?

A. The signal is "QSZ".

Q. 5.20. In general what is the purpose of a service message in radiotelegraph communication?

A. A service message may be used to make corrections to a previously sent radiotelegram.

Q. 5.21. Why are Q-signals or other arbitrary selected procedure signals used in radiotelegraph communications?

A. These signals are used to overcome the obstacle of differing languages and to permit commonly used phrases and expressions to be transmitted with a minimum amount of signalling.

Q. 5.22. What is meant by the following signals: QRA, QRM, QRN, QRT, QRZ, QSA, QSV, QUM, QRL?

A. *Question*	*Answer or Statement*
QRA—What is the name of your station?	The name of my station is
QRM—Are you being interfered with?	I am being interfered with.
QRN—Are you troubled by static?	I am troubled by static.
QRT—Must I stop transmission?	Stop transmission.
QRZ—By whom am I being called?	You are being called by
QSA—What is the strength of my signals (1 to 5)?	The strength of your signals is (1 to 5).
QSV—Must I transmit a series of V's?	Transmit a series of V's.
QUM—Is the distress traffic ended?	The distress traffic is ended.
QRL—Are you busy?	I am busy, please do not interfere.

(See Appendix III for additional Q signals.)

Q. 5.23. If the signal strength of a radiotelegraph signal is reported on a scale of 1, 2, 3, 4, 5, what scale number would indicate a very strong signal? What scale number would indicate a very weak signal?

A. Scale number 5 indicates a very strong signal. Scale number 1 indicates a very weak signal.

Q. 5.24. If upon being called by another station, a called station is busy with other traffic, what should the operator of the called station do?

A. See Question 6.728.

Q. 5.25. Describe a procedure of radiotelegraph transmission in which one station calls another. Give an example.

A. The call is made as follows: Call sign of the station called, not more than three times; the word DE; call sign of the station calling, not more than three times.

Example: WDEF WDEF WDEF DE KABC KABC KABC K.

Q. 5.26. Describe a procedure of radiotelegraph transmission in which one station answers the call of another. Give an example.

A. Station answers the call of Question 5.25 as follows:

KABC KABC KABC DE WDEF WDEF WDEF R K.

Q. 5.27. What is meant by the statement "A station is open to public correspondence"?

A. See Question 6.684.

Q. 5.28. Should the speed of transmission of radiotelegraph signals be in accordance with the desire of the transmitting or receiving operator?

A. In accordance with the desire of the receiving operator since he has to copy the message.

Q. 5.29. After long periods of listening to a CW telegraph signal of constant tone, what adjustment can the operator make to a radio receiver to relieve hearing fatigue?

A. In order to relieve hearing fatigue, the tone of the CW telegraph signal may be changed by varying the setting of the "beat frequency oscillator" on a superheterodyne receiver. For a regenerative receiver, re-tune the detector slightly.

D. The audio tone which results from mixing the "beat frequency oscillator" output with the intermediate frequency in the second detector is equal to the sum or difference between the two frequencies. The "beat frequency oscillator" is usually provided with a control so that its output frequency may be varied within limits. By varying this output frequency a different audio tone is produced, thereby reducing hearing fatigue. See Question 6.534.

Q. 5.30. What is meant by break-in operation at a radiotelegraph station?

A. See Question 6.481.

Q. 5.31. How should the AVC switch be set for reception of CW radiotelegraph signals on a communications receiver designed for both radiotelephone and radiotelegraph reception?

A. The AVC switch should be set to "Off".

Q. 5.32. Explain the use of the crystal filter switch on a communications receiver.

A. See Question 6.605.

Q. 5.33. What adjustment should be made to a radiotelegraph receiver if the receiver "blocks" on the reception of strong signals?

A. If the receiver "blocks", the r-f gain-control setting should be reduced to a point just below that at which the receiver overloads.

Q. 5.34. Describe how to adjust a communications radio receiver for the reception of weak CW signals.

A. See Question 6.544.

Q. 5.35. How should a radiotelegraph receiver be adjusted for the reception of type A-2 emissions?

A. With superheterodyne receivers, the beat-frequency oscillator should be "off." With regenerative receivers, the regeneration control is adjusted to a point just short of oscillation.

Q. 5.36. Sometimes a given radiotelegraph transmitting station can be heard at more than one place on the tuning dial of a receiver. Is this always an indication that the station is transmitting on more than one frequency?

A. Not always. The receiver may be responding to an "image" frequency. The correct tuning of the signal will usually bring in a louder, clearer station.

D. See Question 3.265.

Q. 5.37. How should a manual radiotelegraph transmitting key be adjusted for good operation? Is the adjustment always the same for slow as it is for high speed?

A. A manually operated key may be adjusted as follows:

1. Center the movable contact above the fixed contact by the side thumb screws. Do this by having the thumb screws drawn up a little tight.

2. Loosen the thumb screws a fraction to permit free vertical movement of the movable arm. Tighten the lock nuts.

3. Adjust the contact gap to about 1/32 inch for fast keying and about 1/16 to 3/32 inch for slow keying. Tighten lock nut.

4. Adjust the spring tension to suit the individual's requirements. Tighten lock nut.

In general, for fast keying the gap will be smaller and the spring tension lighter than for slow keying. It is impossible to give exact settings, since these vary with each individual.

Q. 5.38. Describe how an automatic key or "bug" should be adjusted properly to send good readable radiotelegraph signals.

A. A "bug" should be adjusted properly as follows:

1. The bearing supporting the vertical shaft on which the dot-and-dash levers are suspended should be adjusted up or down until the movable dot contact on the vibrator arm makes accurate full-face contact with the stationary dot contact on the post. Then the bearing adjustment screws should be set so that lateral (sidewise) motion of the dot-and-dash levers is free, but so there is no end play (vertical motion) of the levers.

2. The movable dash contact on the dash lever should be adjusted so that it makes full-face contact with the stationary dash contact or the post. Then it should be locked firmly in that position by means of the locking screw.

3. The spacing of the stationary dash contact should next be adjusted to about 1/15 to 1/32 of an inch to suit the sending style of the operator, and the tension spring adjusted accordingly.

4. Adjust the dot lever stop screw so that the "travel" of the dot lever is about 1/16 to 3/16 of an inch and secure it with a lock nut. (It is assumed that the back stop screw is adjusted properly at the factory.)

5. Adjust the spacing of the stationary dot contact so that when the dot lever is pressed and held over, the instrument will make from 12 to 30 clear dots before the moving dot contact settles into steady contact with the staionary contacts. This adjustment will depend partly on the response of the keying relay and associated equipment.

6. The dot speed adjustment weight should be set so that the instrument makes dots at a speed proportional to the speed at which the operator normally makes dashes. This means the instrument should make about three dots in the time the operator normally makes one dash. For practical operating speeds ranging from 20 to 40 English words per minute, this will be a dot speed of from 8 to 16 dots per second.

ELEMENT VI

ADVANCED RADIOTELEGRAPH

Note: A number of the following questions are referenced to questions and answers in Element III, which are identical with the associated questions for Element VI.

Q. 6.01. See Question 3.01.

Q. 6.02. See Question 3.02.

Q. 6.03. See Question 3.03.

Q. 6.04. See Question 3.04.

Q. 6.05. See Question 3.42.

Q. 6.06. See Question 3.29.

Q. 6.07. See Question 3.30.

Q. 6.08. See Question 3.31.

Q. 6.09. See Question 3.36.

Q. 6.10. See Question 3.39.

Q. 6.11. See Question 3.40.

Q. 6.12. See Question 3.41.

Q. 6.13. See Question 3.18.

Q. 6.14. See Question 3.24.

Q. 6.15. See Question 3.23.

Q. 6.16. See Question 3.26.

Q. 6.17. See Question 3.38.

Q. 6.18. See Question 3.57.

Q. 6.19. See Question 3.68.

Q. 6.20. See Question 3.64.

Q. 6.21. See Question 3.65.

Q. 6.22. See Question 3.66.

Q. 6.23. See Question 3.32.

Q. 6.24. See Questions 3.33 and 3.25.

Q. 6.25. See Question 3.34.

Q. 6.26. See Question 3.35.

Q. 6.27. See Question 3.12.

Q. 6.28. See Question 3.13.

Q. 6.29. See Question 3.14.

Q. 6.30. See Question 3.11.

Q. 6.31. See Question 3.10.

Q. 6.32. See Question 3.20.

Q. 6.33. See Question 3.27.

Q. 6.34. See Question 3.08.

Q. 6.35. See Question 3.06.

Q. 6.36. See Question 3.05.

Q. 6.37. See Question 3.238

Q. 6.38. See Question 3.239.

Q. 6.39. See Question 3.235.

Q. 6.40. See Question 3.234.

Q. 6.41. See Question 3.227.

Q. 6.42. See Question 3.240.

Q. 6.43. See Question 3.288.

Q. 6.44. How many watts equal 1 horsepower?

A. One horsepower is equal to 746 watts.

D. The two units, both measuring the rate of doing work, were defined independently. A *watt* is the power corresponding to one ampere flowing at one volt emf (or one coulomb per second through one ohm); a *horsepower* is the power corresponding to lifting 550 pounds at the rate of one foot per second. Careful experiments have shown that 746 watts is equivalent to one horsepower, or roughly 1 H.P. = ¾ kw.

Q. 6.45. What factors determine the heat generated in a conductor carrying an electric current?

A. The heat generated is directly proportional to the value of resistance and to the square of the current.

D. The formula to determine the heat generated (or power dissipation) is, $P = I^2R$. See also Questions 3.64, 3.65, and 3.66.

Q. 6.46. What is the ratio of peak to average value of a sine wave?

A. The ratio is 1.57 to 1, or 1 to 0.636.

Q. 6.47. What is the meaning of the term "leading power factor"?

A. "Leading power factor" means that the current sine wave in a circuit reaches its peak value before the voltage wave. A circuit in which this occurs has a capacitive reactance which predominates over any inductive reactance present.

D. See Question 3.34.

Q. 6.48. See Question 3.232.

Q. 6.49. What load conditions must be satisfied in order to obtain the maximum possible output from any power source?

A. Assuming the power source to have a fixed value of internal impedance, the maximum power will be transferred to the load, when the load impedance is equal to the internal impedance of the source.

D. If it were possible to vary the internal impedance of the source, the maximum power would be transferred to the load when the source impedance was equal to zero.

Q. 6.50. What is the meaning of the term "phase difference"?

A. In comparing two sine waves of the same frequency, "phase difference" means that the two waves do not reach their maximum or minimum values simultaneously.

D. See Question 3.310.

Q. 6.51. What method is used to obtain more than one value of voltage from a fixed-voltage direct-current source?

A. A resistance-type voltage divider may be used.

D. Another method of obtaining more than one voltage value is to connect voltage regulator tubes of suitable values in series, and tap off the desired output voltage from each tube. The current which can be drawn from such a system is limited.

Q. 6.52. See Question 3.287.

Q. 6.53. See Question 3.92.

Q. 6.54. See Question 3.93.

Q. 6.55. See Question 3.91.

Q. 6.56. See Question 3.94.

Q. 6.57. See Question 3.50.

Q. 6.58. See Question 3.47.

Q. 6.59. See Question 3.49.

Q. 6.60. See Question 3.44.

Q. 6.61. See Question 3.43.

Q. 6.62. See Question 3.45.

Q. 6.63. If two 10-watt 500-ohm resistors are connected in series, what is the total power-dissipation capability?

A. The total power dissipation capability is 20 watts or the sum of the two resistor ratings.

D. See Question 3.50.

Q. 6.64. If two 10-watt 500-ohm resistors are connected in parallel, what is the total power-dissipation capability?

A. The total power dissipation capability is 20 watts or the sum of the two individual resistor ratings.

D. See Question 3.50.

Q. 6.65. What is the maximum current-carrying capacity of a resistor marked "5,000 ohms, 2000 watts"?

A. The maximum capacity is .2 ampere.

D. See Question 3.47.

Q. 6.66. See Question 3.300.

Q. 6.67. Two resistors are connected in series. The current through these resistors is 3 amperes. Resistance 1 has a vaue of 50 ohms; resistance 2 has a voltage drop of 50 volts across its terminals. What is the total impressed emf?

A. The total impressed emf is 200 volts.

D. The total impressed emf is equal to the sum of all the individual series voltage drops. Since one voltage drop is already given as 50 volts, it is only necessary to find the other voltage drop, or $E = I \times R = 3 \times 50 = 150$ volts. $E_A = 150 + 50 = 200$ *volts.*

Q. 6.68. Two resistors of 18 and 15 ohms are connected in parallel; in series with this combination is connected a 36-ohm resistor; in parallel with this total combination is connected a 22-ohm resistor. The total current flowing through the combination is 5 amperes. What is the current value in the 15-ohm resistor?

A. The current in the 15-ohm resistor is 0.908 ampere.

D. Step 1: Find the parallel equivalent of the 15-ohm and 18-ohm resistors.

$$R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{15 \times 18}{15 + 18} = \frac{270}{33} = 8.18 \textit{ ohms.}$$

Step 2: Add the parallel equivalent of 8.18 to the series resistance of 36 ohms, making 44.18 ohms. Find the parallel equivalent of 44.18 ohms and 22 ohms.

$$R_T = \frac{44.18 \times 22}{44.18 + 22} = \frac{971.96}{66.18} = 14.69 \textit{ ohms.}$$

Step 3: Find the voltage across the entire network

$$E_A = I_T \times R_T = 5 \times 14.69 = 73.4 \textit{ volts.}$$

Step 4: Find the current through the 18–15–36-ohm branch

$$I = \frac{E}{R} = \frac{73.4}{44.18} = 1.659 \textit{ amperes.}$$

Step 5: Find the current through the 15-ohm resistor

$$I_{15} = I \times \frac{18}{15 + 18} = 1.659 \times \frac{18}{33} = 0.908 \textit{ ampere.}$$

Q. 6.69. A circuit is passing a current of 3 amperes. The internal resistance of the source is 2 ohms. The total external resistance is 50 ohms. What is the terminal voltage of the source?

A. The terminal voltage of the source is 150 volts.

D. The terminal voltage of the source is equal to the voltage drop across the external resistance or $3 \times 50 = 150$ *volts.*

Q. 6.70. A 10,000-ohm 100-watt resistor, a 40,000-ohm 50-watt resistor, and a 5,000-ohm 10-watt resistor are connected in parallel. What is the maximum value of total current through this combination which will not exceed the wattage rating of any of the resistors?

A. The maximum value of total current is .07269 ampere.

D. Since, for any resistor, $E_R = \sqrt{R \times W}$, the voltage ratings are, respectively, $\sqrt{10{,}000 \times 100}$, $\sqrt{40{,}000 \times 50}$, and $\sqrt{5{,}000 \times 10}$. Since they are in parallel, and all have the same applied voltage, the

5,000-ohm resistor, having the lowest voltage rating, determines the voltage for the combination, which is $\sqrt{50,000} = 223.6$ volts. The currents are, respectively, $\frac{223.6}{10,000}$, $\frac{223.6}{40,000}$, and $\frac{223.6}{5,000}$. These are added, for total current: $\frac{894.4}{40,000} + \frac{223.6}{40,000} + \frac{1788.8}{40,000} + \frac{2906.8}{40,000} = 72.69$ *ma.*

Q. 6.71. A certain keying relay coil has a resistance of 500 ohms and is designed to operate on 125 milliamperes. If the relay is to operate from a 110-volt d-c source, what value of resistance should be connected in series with the relay coil?

A. The value of series resistance should be 380 ohms.

D. *Step 1*: Find the normal voltage across the relay coil.

$$E = I \times R = 0.125 \times 500 = 62.5 \text{ volts.}$$

Step 2: Subtract this coil voltage from the line voltage, to find the necessary drop across the series resistor.

$$110 - 62.5 = 47.5 \text{ volts.}$$

Step 3: Find the value of series resistance to give this drop with the specified current.

$R = E/I = 47.5/0.125 = 380$ *ohms*, which is the required value.

Q. 6.72. If the power input to a radio receiver is 75 watts how many kilowatt-hours does the receiver consume in 24 hours of continuous operation?

A. The receiver will consume 1.8 kilowatt-hours.

D. The total power consumption is equal to 75 watts times 24 hours or 1800 watt-hours (1.8 kilowatt-hours).

Q. 6.73. What is the total reactance when two capacitances of equal value are connected in series?

A. The total reactance is equal to the sum of the two individual reactances measured in ohms.

D. See Questions 3.16, 3.51, and 3.313.

Q. 6.74. See Question 3.54.

Q. 6.75. See Question 3.56.

Q. 6.76. See Question 3.51.

Q. 6.77. See Question 3.53.

Q. 6.78. See Question 3.52.

Q. 6.79. See Question 3.55.

Q. 6.80. See Question 3.58.

Q. 6.81. See Question 3.60.

Q. 6.82. See Question 3.61.

Q. 6.83. See Question 3.63.

Q. 6.84. See Question 3.67.

Q. 6.85. See Question 3.262.

Q. 6.86. See Question 3.253.

Q. 6.87. See Question 3.302.

Q. 6.88. See Question 3.305.

Q. 6.89. What is the total impedance of a capacitor and inductor having equal values of reactance, when connected in parallel?

A. The total parallel impedance is resistive and infinite, with zero total reactance.

D. See Question 3.323.

Q. 6.90. What is the total inductance of two coils connected in parallel but without any mutual coupling?

A. The total inductance is equal to the product of the two inductances divided by their sum.

D. The formula for determining the total inductance of two parallel inductances with zero mutual coupling is $L_T = \frac{L_1 \times L_2}{L_1 + L_2}$.

Q. 6.91. What is the total reactance of a series alternating-current circuit containing no resistance, and an equal value of inductive and capacitive reactance?

A. The total reactance is zero at the resonant frequency.

D. See Question 3.16.

Q. 6.92. What is the total inductance of two coils, connected in series, but without any mutual coupling?

A. The total inductance is equal to the sum of the individual inductances.

D. See Questions 4.08 and 4.10.

Q. 6.93. See Question 3.306.

Q. 6.94. A series inductance, acting alone in an alternating-current circuit, has what properties?

A. A series inductance acting alone in an alternating current circuit has the property of causing the circuit current to lag the applied voltage by 90 degrees, and limits the value of current, which is proportional to the voltage and inversely proportional to the frequency and inductance.

D. The current in an inductance causes a magnetic field to be set up around the inductance. This acts in such a way as to produce a maximum value of counter-emf when the current is changing at its maximum rate, which is when it is passing through zero. The counter-emf is minimum when the current is changing at its slowest rate which is when the current is at a maximum value. Due to the above properties the maximum circuit current will lag the maximum applied voltage by 90°. See also Question 3.312 for comparison.

Q. 6.95. What is meant by "shock" excitation of a circuit?

A. Shock excitation is the result of a voltage being momentarily introduced, most commonly into an L-C circuit. Either the capacitor may be charged or a voltage induced in the inductor.

D. The number of oscillations resulting from each shock-excitation will depend upon the Q of the circuit. In order to produce oscillations, the shock-excitation voltage (or current) must be of such characteristic wave shape that it contains frequencies equal to or greater than the natural resonant frequency of the tuned circuit. Once oscillations are produced, they will die out exponentially. (See Question 6.98.)

Q. 6.96. See Question 3.296.

Q. 6.97. What may be the effects of shielding applied to radio-frequency inductances?

A. Shielding of a radio-frequency inductance increases the losses of the inductance, lowers the inductance value and the Q and increases the coil capacity to the shield.

D. For a complete discussion of r-f shielding see Questions 3.348 and 4.186.

Q. 6.98. What is meant by the "flywheel" effect of a tank circuit?

A. The "flywheel" effect of a tank circuit refers to the tendency of a tank circuit to keep oscillating for a time after the excitation energy has been removed.

D. The length of time a tank circuit will continue to oscillate in "flywheel" fashion is a direct function of the Q of the tank circuit. The higher the Q (low losses), the longer the tank will oscillate, as explained in Question 3.235. Such oscillations are damped and die out so that the ratio of successive current (or voltage) maxima is $\epsilon = \frac{RT}{2L} = \epsilon \frac{R}{2Lf}$. The quantity $\frac{R}{2Lf}$ is called the logarithmic decrement of the circuit. The tank circuit will continue to oscillate until all of the stored energy is dissipated in heat in its resistance.

Q. 6.99. Define "power factor."

A. "Power factor" is the ratio between the resistance and the impedance in a circuit. It is also the ratio between the true power and the apparent power of a circuit.

D. See Question 3.34.

Q. 6.100. Define "parasitic oscillations."

A. Parasitic oscillations are defined as "either high or low frequency oscillations occurring in circuits other than the original tank circuits, and at frequencies other than the desired output frequencies."

D. See Question 3.372.

Q. 6.101. What is the effect of parasitic oscillations?

A. The following may result from parasitic oscillations:

1. Generation of spurious frequencies (carrier).
2. Generation of spurious sideband frequencies during modulation.
3. Distortion of the modulated wave.
4. Overheating of the amplifier tube.
5. Reduced efficiency of the amplifier tube at the desired frequency or frequencies.
6. Change of bias (grid leak).

D. See Questions 3.370 and 6.100.

Q. 6.102. See Question 3.220.

Q. 6.103. What changes in circuit constants will double the resonant frequency of a resonant circuit?

A. The following changes can be made:

1. Making C one-fourth of its original value, or
2. Making L one-fourth of its original value, or
3. Halving both L and C, or
4. Decreasing the values of both L and C in any proportion so that their product is made to be one-fourth of its original value.

D. The formula for determining the series resonant frequency of a resonant circuit is $f = \dfrac{1}{2\pi\sqrt{LC}}$. Since the product of $L \times C$ is under the square root sign, this value must be made one-fourth of its original magnitude to double the frequency.

Q. 6.104. How may the Q of a parallel resonant circuit be increased?

A. The Q of a parallel resonant circuit is expressed by the ratio, $\dfrac{\text{energy stored in one cycle}}{\text{energy dissipated in one cycle}}$. In order to increase the Q, it is necessary to decrease the energy dissipation from the circuit. This may be done by the following:

1. Using a condenser with very low losses. (Usually vacuum, air, or mica dielectric).
2. Using coil and condenser supports made of special low loss materials.
3. Using coil forms made of low loss materials.
4. Using low loss core material and coil wire.
5. Reducing coupling to the resonant circuit.

D. See also Questions 4.168 and 6.585.

Q. 6.105. If a parallel circuit, resonant at 1,000 kilocycles, has its values of inductance halved and capacitance doubled, what will be the resultant resonant frequency?

A. The resonant frequency will be the same or 1,000 kilocycles.

D. If both L and C are varied so that their product remains constant, the frequency will remain unchanged. (See also Question 6.103.)

Q. 6.106. What is the resonant frequency of a tuned circuit consisting of a condenser of 500 micromicrofarads, a tuning coil of 150 microhenrys and a resistance of 10 ohms?

A. The resonant frequency is 581 kilocycles.

D. The resonant frequency may be found from the formula,

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(150\times10^{-6})\times(500\times10^{-17})}}$$

$$= \frac{1}{6.28\sqrt{7.5\times10^{-14}}} = \frac{1}{6.28\times2.74\times10^{-7}}$$

$$= 581{,}000 \textit{ cycles} \text{ which is } 581 \text{ kilocycles.}$$

Q. 6.107. See Question 3.301.

Q. 6.108. Define "voltage regulation."

A. See Question 3.403.

Q. 6.109. List four principles by which an emf may be generated by sound waves.

A. Four principles are:

1. Electrostatic (Requires d-c supply at rather high voltage).
2. Piezo-electric.
3. Dynamic.
4. Resistance change. (Requires d-c supply.)

D. See Question 3.04.

Q. 6.110. How can low power factor in an electrical power circuit be corrected?

A. Low power factor is due to a large phase angle between the voltage and current in a circuit and can be corrected by adding either an inductance or capacitance in the circuit to correct a leading or lagging phase angle. (Inductance is used to correct a leading angle, and capacitance is used to correct a lagging phase angle).

D. See Questions 3.34 and 3.311.

Q. 6.111. Define the following terms: "hysteresis," "permeability," "eddy currents."

A. *Magnetic hysteresis* is a property of magnetic material by virtue of which the magnetic flux density corresponding to a given magnetizing force (gilberts, ampere-turns) depends on the previous conditions of magnetization. The effect of hysteresis, when the field is alternating, is an energy loss appearing as heat in the material.

Permeability is the ratio of magnetic flux density in a substance to the magnetizing force which produces it.

Eddy currents are those currents which are induced in the body of a conducting mass by a variation of magnetic flux.

D. See Questions 3.22 and 4.12.

Q. 6.112. What is meant by the "time constant" of certain electrical circuits containing resistance and capacitance?

A. See Question 4.170.

Q. 6.113. What is the reactance of a 0.01-microfarad condenser at a frequency of 300 cycles? What is the reactance of a 2-henry choke coil at the same frequency?

A. The reactance of a 0.01-microfarad condenser at a frequency of 300 cycles is 5,300 ohms. The reactance of a 2-henry choke coil at the same frequency is 37,680 ohms.

D. The reactance of the condenser is found from the formula,

$$X_C = \frac{1}{2\pi fC} = \frac{.159}{3000 \times .01 \times 10^{-6}} = \frac{.159 \times 10^5}{3} = 5{,}300 \text{ ohms.}$$

The reactance of the inductor is found from the formula,

$$X_L = 2\pi fL = 6.28 \times 3{,}000 \times 2 = 37{,}680 \text{ ohms.}$$

Q. 6.114. Assume an inductance of 5 henrys in parallel with a capacitance of 1 microfarad. If there is no resistance in either leg of this circuit, what is the equivalent impedance of the parallel network at resonance?

A. The equivalent impedance of the parallel network at resonance is infinite.

D. See Question 3.323.

Q. 6.115. What is the total impedance of a series a-c circuit having a resistance of 3 ohms, an inductive reactance of 7 ohms, and zero capacitive reactance?

A. The total impedance is 7.62 ohms.

D. The total impedance of a series alternating circuit may be found from the formula:

$$Z_T = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(3)^2 + (7)^2} = \sqrt{58} = 7.62$$
ohms.

Q. 6.116. What is the total impedance of a series alternating-current circuit having an inductive reactance of 14 ohms, a resistance of 6 ohms, and a capacitive reactance of 6 ohms?

A. The total impedance is 10 ohms.

D. The total impedance of a series alternating circuit may be found from the formula:

$$Z_T = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{6^2 + (14 - 6)^2} = \sqrt{36 + 64} = \sqrt{100} = 10 \text{ ohms.}$$

Q. 6.117. If a 220 volt, 60 cycle, single phase line delivers 100 watts at 80 per cent power factor to a load what is the phase angle between the line current and the line voltage? How much current flows in the line?

A. The phase angle is 37°. The current in the line is 0.568 amperes.

D. The power factor is equal to the cosine of the phase angle, and, therefore, the phase angle is that angle whose cosine is .8 (80%). This angle is equal to 37°. 100 watts is delivered to a load. This is the *true power*. Since the power factor equals 80% or .8, the *apparent power* is equal to:

$$\frac{True\ power}{Power\ factor} = \frac{100}{.8} = 125 \text{ volt-amperes.}$$

$$\text{The line current, } I = \frac{(VA)}{E} = \frac{125}{220} = 0.568 \textit{ amperes.}$$

(See also Questions 3.34 and 3.311.)

Q. 6.118. List at least two essentials for making a good soldered connection.

A. Two essentials of good soldering are bright, clean parts and plenty of heat with the minimum amount of solder used, and a good non-corrosive flux, preferably rosin.

Q. 6.119. See Question 3.233.

Q. 6.120. What is the ratio of peak to average values of a sine wave? Peak to effective voltage values of a sine wave?

A. The ratio of peak to average values of a sine wave is 1.57 to 1 or 1 to 0.636.

The ratio of peak to effective voltage values of a sine wave is 1.414 to 1 or 1 to 0.707.

Q. 6.121. Draw diagrams showing various ways by which three power transformers can be connected for operation on a three phase circuit. Show how only two transformers can be connected for full operation on a three phase circuit.

A. See the figures on page 334.

Q. 6.122. See Question 3.62.

Q. 6.123. See Question 3.22.

Q. 6.124. What is the meaning of "residual magnetism"?

A. "Residual magnetism" is the magnetic force which remains in a substance after the original magnetizing force has been removed.

D. See Question 3.28.

Q. 6.125. See Question 3.21.

Q. 6.126. See Question 3.59.

Q. 6.127. Name at least five pieces of radio equipment which make use of electromagnets.

A. The following pieces of radio equipment use electromagnets.

1. Loud speakers.

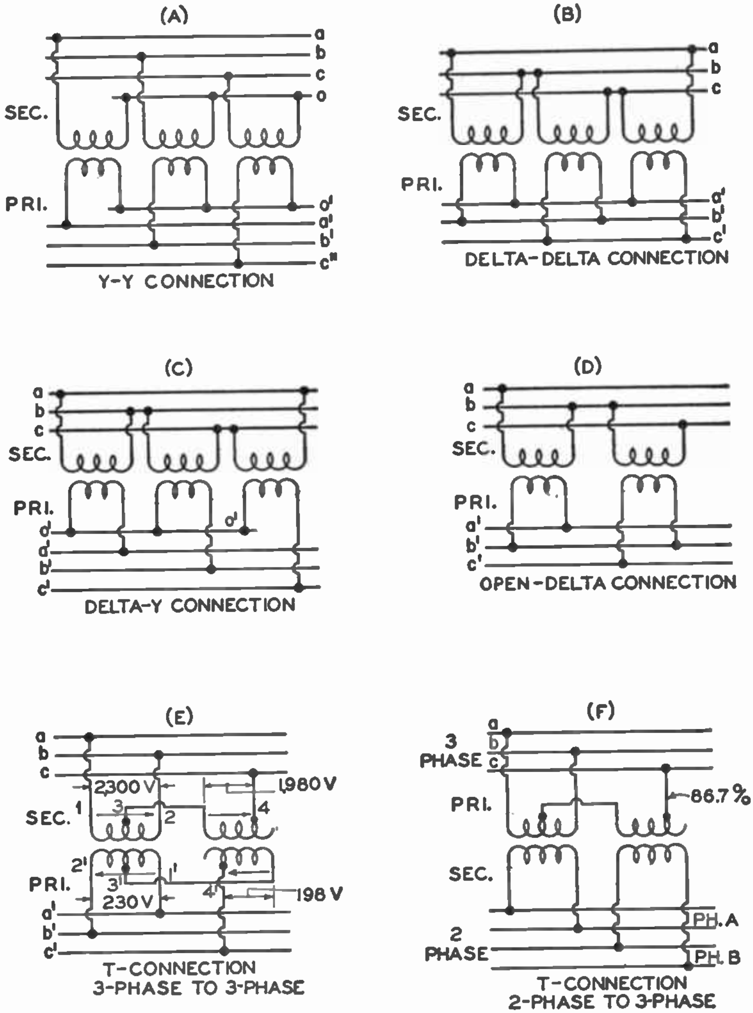


Fig. 6.121. Transformer connections, three-phase circuits.

2. Head phones.
3. Meters.
4. Vibrators.
5. Relays.
6. Motors and generators.

D. Electromagnets differ from permanent magnets in that a constant electric current is required to maintain the strength of the electromagnet.

Q. 6.128. See Question 3.19.

Q. 6.129. See Question 3.176.

Q. 6.130. See Question 3.99.

Q. 6.131. See Question 3.100.

Q. 6.132. Describe the physical structures of the triode, tetrode, and pentode on a comparative basis.

A. 1. The triode is a 3-element tube containing a filament or indirectly heated cathode, a spirally wound wire grid surrounding but insulated from the cathode, and a metallic or carbon plate which completely surrounds but is insulated from the grid and cathode.

2. The tetrode has 4 elements; the additional one is called a screen grid, and is located between the plate and control grid. It is likewise a spirally wound wire grid.

3. The pentode has 5 elements. The same 4 as the tetrode plus another spirally wound wire grid which is located between the screen grid and the plate. This addition is called the suppressor grid.

D. See Questions 3.97, 3.99, 3.100, and 6.139.

Q. 6.133. See Question 3.97.

Q. 6.134. Define the following terms in reference to vacuum tubes: amplification factor, plate resistance, mutual conductance, and maximum inverse plate voltage.

A. For definitions of amplification factor, plate resistance, and mutual conductance (transconductance), see Question 4.184. Maximum inverse plate voltage is the maximum negative anode voltage with respect to the cathode. It is equal to the d-c voltage at the input to the filter plus the peak a-c voltage applied during the non-conducting portion of the cycle of operation of the tube. This is equivalent to the determination of value given in Question 4.99.

Q. 6.135. What is the primary purpose of the control grid of a triode?

A. The primary purpose of the control grid is to provide a means of obtaining amplification in a triode. A relatively small voltage applied to the control grid is able to control large currents due to its close spacing from the cathode relative to the plate spacing.

D. See Question 3.276.

Q. 6.136. What is the primary purpose of the screen grid of a tetrode?

A. The primary purpose in r-f amplifiers is to reduce the interelectrode capacitance between plate and grid and thus reduce the necessity for neutralization.

D. See Questions 3.118 and 3.454.

Q. 6.137. What is the primary purpose of the suppressor grid of a pentode?

A. The suppressor grid being highly negative with respect to the plate returns secondary emission to the plate and increases the permissible gain and the efficiency of the tube.

D. See Questions 3.100 and 3.119.

Q. 6.138. See Question 3.282.

Q. 6.139. Describe the construction of a beam power vacuum tube. In what types of circuits do these tubes find application?

A. A beam power tube usually consists of a cathode, control grid, screen grid, plate, and, in addition two "beam forming" plates on either side of the cathode. These plates are operated at cathode potential. The control grid and screen grid wires are aligned with each other so that the electron stream flows through them in "sheets." This reduces the screen grid current and thus increases the tube efficiency. These "sheets" diverge beyond the screen grid and cross the paths of other sheets thus forming an area of high electron density just short of the plate. This dense negatively charged area serves the same purpose as a suppressor grid, but permits more linear tube operation, with a reduction of third harmonic distortion. The "beam forming" plates confine the electrons to beams and also serve to prevent any stray secondary-emission electrons from approaching the screen grid from the sides of the tube.

The variations in plate current with changes in plate voltage in a beam power tube are very similar to those of a conventional pentode, the main difference being that in circuits where there is considerable plate current flow, the plate current in a beam power tube will be relatively independent of plate voltage down to a lower value of plate voltage than the plate current in a pentode. Thus, the effective operating range of a beam power tube is somewhat greater than that of an equivalent or similar pentode. By concentrating the electrons in smooth beams or sheets (as contrasted with the uneven structure of a suppressor grid) the suppressor action of the space charge formed in a beam power tube provides superior action to that offered by a suppressor grid of the conventional type.

The beam power tube is commonly used as an audio amplifier in the output and power stages of circuits having low- to moderately high-output ratings. To a somewhat lesser extent, the beam power tube is also used as a radio-frequency power amplifier.

D. See also Question 3.97.

Q. 6.140. See Question 3.103.

Q. 6.141. See Question 3.102.

Q. 6.142. See Question 3.106.

Q. 6.143. See Question 3.107.

Q. 6.144. See Question 3.136.

Q. 6.145. See Question 3.122.

Q. 6.146. See Question 3.276.

Q. 6.147. See Question 3.278.

Q. 6.148. See Question 3.281.

Q. 6.149. See Question 3.135.

Q. 6.150. See Question 3.277.

Q. 6.151. See Question 3.275.

Q. 6.152. See Question 3.274.

Q. 6.153. What types of vacuum-tube emitting surfaces respond to reactivation?

A. Ordinarily only thoriated tungsten filaments are reactivated.

D. See Question 3.477.

Q. 6.154. Describe how reactivation may be accomplished.

A. For answer and discussion see Question 3.486.

Q. 6.155. Is a tungsten filament operated at a higher or lower temperature than a thoriated filament? Why?

A. The tungsten filament is operated at a higher temperature.

D. A *thoriated* tungsten filament is much more efficient than a plain tungsten filament because it provides an emission at 1900°K which is greatly in excess of that provided by a pure tungsten filament operating at 2500°K.

Q. 6.156. What is indicated when a blue glow is noticed within a vacuum-tube envelope?

A. This indicates the presence of gas within the tube.

D. See Questions 3.101 and 3.414.

Q. 6.157. Why should the cathode of an indirectly heated type of vacuum tube be maintained at nearly the same potential as the heater circuit?

A. To reduce hum pickup into the cathode and to prevent breakdown of the insulation between heater and cathode.

D. If the potential difference between the heater and cathode is relatively large there is a strong possibility of hum voltages or other stray pickup being introduced into the cathode circuit and causing interference in the amplifier circuit. There is also the possibility that the insulation between heater and cathode may break down or become partially conductive causing a heater-to-cathode short. This might destroy the bias and introduce strong hum voltages into the amplifier.

Q. 6.158. See Question 3.126.

Q. 6.159. See Question 3.124.

Q. 6.160. See Question 3.125.

Q. 6.161. See Question 3.114.

Q. 6.162. See Question 3.115.

Q. 6.163. See Question 3.116.

Q. 6.164. See Question 3.113.

Q. 6.165. See Question 3.112.

Q. 6.166. See Question 3.111.

Q. 6.167. See Question 3.110.

Q. 6.168. See Question 3.117.

Q. 6.169. See Question 3.118.

Q. 6.170. See Question 3.119.

Q. 6.171. See Question 3.104.

Q. 6.172. See Question 3.105.

Q. 6.173. See Question 3.96.

Q. 6.174. See Question 3.137.

Q. 6.175. See Question 3.141.

Q. 6.176. See Question 3.280.

Q. 6.177. See Question 3.279.

Q. 6.178. What are cavity resonators and in what type of radio circuits do they find application?

A. See Question 3.502 for description and discussion. Cavity resonators find application mainly in microwave equipment (1000 megacycles and up) as resonant tank circuits of high Q.

Q. 6.179. What determines the operating frequency of a magnetron oscillator? A klystron oscillator?

A. The operating frequency of a magnetron oscillator is mainly determined by the resonant frequency of its cavity resonators, and to some extent by its operating potentials and magnetic field.

The operating frequency of a klystron oscillator (reflex) is mainly determined by the resonant frequency of its cavity resonators, and may be varied slightly by changing the d-c voltage on its repeller plates.

D. See Questions 8.43 and 8.48.

Q. 6.180. In what radio circuits do klystron and magnetron oscillators find application?

A. See Questions 8.43 and 8.48.

Q. 6.181. See Question 3.130.

Q. 6.182. See Question 3.128.

Q. 6.183. What effect does an incoming signal have upon the plate current of a triode detector of the grid-leak type?

A. For any fixed value of modulated carrier wave strength, the instantaneous values of plate current in a grid-leak detector vary in accordance with the modulation component of the carrier wave. If the carrier is unmodulated, the plate current will be unvarying and will be in inverse proportion to the strength of the carrier wave. The average value of plate current varies in inverse proportion to the strength of the modulated carrier wave applied to the grid circuit.

D. See Questions 3.128 and 3.132.

Q. 6.184. See Question 3.129.

Q. 6.185. See Question 3.132.

Q. 6.186. See Question 3.121.

Q. 6.187. See Question 3.123.

Q. 6.188. See Question 3.127.

Q. 6.189. See Question 3.143.

Q. 6.190. See Question 3.142.

Q. 6.191. A triode transmitting tube, operating with a plate voltage of 1,250 volts, has a filament voltage of 10, filament current of 3.25 amperes, and a plate current of 150 milliamperes. The amplification factor is 25. What value of control grid bias must be used for operation as a class C stage?

A. The control grid bias should be approximately —125 volts.

D. In order to determine the value of bias necessary, an assumption must be made regarding the desired operating characteristics of the amplifier. It is assumed in this case that the value of bias shall be equal to 2½ times the cut-off bias. From this assumption the bias may be calculated as follows:

$$E_c = \frac{-2.5\, E_b}{\mu} = \frac{-2.5 \times 1250}{25} = -125 \textit{ volts}$$

Q. 6.192. What currents will be indicated by a milliammeter connected between the center tap of the filament transformer of a tetrode, and negative high voltage (ground)?

A. The reading on a milliammeter connected in this manner will be equal to the combined plate and screen-grid currents.

D. If the amplifier is operated as a class B or C amplifier in which grid current is drawn, the reading of the milliammeter will also include the effect of the grid current. In other words, it measures the total filament emission current.

Q. 6.193. What is a dynatron oscillator? Explain its principle of operation.

A. A dynatron oscillator is a tuned circuit oscillator which depends upon the negative resistance characteristic of a tetrode tube for its operation.

D. See Question 3.428, also Questions 3.412 and 3.426.

Q. 6.194. What is an electron-coupled oscillator? Explain its principle of operation.

A. See Questions 3.76 and 3.327.

Q. 6.195. Name four materials which can be used as crystal detectors.

A. The following materials may be used as crystal detectors:

1. Silicon.
2. Carborundum.
3. Galena.
4. Iron pyrites.

D. When galena is used, a fine pointed wire resting lightly on the crystal is used to provide contact. Silicon and iron pyrites may be utilized with higher pressure contacts and so are more stable, however, these latter types are less efficient as a rectifier for small signals. Carborundum requires still more pressure and is correspondingly less sensitive. Crystals are used at the present time in emergency receivers and in ultra-high-frequency equipment.

Q. 6.196. See Question 3.131.

Q. 6.197. See Questions 3.139 and 3.138.

Q. 6.198. See Question 3.101.

Q. 6.199. What is the function of a quartz crystal in a radio transmitter?

A. The function of a quartz crystal in a radio transmitter is to provide a high degree of master oscillator frequency stability.

D. See Question 3.419.

Q. 6.200. Name four advantages of crystal control over tuned circuit oscillators.

A. Four advantages are:

1. Very high Q in relatively small dimensions.
2. Compact in size.
3. Excellent frequency stability.

D. See Question 3.423.

Q. 6.201. Why is the temperature of a quartz crystal usually maintained constant? What does the expression "a low temperature coefficient crystal" mean?

A. The temperature of a quartz crystal is maintained constant in order to maintain a fixed frequency output from the crystal.

"A low temperature coefficient" means that the crystal will undergo very small changes in its operating frequency with relatively large temperature variations.

D. See Questions 3.421 and 3.418.

Q. 6.202. Why is a separate source of power sometimes desirable for crystal-oscillator units in a transmitter?

A. To prevent "dynamic instability" of the crystal oscillator.

D. See Question 3.422.

Q. 6.203. What does the expression "the temperature coefficient of an X-cut crystal is negative" mean?

A. The expression means that the operating frequency of the crystal will decrease as the temperature increases, and increase as the temperature decreases.

D. See Question 3.417.

Q. 6.204. What will be the effect of applying a direct-current potential to the opposite plane surfaces of a quartz crystal?

A. The crystal plate will undergo a physical distortion or deformation.

D. See Question 3.416.

Q. 6.205. What does the expression "the temperature coefficient of a Y-cut crystal is positive" mean?

A. The expression means that the operating frequency of the crystal will increase as the temperature increases, and decrease as the temperature decreases. Such a characteristic is typical of a *Y*-cut crystal.

D. See Question 3.414.

Q. 6.206. What is a thermocouple?

A. A thermocouple consists of two dissimilar metals such as constantan and a platinum alloy which are joined together and produce a current between them when their junction is subjected to heat. Thermocouples are commonly used in r-f ammeters.

D. See Question 3.183.

Q. 6.207. What are wave guides, and in what type radio circuits do they find application?

A. For description and discussion, see Question 3.502. Wave guides find application as transmission lines at microwave frequencies (1000 megacycles and up).

Q. 6.208. See Question 3.528.

Q. 6.209. See Question 3.293.

Q. 6.210. See Question 3.95.

Q. 6.211. See Question 3.15.

Q. 6.212. See Question 3.16.

Q. 6.213. See Question 3.17.

Q. 6.214. Draw a circuit diagram showing the principle of operation of a telegraph keying relay.

A. See Question 6.479.

Q. 6.215. What is meant by "self-wiping" contacts as used in connection with relays?

A. "Self-wiping" contacts are contacts which slide together on opening and closing.

D. The wiping action serves to keep the contact surfaces clean and shiny. The other type of contact surfaces merely butt together and so are not self-cleaning.

Q. 6.216. Why are permanent magnets used in head telephones? In direct-current meters?

A. Permanent magnets are used in head telephones in order to place the diaphragms under tension so that the sensitivity of the telephones will be increased. The use of permanent magnets also improves the frequency response and prevents production of second harmonics in the telephones. Permanent magnets are used in d-c meters to provide a magnetic field of constant flux density. Thus the torque in the moving coil is proportional to the current through the coil and the accuracy of the meter is improved.

D. See Questions 3.215 and 3.184.

Q. 6.217. What emergency repairs may be made to an inductance coil having burned or charred insulation?

A. If the insulation has deteriorated to the point where turns are short circuited, it is generally impractical to attempt any repair short of rewinding the inductance coil with good wire.

D. If shorted turns do not exist in the inductance the inductance may be temporarily repaired by coating it liberally with low-loss insulating varnish or collodion. The operating potentials should be reduced if possible.

Q. 6.218. Name four indications of a defective vacuum tube in a transmitter.

A. Some possible indications are:

1. "Gas glow" within tube.
2. Excessive plate color due to overheating.
3. No light from filament.
4. Insufficient or excessive plate current.

5. Reduced output.
6. Possible internal arcing.
7. Fluctuating plate or grid current, or both.

D. See also Question 3.377.

Q. 6.219. What factors determine the breakdown voltage rating of a condenser?

A. The breakdown voltage rating of a condenser is determined primarily by the characteristics of the dielectric material; that is, the type of dielectric used, and its thickness.

D. The most common types of dielectrics used are mica, paper, ceramics, and electrolytic films. Mica dielectrics have low power factor, high breakdown voltage ratings and very low losses. Paper dielectrics are impregnated with oil or wax, have reasonably high power factor, and moderate breakdown voltage ratings. Ceramic dielectrics are particularly useful in obtaining controlled temperature coefficients, have a high dielectric constant, low power factor, and high breakdown voltage. The breakdown voltage of an electrolytic film depends upon the voltage which was used to form it. (See Question 6.360.)

Q. 6.220. What cleaning agents may be used to clean the surfaces of a quartz crystal? Is such cleaning ever necessary? Explain.

A. The crystal surfaces must be free of dirt or grease in order to operate properly. The faces of the crystal should not be touched with the fingers, and may be cleaned with soap and water or carbon tetrachloride.

D. See Question 3.425.

Q. 6.221. See Question 3.98.

Q. 6.222. See Question 3.286.

Q. 6.223. What are some uses of a low-pass filter network?

A. The most common use of a "low-pass" filter network is as a ripple filter in power supplies.

D. See Question 4.96. Other uses for low-pass filters are:

1. Line noise filters.
2. Harmonic suppression filters in antenna systems.
3. Tone control systems.
4. Cross-over networks.
5. Output filter of detector circuits.

Q. 6.224. What is a "swinging choke"?

A. A "swinging choke" is a special type of power supply filter choke coil whose inductance decreases with increasing values of direct current, and increases with decreasing values of direct current, within specified limits. The air gap of the core of such a choke is extremely small to permit some degree of core saturation with relatively large values of direct current.

D. See Question 3.405.

Q. 6.225. See Question 3.228.

Q. 6.226. See Question 3.229.

Q. 6.227. See Question 3.231.

Q. 6.228. See Question 3.248.

Q. 6.229. See Question 3.249.

Q. 6.230. What are the advantages of the single-button carbon microphone?

A. The advantages of the single-button carbon microphone over other conventional types are, its high output voltage and sensitivity, and its low cost.

D. The single-button carbon microphone has an advantage over the double-button carbon microphone, in that it is not necessary to achieve a balance of button currents. For disadvantages see Question 4.38. (See also Questions 3.214, 3.216, and 3.338.)

Q. 6.231. See Question 3.216.

Q. 6.232. Draw a circuit diagram showing how a microphone can be connected to an audio amplifier.

A. See Question 3.329.

Q. 6.233. See Question 3.215.

Q. 6.234. In the operation of a class B audio amplifier stage, should the plate current fluctuate or should it remain at a steady value?

A. The average plate current of a class B amplifier varies normally during operation, where the input signal is not a constant amplitude, sinusoidal voltage. (It practically never is, except possibly during tests.)

D. With no input signal applied to the class B amplifier grids, the plate current will be extremely small. (This is an advantage in portable or high power equipment where conservation of the power supply is essential.) The plate current will vary in direct proportion to the amplitude of the grid signal, and since an audio wave contains many harmonic frequencies, the shape and amplitude of the modulating signal is constantly changing. This in turn causes consequent variations of plate current. If the modulator were operated class A, the plate current would remain substantially constant, with or without excitation.

Q. 6.235. What turns ratio should a transformer have which is to be used to match a source impedance of 500 ohms to a load of 10 ohms?

A. The turns ratio should be approximately 7.1 to 1.

D. The approximate turns ratio may be calculated from the formula:

$$\frac{N_p}{N_s}=\sqrt{\frac{Z_p}{Z_s}}=\sqrt{\frac{500}{10}}=\sqrt{50}=7.1.$$

Q. 6.236. What types of microphones have a high impedance output?

A. The crystal and condenser types of microphones have a high impedance output.

D. Any type of microphone may appear to have an *effective* high impedance output if a suitable output transformer is connected to the microphone. (See also Questions 3.329 and 3.337.)

Q. 6.237. See Question 3.217.

Q. 6.238. Why do headphone receivers used in radio communication usually have high impedance windings?

A. High reactance head telephones are more satisfactory because they can usually be operated without the necessity of an impedance matching transformer.

D. See Question 3.213.

Q. 6.239. What is the purpose of a "choke" coil?

A. In general, the purpose of a choke coil is to offer a relatively high impedance to alternating currents and a low resistance to direct. currents.

D. See Questions 3.180, 3.400, and 3.488. Radio frequency choke coils (Question 3.357) are commonly used at frequencies near the natural resonant frequency of the choke coil. That there is a natural resonant frequency is due to a parallel resonant condition resulting from the fact that the inductance of the choke coil is effectively in parallel with its distributed capacitance. Thus, the choke coil may offer an impedance which is inductive, resistive or capacitive, depending upon whether the operating frequency is below, at, or above the natural resonant frequency of the choke. A choke coil may have several resonant frequencies, but this condition is usually eliminated by proper design, as the impedance characteristic resulting from such a situation would be generally unsatisfactory, with the choke becoming an r-f short circuit at certain frequencies.

The desirable characteristics of a radio frequency choke are:

(1) High a-c impedance over the desired operating frequency range.

(2) A high ratio of inductance to distributed capacitance..

(3) A single, natural resonant frequency over the desired operating frequency range.

(4) High Q (low r-f losses).

(5) Sufficient d-c current rating.

(6) Low d-c resistance.

Q. 6.240. See Question 3.79.

Q. 6.241. See Question 3.80.

Q. 6.242. See Question 3.81.

Q. 6.243. See Question 3.82.

Q. 6.244. See Question 3.78.

Q. 6.245. See Question 3.86.

Q. 6.246. Why is correct grid bias important in an audio-frequency amplifier?

A. In an audio-frequency amplifier, it is essential that the value of bias should be correct in order to minimize distortion of the output signal.

D. See Questions 3.109, 3.114, 3.122, and 3.135.

Q. 6.247. See Question 3.108.

Q. 6.248. See Question 3.109.

Q. 6.249. In a class A audio-frequency amplifier, what is the main advantage obtained through the use of two triodes in push-pull as compared to parallel operation?

A. Advantages of push-pull operation are:

1. Increased power output.
2. Cancellation of even harmonic distortion in the output.
3. Reduction of hum.
4. Reduction of regenerative feedback.
5. Elimination of d-c core saturation.
6. Elimination of cathode by-pass condenser.

D. See Question 3.460.

Q. 6.250. What is the maximum permissible rms value of audio voltage which can be applied to the grid of a class A audio amplifier which has a grid bias of 10 volts?

A. The maximum rms value is 7.07 volts, assuming sine-wave voltage.

D. In a class A amplifier the peak value of the alternating grid voltage should not exceed the value of bias (10 volts) in order that grid current shall not be drawn. Grid current is undesirable in a class A amplifier, because of the distortion which would be introduced. The peak value of the audio voltage must not exceed 10 volts and the rms value, therefore, equals $10 \times .707 = 7.07$ volts.

Q. 6.251. List four causes of distortion in a class A audio amplifier.

A. See Question 3.437.

Q. 6.252. Name four applications for vacuum tubes operating as class A audio amplifiers.

A. Several applications are:

1. Audio voltage amplifiers.
2. Audio power amplifiers.
3. Oscilloscope amplifiers.
4. Microphone pre-amplifiers.
5. Line amplifiers.
6. Modulators.
7. Phonograph amplifiers.

D. See Questions 3.106, 3.133, and 3.134.

Q. 6.253. Why is a push-pull audio-frequency amplifier preferable to a single-tube stage?

A. See Question 3.436, which compares push-pull with two tubes in parallel. In addition, when compared with a single-tube stage, the power output is doubled.

Q. 6.254. Draw a simple schematic diagram showing a method of "direct" coupling between two stages of an audio-frequency amplifier.

A. See Question 3.452.

Q. 6.255. What is the direct-current plate voltage of a resistance-coupled amplifier stage which has a plate-supply voltage of 260 volts, a plate current of 1 milliampere, and a plate-load resistance of 100,000 ohms?

A. The d-c plate voltage is 160 volts.

D. The d-c plate voltage (E_b) is the difference between the d-c plate supply voltage (E_{bb}) and the drop across the plate load resistance (R_L). The drop across the plate load resistance equals $100{,}000 \times .001 = 100$ volts. $E_b = E_{bb} - E_{R_L} = 260 - 100 = 160$ *volts.*

Q. 6.256. Why is it necessary to use two tubes in a class B audio amplifier?

A. Two tubes in push-pull must be used in order to prevent the excessive distortion which would result from the use of only one tube in class B. This is true because each tube conducts for only about 180° of each input cycle.

D. See Questions 3.107 and 3.336.

Q. 6.257. What would be the effect of leakage in the coupling condenser in a conventional resistance-coupled audio-frequency amplifier?

A. See Question 3.199.

Q. 6.258. Why is it not feasible to employ a vacuum tube operated class C as an audio amplifier, either singly or in push-pull?

A. See Question 3.137.

Q. 6.259. How may even harmonic energy be reduced in the output of an audio-frequency amplifier?

A. Even harmonic energy may be reduced in the output of an audio-frequency amplifier by operating the stage push-pull, and if a single tube amplifier by operating the stage only on the linear part of the tube's characteristic curve.

D. See Question 3.436.

Q. 6.260. What is the main advantage of a tuned audio-frequency amplifier in a receiver used for the reception of radiotelegraph signals?

A. The main advantage is a reduction in interference from unwanted signals.

D. In the reception of radiotelegraph signals a "beat-frequency" oscillator is usually provided which beats against the i-f carrier frequency in the second detector. As a result of the "beating" process an audible sum or difference frequency is produced which is fed to the audio amplifier. Assuming that the desired audio beat frequency is 1000 cycles, the audio amplifier may be equipped with a filter which will pass only 1000 cycles and reject all other frequencies. Thus any noises, or other beat frequencies which are outside of 1000 cycles, will not be accepted by the audio amplifier, resulting in a cleaner note and a reduction of interference. (See also Question 6.601 for the use of a sharply tuned i-f filter to reduce unwanted noise.)

Q. 6.261. What is the purpose of decoupling networks in the plate circuits of a multistage audio amplifier?

A. The purpose of decoupling networks is to prevent oscillations from occurring in a multistage audio amplifier.

D. It is common practice to supply plate and screen grid supply voltages for a multistage audio amplifier from a single power source. The output impedance of a power supply (unregulated) consists mainly of the reactance of the output filter condenser. This reactance is a common impedance coupling element between all stages. If the amplifier contains high gain stages, there is a possibility of sufficient feedback voltages being developed across the reactance of the output condenser to sustain oscillations. Since the reactance of a condenser increases as the frequency decreases, such oscillations, if they occur, will most likely be of a very low frequency. (See also Question 3.510.)

Q. 6.262. Why is an audio transformer seldom employed as the output device to be used in the plate circuit of a tetrode audio-amplifier stage?

A. Because an ordinary transformer cannot supply enough impedance to the plate circuit.

D. The average tetrode (or pentode) voltage amplifier tube has a value of plate impedance approaching or exceeding one megohm. The value of plate load impedance needed may be as high as 1 megohm. It is impractical to build a transformer of reasonable size or cost which could present such a high value of impedance to the plate circuit. Resistors are commonly used with capacitive coupling.

Q. 6.263. What is the chief advantage of class A audio operation as compared to other classes of audio-frequency amplifiers?

A. The chief advantage of class A audio operation is the low distortion of the output signal.

D. See Question 6.252, which lists additional references.

Q. 6.264. What is the principal advantage of transformer coupling compared to resistance coupling, as used in audio-frequency amplifiers?

A. The principal advantage of transformer coupling is the greater gain which may be obtained per stage. This is due to the fact that a step-up turns ratio may be used to provide a similar step-up of the voltage ratio.

D. Another advantage of transformer coupling is the fact that it may also be used to provide necessary impedance matching in audio amplifiers. A disadvantage of transformer coupling is that a transformer with good frequency response is necessarily expensive. Another disadvantage lies in the large weight and bulk of the transformer.

Q. 6.265. What factors determine the efficiency of a power transformer?

A. The efficiency is determined by the following factors:

a. Eddy current losses.

b. Hysteresis losses.

c. Copper losses.

These three depend, in turn, upon the following:

1. Leakage reactance of coils.
2. Load on secondary.
3. Power factor of load.
4. Core shape and material.
5. Frequency.
6. Applied voltage.

D. See Questions 4.12 and 4.13.

Q. 6.266. What factors determine the ratios of primary and secondary currents in a power transformer?

A. The ratios of primary and secondary currents are approximately in inverse ratio to the turns ratio.

D. The ratio of currents is also affected to some extent by the diameter of the primary and secondary wire. (See also Question 3.318.) The current ratio is in inverse proportion to the voltage ratio.

Q. 6.267. What is the secondary voltage of a transformer which has a primary voltage of 100, primary turns 200, and secondary turns, 40?

A. The secondary voltage is approximately 20 volts.

D. The voltage ratio of a transformer is approximately equal to the turns ratio or $\frac{E_s}{E_p} = \frac{N_s}{N_p}$. Solving for E_s, $E_s = \frac{N_s \times E_p}{N_p} = \frac{40 \times 100}{200} = 20$ *volts.*

Q. 6.268. What factors determine the no-load voltage ratio of a power transformer?

A. Under no-load conditions, the voltage ratio of a power transformer is determined by the turns ratio.

Q. 6.269. What is the relationship between the turns ratio and the impedance ratio of the windings of a transformer?

A. The turns ratio of a transformer varies as the square root of the impedance ratio, or the impedance ratio varies as the square of the turns ratio.

D. See Questions 4.15 and 4.16.

Q. 6.270. See Question 3.87.

Q. 6.271. See Question 3.88.

Q. 6.272. See Question 3.147.

Q. 6.273. See Question 3.151.

Q. 6.274. See Question 3.154.

Q. 6.275. See Question 3.261.

Q. 6.276. See Question 3.241.

Q. 6.277. How can the condition of charge of dry "B" batteries be determined?

A. The condition of charge can be determined by measuring the terminal voltage under normal load.

D. A loss of 20% of the original voltage under normal load conditions means that the internal resistance of the battery has risen by 20% and will continue to increase at a comparatively rapid rate. Consequently, the battery should be replaced.

Q. 6.278. What precaution should be observed in storing spare "B" batteries?

A. The batteries should be stored in a dry place and care taken to see that conductors do not fall across the terminals.

D. It should be remembered that regardless of any precautions, the shelf life is definitely limited by "local action."

Q. 6.279. Draw a sketch showing the construction of a storage cell.

A. See the figure.

Q. 6.280. Define "specific gravity" as used in reference to storage batteries.

A. "Specific gravity" as used in reference to liquids is a means of comparing the weight of a given volume of liquid with the same volume of water. The "specific gravity" of water is taken as 1.000.

D. "Specific gravity" is actually a ratio, as follows: $\textit{Specific gravity} = \frac{\textit{Weight of liquid}}{\textit{Weight of water}}$. In a lead-acid storage battery which is fully charged, the electrolyte has a "specific gravity" of about 1.280. This means that the weight of the electrolyte is 1.280 times greater than the weight of an equal volume of water.

Q. 6.281. What are the main differences between Edison and lead-acid types of storage batteries?

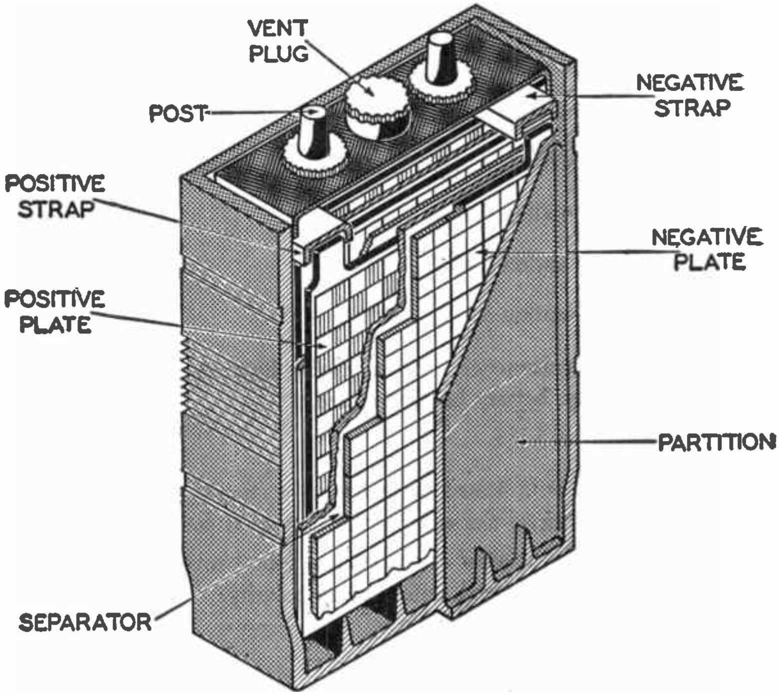


Fig. 6.279. Sectional view of storage cell.

A. The main differences lie in the composition of plates and electrolyte, charging techniques and testing for state of charge. The lead-acid batteries have lead and lead compound plates in sulphuric acid electrolyte; the Edison-type batteries have plates of nickle, iron and compounds thereof in hydroxide-solution electrolyte.

D. For lead-acid cell, see Questions 3.144, 3.150, 3.155, 3.158, and 3.163.

For Edison cell, see Questions 3.145, 3.148, 3.149, 3.152, 3.156, and 3.160.

Q. 6.282. See Question 3.150.

Q. 6.283. See Questions 3.144 and 3.146.

Q. 6.284. See Question 3.149.

Q. 6.285. See Questions 3.145 and 3.148.

Q. 6.286. See Question 3.156.

Q. 6.287. See Question 3.152.

Q. 6.288. See Question 3.158.

Q. 6.289. See Question 3.159.

Q. 6.290. See Question 3.160.

Q. 6.291. See Question 3.163.

Q. 6.292. See Question 3.162.

Q. 6.293. See Question 3.161.

Q. 6.294. If a hydrometer is not available how can the condition of charge of a storage battery be determined?

A. See Question 3.163.

Q. 6.295. What is indicated if, in testing a storage battery, the voltage polarity of some of the cells in the battery is found reversed?

A. If the voltage polarity of the cells is found reversed, it indicates that the battery was charged with reverse polarity.

D. See Questions 3.200 and 6.316.

Q. 6.296. See Question 3.203.

Q. 6.297. See Question 3.201.

Q. 6.298. See Question 3.205.

Q. 6.299. See Question 3.206.

Q. 6.300. See Question 3.207.

Q. 6.301. See Question 3.208.

Q. 6.302. See Question 3.209.

Q. 6.303. See Question 3.202.

Q. 6.304. See Question 3.259.

Q. 6.305. See Question 3.260.

Q. 6.306. What is the meaning of "electrolyte"? List four types of radio equipment in which it may be used.

A. An electrolyte is a liquid capable of conducting electricity, but which undergoes decomposition while so doing. Four types of radio equipment using an electrolyte are:

1. Electrolytic condenser.
2. Storage battery cell.
3. Electrolytic detector.
4. Electrolytic rectifier.

D. See Question 3.240.

Q. 6.307. What is the effect of low temperatures upon the operation of a lead-acid storage battery?

A. In general, the capacity of a lead-acid battery is decreased when low temperatures are present.

D. An important factor to be considered when lead-acid batteries are used under conditions of very low temperature is the specific gravity of the electrolyte. If the specific gravity is permitted to fall too low, there is a strong possibility that the electrolyte may freeze and split the battery. If the battery is kept fully charged, the freezing temperature is very low.

Q. 6.308. See Question 3.292.

Q. 6.309. Draw a diagram of the charging circuits of two batteries using a four-pole double-throw switch such that while one battery is on charge the other is on discharge. Indicate the d-c power source, voltage dropping resistors, and connections to the battery load.

A. See the figure.

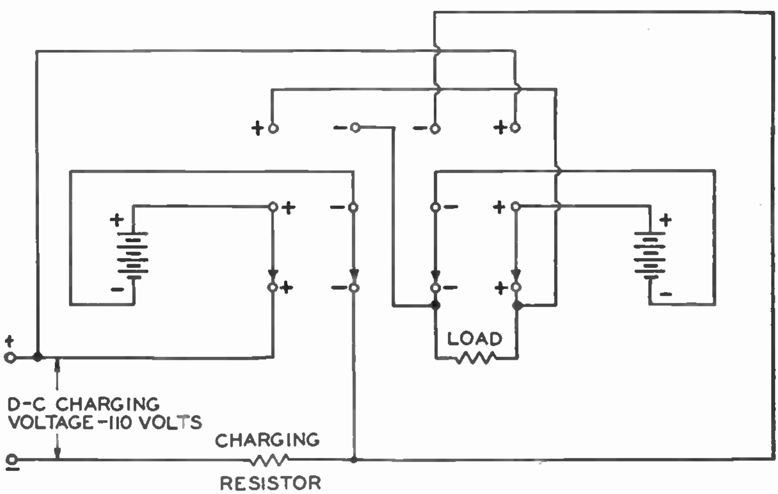


Fig. 6.309. Two-battery switching circuit, to interchange load and charging source.

Q. 6.310. See Question 3.204.

Q. 6.311. A storage battery with a terminal voltage of 12.5 is to be trickle charged at a 0.5 ampere rate. What value of resistance should be connected in series with the battery if the trickle charge is to be made from a 110 volt d-c line?

A. The value of series resistance should be 195 ohms.

D. The line voltage is given as 110 volts and the terminal battery voltage as 12.5 volts. The series resistor must drop the *difference* between these two voltages, or 97.5 volts at .5 ampere. $R_{series} = \frac{97.5}{.5} = 195$ *ohms.*

Q. 6.312. A discharged storage battery of three cells has an open-circuit voltage of 1.8 volts per cell and an internal resistance of 0.1 ohm per cell. What potential is necessary to produce an initial charging rate of 10 amperes?

A. The necessary charging potential is 8.4 volts.

D. In order to produce an initial charging rate of 10 amperes, the charging potential must be equal to the sum of the open circuited voltages of the three cells plus the internal drop in the three cells when a 10 ampere charging current exists.

Step 1: The open circuited voltage of three cells equals $1.8 \times 3 = 5.4$ volts.

Step 2: The internal resistance of the three cells equals $.1 \times 3 = .3$ ohm.

Step 3: The internal voltage drop of the three cells for a 10 ampere charging rate equals $.3 \times 10 = 3$ volts.

Step 4: The charging potential equals the sum of the voltages in steps 1 and 3, or $5.4 + 3 = 8.4$ *volts.*

(Compare Question 3.509.)

Q. 6.313. What capacity of storage battery is required to operate a 50-watt emergency transmitter for 6 hours, assuming a continuous transmitter load of 70 per cent of the key-locked demand of 40 amperes? The emergency light load is 1.5 amperes.

A. The actual capacity according to the load requirements should be 177 ampere-hours. A standard heavy duty battery which would fulfill the above requirements would be rated at about 210 ampere-hours.

D. The total ampere-hour capacity which is actually required is found by adding the requirements of the emergency light load to 70 per cent of the continuous transmitter load.

Step 1: The ampere-hour requirement of the light load equals 1.5 amperes $\times 6 = 9$ ampere-hours.

Step 2: The ampere-hour requirement of the continuous transmitter load equals 40 amperes $\times 6 \times .7 = 168$ ampere-hours.

Step 3: The total required capacity equals the sum of the two above required capacities or $168 + 9 = 177$ *ampere-hours.*

Q. 6.314. If you found that it was impossible to keep the receiver-storage A battery charged, and at the same time maintain the required watch period, what remedy may be found?

A. The remedy may be to increase the charging rate of the storage battery.

D. The emergency power supply on board a cargo vessel (on which a separate main and emergency installation is not provided), subject to Title III, Part II of the Communications Act, while being navigated in the open sea, is authorized to be used only for emergency communication except that it may be used for routine communication for a period not to exceed one hour per day in the aggregate. However, a storage battery which is the emergency power supply or a part thereof, may be used at any time to maintain a watch for safety purposes if such use will not reduce the ability of the emergency power supply to energize the emergency installation for a period of at least six consecutive hours.

Q. 6.315. What could cause abnormally low voltage at the input power terminals of a lifeboat radiotelegraph transmitter, while it is in operation?

A. This could be caused by an excessive overload or by the battery being in a partially discharged condition.

Q. 6.316. If an auxiliary storage battery has a voltage of 12.4 volts on open circuit, and 12.2 volts when the charging switch is closed, what is the difficulty?

A. The charging polarity is reversed.

D. The fact that the battery voltage under charging conditions decreases rather than increases indicates that the charging current is in the wrong direction in the battery. If the charging circuit were equipped with a reverse current relay this condition could not exist.

The reverse current relay has two main functions:

(1) It prevents the battery from discharging back into the charging source.

(2) It prevents a reversed charging current from being applied to the battery.

Q. 6.317. Why should the tops of the lead-acid cell or batteries be kept free from moisture?

A. The tops of the batteries should be kept free from moisture in order to prevent slow discharge of the batteries and to reduce the formation of terminal corrosion.

D. See also Question 3.150.

Q. 6.318. How may the condition of charge of an Edison cell be determined?

A. See Question 3.160.

Q. 6.319. What special precautions should be taken when lead-acid cells are subject to low temperatures?

A. The cells should be kept fully charged to prevent freezing and to provide the maximum capacity possible.

D. See Question 6.307.

Q. 6.320. What should be done if the electrolyte in a lead-acid storage cell becomes low due to evaporation?

A. If the level of the electrolyte drops below the tops of the plates, pure water should be added to bring the level about ¼ inch above the tops of the plates.

D. See Question 3.203.

Q. 6.321. Why should an Edison storage battery not be charged at less than the normal rate specified by the manufacturer? Explain.

A. The charging rate of an Edison storage battery should not be less than the normal value specified by the manufacturer, in order that the capacity of the battery shall be maximum after charge.

D. During charge the positive plate of an Edison storage battery undergoes chemical variations such that it changes from a lower to a higher oxide of nickel, while the negative plate changes from iron oxide to metallic iron. These chemical reactions are not fully accomplished at low charging rates.

Q. 6.322. Lacking an hydrometer, how may the stage of charge of a storage battery be determined?

A. The charge may be determined by measuring the voltage of the battery under load conditions. If the battery is being charged, it will begin to "gas" very freely when nearing the completion of the charge.

D. See Question 3.163.

Q. 6.323. Your emergency storage battery has a specific gravity reading of 1.120. What should be done?

A. The battery should be placed on charge at once and the level of electrolyte should be brought about a quarter-inch above the top of the plates. The fully charged reading is approximately 1.280 to 1.300.

D. See Question 3.205.

Q. 6.324. Why should care be taken in the selection of water to be added to a storage cell to replace the loss by evaporation?

A. The water added to a storage cell should be chemically pure, or distilled, water. Any impurities would increase the local action of the cell (Question 3.201) and might possibly ruin it.

D. See Question 3.205.

Q. 6.325. If you placed the emergency batteries on charge and the overload circuit breakers refuse to stay closed, what is the trouble?

A. If the overload circuit breakers refuse to stay closed, the following may be the trouble:

1. Defective (internally shorted) cells.
2. Reversed charging polarity.
3. Grounded circuit connections.

Q. 6.326. See Question 3.153.

Q. 6.327. See Question 3.09.

Q. 6.328. See Question 3.07.

Q. 6.329. See Question 3.157.

Q. 6.330. Why does the charging rate to a storage cell, being charged from a fixed-voltage source, decrease as the charging progresses?

A. The charging rate to a storage cell automatically decreases as the charging progresses because as the cell voltages increase, more opposition is offered to the charging voltage and consequently the effective charging potential is reduced, decreasing the charging current.

Q. 6.331. Draw a simple schematic diagram of a rectifier and filter for supplying plate voltage to a radio receiver.

A. See Question 3.488.

Q. 6.332. Explain the principle of operation of the cold-cathode gaseous rectifying diodes.

A. See Question 3.389.

Q. 6.333. Discuss the uses of copper oxide rectifiers.

A. The most common use of copper oxide rectifiers is their use in rectifying a-c voltages of low and medium frequencies so that a-c measurements can be made with d-c meters. Other uses are to supply field-excitation current for speakers, and for battery charging.

D. See Question 6.189.

Q. 6.334. See Question 3.177.

Q. 6.335. Compare the advantages and disadvantages of high-vacuum and hot-cathode mercury vapor rectifier tubes.

A. Advantages of mercury-vapor rectifier tubes are:

1. A low internal voltage drop of 10 to 15 volts, which remains constant under varying load conditions, thus making for good voltage regulation.
2. Permits the use of oxide coated cathodes, with their lower filament power requirements.
3. Cooler operation due to the low internal drop.
4. Greater efficiency and economy in high voltage, high current operation.

Disadvantages of mercury-vapor rectifier tubes are:

1. Produces radio frequency interference due to ionization of mercury or gas.
2. Relatively low inverse peak voltage rating.
3. Filament may be damaged if not pre-heated before plate voltage is applied.

Advantages of high-vacuum rectifier tubes are:

1. Higher peak inverse voltage rating for a given size of tube.
2. Will stand more abuse without breakdown.
3. Does not generate r-f interference (hash).

Disadvantages of high-vacuum rectifier tubes are:

1. Voltage drop across the tube varies with load current changes making for poorer voltage regulation.
2. Higher filament power requirements.
3. Tube runs hotter due to larger voltage drop.

D. See Question 3.177.

Q. 6.336. Describe the construction and the operation of rectifier tubes that are used for charging batteries. Draw a diagram of a battery charging circuit employing such a tube.

A. Rectifier tubes used for battery charging are usually of the "tungar" type. The tungar tube consists of a relatively heavy, coiled, thoriated tungsten filament which is mounted horizontally between two vertical metal supporting rods. The plate consists of a small graphite button mounted above the filament. The bulb is first evacuated and then filled with argon gas to a pressure of about 5 cm. of mercury. A magnesium getter is fastened around the plate and is flashed after evacuation by heating the plate. This serves the purpose of absorbing any air remaining in the bulb after evacuation. The filament is operated at a very high temperature and its emission efficiency is many times greater than that of filaments used in high-vacuum tubes. When the plate is positive with respect to its cathode, electrons flow from cathode to plate and collide with gas atoms. Positive ions are formed which neutralize the space charge so that saturation current may exist with a

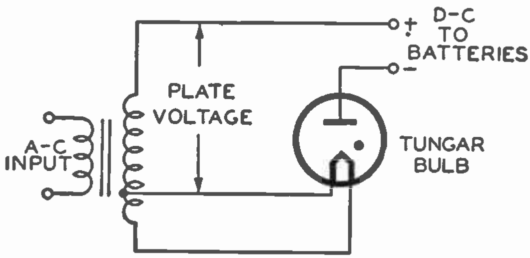


Fig. 6.336. "Tungar" battery-charging circuit.

tube drop of 10 volts or less. (For diagram of charging circuit see the figure.)

D. A circuit commonly used for battery charging, using a tungar tube is shown in the figure. The lower end of the secondary is wound with very heavy wire in order to supply the necessary large filament current. For the 5-ampere tungar bulb the filament current is 14 amperes. The plate voltage is supplied by the upper end of the secondary winding. The efficiency of the tungar tube is low since about 40 watts is required for filament power and about 50 watts is lost in plate dissipation when delivering 5 amperes to a 6-volt battery. The efficiency of the tungar tube compares favorably with that of a motor generator set, and is much better than when charging batteries from a 110-volt d-c line through a resistance.

Q. 6.337. Draw a simple schematic diagram of a cold cathode electron tube connected as a voltage regulator. As a rectifier.

A. See the figures. A and B are voltage regulator circuits; C is a cold-cathode rectifier circuit.

D. See Question 3.389.

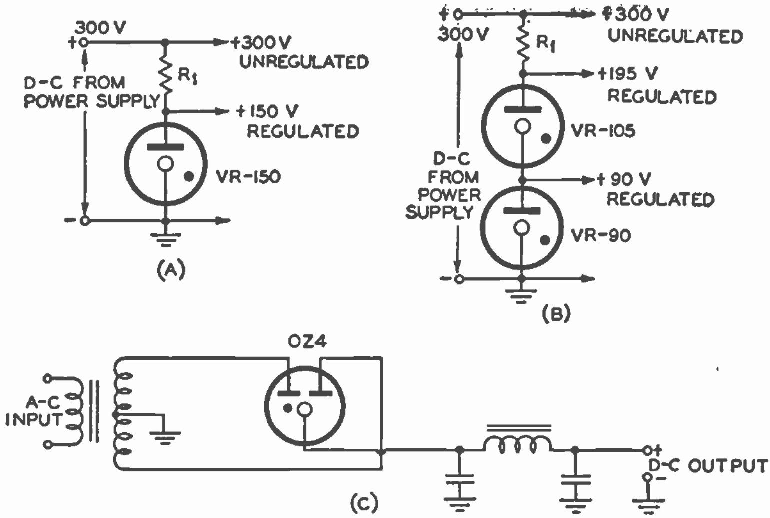


Fig. 6.337. Applications of cold-cathode electron tubes.

Q. 6.338. Why should the temperature of the filament or heater in a mercury-vapor rectifier tube reach normal operating temperature before the plate voltage is applied?

A. The filament or heater should reach normal operating temperature before applying plate voltage in order to completely vaporize the mercury within the tube and to permit the tube to reach its correct operating temperature, thereby avoiding damage to the cathode.

D. See Questions 4.101 and 4.102.

Q. 6.339. What are the advantages of the high-vacuum rectifier tube as compared to the hot-cathode gas filled tube?

A. Advantages are as follows:

1. Higher peak inverse voltage rating for a given size of tube.
2. Will stand more abuse without breakdown.
3. Does not generate r-f interference (hash).

D. See Question 3.177.

Q. 6.340. What action permits the high-conductance currents of the hot-cathode gas-filled rectifier tube?

A. In a mercury-vapor rectifier tube positive ions are produced which tend to neutralize the negative space charge and thus permit higher conduction currents to take place. Electrons which are removed from the positive ions also add to the plate current.

D. See Questions 3.179 and 3.386.

Q. 6.341. Draw a simple circuit diagram of a voltage doubling power supply using two one-half wave rectifiers.

A. See Question 4.178.

Q. 6.342. See Question 3.178.

Q. 6.343. What is the principal function of the filter in the power supply?

A. The principal function of the filter is to remove the variations in amplitude of the rectifier output and provide a relatively unvarying d-c voltage for use in the various circuits.

D. See Question 3.488.

Q. 6.344. What are the relative advantages of the condenser-input and choke-input filters when used with rectifiers?

A. The principal advantage of a condenser-input filter is that it provides a relatively higher output voltage under reasonably light load conditions. The choke-input filter offers better voltage regulation and is adaptable for use with mercury-vapor rectifier tubes.

D. See Questions 3.399 and 3.401.

Q. 6.345. What is the primary advantage to be obtained by shunting a high-resistance fixed resistor across each unit of a high-voltage series condenser bank in the power-supply filter circuit of a transmitter?

A. The purpose of shunting a resistor across each condenser is to insure that the correct voltage appears across each unit.

D. See Question 3.181.

Q. 6.346. If part of the secondary winding of the power transformer of a transmitter were accidently shorted, what would be the immediate effect?

A. The current in the primary would rise to an excessive value, and a fuse or circuit breaker would act to open the primary circuit.

D. If a short circuit occurred in the secondary winding of a power transformer a very large value of secondary current would exist. This large secondary current would in turn produce a very strong magnetic field which would cut the primary winding in such a manner as to oppose the normal counter-emf developed in the primary. The effective inductance, and, therefore, inductive reactance of the primary would be greatly reduced, permitting the primary current to rise to an excessive value, unless some protective device acts to open the primary circuit.

A short circuited turn, or turns, anywhere in a transformer tends to increase primary current in the same manner that a normal load does, but to a much greater extent. The increased current in the primary and in the short circuited turn will overheat and burn the transformer unless there are other means of limiting or shutting off the current. See also Question 6.377.

Q. 6.347. Why are bleeder resistances used in power supplies?

A. The primary purpose of a "bleeder" resistance in conventional power supplies is to improve the regulation output voltage.

D. See Question 3.182.

Q. 6.348. What is the ratio of the frequencies of the output and input circuits of a single-phase full-wave rectifier?

A. The ratio of output to input frequencies is 2 to 1.

D. See Question 4.173.

Q. 6.349. Why is a condenser sometimes placed in series with the primary of a power transformer?

A. A condenser may be placed in series (or parallel) with the primary of a power transformer for the purpose of improving the power factor of the system.

D. When a power transformer is connected across a power line, it sometimes causes a lagging power factor to exist due to the inductive reactance of the transformer. For the most efficient utilization of power, the power factor should be equal to unity. By connecting a condenser in series (or parallel) with the transformer primary, the power factor may be improved with a resultant increase in power utilization efficiency. When a condenser is placed in *series* with the primary of a transformer, it should be realized that a possible series resonant condition may result. In this event both the primary and secondary voltages may rise excessively.

Q. 6.350. Why are small resistors sometimes placed in series with each plate load of mercury-vapor rectifier tubes connected in parallel?

A. Small resistors are used to insure that *both* tubes will ionize and carry the load.

D. See Question 4.174.

Q. 6.351. What is the maximum allowable total secondary voltage of a transformer to be used as a center-tapped full-wave rectifier in

connection with rectifier tubes having a peak inverse voltage rating of 10,000 volts?

A. Without allowing for any safety factor, the maximum allowable total secondary voltage is 7,070 volts, rms.

D. In a full wave rectifier, the inverse peak voltage across the non-conducting tube is equal to the full voltage (rms) of the transformer secondary, minus the drop in the conducting tube and active portion of the secondary winding. From a practical consideration the last two factors may be neglected. The maximum allowable total secondary voltage, is therefore, $10{,}000 \times .707 = 7{,}070$ volts, rms. (See also Question 4.99.)

Q. 6.352. What would happen if a transformer, designed for operation on 60-cycle voltage were connected to a 120-cycle source of the same voltage?

A. The impedance of the transformer would be greater and thus the current would be reduced.

D. If the same load were applied to the secondary there would be a slight decrease in the power delivered to the load due to the reduced value of line current. See also Question 3.515.

Q. 6.353. What would happen if a transformer, designed for operation on 500 cycles, were connected to a 60-cycle source of the same voltage?

A. The primary winding would draw an excessive amount of current from the line due to the decrease of primary reactance. The transformer would overheat, and the primary might burn out.

D. See Question 3.515.

Q. 6.354. A marine transmitter uses 500-cycle alternating current for plate supply. It is rectified by a full-wave rectifier circuit, but is not filtered. How would the emission be classified?

A. The emission would be classified as A2 or modulated continuous wave.

D. Since the 500 cycle alternating current is rectified by a full wave rectifier circuit, the ripple frequency equals 1000 cycles. The plate supply is not filtered, and the output of the transmitter will be varied at the 1000 cycle rate, thus providing a modulated continuous wave with a 1000 cycle tone.

Q. 6.355. What is the purpose of an air gap in the core of a filter choke coil?

A. The purpose of an air gap in the core of a filter choke coil is to increase the effective inductance for the a-c component of current by decreasing the d-c saturation.

D. If an air gap is introduced into the iron core of a filter choke coil the inductance of the coil in general is decreased. If the coil is passing both a-c and d-c current the air gap may decrease the constant flux so that the effective inductance for the a-c component of current is actually increased. There is one particular air gap for which the effective a-c inductance is maximum when all other operating conditions are fixed. As the d-c current is increased the optimum air gap is also increased and the corresponding a-c inductance is decreased. (See also Questions 3.397 and 3.398.)

Q. 6.356. What is the effect of loose laminations in a filter choke?

A. Loose laminations will cause a buzzing or chattering sound.

Q. 6.357. What is meant by "regulation" of a power supply? What causes poor regulation?

A. "Voltage regulation" expresses the ratio between the amount of voltage drop under full load conditions from the no-load value, to the full load voltage. This ratio is multiplied by 100 to express it as a percentage. Poor regulation may be caused by:

1. High resistance filter chokes.
2. Insufficient filter capacity.
3. Saturation of iron core of filter chokes.
4. No bleeder resistance.
5. Varying drop in rectifier tube with changing load (high-vacuum type).

D. See Questions 3.402 and 3.403.

Q. 6.358. Why should the metallic case of a high-voltage transformer be grounded?

A. The metallic case of a high-voltage transformer should be grounded primarily as a protective measure for personnel handling the equipment.

D. When the metallic case is grounded, it prevents the building up of high static voltages between the case and ground. This also protects personnel in the event that the high voltage winding should become shorted to the metallic case.

Q. 6.359. How may a filter condenser be checked for leakage?

A. A filter condenser should be checked for leakage current with its normal operating voltage applied, by means of a milliammeter.

D. While some indication of the condition of a condenser may be found from a simple ohmmeter check, the proper method involves the application of normal operating potentials. The method of testing a standard 8 microfarad 450 volt electrolytic condenser is as follows: The condenser is connected in series with a 450 volt d-c source, a milliammeter (about 10 ma. full scale) and a resistance of about 50,000 ohms shunted by a switch. The condenser is permitted to charge for 5 minutes after which the shunting switch is closed. The milliammeter is then read. A well made electrolytic condenser will have a very small leakage current when in continuous use. On intermittent operation the normal value of leakage current of an electrolytic condenser is in the order of 50 to 100 microamperes per microfarad. For example an 8 microfarad 450 volt electrolytic condenser in good condition will have a leakage current of about .5 milliamperes. The maximum leakage current should not exceed about 5 milliamperes.

Q. 6.360. Explain the principle of operation of an electrolytic condenser. What precaution should be observed when connecting electrolytic condensers in series?

A. The properties of the electrolytic condenser are due to a dielectric film of an oxide which is formed on the positive plate of the condenser. When connecting electrolytic condensers the polarity marked on the body of the component must be observed. If this precaution is not observed the condenser will be ruined.

D. An electrolytic condenser consists of four basic parts: the anode (positive plate), the cathode (negative plate), the electrolyte, and the dielectric film which is formed electrochemically on the surface of the anode. The dielectric material of an electrolytic condenser consists of an extremely thin oxide film which is formed upon the surface of the anode. Certain metals, including aluminum, when immersed in special electrolytic solutions, will form a non-conducting film upon the surface when a current is passed though the metal and electrolyte to another metal plate. This film will be of such a nature as to oppose the flow of current, and will act as an insulator only as long as the same "forming" polarity is maintained. Thus an electrolytic condenser is formed, utilizing aluminum as the plates and the oxide film as the dielectric. Because the film is very thin, the capacity is very high for a given physical size. (See also Questions 3.258 and 6.634.)

Q. 6.361. See Question 3.175.

Q. 6.362. See Question 3.180.

Q. 6.363. See Question 3.181.

Q. 6.364. What is a desirable feature of an electrolytic condenser as compared with other types?

A. The primary advantage of an electrolytic condenser is that a large capacitance may be obtained with a condenser of small physical dimensions. Another advantage is the self-healing characteristic of *wet*-type electrolytic condenser.

D. See Question 6.360.

Q. 6.365. Indicate the approximate values of power-supply filter inductances encountered in practice.

A. The most common values of chokes range from about 5 henrys to 30 henrys.

D. Common current ratings for receiver chokes range from about 50 milliamperes to 200 milliamperes. The d-c resistance of the chokes range from about 300 ohms to about 1000 ohms. For transmitters, inductances are in the order of 5 henrys, and may be designed to pass up to two amperes. (See also Questions 3.397, 3.398, and 3.404.)

Q. 6.366. A radio receiver has a power transformer and rectifier designed to supply plate voltage to the vacuum tubes at 250 volts when operating from a 110-volt 60-cycle supply. What will be the effect if this transformer primary is connected to a 110-volt direct-current source?

A. The primary would overheat and burn out, unless fuses or other protection operated to interrupt the current.

D. See Questions 3.176 and 3.317.

Q. 6.367. See Question 3.172.

Q. 6.368. See Question 3.173.

Q. 6.369. See Question 3.170.

Q. 6.370. Explain the principle of operation and list the main characteristics of a compound-wound d-c motor and explain how the speed is regulated.

A. The main characteristics of a compound direct-current motor are constant speed under changing load conditions and low starting torque. The flat-compounded motor is basically a shunt wound motor with the addition of a series field wound in opposition to the shunt field. If the load increases, the motor tends to slow down, and more current is drawn through the series field opposing and weakening the shunt field. This weakened field develops less counter-emf in the armature, which draws additional current and speeds up. Such a motor may be used in many applications where constant speed is desired, as in motor-generator sets with varying generator loads.

D. See also Questions 3.165 and 3.170.

Q. 6.371. See Question 3.164.

Q. 6.372. See Question 3.169.

Q. 6.373. Why is a series motor not used in radio power-supply motor-generators?

A. Motor generator sets required constant voltage output under varying load conditions. A series motor changes speed radically under different load conditions, and may destroy itself if the load is removed entirely.

D. See Question 3.173.

Q. 6.374. What is the danger of operating a d-c series motor without a load?

A. If a d-c series motor is operated without a load, the speed will increase until the motor is finally destroyed by centrifugal action.

D. See Question 3.173.

Q. 6.375. See Question 3.167.

Q. 6.376. See Question 3.165.

Q. 6.377. What will be the effect(s) of a short circuit in an armature coil in a direct-current motor?

A. A short circuit in an armature coil will cause excessive sparking at the commutator brushes, overheating of the machine, reduction of speed under load and excessive armature current.

D. The effects of a short circuit in an armature coil are similar to the effects of a short circuit in the windings of a transformer. A very large circulating current would be set up in the shorted portion, and the magnetic field thus produced would be in such a direction as to cancel the normal magnetic field of the armature. This would result in a decreased amount of torque and speed and an excessive armature current with attendant overheating. (See also Questions 3.168 and 6.346.)

Q. 6.378. When starting a direct-current motor-generator set, what adjustment should be made to the motor field rheostat?

A. The motor-field rheostat should be set for minimum resistance in the field circuit.

D. This setting is necessary in order to permit maximum current in the field which develops the maximum counter-emf in the armature and thus limits armature current. (See also Questions 3.391, 3.395, and, for diagram, 3.172.)

Q. 6.379. What may be the trouble if a motor generator fails to start when the starter button is depressed?

A. Any of the following troubles may be present:

1. Broken connections.
2. Blown fuse or tripped circuit breaker.
3. Open field.

4. Open armature.
5. Open motor-field rheostat.
6. Defective starter.
7. Defective brushes.

D. See Questions 6.382 and 6.377. (See diagram, Question 3.172.)

Q. 6.380. Explain the principle of operating and list the main operating characteristics of a d-c shunt generator and a d-c compound generator. Explain how the voltage of a d-c generator can be controlled. Draw a simple schematic diagram of each of these types of generators.

A. The main characteristic of a self-excited shunt-wound d-c generator is the good voltage regulation under varying load conditions. The starting of such a generator takes advantage of the residual magnetic field of the field poles. As the armature starts rotating, an emf is induced into it due to the residual field. The first emf causes some current to flow through the high resistance field, thus increasing the field strength and the output voltage to normal value. Most of the current is delivered to the load, due to the high field resistance. The field is composed of very many turns of fine wire. A series field rheostat is used to control the output voltage. Part A of the figure indicates the circuit.

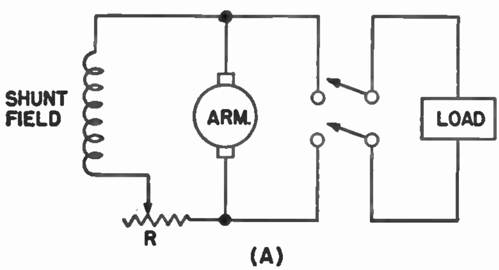


Fig. 6.380(A). Voltage control of shunt d-c generator.

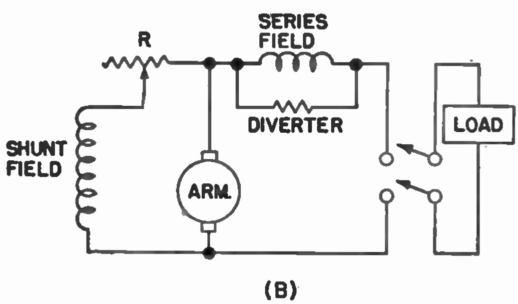


Fig. 6.380(B). Voltage control of compound d-c generator.

The compound generator (part B of the figure) has two sources of field excitation. One is the shunt connected field which is energized directly from the generator terminals. The other is the series connected field which is energized by the load current. The two fields are generally connected as to be aiding. The compound generator combines the rising voltage characteristic of the series generator (with increasing load), with the falling voltage characteristic of the shunt generator. By governing the amount of series field excitation the compound generator may be caused to have a nearly constant voltage characteristic under changing loads. Compound generators are provided with a "diverter," or resistance shunt across the series field, in order to control the strength of the series field current.

Q. 6.381. See Question 3.174.

Q. 6.382. When increased output voltage is desired from a motor-generator set what is the usual procedure?

A. The output voltage is increased by decreasing the resistance of the rheostat in series with the generator field.

D. The usual method of controlling the output voltage of a motor-generator set is by means of a series-field rheostat connected in the generator field. The output voltage is proportional to the field strength, which (normal operating range) is closely proportional to the current through the generator field windings. To increase the output voltage, it is necessary, therefore, to decrease the resistance of the generator-field rheostat.

Q. 6.383. Describe the construction of a dynamotor. What are its operating characteristics?

A. See Question 3.505.

Q. 6.384. How may the voltage output of a dynamotor be regulated?

A. Normally, the output voltage of a dynamotor may be regulated only by changing the speed of the motor. A series resistance in the output line could be used to reduce the available output voltage.

D. See Question 3.505.

Q. 6.385. What is the principal advantage of the dynamotor, rather than the motor generator, to furnish plate power to a small mobile transmitter? Principal disadvantage?

A. The principal advantages of a dynamotor are its compactness and operating efficiency. It is possible to operate dynamotors from storage batteries. One disadvantage of a dynamotor is that its voltage output is dependent on the stability of the source voltage.

D. See Question 3.505.

Q. 6.386. See Question 3.168.

Q. 6.387. See Question 3.210.

Q. 6.388. See Question 3.211.

Q. 6.389. See Question 3.212.

Q. 6.390. Why should emery cloth never be used to clean the commutator of a motor or generator?

A. The use of emery cloth for cleaning commutators should be avoided since emery cloth contains conducting particles. Such particles may lodge between commutator segments and cause short circuits.

D. See Question 3.393.

Q. 6.391. If a 3-horsepower 100-volt direct-current motor is 85 per cent efficient when developing its rated output, what will be the line current?

A. The line current will be 23.93 amperes.

D. Step 1: Find the number of watts in 3-horsepower.
(1 horsepower = 746 watts) 746 × 3 = 2,238 watts.

Step 2: Find the line current at 100% efficiency.

$$I_{L\text{-}100} = \frac{P}{E} = \frac{2{,}238}{110} = 20.345 \ \textit{amperes.}$$

Step 3: Find the line current at 85 per cent efficiency.

$$I_L = \frac{20.345}{.85} = 23.93 \ \textit{amperes.}$$

(Compare Question 6.394.)

Q. 6.392. Explain the principle of operation of an induction motor and how such motors are started.

A. Induction motors consist basically of two parts: an outer stationary hollow structure which is built of slotted, laminated sheet-steel punchings (the stator), and an inner core of somewhat similar construction (the rotor). The rotor is free to turn within the stator and separated from it by a very small air gap. The stator is provided with a field winding which provides the necessary flux which is used to drive the rotor. The most commonly used rotor is the so called squirrel-cage type which consists of a number of conductors arranged as a cylinder and connected together at each end. In order for an induction motor to be self starting, a rotating field must be produced. (A rotating field can be obtained directly from two- or three-phase supplies, or as described below for single phase use.) When the conductors of the rotor are cut by the rotating field a very strong current is induced in them. The resultant rotor field reacting against the rotating field causes the rotor to revolve. The rotor must revolve at a rate slightly slower than the rotating field to maintain induced current, and, therefore, torque.

In a single phase induction motor, two stator windings are provided, one a starting winding and the other a running winding. A "phase-splitting" arrangement is provided, by connecting in series with the starting winding either a large inductance or capacitance. The currents through the two windings are out of phase and produce a rotating field which starts the motor and brings it up to running speed. When the motor is up to speed, a centrifugally operated switch cuts out the starting winding and the motor continues to run on the running winding.

Q. 6.393. See Question 3.299.

Q. 6.394. What is the line current of a single phase 7-horsepower alternating-current motor when operating from a 120-volt line at full rated load and at a power factor of 0.8 and 95 per cent efficiency?

A. The line current is 57.2 amperes.

D. One horsepower = 746 watts.

Step 1: Find the number of watts corresponding to 7 horsepower or $7 \times 746 = 5{,}222$ watts.

Step 2: Find the power input in watts at 95 per cent efficiency.

$$P_{in} = \frac{P_{out}}{Efficiency} = \frac{5{,}222}{.95} = 5{,}497 \text{ watts.}$$

Step 3: Determine the line current.

$$I = \frac{P}{E \times p.f.} = \frac{5{,}497}{120 \times .8} = 57.2 \textit{ amperes.}$$

(Compare Question 6.391.)

Q. 6.395. In what units is the alternator output ordinarily rated?

A. Alternators are usually rated in volt-amperes output.

D. Since with a low power-factor load the current may be quite large with only a small amount of power being delivered, an alternator may be delivering its maximum rated current long before the actual power capabilities are realized. Therefore, alternators are usually rated in volt-amperes rather than in watts; occasionally, however, they may be rated in watts at a specified power factor. (See Questions 3.29, 3.34, and 6.99.)

Q. 6.396. What conditions must be met before two a-c generators can be operated in parallel?

A. Before two a-c generators can be connected in parallel the following conditions must be met:

1. The excitation of one generator must be such that its output voltage is equal to the voltage of the other generator.
2. The frequency of one generator must be exacty the same as the frequency of the other generator.
3. The phase rotation (in 2 or 3 phase machines) must be the same in both generators.
4. The relative phase positions of the two generators must be the same.

D. There are various other conditions which must be fulfilled in a *synchronous* system. A discussion of these conditions is considered to be beyond the scope of this book. In practice special equipment such as a system of lamps, or a device called the " synchronoscope" is used to determine the proper conditions for connecting the two generators together.

Q. 6.397. What is the effect of an inductive load on the output voltage of an alternator?

A. The output voltage of an alternator will decrease under load to an extent which depends upon the reactance of the load.

D. In addition to a decrease of voltage, a lagging power factor will be introduced into the alternator circuit. (See also Questions 3.34, 3.308, and 6.94.)

Q. 6.398. Draw a simple schematic circuit diagram of three kinds of d-c motors, including a starting device.

A. See Question 6.630.

Q. 6.399. See Question 3.74.

Q. 6.400. See Question 3.76.

Q. 6.401. See Question 3.70.

Q. 6.402. See Question 3.71.

Q. 6.403. See Question 3.72.

Q. 6.404. See Question 3.73.

Q. 6.405. See Question 3.77.

Q. 6.406. See Question 3.69.

Q. 6.407. Draw a simple schematic diagram of a crystal-controlled oscillator using a tetrode-type tube. Indicate power-supply polarity where necessary.

A. See the figure.

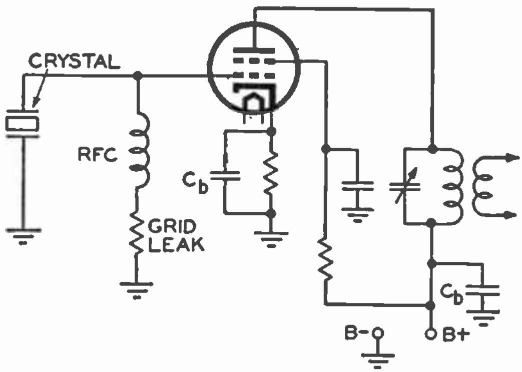


Fig. 6.407. Crystal-controlled tetrode oscillator.

D. Other crystal oscillator circuits are given in Questions 3.73, 3.77, and 4.80.

Q. 6.408. What will be the effect of a high degree of coupling between the plate and grid circuits of a quartz-crystal oscillator?

A. The crystal might overheat and break.

D. See Question 3.420.

Q. 6.409. Draw a simple schematic diagram of a crystal-controlled oscillator and means of coupling to the following radio-frequency amplifier stage, showing power-supply polarities.

A. See Question 6.407.

Q. 6.410. What type of oscillator depends upon secondary emission from the anode for its operation?

A. The operation of a dynatron oscillator depends upon the negative resistance characteristic of a tetrode tube, which is a consequence of secondary emission.

D. See Questions 3.412, 3.426, and 3.428.

Q. 6.411. Draw a simple schematic diagram of a dynatron oscillator using a tetrode, indicating polarity of power-supply voltages.

A. See Question 3.412.

Q. 6.412. Why is an additional plate-grid feedback condenser sometimes necessary in a crystal oscillator?

A. To provide additional feedback voltage.

D. A crystal oscillator which employs a pentode or tetrode type of tube and which operates at moderate frequencies may not receive sufficient feedback voltage due to the very low value of grid to plate interelectrode capacitance. In this event a small capacitance in the order of 2 $\mu\mu$f may be connected between the plate and grid of the tube.

Q. 6.413. Draw a simple schematic diagram of a Pierce oscillator.

A. See the figure.

D. Part B of the figure is an explanatory diagram for the circuit given in part A. The dotted lines indicate capacity between the tube elements. C_2 blocks the d-c plate voltage from the crystal. C_1 decreases the capacitive reactance between grid and cathode, to keep the feedback down to its proper value. Since the crystal acts as a tank circuit, with the cathode returning to an intermediate point, determined by the relation of C_{pk} to C_1 and C_{gk}, its operation is electrically equivalent to a Colpitts oscillator (Question 3.74).

Q. 6.414. What is the principal advantage to be gained by the use of a crystal-controlled oscillator in a marine radiotelegraph transmitter?

A. The principal advantage in the use of a crystal-controlled oscillator is the excellent frequency stability which may be obtained.

D. See Questions 3.419, 3.421, and 6.200.

Q. 6.415. Discuss the advantages and disadvantages of self-excited oscillator and master-oscillator power-amplifier transmitters.

A. A self-excited oscillator type of transmitter has the advantage of simplicity in construction and has less tubes and parts than a master-oscillator power-amplifier type of transmitter. It has less tuning adjustments and is easier to operate and maintain.

D. The self-excited oscillator transmitter has poor stability and is readily subject to frequency variations due to such causes as a swinging antenna. The self-excited oscillator must deliver a relatively large power output, a condition which is not desirable where good stability is required. When a master-oscillator power-amplifier type of transmitter is employed, the oscillator is not required to deliver nearly as much power output, and, therefore, may be designed with more attention given to stability rather than output power. The power-amplifier serves the function of a buffer stage and thus isolates the oscillator from variations in antenna loading to a large degree. The self-excited oscillator

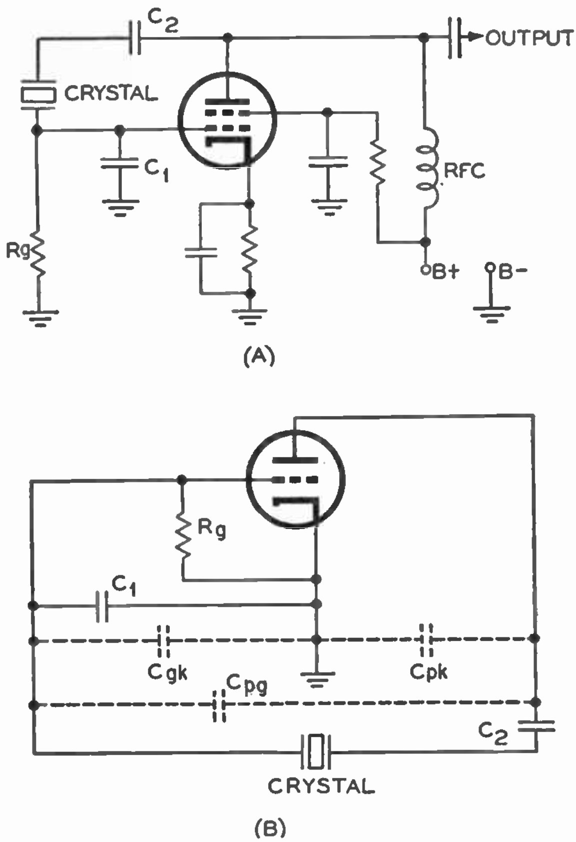


Fig. 6.413. (A) Pierce oscillator, and (B) explanatory diagram for (A).

type of transmitter is scarcely if ever used in modern equipment except possibly as emergency equipment. (See also Questions 3.364 and 3.366.)

Q. 6.416. What is the primary function of the power-amplifier stage of a marine radiotelegraph transmitter?

A. The primary function of the power amplifier stage is to improve the frequency stability of the oscillator. The power amplifier also provides greater power output and greater rejection of the oscillator harmonic output.

D. See Question 3.366.

Q. 6.417. See Question 3.298.

Q. 6.418. See Question 3.83.

Q. 6.419. What class of amplifier should be employed in the final amplifier stage of a radiotelegraph transmitter for maximum plate efficiency?

A. For maximum efficiency a class C amplifier should be used since distortion of a modulated wave is not an important consideration here.

D. See Question 3.104.

Q. 6.420. Under what class of amplification are the vacuum tubes in a linear radio-frequency stage, following the modulated stage, operated?

A. Such tubes are operated class B.

D. Any stages which are required to amplify a modulated wave must be operated as linear amplifiers in order that the modulation components shall not be distorted. Class C operation can not be used because of the extreme distortion which would result. It would be possible to employ class A except for its very low efficiency. Thus class B operation is the logical choice both from the standpoint of low distortion and of efficiency. It is usually preferred to operate at least the final class B amplifier in push-pull. (See also Question 3.107.)

Q. 6.421. If a final radio-frequency amplifier, operated as class B linear, were excited to saturation with no modulation, what would be the effects when undergoing modulation?

A. A condition of negative carrier shift would result since the plate current would be unable to increase properly on the modulation peaks, but could decrease to zero for 100% modulation.

D. See Questions 3.378 and 4.51.

Q. 6.422. Define a class C amplifier.

A. See Question 3.104.

Q. 6.423. Discuss the effects of insufficient radio-frequency excitation on a class C modulated radio-frequency amplifier insofar as the output signal waveform is concerned.

A. This will result in a positive carrier shift due to flattening of the negative modulation peaks.

D. This condition is similar to that resulting from overmodulation. In both cases the negative modulation cycles are flattened. Distortion of the output wave results and there may be adjacent channel interference due to the generation of spurious harmonic frequencies. (See also Questions 3.360 and 4.119.)

Q. 6.424. What is the second harmonic of 380 kilocycles?

A. The second harmonic of 380 kilocycles is 760 kilocycles.

D. A harmonic is a frequency that is some integral multiple of the fundamental frequency. The second harmonic is twice the fundamental frequency. In this example, the fundamental frequency is 380 kilocycles, hence the second harmonic is 760 kilocycles.

Q. 6.425. What are the effects of overexcitation of a class B amplifier grid circuit?

A. The following effects may result from overexcitation of a class B amplifier grid circuit:

1. Excessive grid current.
2. Excessive plate current.
3. Decreased plate efficiency.
4. Excessive distortion and non-linearity of operation.
5. Decreased power output.
6. Excessive plate dissipation.

D. See Question 3.107.

Q. 6.426. What is the function of a grid leak in a class C amplifier?

A. See Question 3.368.

Q. 6.427. Describe how a radio-frequency amplifier stage may be neutralized. What precautions must be observed?

A. See Question 3.441. See also Question 3.307 for general discussion of neutralization.

Q. 6.428. Why is a speech amplifier used in connection with the modulator of a radiotelephone transmitter?

A. Speech (voltage) amplifiers (sometimes called pre-amplifiers) are used in order to raise the signal to noise ratio and the output voltage of of microphones, phono-pickups, and similar equipment.

D. See Question 4.28.

Q. 6.429. If the first speech-amplifier tube of a radiotelephone transmitter were overexcited, but the percentage modulation capabilities of the transmitter were not exceeded, what would be the effect upon the output?

A. See Question 3.334.

Q. 6.430. How should the bias of a grid-modulated radio-frequency stage be adjusted?

A. The d-c grid bias is normally adjusted to a value varying from 1½ to 3 times the plate current cut-off value.

D. The actual value of bias used is not extremely critical and is a function of the available modulating voltage, and the desired operating efficiency. The efficiency of a grid-bias modulated class C amplifier is only about half that of a properly designed unmodulated class C amplifier and therefore the output is correspondingly less.

Q. 6.431. Compare the characteristics of plate and grid-bias modulation.

A. The characteristics of plate modulation are as follows:

1. Audio power for 100% modulation equals 50% of d-c input power to r-f modulated amplifier.
2. Plate voltage of modulated amplifier varies in proportion to audio modulating signal.
3. Load presented to the modulator tube consists of the d-c plate impedance of the modulated amplifier.
4. The r-f output voltage of the modulated amplifier is a linear function of the applied plate voltage.
5. Modulated amplifier operates class C.
6. Grid bias should be obtained partly from a fixed source and partly from grid-leak bias.
7. The d-c plate current of the modulated amplifier is constant with or without modulation.
8. High class C efficiency of the modulated amplifier.
9. Easy to adjust.
10. Constant grid excitation voltage.
11. Very low distortion.

The characteristics of grid modulation are:

1. Modulation power required is comparatively small. (Just enough to overcome grid circuit losses.)
2. Grid bias varies in proportion to the audio modulating signal.
3. D-c plate voltage kept constant.
4. R-f stage operated class C.
5. Carrier output is only about ¼ of power obtained using same tube modulated.
6. Relatively poor efficiency.
7. Constant grid excitation carrier signal.
8. Carrier efficiency about 35 to 40%.
9. Bias source must have good regulation. (No grid-leak bias.)
10. Driver regulation must be good.

(See also Questions 3.335, 6.430, and 6.434.)

Q. 6.432. What is meant by "low-level modulation"?

A. See Questions 3.334 and 3.336.

Q. 6.433. Should the efficiency of a grid-bias modulated stage be maximum at complete modulation or zero modulation? Explain.

A. The efficiency of a grid-bias modulated stage should be maximum at complete modulation and minimum at zero modulation.

D. The plate efficiency of a grid-bias modulated class C r-f amplifier under unmodulated conditions is about ½ of the amplifier efficiency realized during the 100% modulation peaks. This averages between 30 and 40% in typical cases. When the wave is 100% modulated, the plate efficiency averages about 45 to 60%. The carrier power obtained from a grid-bias modulated stage is about ¼ of the power obtainable from the same tube operated as an ordinary class C amplifier. See also Questions 6.430 and 6.439.

Q. 6.434. Does grid current flow in the conventional grid-bias modulated stage of a radiotelephone transmitter, under modulated conditions?

A. Grid current may exist during the positive portions of the audio frequency cycle.

D. If maximum output from a grid-modulated amplifier is to be achieved, it is necessary that the grid be driven positive (and draw current) on the modulation crests (peaks). However, it must be realized that grid current may cause distortion due to an impedance drop in the driver. It is essential, therefore, that the impedance presented by the driver be a low value to insure output voltage regulation. Where minimum distortion is desired, the grid is not permitted to draw current. This operating condition results in a reduction of both output and operating efficiency, but this is the price which must be paid for the improved quality. (See also Question 6.433.)

Q. 6.435. What might be the cause of a positive shift in carrier amplitude during modulation?

A. The following are causes of positive carrier shift:

1. High or low frequency parasitic oscillations.
2. Excessive audio drive.
3. Incorrect tuning of final amplifier.
4. Insufficient r-f excitation.
5. Incorrect neutralization.

D. See Question 4.50 (for further references), 4.51, and 4.52.

Q. 6.436. What is the ratio between the direct-current power input of the plate circuit of the stage being plate modulated, and the output audio power of the modulator for 100 per cent sinusoidal modulation?

A. For 100% modulation, the d-c power input to the modulated r-f amplifier should be twice the a-c power output from the modulator.

D. See Question 3.340.

Q. 6.437. What increase in antenna current will be observed when a radiotelephone transmitter is 100 per cent modulated by a sinusoidal waveform?

A. The antenna current will increase by 22.5%.

D. See Question 3.345.

Q. 6.438. Why is a series resistor used in the direct-current plate supply of a modulated radio-frequency amplifier, between the amplifier and the modulator, in a Heising modulation system?

A. A series resistor is used between the modulator and r-f amplifier in order that 100% modulation may be obtained from the Heising modulator.

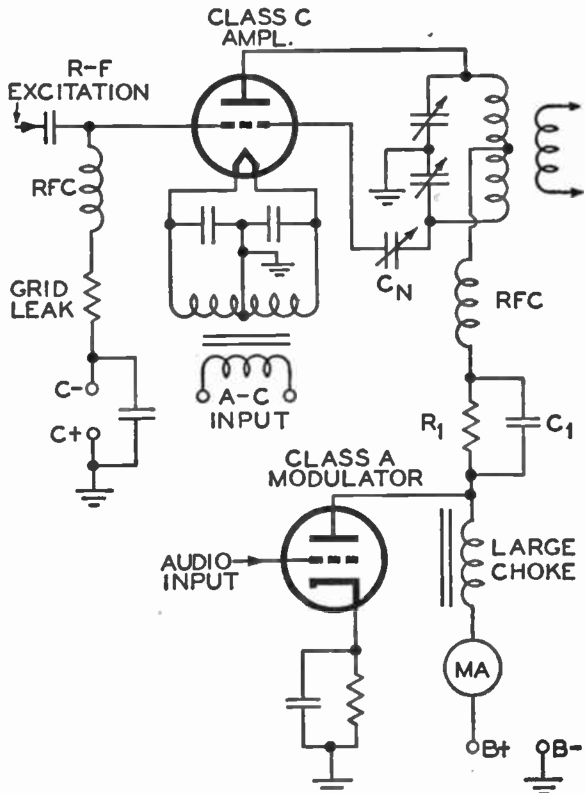


Fig. 6.438. Heising modulation system.

D. Refer to the figure for a diagram of a Heising modulator. If the dropping resistor R_1 were not present, the highest percentage of modulation obtainable would be about 55%. For 100% modulation of a class C amplifier, the crest value of the modulating voltage must equal the direct-plate voltage. However, a class A modulator cannot generate an output voltage with a crest value which is appreciably greater than one-half of the direct plate voltage, if the distortion is to be maintained within reasonable limits. Thus in this case the percentage of modulation is limited to a maximum value of slightly greater than 50%. For purposes of efficient radiation it is desirable that higher percentages of modulation be utilized. (See Question 3.342.) Higher percentages of modulation (up to 100%) may be obtained by the use of a series dropping resistor (R_1). For example, if the original circuit did not contain a series dropping resistor and the direct-plate voltages were equal in value and had a magnitude of 400 volts, the maximum percentage of modulation obtainable without serious distortion would be in the order of 50%. If the power supply voltage were increased to 800 volts and a suitable series resistor were inserted to maintain the 400 volt potential at the plate of the r-f amplifier tube, 100% modulation could be easily obtained. Furthermore the increased plate voltage (400 to 800 volts) of the modulator tube effectively increases its available power output by about 4 times which is necessary to achieve 100% modulation instead of 50% modulation. This is true because the power output of a class A modulator varies approximately as the square of the direct-plate voltage. The purpose of the condenser C_1 is to prevent any attenuation of the modulation voltages across R_1.

Instead of a series plate resistor, it is practical to use a transformer to obtain the desired modulation voltage from the modulator tube; such a circuit is given in Question 4.41.

Q. 6.439. What is the purpose of a plate choke as used in Heising modulation?

A. The purpose of the plate choke is to build up audio modulating voltages which are then fed to the plate of the r-f modulated amplifier to produce plate modulation.

D. The Heising modulation system is also called the "constant current" system since the total current in the plate choke remains substantially constant during modulation. Both the modulator tube and r-f amplifier tube receive their plate potentials through the plate choke. This means that the total current in the choke at any given instant is the sum of plate currents of both tubes. The action of the system is as follows: Assume first that no modulating signal is present at the grid of the modulator tube but that r-f excitation voltage is present at the grid of the modulated r-f amplifier. A certain total d-c current will exist in the plate choke. This plate choke has a very high inductance value (30 to 200 henrys) so that it tends to oppose any change in the total d-c current in it. When an alternating signal is applied to the grid of the modulator tube its plate current will vary in proportion to the grid signal. When the modulator tube grid is driven in the positive direction, the modulator plate current increases. The choke coil tends to oppose the increased current by developing a voltage across its terminals in opposition to the supply voltage. Thus the total d-c voltage supplied to the plate of the r-f amplifier is reduced by an amount equal to the voltage developed across the choke. Since its plate voltage is reduced, the r-f amplifier current is proportionately reduced, and the total current in the plate choke remains substantially constant. When the modulator tube grid swings in the negative direction, the modulator plate current decreases. The choke coil tends to oppose any decrease in current by developing a voltage across its terminals which aids the supply voltage. The total d-c voltage supplied to the plate of the r-f amplifier is increased by an amount equal to the voltage developed across the choke. The plate voltage of the r-f amplifier is thus increased, and its current requirements are also proportionately increased, again maintaining substantially constant, the total current in the choke. See Question 4.41 for a schematic diagram of such a modulation system.

Q. 6.440. The direct-current plate input to a modulated class C amplifier, with an efficiency of 60 per cent, is 200 watts. What value of sinusoidal audio power is required in order to insure 100 per cent modulation? 50 per cent modulation?

A. At 100% modulation, an audio power of 100 watts is required. At 50% modulation, an audio power of 25 watts is required.

D. For 100 per cent modulation the modulator stage must supply audio power equal to half of the d-c input power to the r-f modulated amplifier. In this problem the needed audio power is $\frac{200}{2} = 100$ watts. For 50 per cent modulation the modulator stage must supply audio power equal to 12.5 per cent of the d-c input power to the r-f modulated amplifier, or $200 \times .125 = 25$ *watts.* See Question 3.340.

Q. 6.441. A ship's transmitter has an antenna current of 8 amperes using A1 emission. What would be the antenna current when this transmitter is 100 per cent modulated by sinusoidal modulation?

A. The antenna current would be 9.8 amperes.

D. Under conditions of 100% sinusoidal modulation, the antenna current will increase by 22.5 per cent. The modulated antenna current, therefore equals $1.225 \times 8 = 9.8$ *amperes.* (See also Question 3.345.)

Q. 6.442. If a transmitter is adjusted for maximum power output for telegraph operation, why must the plate voltage be reduced if the transmitter is to be amplitude-modulated?

A. The plate voltage must be reduced in order not to exceed the plate dissipation rating of the power-amplifier tubes.

D. The average telegraph transmitter is desired to operate at maximum efficiency with a given type tube. This means that the power amplifier tubes are dissipating the maximum allowable power when adjusted for maximum power output for telegraph operation. If the same (maximum) plate voltage were maintained and the transmitter were amplitude modulated, the tubes would have to dissipate 1.5 times as much power as during telegraph operation, and would probably be damaged. In order to provide safe operation for 100% modulation, the plate voltage should be reduced to a value not over two-thirds of its maximum rating.

Q. 6.443. In a series fed plate circuit of a vacuum tube amplifier, what would be the result of a short circuit of the plate by-pass condenser?

A. A short circuit of the plate by-pass condenser would short out the power supply, removing the plate voltage and possibly damaging the power supply.

Q. 6.444. In a shunt fed plate circuit of a vacuum tube amplifier what would be the result of a short circuit of the plate RF choke coil?

A. In a shunt fed amplifier, if the r-f choke shorted, then the plate tank circuit would be effectively shorted as far as r-f is concerned. The d-c plate current would increase considerably (possibly to excess) and no r-f output could be expected since the plate is now at r-f ground potential.

Q. 6.445. What is the total band width of a transmitter using A2 emission with a modulating frequency of 800 cycles and a carrier frequency of 500 kilocycles?

A. Assuming pure sinusoidal modulation at a frequency of 800 cycles, the total band width is 1600 cycles.

D. The total band width is the difference between the upper and lower sideband frequencies. The upper sideband frequency equals 500,000 + 800 = 500,800 cycles. The lower sideband frequency equals 500,000 — 800 = 499, 200 cycles. The total bandwidth therefore equals 1600 cycles, or the difference between the two sideband frequencies.

Q. 6.446. What is the correct value of negative grid bias for operation as a class B amplifier, for a vacuum tube of the following characteristics: Plate voltage 1,000, plate current 127 milliamperes, filament voltage 4 volts, filament current 5.4 amperes, mutual conductance 8,000 micromhos, and amplification factor 25?

A. The value of grid bias voltage is approximately 40 volts.

D. The approximate value of grid bias voltage for class B operation is found from the formula, $E_c = \frac{E_b}{\mu} = \frac{1000}{25} = 40 \textit{ volts.}$

Q. 6.447. What is the meaning of "carrier shift"? What may cause a positive carrier shift in a linear radio-frequency amplifier output?

A. "Carrier shift" occurs when the relative amplitudes of the positive and negative modulation peaks are unsymmetrical. The shift is one of amplitude and not of carrier frequency. For causes see Question 6.435.

D. See Question 3.378.

Q. 6.448. Name three instruments which may be used as indicating devices in neutralizing a radio-frequency amplifier stage.

A. The following indicating devices may be used to determine correct neutralization.

1. A neon bulb.
2. A low current flashlight bulb connected to a small loop of wire.
3. The amplifier grid current meter.
4. A sensitive wavemeter.
5. A sensitive thermocouple meter attached to a small loop of wire.
6. A thermocouple meter connected in series with the plate tanks.

D. See Question 3.441.

Q. 6.449. See Questions 3.90 and 3.138.

Q. 6.450. Draw a block diagram of a MOPA radiotelegraph transmitter with the master oscillator operating on 2017.5 kilocycles and the transmitter output on 8070 kilocycles.

A. See the figure.

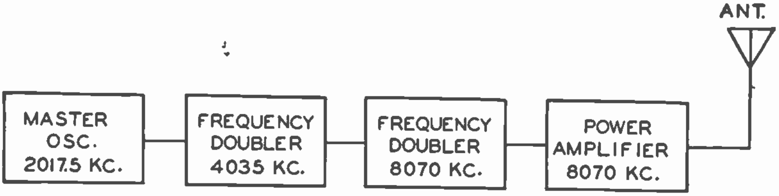


Fig. 6.450. Block diagram of MOPA transmitter.

Q. 6.451. What factors are most important in the operation of the vacuum tube as a frequency doubler?

A. The most important factors are as follows: (*a*) the plate tank should be tuned to twice the grid circuit frequency, (*b*) the grid bias should be very large, about 10 times cut-off for efficient operation, (*c*) the grid driving voltage must be very large, (*d*) the plate voltage should be comparatively high, (*e*) the plate tank circuit should have a low C to L ratio.

D. See Question 3.138.

Q. 6.452. See Question 3.294.

Q. 6.453. What precautions should be observed in tuning a transmitter to avoid damage to components?

A. A transmitter should be adjusted at reduced power in order to protect the amplifier tubes and the power supply from severe overloads.

D. Under normal operating conditions the plate tank circuits of the various r-f amplifiers are tuned for minimum d-c plate current. If the tank circuits are seriously detuned, the plate currents may rise to dangerously excessive values, possibly damaging tubes and power supply. Too much coupling between the antenna and final amplifier could also cause excessive plate current even though the final amplifier was tuned to the minimum plate current point. When attempting adjustment of the various circuits of a transmitter, the power should first be reduced to a relatively low value to prevent damage to the component parts of the transmitter.

Q. 6.454. Draw a complete schematic diagram of a system of inductive coupling between the output of a radio-frequency amplifier and an antenna system.

A. See part A of the figure for Question 3.83.

Q. 6.455. What is the result of excessive coupling between the antenna and output circuits of a self-excited type of vacuum-tube transmitter?

A. See Question 6.471.

Q. 6.456. Draw a simple schematic diagram of a system of keying in the primary of the transformer supplying high voltage to a vacuum-

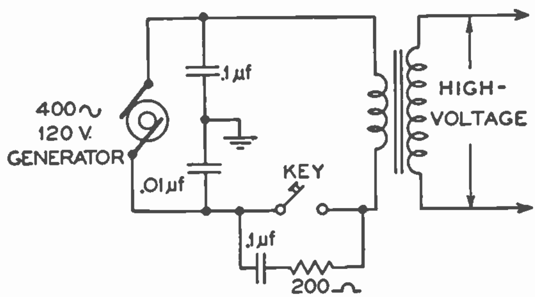


Fig. 6.456. Transformer-primary keying.

tube transmitter. Indicate any values of inductance, resistance, capacitance which may be deemed necessary to fully understand the correct operation of this type of keying.

A. See the figure.

D. See Question 6.485.

Q. 6.457. In a transmitter involving a master oscillator, intermediate amplifier and final amplifier, describe the order in which circuits should be adjusted in placing this transmitter in operation.

A. The master-oscillator should first be adjusted, then the intermediate amplifier, next the final amplifier and finally the antenna circuit.

D. See Question 6.458.

Q. 6.458. Should the antenna circuit of a master-oscillator, power-amplifier type of transmitter be adjusted to the resonant frequency before the plate-tank circuit of the final stage? Give the reason(s) for your answer.

A. No. The plate tank circuit of the final stage should be tuned first. If the final amplifier stage is not tuned for a plate current dip, its plate current may be excessive. The plate circuit should be tuned first without a load so that the proper dip point may be found. Then the antenna circuit should be tuned to resonance, at which point, both the antenna current and plate current will rise. At resonance the antenna current will be a maximum. The plate tank circuit and antenna circuit should then be retuned, the plate tank circuit for minimum plate current, and the antenna circuit for maximum antenna current. (See Question 6.457.)

Q. 6.459. What may cause a radio-frequency amplifier to have excessive plate current?

A. Several causes of excessive plate current in a radio-frequency amplifier are:

1. Plate tank circuit off resonance.
2. Excessive loading of plate tank.
3. Defective tube.
4. Insufficient bias.
5. Excessive plate and screen voltage.
6. Excessive excitation voltage.
7. Parasitic oscillations.
8. Improper neutralization.

D. See Questions 3.141, 3.383, and 3.469.

Q. 6.460. What are the disadvantages of using a self-excited oscillator type of transmitter for shipboard service?

A. A self-excited oscillator type of transmitter is undesirable because of its frequency instability.

D. See Questions 6.415, 6.495, and 6.471.

Q. 6.461. How is the degree of coupling varied in a pi network used to transfer energy from a vacuum-tube plate circuit to an antenna?

A. The degree of coupling in a pi network may be varied by adjusting the series condensers.

D. For a diagram of a pi network, see the figure. Condenser C_2 and C_3 are simultaneously varied to adjust the degree of coupling.

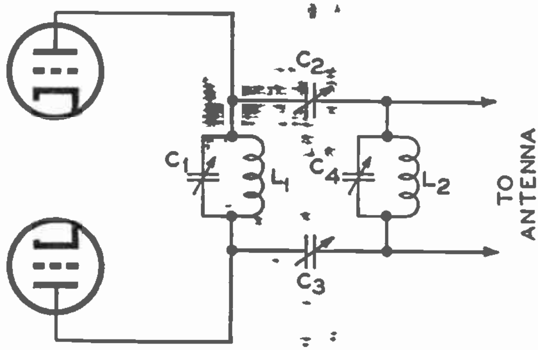


Fig. 6.461. Variable coupling pi network.

Q. 6.462. See Question 3.263.

Q. 6.463. Why is it sometimes necessary to provide a radio-frequency filter in the plate circuit of a detector tube?

A. Such a filter is sometimes used in order to prevent r-f variations from affecting the following audio stages.

D. Since the output of a detector contains r-f as well as a-f components, a filter should be used between the detector output and the input to the first a-f amplifier which will remove the r-f components. The filter must be of such a nature as not to alter the impedance of the detector load circuit and may be in the form of an *R-C* or *L-C* circuit.

Q. 6.464. In a radio-frequency amplifier, employing fixed bias, as the plate circuit is varied in adjustment from a point below resonance to a point above resonance, what effect will be observed on the grid current?

A. The grid current will ordinarily rise slightly as the plate tank circuit is tuned to its resonant frequency.

D. The total cathode current of a radio frequency amplifier tube divides between the plate and control grid (and screen grid if any) of the amplifier tube in proportion to the relative potentials on these elements. When the plate tank circuit is tuned to resonance, the maximum tank circuit swing will exist. Thus, at the time the tube conducts (when grid is on positive swing) the instantaneous plate voltage is at its minimum positive value. The cathode current will divide between the grid and plate, and since at resonance the instantaneous potentials of plate and grid are approximately equal, there will be a maximum value of grid current at resonance. When the plate tank is tuned off resonance, the tank circuit swing decreases, so that the instantaneous plate voltage is higher during conduction, while the maximum grid voltage remains practically constant. Due to the higher instantaneous plate voltage, the grid current decreases. This is caused in the main by the increased electron velocity within the tube.

Q. 6.465. In a self-biased radio-frequency amplifier stage having a plate voltage of 1,250 volts, a plate current of 150 milliamperes, a grid current of 15 milliamperes, and a grid-leak resistance of 4,000 ohms, what is the value of the operating grid bias?

A. The value of operating bias is 60 volts.

D. The operating bias is found by determining the voltage drop across the grid-leak resistance. Since both the value of grid-leak resistance and grid current are given, the bias may be easily found as: $E_c = I_c \times R_g = .015 \times 4{,}000 = 60$ *volts*. (Compare Question 3.142.)

Q. 6.466. In a series-fed plate circuit of a vacuum-tube amplifier, what could be the effect of a short circuit of the plate-supply by-pass condenser?

A. See Question 6.433.

Q. 6.467. In a shunt-fed plate circuit of a vacuum-tube amplifier, what would be the effect of an open circuit in the plate radio-frequency choke?

A. The amplifier would be inoperative due to the fact that there would be no plate potential present.

D. If another amplifier followed the one in question, it might receive some drive due to coupling through interelectrode capacitance. However, if the amplifier with the open choke were properly neutralized, no driving power would be available in the absence of plate voltage.

Q. 6.468. Explain how you would determine the value of the cathode-bias resistor for a specific amplifier stage.

A. See Question 3.143.

Q. 6.469. Draw a simple schematic diagram showing a method of link coupling between two radio-frequency amplifier stages.

A. See Question 3.360.

Q. 6.470. What is the advantage of link coupling between radio-frequency amplifier stages?

A. The main advantages of link coupling are the extreme flexibility of mechanical construction possible, and a reduction of tube capacitance effects on the L/C ratio of the tank circuits.

D. See Question 3.140.

Q. 6.471. What is the effect of excessive coupling between the output circuit of a simple oscillator and an antenna?

A. Excessive coupling will result in great instability of the oscillator. The plate current may rise to an excessive value, and "split tuning" will result.

D. For a discussion of "split tuning," see Question 6.474.

Q. 6.472. How is the power output of a marine vacuum-tube radiotelegraph transmitter usually adjusted?

A. A marine radiotelegraph transmitter should be adjusted to radiate the minimum amount of power necessary to insure reliable communication. The power output may be controlled by varying the plate supply generator field rheostat.

Q. 6.473. Why should a transmitter be tuned initially at reduced power?

A. See Question 6.453.

Q. 6.474. What is meant by "split tuning"?

A. "Split tuning" or "double hump" tuning is an effect which results from excessive coupling between two tuned circuits, which are resonant at the same frequency.

D. If the frequency response curve of a circuit having "split tuning" is examined, it will be found that *two* definite resonant peaks are present separated by a valley. The distance between the two peaks increases as the coupling is tightened, and the two peaks will merge into one at a looser coupling value. The maximum degree of coupling for which the secondary circuit resonance curve shows only one resonant peak is called "critical coupling." At "critical coupling" the maximum current exists in the secondary circuit, but the resonant peak is somewhat broadened thereby decreasing the selectivity of the circuit. The resonant peak of the secondary circuit is sharpened but also decreased in magnitude as the coupling is reduced below "critical coupling."

Q. 6.475. What is meant by a "self-rectified" circuit, as employed in marine vacuum-tube telegraph transmitters?

A. A "self-rectified" circuit is an oscillator circuit in which the unfiltered a-c voltage is applied to the plate of the oscillator tube, which operates only upon the positive alternations of the a-c voltage. This provides a tone frequency for A2 emission. See Question 6.483 for schematic diagram.

D. Transmitters utilizing this principle are practically obsolete today.

Q. 6.476. If the power of a 500 kilocycle transmitter is increased from 150 watts to 300 watts what would be the percentage change in field intensity at a given distance from the transmitter? What would be the db change in field intensity?

A. The field intensity will be increased by 1.414 times. The *db* change in field intensity (voltage) is 3 *db*.

D. It is stated that the output is *doubled*. The field intensity is a measure of voltage (microvolts per meter) which varies as the square root of power, $E = \sqrt{W \times Z}$. The field intensity will vary, as the square root of Z, or by 1.414 times.

The *db* change is proportional to the logarithm of the field intensity ratio of 1.414 to 1. $N = 20 \log \frac{E_2}{E_1} db = 20 \log (1.414) = 20 \times 0.15 = 3\ db$.

Q. 6.477. Draw a sketch of a typical shipboard antenna for transmitting on 500 kilocycles showing the supporting insulators, the safety link and the lead-in wire. How does voltage vary along the length of the lead-in and along the antenna?

A. See the figure. Part A shows the installation, and Part B shows the voltage and current distribution.

Q. 6.478. Draw a block diagram of an FM transmitter.

A. See Question 3.493.

D. For a block diagram of an f-m receiver, see Question 3.492.

Q. 6.479. Show by a diagram how a radiotelegraph transmitter can be keyed by the use of a keying relay.

A. See the figure.

Q. 6.480. List the various points in a radiotelegraph transmitter where keying can be accomplished.

A. Keying of a radiotelegraph transmitter can be accomplished at the following points:

1. Primary of power transformer (plate).
2. Filament center tap (or cathode).
3. Screen grid circuit.
4. Control grid circuit (blocked grid keying).
5. Direct current supply.
6. Plate circuit.

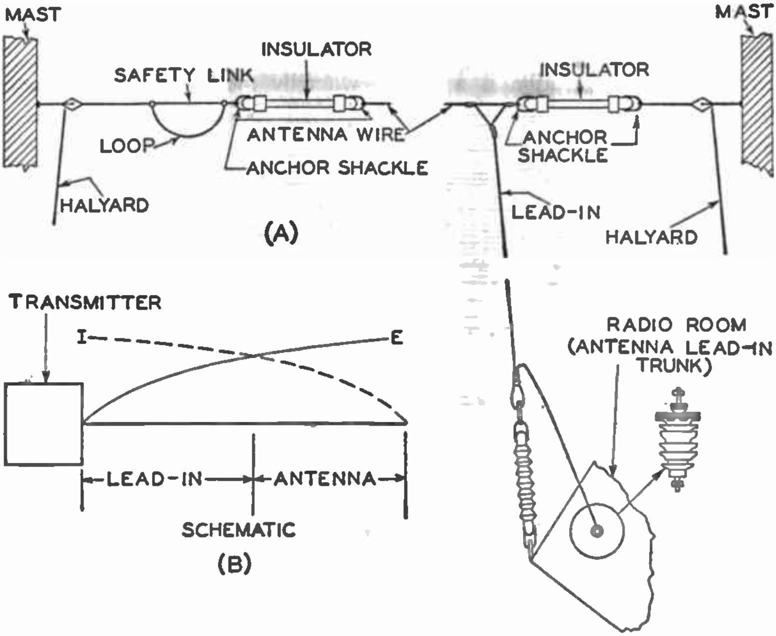


Fig. 6.477. (A) Shipboard antenna installation, and (B) Voltage and current distributions in shipboard antenna.

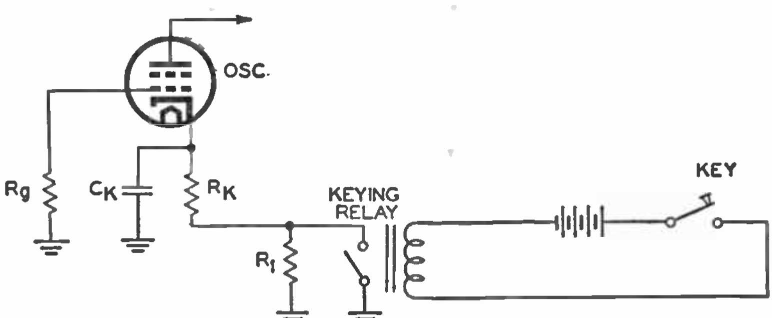


Fig. 6.479. Keying a transmitter by use of a keying relay.

D. Of the above mentioned methods, block-grid keying appears to be the most satisfactory system. This is because the oscillator, buffer amplifier, and power amplifier can all be conveniently keyed simultaneously, which prevents the high-power tubes from drawing excessive plate current during the time when the key is *up* and excitation is removed. (See Questions 6.605, 6.503, 6.456, and 6.485.)

Q. 6.481. What is meant by break-in operation at a radiotelegraph station and how is it accomplished?

A. Break-in operation is a system whereby the receiving operator may interrupt the transmitting operator at any point during transmission. It is accomplished by means of a break-in relay which changes the antenna from receiving to transmitting positions during keying.

Q. 6.482. What is meant by frequency-shift keying, and how is it accomplished?

A. Frequency-shift keying (F1 emission; see Question 3.462) is a means of keying a radiotelegraph transmitter by changing the frequency of its output when the key is depressed, rather than turning the transmitter on and off during keying. It may be accomplished by connecting a keyed reactance tube (Question 4.221) across the master-oscillator so that the resonant frequency is changed by about 800 cycles as keying takes place.

D. Frequency shift keying has several important advantages over "on-off" keying as follows:

1. A reduction of transmitted bandwidth, especially for high speed (machine) keying.
2. On increase of signal-to-noise ratio at the receiving end.
3. A possible reduction of fading.

When a transmitter is being keyed, frequencies other than the carrier frequency are radiated. These are called sidebands and their relative amplitude and frequency depend largely upon the rate of keying, and the shape of the keyed characters (see Question 6.484). If the keyed characters have a square shape, the side frequencies will extend out on each side of the carrier for great distances. On the other hand, if the keyed characters can be rounded off and kept that way during transmission, the sidebands will be greatly attenuated. Rounding of the keyed characters in "on-off" keying cannot be easily accomplished, since clipping and limiting in class C amplifiers effectively squares up any rounding-off which might have been originally produced.

In frequency-shift keying, rounding may be accomplished by passing the square characters through a suitable low-pass filter. The keying stage produces frequency modulation of the output, and the rounded characters are able to retain their original shape.

At the receiving end a considerable increase in signal-to-noise ratio is noted in frequency shift keying. The main reason for this is the fact that a carrier is always present (although shifted) and noise pulses are not able to actuate the signal recorder of the receiving equipment readily.

The possible reduction of fading is due to the fact that the energy in the transmitted wave is distributed over a *band* of frequencies, each frequency of which may have somewhat different fading characteristics.

Q. 6.483. Draw a simple circuit diagram of a transmitter using an oscillator coupled to the antenna, with the oscillator using a self-rectifying circuit for operation directly from an a-c generator.

A. See the figure.

Q. 6.484. Does the code speed or number of words per minute transmitted have any effect on the bandwidth of the emission from a radiotelegraph transmitter?

A. The bandwidth of the emission from a radiotelegraph transmitter increases as the code speed is increased.

D. Keying a radiotelegraph transmitter is equivalent to amplitude-modulating it with approximately square characters. It therefore follows that if the keying (code) speed is increased, the fundamental modulation frequency is also increased; this in turn increases the width of the sideband frequencies from the carrier frequency.

From a more practical standpoint, it should be realized that the shape of the keyed characters is usually much more important than their repetition rate, in its effect upon bandwidth. For example, if the keyed characters were perfectly square, the sideband frequencies would theoretically be infinite. To reduce this type of excessive sideband radiation, "lag" circuits are used to round off the shape of the dots and dashes. (See also Question 6.503, and the discussion for Question 6.482.)

Q. 6.485. How is the keying of a simple-oscillator type of emergency marine transmitter usually accomplished?

A. The key is usually inserted in series with the primary of the high voltage plate transformer.

D. See Question 6.456.

Q. 6.486. If the plate current of the final radio-frequency amplifier in a transmitter increased and radiation decreased, although the antenna circuit is in good order, what would be the possible causes?

A. The possible causes are:

1. Neutralization may have been upset.
2. Parasitic oscillations may have started.
3. The grid excitation may have decreased.
4. The bias may have been decreased or lost entirely.
5. Faulty tube.
6. Plate circuit may have been accidentally detuned.

D. See Questions 3.307, 3.370, 3.372, 3.434, and 4.124.

Q. 6.487. What care should be taken in hoisting the antenna of a shipboard radiotelegraph station to avoid damage to the antenna wire and insulators?

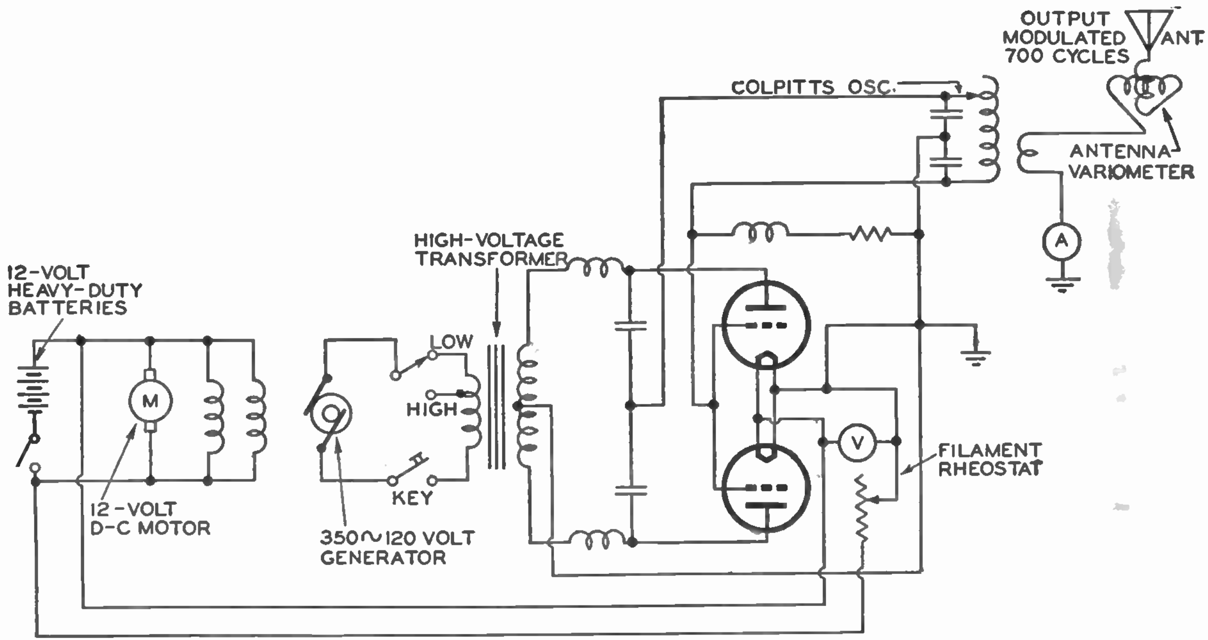


Fig. 6.483. Transmitter using self-rectifying oscillator.

A. Care should be taken when hoisting the antenna to avoid kinking the wire and smashing the insulators against metal objects.

Q. 6.488. If a 500-kilocycle transmitter of constant power produces a field strength of 100 microvolts per meter at a distance of 100 miles from the transmitter, what would be the theoretical field strength at a distance of 200 miles from the transmitter?

A. The theoretical field strength would be 50 microvolts per meter.

D. The field strength (voltage) varies inversely as the distance from the antenna. (Power varies inversely as the square of the distance.) Since the distance from the antenna is doubled, the field intensity is reduced to one-half of its original value, or 50 microvolts.

Q. 6.489. If the antenna current at a 500 kilocycle transmitter is reduced 50 percent what would be the percentage change in the field intensity at the receiving point?

A. The field intensity will be reduced by 50 percent.

D. The field intensity is directly proportional to the antenna current and is thus reduced by the same percentage as the antenna current, or by 50%.

Q. 6.490. At what point on a shipboard antenna system will the maximum potential be found?

A. The maximum r-f potential on a shipboard antenna system will exist at the end of the antenna farthest from the transmission line connection.

D. Maximum current and minimum voltage will exist at a point close to the transmitter proper. The r-f potential on the antenna system will be a maximum at a point which is located an electrical quarter-wave length distant from the point of maximum r-f current. If the antenna system is less than one quarter wavelength long, the maximum potential point will appear at the far end of the antenna system.

Q. 6.491. What are some of the indications of a defective vacuum tube in a transmitter?

A. Some possible indications are:

1. "Gas glow" within tube.
2. Excessive plate color due to overheating.
3. No light from filament.
4. Insufficient or excessive plate current.
5. Reduced output.
6. Possible internal arcing.
7. Fluctuating plate or grid current, or both.

D. See Questions 3.376 and 3.377.

Q. 6.492. A master-oscillator power-amplifier type of transmitter has been operating normally. Suddenly the antenna ammeter reads zero, although all filaments are burning and plate and grid meters are indicating normal voltages and currents. What would be the possible cause(s)?

A. The cause may be a short circuited ammeter, or for a remote-reading meter, an open connection.

D. Since it is indicated that the other meter readings are all normal, the transmitter is obviously radiating properly. The zero indication on the antenna ammeter can only mean that the meter itself is defective.

Q. 6.493. What is the effect upon a transmitter of dirty or salt-encrusted insulation?

A. The following effects may be noted:

1. Erratic readings of antenna current and plate milliammeter readings.
2. Increased corona discharge and other losses.
3. Decreased radiation power.

Q. 6.494. Describe a means of reducing the sparking at the contacts of a key used in a radiotelegraph transmitter.

A. Sparking, and interference due to sparking, may be reduced by connecting a suitable key-click filter across the radiotelegraph key.

D. Any sparking at the key contacts will cause damped oscillations to be set up in the *L* and *C* components of the keying circuit. These oscillations may cause modulation of the transmitter output or may be radiated by the connecting wires in the keying circuit. Radiation from the keying circuit wiring may be greatly reduced by isolating the key from its wiring by means of a suitable low pass filter. Such a filter may consist of an r-f choke in each key lead (2.5 to 80 millihenrys) and a condenser connected across the key contacts (.001 to .1 μf). (See also Question 6.503.)

Q. 6.495. What will be the effect of a swinging antenna upon the output of a self-excited oscillator transmitter? A master-oscillator power-amplifier transmitter?

A. In a self-excited oscillator a swinging antenna will cause serious frequency instability. In a master-oscillator power-amplifier transmitter, the effect of a swinging antenna upon the oscillator frequency will be greatly reduced due to the buffer action of the master-oscillator.

D. See Questions 3.364, 3.366, and 6.415.

Q. 6.496. What effect upon the plate current of the final-amplifier stage will be observed as the antenna circuit is brought into resonance?

A. The plate current of the final amplifier stage will increase as the antenna circuit is brought into resonance.

D. With no load of the final amplifier the plate current will be at its lowest value. This is so because the Q and the impedance of the plate tank will be a maximum and, therefore, the amplitude of plate voltage swing will also be a maximum. In class C operation the only period during which the tube conducts is when the instantaneous plate voltage is at or near its minimum value, and, therefore, the plate current will also be at its minimum value. When the antenna circuit is brought into resonance, power is taken from the final amplifier by the antenna. As a result the plate tank circuit impedance and Q are lowered, and the minimum instantaneous value of plate voltage will be greater than before. The plate current in turn will, therefore, increase.

Q. 6.497. How may instruments used to indicate various direct currents and voltages in a transmitter be protected against damage due to stray radio-frequency energy?

A. The following precautions may be taken to protect instruments against damage due to stray radio-frequency energy:

1. An r-f by-pass condenser of low reactance may be connected across the meter terminals.
2. Two condensers in series may be connected across the meter terminals and the center connection grounded.
3. The meter case may be shielded and grounded.
4. The connecting leads to the meter may be shielded and grounded.
5. Ammeters may be placed in the low potential side of the circuit.
6. Small r-f chokes and by-pass condensers may be connected in the meter leads.

Q. 6.498. In a radiotelegraph transmitter employing a direct-current generator as a source of plate voltage, an alternating-current generator as filament supply and grid-bias keying, if it is noted that when the key contacts are open the emission continues, what could be the trouble?

A. The trouble would be caused by insufficient grid blocking bias being applied to the grid when the key is open.

D. Some possible faults which might cause such a condition are:

1. Burned-out or shorted bias resistor.
2. Shorted key circuit.
3. Shorted key click filter.

4. Shorted keying relay.
5. Grid return shorted to ground. See also Question 3.381.

Q. 6.499. A station has an assigned frequency of 8000 kilocycles and a frequency tolerance of plus or minus 0.04 per cent. The oscillator operates at one-eight of the output frequency. What is the maximum permitted deviation of the oscillator frequency, in cycles, which will not exceed the tolerance?

A. The maximum permitted deviation is ±400 cycles.

D. The tolerance at the output frequency is 0.04 per cent of 8000 kilocycles, or $0.0004 \times 8000 = 3.2$ kilocycles. The oscillator operates at one-eighth of the output frequency, therefore the oscillator tolerance must be one-eighth of the output frequency tolerance: $\frac{3.2\ kilocycles}{8} =$ 0.4 *kilocycles* or 400 *cycles.*

Q. 6.500. A transmitter is operating on 5000 kilocycles, using a 1000-kilocycle crystal with a temperature coefficient of —4 cycles/megacycle/degree centigrade. If the crystal temperature increases 6 degrees centigrade, what is the change in the output frequency of the transmitter?

A. The change in the output frequency is a decrease of 120 cycles or a new operating frequency of 4999.88 kilocycles.

D. Since the crystal has a negative temperature coefficient the change of output frequency equals -4×5 (megacycles) $\times$ 6 (degrees) $= -120$ cycles. The new operating frequency equals 5,000,000 —120 cycles or 4999.88 *kilocycles.*

Q. 6.501. What should be the approximate surge impedance of a quarter wavelength matching line used to match a 600 ohm feeder to a 70 ohm antenna?

A. The approximate surge impedance should be 204 ohms.

D. The required surge impedance for a "Q" matching section is found from the formula $Z_o = \sqrt{Z_{ant} \times Z_{Line}} = \sqrt{70 \times 600} = \sqrt{4.2 \times 10^4} = 205$ ohms. See also Questions 4.198, 4.199, and 4.202.

Q. 6.502. What determines the surge impedance of a 2-wire non-resonant radio frequency transmission line?

A. The surge impedance (or characteristic impedance) of any 2-wire transmission line is dependent upon three factors. These are: (1) the diameter of the conductors, (2) the spacing between the conductors, (3) the dielectric constant of the insulating material. The fact of resonance or non-resonance is of no consequence in determining the surge impedance

D. See Questions 4.198, 4.199, and 4.202.

Q. 6.503. Draw a simple schematic diagram of a key-click filter suitable for use when a vacuum-tube transmitter is keyed in the negative high-voltage circuit.

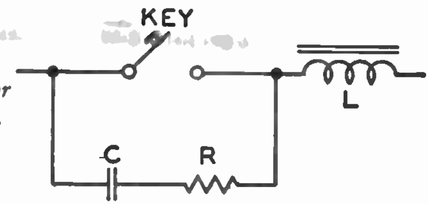


Fig. 6.503. Key-click filter, for negative high-voltage keying.

A. See the figure.
D. See Question 6.494.

Q. 6.504. What is the crystal frequency of a transmitter having three doubler stages and an output frequency of 16,880 kilocycles?

A. The crystal frequency is 2110 kilocycles.

D. It is stated that the output frequency after passing through three doubler stages is 16,880 kilocycles. The total frequency multiplication is 2 × 2 × 2 = 8 times. The crystal frequency therefore equals $\frac{16{,}880}{8} = 2110$ *kilocycles.*

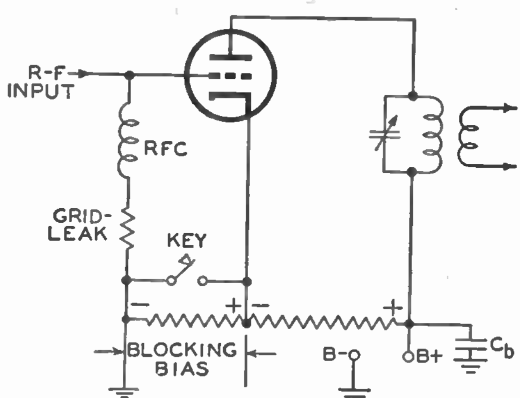


Fig. 6.505. Grid-blocking method of transmitter keying.

Q. 6.505. Draw a simple schematic diagram showing how a radiotelegraph transmitter may be keyed by the grid-blocking method.
A. See the figure.

Q. 6.506. See Questions 3.219 and 3.218.

Q. 6.507. See Question 3.221.

Q. 6.508. See Question 3.222.

Q. 6.509. See Question 3.223.

Q. 6.510. See Question 3.224.

Q. 6.511. See Question 3.226.

Q. 6.512. See Question 3.252.

Q. 6.513. See Question 3.246.

Q. 6.514. What is the difference between a Hertz and a Marconi antenna?

A. The basic difference between a Hertz and a Marconi antenna lies in their physical length. A Hertz antenna (ungrounded) is a half-wavelength long (electrically) and is usually fed at the center (maximum current point, low impedance). A Marconi (grounded) antenna is a quarter-wavelength long (electrically) and is usually fed at the maximum current point which generally occurs at the transmitter end of the antenna.

D. See also Questions 3.221, 3.222, 3.223, and 6.515.

Q. 6.515. Draw a diagram showing how current varies along a half-wavelength Hertz antenna.

A. See the figure, which shows both voltage and current distribution.

D. See Question 6.514.

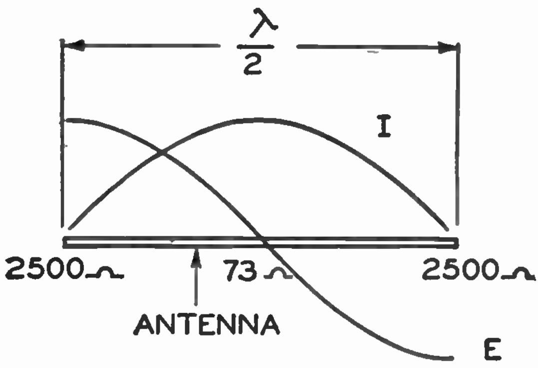


Fig. 6.515. Current and voltage distribution on Hertz antenna.

Q. 6.516. What is meant by polarization of a radio wave? How does polarization affect the transmission and reception of a radio wave?

A. The polarization of a radio wave is determined by the direction of the plane of the electrostatic field of the wave.

D. See Questions 3.490 and 3.491.

Q. 6.517. See Question 3.242.

Q. 6.518. See Question 3.243.

Q. 6.519. See Question 3.244.

Q. 6.520. See Question 3.245.

Q. 6.521. What is meant by harmonic radiation?

A. Harmonic radiation is radiation occurring on frequencies which are whole multiples of the original desired transmitter frequency.

D. See Questions 3.232, 6.522, and 6.523.

Q. 6.522. Why does harmonic radiation from a transmitter sometimes cause interference at distances from a transmitter where the fundamental signal cannot be heard?

A. Harmonic radiation from a transmitter may cause interference, where the fundamental signal cannot be heard, since the higher frequencies may travel a greater distance. Such long-distance transmission may occur because of refraction and reflection from the ionosphere layers, the "skip" distance characteristics depending upon the frequency.

D. Harmonic radiation always takes place at frequencies which are multiples of the carrier frequency. For example, a transmitter operating on 7000 kc may transmit a strong harmonic on 14,000 kc. In the daytime, with medium power output, it may be expected that the consistent communication range will be several hundred miles on 7000 kc. The second harmonic on 14,000 kc may easily cover several thousand miles due to the greater skip distance at the higher frequency, but may not be heard well within a few hundred miles of the station.

Q. 6.523. What is the primary reason for the suppression of radio-frequency harmonics in the output of a transmitter?

A. The primary reason for the suppression of radio-frequency harmonics is to prevent interference from occurring with other radio services, and to restrict the band width of the particular station to the legal limits.

D. See Questions 3.371 and 4.62.

Q. 6.524. Draw a simple schematic diagram of a wave trap in an antenna circuit for attenuating an interfering signal.

A. See Question 3.271.

Q. 6.525. Define type A1, A2, A3, A4, and B emission.

A. For types A1. A2, A3, and A4 emission see Question 3.462. Type B emission, which is the emission of a spark transmitter, is classified as damped waves and oscillations of which the amplitude, after having reached a maximum, decreases gradually, the wave trains being keyed according to a telegraph code.

Q. 6.526. Name four devices that could be used to indicate oscillation in a crystal oscillator.

A. The following devices could be used:

1. Plate d-c milliammeter.
2. Grid d-c ammeter.
3. Thermogalvanometer.
4. Wavemeter.
5. Neon bulb.
6. Flashlight bulb on loop of wire.
7. High reactance d-c voltmeter to measure grid-bias voltage.
8. Frequency meter (heterodyne type).

D. See also Question 6.557.

Q. 6.527. Why is an artificial antenna sometimes used in testing a transmitter? By what other names is this instrument known?

A. An artificial antenna is sometimes used in testing a transmitter in order to prevent undesired radiation. Another name for this device is "dummy" antenna.

D. See Question 3.380.

Q. 6.528. What are the general characteristics of the emission of a radiotelegraph transmitter which uses a chopper to obtain A2 emission?

A. When the key is held down the emitted wave consists of constant-amplitude trains of oscillation which are interrupted or broken up at a very rapid rate. The rate of interruption is generally at a low audio frequency rate in the order of 400 cycles.

D. The system of producing A2 emission by the use of a "chopper" may be thought of as a double keying system. One key is the automatic "chopper" which turns the transmitter on and off at a rapid rate, while the other key is the normal hand operated key which turns the transmitter on and off at a much slower code character rate.

Q. 6.529. In general, what advantage may be expected by the use of high frequencies in radio communication?

A. Some advantages of high frequency radio communication are:

1. Antenna systems may be constructed with smaller elements.

2. Highly efficient directional antenna systems may be more easily constructed at high frequencies.

3. Direct wave communication is possible with attendant freedom from fading effects.

4. The upper frequencies are substantially free of atmospheric interference.

5. The use of such devices as waveguides becomes practical.

6. Wide-band modulation, such as used in a television station, becomes practical at the higher frequencies.

7. Small antennas permit efficient mobile operation.

8. Transmission may be accomplished over long distances with relatively low power.

D. Some disadvantages of high frequency communication are:

1. It is difficult to design stable and efficient circuits for transmitters and receivers operating at very high frequencies.

2. Man-made noises, such as ignition noises, X-ray and diathermy noises, become very annoying at the higher frequencies.

3. Reflections may easily occur from buildings, airplanes and other objects, sometimes causing distortion of the received signal. (Reflections are no disadvantage in the case of radar systems, since this is the basis of their operation.)

Q. 6.530. Why do many marine transmitters employ variometers rather than variable condensers as the tuning elements?

A. Variometers are sometimes preferred over variable condensers as the tuning adjustments for marine transmitters, especially those operating in the medium frequency bands. The size of variable tuning condensers becomes prohibitive in the medium frequency ranges, necessitating the use of fixed condensers and variable inductances.

D. As an example, the required magnitude of tuning capacitance for one typical medium frequency (350 to 500 kilocycles) marine transmitter is 4000 micromicrofarads. To construct a variable condenser of this value, and with the required voltage rating would result in an extremely large and cumbersome device. On the other hand a fixed condenser of this value and voltage rating can easily be made compact, light, and relatively trouble-free. A variable inductance (variometer) of the required value may be made a relatively compact device. The variometer may also be used as an efficient antenna loading coil.

Note: It is more recent practice to vary the inductance by means of movable powdered iron cores (Question 6.585).

Q. 6.531. What is the relationship between the antenna current and radiated power of an antenna?

A. The radiated power of an antenna is expressed by the formula,

$$P = I^2 \times \textit{radiation resistance.}$$

D. See Question 3.321.

Q. 6.532. What is the purpose of the iron compound cylinders which are found in the inductances of certain marine radiotelephone transmitters? The position of the cylinders, with respect to the inductances is adjustable for what purpose?

A. The primary advantage of using special iron cores in radio frequency inductances is the increase of Q, selectivity and gain of the circuits employing such cores.

D. See Question 6.585.

Q. 6.533. What is the meaning of "high-level" modulation?

A. See Questions 3.334 and 3.336.

Q. 6.534. Draw a block diagram of a superheterodyne receiver capable of receiving continuous wave radiotelegraph signals.

A. See the figure.

D. Note that this is similar to the block diagram in Question 3.512, except for the addition of a beat frequency oscillator, which may be turned off for the reception of modulated signals. Since there is no audio component in the received c-w telegraph signal, a separate oscillator, differing from the intermediate frequency by some selected value (for example, 1 kc), is used to beat against, or modulate, the i-f signal. After detection in the second detector, the beat frequency is audible, permitting the signals to be heard. See Question 3.492 for a block diagram of a superheterodyne receiver for f-m reception.

Q. 6.535. Draw a block diagram of a superheterodyne receiver designed for reception of FM signals.

A. See Question 3.492 for diagram and discussion.

Q. 6.536. Draw a block diagram of a tuned radio-frequency type receiver.

A. See the figure.

D. See also Question 3.514 for a schematic diagram.

Q. 6.537. Describe the principle of operation of a "superregenerative" receiver.

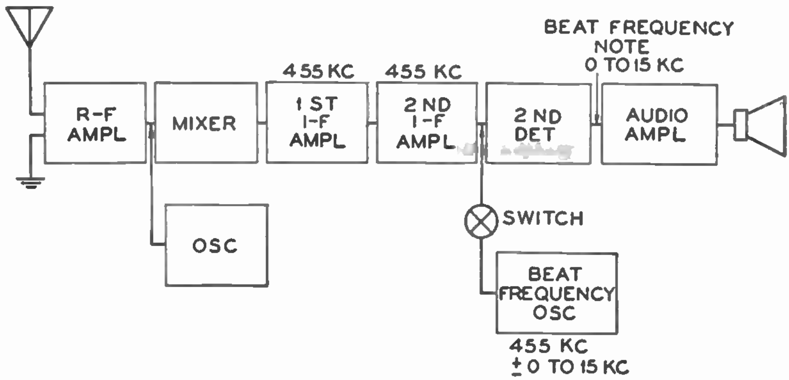


Fig. 6.534. Block diagram of superheterodyne receiver, adaptable for reception of c-w signals.

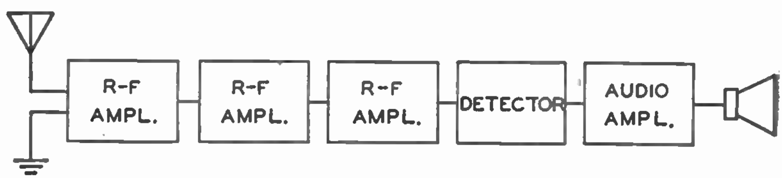


Fig. 6.536. Block diagram of trf receiver.

A. A "superregenerative" receiver is a form of regenerative receiver in which the detector is caused to break in and out of oscillation at a rate which is above audibility. Such a receiver has excellent sensitivity but poor selectivity.

D. The action of the detector breaking in and out of oscillation is termed "quenching," and the rate at which this occurs is called the "quench frequency." In general there are two methods of quenching, "separate" quenching, and "self" quenching. In "separate" quenching a separate low-radio-frequency oscillator is employed, which in effect modulates the grid of the superregenerative detector so that in the absence of any incoming signal it breaks in and out of oscillation at the quench frequency. With no input signal, these oscillations are initiated or "triggered off" by random noise impulses. When an incoming signal is present whose amplitude is somewhat greater than the amplitude of the random noise impulses the starting time of the buildup of the oscillations is advanced by an amount which is determined by the actual amplitude of the incoming signal. This earlier starting time also causes the maximum amplitude of the oscillations to be greater than when no signal is present. These variations in oscillating time and strength are rectified by the detector and provide an output proportional to the modulation envelope. Since much of the amplification of the signal takes place when the circuit is oscillating, tremendous gains result.

In "self" quenching, a grid leak bias network is employed in the detector circuit which has a time constant such that a "blocking" bias is periodically generated, causing interrupted oscillations to take place. When no incoming signal is present the start of the oscillations is initiated by random noise pulses. When an incoming signal is received whose amplitude is greater than the amplitude of the random noise pulses, the build up time of the oscillations is advanced so the peak of oscillations is reached sooner and the end of the oscillation train is also reached sooner. As a result, the quench frequency is caused to increase in proportion to the signal strength. The amplitude of oscillations and their general envelope pattern is *not* affected by the signal strength in this case. Because of the relatively short time constant in the plate circuit, the rectified output resulting from the variations in quench frequency is proportional to the modulation envelope. Superregenerative receivers are chiefly employed in the band of frequencies ranging from 30 to 300 megacycles. At these high frequencies, superregenerative receivers provide a simple method of obtaining large amounts of r-f gain which would be considerably more difficult to obtain in more conventional circuits.

Q. 6.538. What is the purpose of a tuned radio-frequency amplifier stage ahead of the mixer stage in a superheterodyne receiver?

A. The following advantages are obtained by the use of a tuned radio frequency stage.

(1) Improved receiver sensitivity.

(2) Improved receiver selectivity.

(3) Greater image rejection.

(4) Decreases the required gain of the mixer and i-f amplifier, thus improving the receiver stability.

(5) Improves signal to noise ratio of the receiver.

(6) Reduces interference from signals at intermediate frequency.

(7) Reduces local oscillator radiation from the receiving antenna. (This is very important in television.)

D. See Question 3.351.

Q. 6.539. What is the "mixer" tube in the superheterodyne receiver?

A. See Question 3.273. The mixer is also called the first detector.

Q. 6.540. Knowing the intermediate frequency and the signal to which a superheterodyne receiver is tuned, how would you determine the most probable frequency on which "image" reception would occur?

A. See Questions 3.265 and 3.354.

Q. 6.541. A superheterodyne receiver is adjusted to 2738 kilocycles. The intermediate frequency is 475 kilocycles; what is the frequency to which the grid circuit of the second detector must be tuned?

A. The grid circuit (or diode plate circuit) of the second detector must be tuned to 475 kilocycles.

D. It is stated that the intermediate frequency of the receiver is 475 kilocycles. Since the second detector is the termination of the intermediate frequency amplifier, it follows that the tuned input circuit of the second detector must be tuned to the same frequency as the intermediate frequency amplifier or 475 kilocycles.

Q. 6.542. Explain the reasons why a superheterodyne receiver may not be successfully used for reception of frequencies very near the frequencies of the intermediate amplifer.

A. Those frequencies which were very near to the intermediate frequency would be permitted to pass directly through the intermediate frequency amplifier, and would not be greatly affected by the tuning of the r-f or oscillator stages.

D. The disadvantage arising from this situation lies in the fact that any signal which had a frequency relatively close to the intermediate frequency might be continuously present in the output of the receiver regardless of the dial setting. Such a condition could be overcome by employing a suitable trap circuit, by the use of one or more stages of tuned r-f amplifiers preceding the mixer and by the use of adequate shielding of the r-f sections of the receiver. (See also Question 3.271.)

Q. 6.543. Why do some superheterodyne receivers employ a crystal controlled oscillator in the first detector?

A. Some superheterodyne receivers employ a crystal oscillator in order to insure maximum stability of receiver operation.

D. In a superheterodyne receiver, the correct setting and calibration of the mixer oscillator is of critical importance since the oscillator frequency "beating" with the incoming signal produces the correct intermediate frequency. Radio-frequency circuits (r-f amplifier and mixer) do not tune very sharply and can vary considerably without causing much trouble. It is, therefore, desirable whenever practical to employ a crystal-controlled oscillator to provide maximum stability. Crystal oscillators are frequently used in communications receivers operating on certain pre-determined channel frequencies. In this case a separate crystal is switched in for reception on any particular channel. This system is impractical where variable tuning is required. (See Question 6.601.)

Q. 6.544. How should a superheterodyne communications receiver be adjusted for maximum response to weak CW signals? To strong CW signals?

A. To obtain maximum response to weak signals, the r-f gain control should be fully advanced, the beat frequency oscillator control varied for the clearest tone signal, and the audio volume control advanced to the best possible volume. If it is feasible, the degree of coupling between the beat frequency oscillator and 2nd detector may be adjusted for maximum output. The tuning dial (or dials) should be very carefully adjusted for maximum output, and the AVC switch turned to the "Off" position. With a strong signal, the AVC may be left on, the r-f gain control should be somewhat reduced to prevent excessive distortion, and the beat-frequency oscillator control should be varied for the desired output frequency.

Q. 6.545. Why should a superheterodyne receiver, used for reception of A1 signals, be equipped with at least one stage of radio-frequency amplification ahead of the first detector?

A. See Question 3.351.

Q. 6.546. What is the chief advantage to be gained in the utilization of high intermediate frequencies in a superheterodyne receiver?

A. The chief advantage in the utilization of high intermediate frequencies is the reduction of image frequency response.

D. A high intermediate frequency is desirable in order to place the image frequency as far as possible from the normal received signal so that the image frequency may be effectively suppressed in the tuned r-f amplifier and mixer circuits. This may be illustrated by the following example: Assume that the desired carrier signal is 1000 kilocycles, the oscillator frequency 1050 kilocycles, and the intermediate frequency 50 kilocycles. The image frequency equals twice the intermediate frequency plus the carrier frequency or $(2 \times 50) + 1000$ kilocycles $= 1100$ kilocycles. Since the image is removed only 100 kilocycles from the desired carrier, the r-f and mixer circuits will not offer too much rejection to the image frequency. On the other hand, if the oscillator frequency were 1500 kilocycles, the intermediate frequency would then be 500 kilocycles and the image would equal $(2 \times 500) + 1000$ kilocycles $= 2000$ kilocycles.. The image is now removed from the desired signal by 1000 kilocycles and will be greatly attenuated by the r-f and mixer circuits.

Q. 6.547. If a superheterodyne receiver is receiving a signal on 1000 kilocycles and the mixing oscillator is tuned to 1500 kilocycles, what is the intermediate frequency?

A. The intermediate frequency is 500 kilocycles.

D. The intermediate frequency of a superheterodyne receiver is equal to the difference between the local oscillator frequency and the incoming signal frequency or 1500 kilocycles — 1000 kilocycles = 500 kilocycles.

Q. 6.548. How may image response be minimized in a superheterodyne receiver?

A. "Image response" may be minimized by the use of one or more tuned r-f stages ahead of the mixer and by the choice of a suitable intermediate frequency.

D. The intermediate frequency should be of such a value that the image frequency will fall outside of the desired operating range of the receiver if possible. (See also Questions 3.271 and 3.351.)

Q. 6.549. In a tuned radio frequency receiver, what is the advantage of heterodyne reception as compared to autodyne reception?

A. The heterodyne method has the advantage of greater sensitivity, wider control of the beat frequency and in general more stable operation of the circuit.

D. In the autodyne method the detector itself is in an oscillating condition. If a beat frequency other than zero beat is to be produced, the autodyne detector must be tuned somewhat away from the frequency of the incoming signal so that the difference frequency between the two signals may be obtained. Since the tuned circuits of the detector are not resonant to the incoming frequency a reduction of gain and sensitivity will inevitably result. In the heterodyne method a separate oscillator is utilized and the detector itself is not in an oscillating condition. Thus the tuned circuits of the detector may be set to resonate correctly at the frequency of the incoming signal and maximum sensitivity results. The separate oscillator may be set to produce any beat frequency which is desired.

Q. 6.550. See Question 3.267.

Q. 6.551. Discuss the relative advantages and disadvantages of a stage of radio-frequency amplification as compared to a stage of audio-frequency amplification, for use in connection with a regenerative receiver.

A. The following are advantages of a stage of r-f amplification:

1. Improved receiver sensitivity.
2. Improved receiver selectivity.
3. Improves the receiver signal to noise ratio.
4. Greatly reduces coupling from the oscillating detector to the antenna circuit, thus reducing radiation from the receiver.
5. Isolates the isolating detector from the loading effects of the antenna thus permitting more efficient and more stable operation of the detector.

D. The relative disadvantages of a stage of r-f amplification rather than a stage of a-f amplification are:

1. If it is desired to operate a loudspeaker a power audio amplifier would still be needed.

2. An audio amplifier could probably have greater gain than an r-f amplifier, but since this would not improve the signal to noise ratio, the benefits would be rather doubtful.

3. An r-f amplifier requires additional tuned circuits and tuning elements.

4. Shielding will probably be necessary.

5. Neutralization may be necessary if a triode is used. (See also Question 3.56.)

Q. 6.552. What controls determine the selectivity of a three-circuit receiver?

A. The selectivity of a three-circuit receiver (regenerative circuit) is mainly determined by the setting of the regeneration control.

D. The selectivity may also be varied by changing the degree of coupling between the three coils, and by changing the value of grid-leak resistance. (See also Questions 3.200 and 3.349.)

Q. 6.553. What are the objections to the operation of a regenerative, oscillating-detector receiver, when directly coupled to the antenna?

A. The main objection is that the antenna will radiate energy and cause interference to other receivers.

D. When a detector is in an oscillating condition, it produces radio-frequency energy at the approximate frequency to which the tuned circuits are resonant. If such a detector is connected to an antenna, the radio frequency energy will be radiated and may affect receivers at a considerable distance from the antenna. This radiated energy may beat with other carrier frequencies and cause heterodyning interference in a number of receivers.

Q. 6.554. If a ship's regenerative receiver failed to oscillate when the regeneration control was advanced, explain the possible causes and remedies.

A. See Question 3.200.

Q. 6.555. Explain how you would test the various components of a receiver of the three-circuit regenerative type in trouble shooting.

A. The various components of a three-circuit regenerative receiver may be tested as follows:

1. Check all tubes, or replace all tubes if no checker is available.

2. Check for proper tube operating voltages, and power supply operation with a suitable voltmeter.

3. Check the continuity of the primary, secondary and tickler coil. Check also for possible shorted turns in any of these coils.

4. If a tapped switch is employed, check for proper contacting on each position.

5. Check all flexible pigtail connections.

6. Check for shorted variable condenser plates.

7. Check for poor electrical contact to the rotor of variable condenser.

8. Check grid leak for open circuit.

9. Check grid condenser for short circuit.

10. Check audio transformer (or headphones) for continuity.

11. Check rheostats, switches, jacks and cords for open circuits or poor contacting.

12. Check antenna and ground connections and all wiring.

Q. 6.556. What may be the causes of noisy operation of a regenerative, three-circuit receiver having two stages of audio-frequency amplification?

A. Noisy operation may be caused by the following:

1. Noisy regeneration control.
2. Defective tubes.
3. Defective audio transformer.
4. Critical adjustment of the regeneration control.
5. Defective grid resistance of grid condenser..
6. Poor connections.
7. Defective elements in the power supply.

D. See also Questions 3.198 and 3.200.

Q. 6.557. Describe how you could test a regenerative receiver to determine if the detector were in an oscillating condition.

A. The following tests could be applied to determine if the detector were oscillating:

1. "Tune" in the oscillations on a heterodyne frequency meter.

2. Check the grid-bias with a high impedance voltmeter. It will be considerably higher when the detector is oscillating, than when it is not. If the voltmeter is not high-impedance, the oscillations may be stopped when the meter is applied.

3. Test for oscillations with a sensitive wavemeter.

4. Touch the finger or a grounded wire to the grid circuit. If the circuit was oscillating, a characteristic "plop" will be heard.

5. Vary the regeneration control to its maximum limits. The characteristic "plop" will be heard as the circuit goes in and out of oscillation..

D. See also Question 6.526.

Q. 6.558. Using a regenerative receiver, without radio-frequency amplifier stages, describe how you would adjust to receive radiotelegraph signals through interference.

A. In order to receive radiotelegraph signals through interference, it is necessary to adjust the receiver so as to provide the maximum selectivity and gain at the incoming signal frequency.

D. The selectivity and gain of a regenerative receiver can be improved by maintaining the Q of the tuned grid circuit as high as possible. One possible method of increasing the Q would be to reduce the degree of coupling between the primary (antenna) and secondary (grid) coils. The tuning adjustments should be very critically set for maximum response to the incoming signal. Another method of increasing the effective Q is to provide the maximum possible regeneration just short of oscillation during the reception of A2 signals, and to place the receiver in an oscillating condition during the reception of A1 signals. (See also Questions 3.267, 3.349, and 6.557.)

Q. 6.559. If broadcast signals interfered with your reception of signals of 500 kilocycles while aboard ship, how would you reduce or eliminate such interference?

A. Such interference may be reduced or eliminated by the use of a suitable wave trap which is resonated so as to reject the undesired signals.

D. For circuit diagrams of wavetraps, see Question 3.513.

Q. 6.560. See Question 3.268.

Q. 6.561. See Question 3.247.

Q. 6.562. Name three causes of an audio "howl" in a regenerative receiver.

A. An audio howl in a regenerative receiver may be caused by a "fringe" setting of the regeneration control, a defective tube, or an open grid resistor.

D. Any condition which would cause the regenerative detector to break in and out of oscillation at an audio rate will cause an audio howl to appear in the output of the receiver. (See also Question 3.350.)

Q. 6.563. Draw a diagram of a crystal detector receiver and explain its principle of operation. Name two substances that can be used as the crystal in such a receiver.

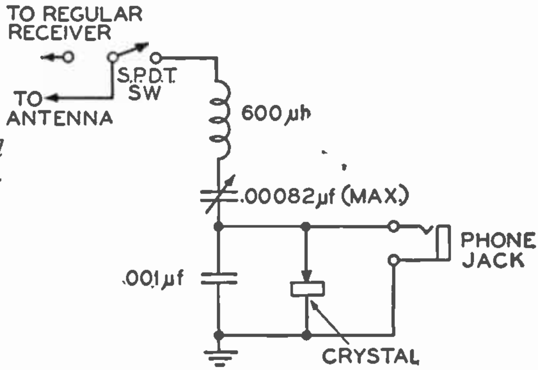


Fig. 6.563. Crystal detector receiver circuit.

A. For diagram, see the figure. The receiver is tuned to the desired frequency by varying the tuning capacitor until series resonance is accomplished. The crystal acts as a half wave rectifier, causing the .001 μf condenser to charge from the input signal and discharge through the headphones at a rate which is the same as the modulation component of the incoming signal.

Some materials that can be used as the crystal are galena, silicon, and iron pyrites.

D. See Questions 3.230, and 6.195.

Q. 6.564. Draw a simple schematic circuit diagram of an FM receiver discriminator.

A. See Question 4.236.

Q. 6.565. If signals are heard with the headphones plugged into the detector plate circuit of a receiver, but no signals are heard when the phones are plugged into the first audio-frequency stage plate circuit, what might be the cause and how could it be remedied?

A. Some of the causes which might produce such a condition are:

1. Open winding of the coupling transformer (if used.)

2. Defective coupling condenser or grid resistor (if R-C coupling is used.)

3. Defective tube.

4. Improper operating potentials.

D. In the case of an open secondary winding a satisfactory repair could be made by disconnecting the secondary winding and changing the coupling system to impedance coupling by adding a grid resistor and coupling condenser. In the case of the other three faults repairs could be made by replacing the defective units.

Q. 6.566. See Question 3.272.

Q. 6.567. See Question 3.271.

Q. 6.568. See Question 3.285.

Q. 6.569. Give four reasons which would prevent a regenerative receiver from oscillating.

A. See Question 3.200.

Q. 6.570. Why are by-pass condensers used across the cathode-bias resistors of a radio-frequency amplifier?

A. The purpose of the cathode by-pass condenser is to prevent variations of bias during excitation of the amplifier.

D. See Question 3.438.

Q. 6.571. What is the purpose of shielding between radio-frequency amplifier stages?

A. In general, shielding of the various r-f and i-f components of a receiver prevents electromagnetic and electrostatic coupling between these elements and improves the overall stability of the receiver.

D. See Question 3.348.

Q. 6.572. Draw a simple schematic diagram showing a method of "impedance" coupling between two stages of a radio-frequency amplifier.

A. See Question 3.84.

Q. 6.573. Draw a simple schematic diagram showing a method of inductive or transformer coupling between two stages of a radio-frequency amplifier.

A. See Question 3.85.

Q. 6.574. What is the purpose of an electrostatic shield?

A. The purpose of a "Faraday" screen (or shield) is to minimize the transfer of harmonic frequencies between two inductively coupled circuits due to the capacity between the two coils. The two coils in question are usually the plate tank circuit coil of the final r-f amplifier and the coupling coil to the antenna system.

D See Questions 3.373 and 4.26.

Q. 6.575. What is the purpose of an auxiliary receiving antenna installed on a vessel which is also fitted with a direction finder?

A. The use of an auxiliary antenna enables the radio operator to maintain the compulsory watch on 500 kilocycles on the ship's receiver, whether or not the direction finder is in use.

Q. 6.576. How is automatic volume control accomplished in a receiver?

A. By feeding back, into the control grids of the i-f and r-f amplifiers, a negative d-c bias which is proportional to the average magnitude of the received carrier wave.

D. See Question 6.353 for an explanation, and Question 4.212 for diagram of the circuit supplying AVC voltage.

Q. 6.577. What is the purpose of a center tap connection in a filament supply transformer?

A. To prevent hum voltages from modulating the normal signal.

D. See Question 3.470.

Q. 6.578. See Question 3.84.

Q. 6.579. See Question 3.85.

Q. 6.580. See Question 3.89.

Q. 6.581. See Question 3.200.

Q. 6.582. See Question 3.198.

Q. 6.583. See Question 3.273.

Q. 6.584. See Question 3.284.

Q. 6.585. What is the advantage of using iron cores of special construction in radio-frequency transformers and inductances?

A. The primary advantage of using special iron cores in radio frequency inductances is the increase of Q, selectivity, and gain of the circuits employing such cores.

D. The most effective type of magnetic core employed at high frequencies is one which is constructed of a very fine powder or dust of molybdenum permalloy, or of iron. The metal dust is mixed with an insulating binder and is then compressed into a core of the desired form. The insulating binder effectively insulates the various particles and provides a core with very low eddy-current losses. The smallest particles are used at the higher frequencies. Powdered iron cores are often employed in intermediate frequency amplifier coils. The gain of an i-f amplifier is largely determined by the parallel impedance of the i-f tuned circuits, which equals $\frac{L}{CR}$, where L is the inductance of the coil, C is the tuning capacitance and R is the effective resistance of the coil. For the greatest gain and selectivity the L to C ratio should be large. The addition of the iron core increases the "Q" of a coil, by increasing L much more than it does R; this increases the ratio L/R, which determines Q. Another advantage of powdered iron cores is that it makes it possible to adjust the tuning (and sometimes selectivity) of the coils by screwing the cores in or out of the coils. (See Question 6.530.) Thus fixed capacitors of low temperature coefficient may be used to improve the stability of the amplifier.

Q. 6.586. In the operation of a regenerative type receiver how is oscillation of the detector indicated?

A. See Question 6.557.

Q. 6.587. Draw a diagram of a superheterodyne receiver with automatic volume control and explain the principle of operation.

A. See the figure.

D. For a basic discussion of superheterodyne receiver, see Question 3.264. For discussion of automatic volume control see Question 3.353.

Q. 6.588. To what frequency, or band of frequencies, is an approved auto-alarm receiver tuned?

A. The auto-alarm receiver is tuned to a center frequency of 500 kilocycles, but is able to respond to a band of frequencies from 487.5 to 512.5 kilocycles (plus and minus 12.5 kilocycles). This wide-band response is provided to insure reception of an auto-alarm signal from a transmitter which may not be accurately tuned to 500 kilocycles.

D. See Appendix V.

Q. 6.589. What signal will cause an approved auto-alarm receiver to ring the warning bell?

A. The signal may be either the true or a false auto alarm signal. The true signal consists of four consecutive dashes ranging from 3.5 to 4.5 seconds separated by spaces ranging from .1 to 1.5 seconds. However, the combination of dash and space may not exceed 5 seconds.

D. See Appendix V.

Q. 6.590. What factors determine the setting of the sensitivity control of an auto-alarm receiver approved for installation on a vessel of the United States?

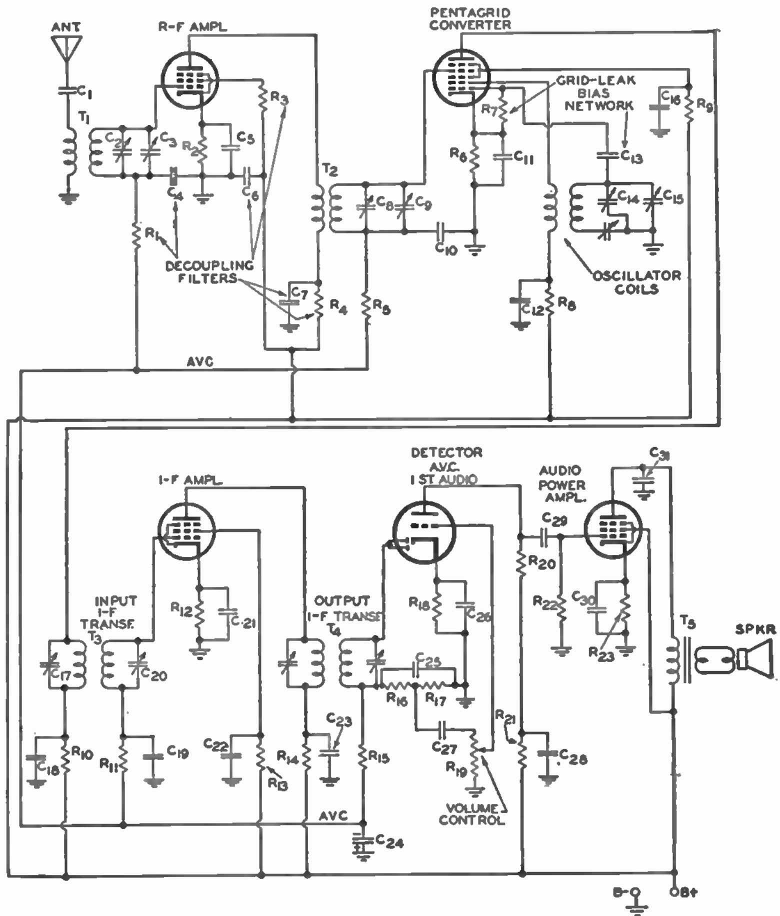


Fig. 6.587. Diagram of superheterodyne receiver.

A. The factors which determine the setting of the sensitivity control are the prevailing static and radio interference present at any given time.

D. The following procedure may be employed in adjusting the setting of the sensitivity control: The control should first be turned to its maximum counter-clockwise position, corresponding to minimum receiver sensitivity. The control is then advanced so that the signal relay is occasionally or continuously chattering depending upon noise conditions. If the sensitivity is set too high and the noise level is high, the receiver will be blocked and unable to receive the auto-alarm signal. On the other hand a low setting of the sensitivity control will prevent a relatively weak signal from operating the alarm. (See also Appendix V.)

Q. 6.591. If you were a radio operator on a vessel of the United States, equipped with an approved type of auto alarm which employs a linear detector and an electronic selector, what factors cause the bell to sound? The warning lights to operate?

A. The following factors will cause the bell to sound:

1. Receipt of the true auto alarm signal.

2. Receipt of a false auto alarm signal due to bursts of code signals and interference. (Probably will not repeat.)

3. Low or no line voltage (110 volts d-c).

4. Any open vacuum tube filament (series connected).

5. Low battery voltage (below 4.5 volts).

The following factors will cause the warning light to operate:

1. Receipt of first and subsequent dashes of correct auto-alarm signal.

2. Receipt of a continuous signal, static, or other interference, lasting in excess of 3.5 seconds.

3. Sensitivity control set too high.

4. Low or no battery supply voltage.

D. See Appendix V.

Q. 6.592. With an auto alarm of the type which employs a square-law detector and a mechanical selector, what factors cause the bell to sound? The warning lights to operate?

A. The following factors will cause the bell to sound:

1. Receipt of the true auto alarm signal.

2. Low battery voltage.

3. Filament circuit open.

4. Twenty-four volt circuit to receiver open.

5. Battery charger fuse blown.

6. Motor stopped or running too slow.

7. Open in 24-volt circuit to auto alarm equipment.

The following factors will cause the warning light to operate:

1. Reception of a signal longer than 4.5 seconds.

2. Prolonged strong noise interference and static.

3. Sensitivity adjustment too high.

4. Failure of ship's 115-volt line, or low line voltage (below 70 volts).

Q. 6.593. With an auto alarm of the type which employs a linear detector and an electronic selector, what is the most probable cause of the intermittent ringing of the bells?

A. Intermittent ringing of the bells could be caused by:

1. An intermittent vacuum tube filament.
2. Fluctuating line voltage. (Decreasing to a low value and returning to normal.)
3. Faulty contacts or relay adjustment of warning relay #8.

D. See Question 6.594 and Appendix V.

Q. 6.594. If you were a radio operator on a vessel of the United States, equipped with an approved type of auto alarm which employs a linear detector and an electronic selector, what would result upon failure of a vacuum-tube filament?

A. If a filament opened, the alarm bells would sound.

D. (See Appendix V for diagram.) If a filament opened, this would result in a loss of holding current in warning relay #8. The contacts of relay #8 would close, energizing the bell relay #7 and cause the bells to sound.

Q. 6.595. If an auto-alarm bell rings, and upon pressing the release button it stops, what could be the cause(s) of the ringing?

A. The cause of the ringing could be the reception of either a true or false alarm signal.

D. See Appendix V.

Q. 6.596. If an auto-alarm bell rings, and upon pressing the release button it does not stop, what could be the cause(s)?

A. Any of the following could be the cause:

1. Ground on alarm bell relay circuit.
2. Bell relay #7 stuck.
3. Failure of line voltage.
4. Low line voltage.
5. Open filament.
6. Motor stopped or running too slow.
7. Low battery voltage.

D. See Appendix V. See also Question 6.592.

Q. 6.597. With an auto alarm of the type which employs a square-law detector and a mechanical selector, why does this receiver not respond to type A1 emission?

A. This alarm receiver does not respond to A1 emission because it requires a modulated input signal.

D. The percentage of modulation should be at least 30 per cent at frequencies between 100 and 2500 cycles.

Q. 6.598. If the vacuum-tube heater burns out, in an approved auto-alarm, what causes the warning bells to ring?

A. The bells are caused to ring by the de-energizing of a series heater relay, which causes a pair of contacts to close and they in turn energize the bell relay, which applies operating voltage to the bells. (See Question 6.594.)

D. See Appendix V.

Q. 6.599. Why are the unused portions of inductances in receivers sometimes shorted?

A. In receivers, unused portions of inductances are often short circuited in order to reduce any losses which might occur in these unused windings.

D. If the unused portions of an inductance are not short circuited, there exists a definite possibility of a series resonant condition existing between the unused turns and some stray capacity. Such a condition would cause a relatively large series resonant current to exist in the unused turns and additional losses would then occur in the unused turns which would not be present if these turns were short circuited. In transmitters the procedure of short-circuiting unused portions of inductances is not followed because the relatively high power level existing in the circuits would cause additional losses to take place due to the high value of current in the short circuited turns. The extremely low power level in receivers makes it possible to short circuit such turns without increasing the losses.

Q. 6.600. How may harmonic radiation by a transmitter be prevented?

A. Harmonic radiation of a transmitter may be prevented by the use of a Faraday shield between the final amplifier and antenna circuit, and by the use of suitable tuned filters in the transmission line system.

D. See Questions 3.373 and 4.62. (Also refer to Questions 6.523, 6.521, and 6.522.)

Q. 6.601. What is a "crystal filter" as used in a superheterodyne receiver?

A. A "crystal filter" consists of a high-Q piezo-electric quartz plate together with suitable coupling, tuning and phasing circuits which is used for the purpose of obtaining very high degrees of selectivity in a superheterodyne receiver.

D. A "crystal filter" is often located immediately preceding the first i-f amplifier in a superheterodyne receiver. The crystal is caused to be resonant at the intermediate frequency. Due to its extremely high Q and, therefore, its very sharp selectivity, such a filter provides a characteristic which discriminates to a great degree against signals which are very close in frequency to the desired signal. The band width of the receiver is greatly reduced and this is of considerable value in reducing the response of the receiver to noise impulses, which generally cover a wide frequency range. Due to the reduced bandwidth the quality of voice or music reception will be greatly impaired and some filters are, therefore, equipped with a system to reduce the selectivity of the crystal circuit. A "phasing control" is usually provided which makes it possible to shift the operating frequency of the crystal to some degree and thus permit adjustable rejection of undesired signals. (See also Question 6.543.)

Q. 6.602. What means are usually provided to prevent operation of the ship's transmitter when the auto-alarm receiver is in use?

A. The keying circuit of the ship's transmitter is disconnected when the auto-alarm antenna switch is placed in the auto-alarm operating position.

Q. 6.603. What is indicated in a radiotelephone transmitter by an increase in antenna current without carrier shift?

A. This indicates that normal undistorted modulation is taking place.

D. See Question 3.345.

Q. 6.604. If a vacuum tube in the only radio-frequency stage of your receiver burned out, how could you make temporary repairs to permit operation of the receiver if no spare vacuum tube was available?

A. See Question 3.355.

Q. 6.605. What is the purpose of a crystal filter in the i-f stage of a superheterodyne communications receiver? Under what conditions is this filter used?

A. The purpose of a crystal filter in the i-f stage of a superheterodyne receiver is to provide a very high degree of selectivity in the receiver. The filter is used to reduce interference due to noise and stations adjacent to the desired station.

D. See Question 6.601.

Q. 6.606. See Question 3.184.

Q. 6.607. See Question 3.193.

Q. 6.608. See Question 3.190.

Q. 6.609. See Question 3.187.

Q. 6.610. See Question 3.185.

Q. 6.611. See Question 3.186.

Q. 6.612. See Question 3.183.

Q. 6.613. See Question 3.194.

Q. 6.614. See Question 3.195.

Q. 6.615. See Question 3.197.

Q. 6.616. See Question 3.303.

Q. 6.617. Draw a simple circuit diagram showing the principle of operation of an ohmmeter.

A. See Question 3.499.

Q. 6.618. See Question 3.304.

Q. 6.619. See Question 3.236.

Q. 6.620. See Question 3.237.

Q. 6.621. What is indicated if a voltmeter connected between the negative side of a ship's d-c line and ground reads the full line voltage?

A. This indicates that the positive side of the line, rather than the negative side is grounded. (The generator terminals should be reversed.)

Q. 6.622. See Question 3.189.

Q. 6.623. See Question 3.191.

Q. 6.624. How may the power in an alternating-current circuit be determined?

A. The power in an alternating-current circuit may be determined by means of a wattmeter, or by multiplying the product of circuit voltage and current by the power factor.

D. See Questions 3.34 and 3.183.

Q. 6.625. The product of the readings of an alternating-current voltmeter and ammeter in an alternating-current circuit is called what?

A. This is called the "apparent power."

D. See Question 3.34. "Apparent power is the quantity obtained simply by multiplying $E \times I$ of a circuit. It does not take into account any phase angle or power factor. The unit is the volt-ampere, or kilo-volt-ampere, rather than the watt or kilowatt.

Q. 6.626. See Question 3.192.

Q. 6.627. See Question 3.188.

Q. 6.628. How may the range of a thermocouple ammeter be increased?

A. By the use of a current transformer or a condenser shunt.

D. A current transformer may be used at low or moderate r-f frequencies provided that capacitive coupling between the primary and secondary is negligible.

A condenser shunt may be used in the measurement of large currents. This consists of a high-reactance condenser in a series with the thermocouple heater and a low-reactance condenser across the above series combination.

Q. 6.629. Does the scale of an a-c ammeter indicate peak, effective, or average current values? Explain your answer.

A. The scale of the conventional type of a-c ammeter indicates the effective (rms) value of current.

D. See Question 3.192.

Q. 6.630. By what factor must the voltage of an alternating-current circuit, as indicated on the scale of an alternating-current voltmeter, be multiplied in order to obtain the average voltage value?

A. The scale reading must be multiplied by the factor 0.9.

D. An a-c voltmeter has a scale which is calibrated to read the rms value or 0.707 of peak. The average value equals 0.636 of peak and the ratio of the two equals $\frac{0.636}{0.707} = 0.9$. The scale reading must therefore be multiplied by 0.9 to obtain the *average* value. It is understood that this is the average value over one-half cycle; the average value of a sine wave over a full cycle is of course zero.

Q. 6.631. A milliammeter with a full-scale deflection of one milliampere and having an internal resistance of 25 ohms is used to measure an unknown current, by shunting it with a 4-ohm resistance. When the meter reads 0.4 milliampere, what is the actual value of current?

A. The actual value of current is 2.9 milliamperes.

D. See Question 3.48.

Q. 6.632. If a direct-current voltmeter is used to measure effective alternating voltages by the use of a bridge-type full-wave rectifier of negligible resistance, by what factor must the meter readings be multiplied to give corrected readings?

A. The meter readings must be multiplied by a factor of 1.11.

D. The usual type of d-c meter responds to the average value of the applied voltage or .636 times the peak value (E_{peak}). The voltmeter deflection (E_M) therefore is $E_M = .636 \times E_{peak}$. E_{peak} is also equal to $1.414 \times E_{rms}$, therefore, $E_M = .636 \times (1.414 \times E_{rms}) = 0.9\ E_{rms}$, and $E_{rms} = \dfrac{E_M}{0.9} = 1.11\ E_M$. The scale readings therefore must be multiplied by 1.11 for correct readings.

Q. 6.633. By what factor must the voltage of an alternating-current circuit, as indicated on the scale of an alternating-current voltmeter, be multiplied in order to obtain the peak value?

A. The multiplying factor is 1.414.

D. The scale of an a-c voltmeter reads the rms or effective value which equals 0.707 of peak. Therefore, the multiplying factor must be $\dfrac{1}{0.707}$ or 1.414 to obtain peak values.

Q. 6.634. What precautions should be used when an absorption type of frequency meter is used to measure the output of a self-excited oscillator?

A. The pickup coil of the absorption type frequency meter should be coupled as loosely as possible to the circuit under measurement in order to reduce errors in the readings.

D. See Question 3.433.

Q. 6.635. What is the meaning of "zero beat" as used in connection with frequency-measuring equipment?

A. "Zero beat" occurs when two frequencies are being mixed together and have no difference frequency between them. To achieve this both frequencies must be the same.

D. See Question 3.432.

Q. 6.636. If a wavemeter, having an error proportional to the frequency, is accurate to 20 cycles, when set at 1000 kilocycles, what is its error when set at 1250 kilocycles?

A. The error is 25 cycles.

D. Since it is stated that the error is proportional to frequency, a ratio may be set up as follows:

$\frac{20}{1000} = \frac{X}{1250}$; solving for X, $X = \frac{25{,}000}{1{,}000} = 25$ *cycles.*

Q. 6.637. What precautions should be taken before using a heterodyne type of frequency meter?

A. The following precautions should be taken:

1. All operating potentials should be correct.
2. The equipment should be mechanically rigid.
3. The equipment should be permitted to heat up for about a half-hour before using.
4. Before using, the frequency meter should be calibrated by zero-beating against a standard frequency crystal oscillator.

D. See Question 3.431.

Q. 6.638. What are the advantages and disadvantages of using an absorption type wavemeter in comparision to other types of frequency meters?

A. An absorption type wavemeter has the advantages of being light, compact, and needing no power supply. Its disadvantages are its limited accuracy of calibration, and its detuning and loading effects upon the circuit under measurement.

D. See Questions 3.433 and 3.498, regarding absorption type meters. For discussion of heterodyne frequency meters, see Questions 3.431, 3.432, 4.167, and 6.637.

Q. 6.639. Draw a simple schematic diagram of an absorption type wavemeter.

A. See Question 3.498, as well as the previous question.

Q. 6.640. An absorption type wavemeter indicates that the approximate frequency of a ship transmitter is 500 kilocycles and at the same time the transmitter signal produces a zero beat on an accurately calibrated heterodyne frequency meter at a dial reading of 374.1. The frequency meter calibration book indicates dial readings of 367.0, 371.5 and 376.0 for frequencies of 499.4/998.8, 499.6/999.2 and 499.8/999.6 kilocycles, respectively. What is the frequency of the ship transmitter?

A. The frequency of the ship transmitter is 499.7144 kilocycles.

D. Since the absorption type wavemeter indicates 500 kilocycles the transmitter frequency must be approximately this value and the second harmonic readings of the heterodyne frequency meter (998.8, 999.2, 999.6) can be ignored. Tabulating the information given concerning the heterodyne frequency meter, we have:

Dial reading	*Frequency in kilocycles*
367.0	499.4
371.5	499.6
374.1	?
376.0	499.8

Examining these figures it will be found that the frequency varies by .2 kilocycle when the dial reading changes by 4.5 divisions. The frequency change for 1 dial division equals $\frac{.2 \text{ kc}}{4.5} = .044$ kc. The desired dial reading of 374.1 follows the dial reading of 371.5 corresponding to 499.6 kilocycles. The increase of dial divisions equals 374.1 minus 371.5, or 2.6 divisions. The frequency increase corresponding to an increase of 2.6 divisions equals $2.6 \times .044$ kilocycle $= 0.1144$ kilocycle. The actual frequency of the ship transmitter is $499.6 + 0.1144$ kilocycle $= 499.7144$ kilocycles.

Q. 6.641. A certain frequency meter contains a crystal oscillator, a variable oscillator and a detector. What is the purpose of each of these stages in the frequency meter?

A. The purpose of the crystal oscillator is to provide a standard reference frequency, which is zero-beat against the variable oscillator at various dial positions to provide an accurate means of calibrating the dial of the variable oscillator. The purpose of the variable oscillator is to provide a variable frequency of known accuracy which is zero beat against the incoming signal to provide a means of measuring the frequency of the incoming signal.

The detector stage provides a means of beating the two signals together in order to be able to extract an audible beat note (or zero beat).

D. For absorption type wavemeter, see Questions 3.433 and 3.498.

For heterodyne frequency meter, see Questions 3.431, 3.432, 4.110, and 4.167.

Q. 6.642. What is a "multivibrator"? Explain its principle of operation.

A. See Question 3.429.

Q. 6.643. Draw a simple circuit diagram of a multivibrator oscillator.

A. See Question 4.104.

Q. 6.644. What determines the fundamental operating frequency of a multivibrator oscillator?

A. The fundamental operating frequency is determined by many factors, but mostly by the grid coupling constants to each tube. (Resistance and capacity.)

D. See Questions 3.429 and 4.104.

Q. 6.645. How do multivibrator oscillators differ from Hartley oscillators? In what circuits do multivibrator oscillators find application?

A. Multivibrator oscillators differ fundamentally from Hartley oscillators in that multivibrators depend upon resistance-capacity circuits for their operating frequency, while Hartley oscillators depend upon inductance-capacity circuits for their operating frequency.

Multivibrators are used as:

1. Harmonic generators.
2. Saw-tooth generators.
3. Electronic switches.
4. Square wave generators.

D. See Questions 3.367, 3.429, and 4.104.

Q. 6.646. See Question 3.291.

Q. 6.647. See Question 3.290.

Q. 6.648. What is the directional reception pattern of a loop antenna?

A. See the figure.

D. See Question 3.252.

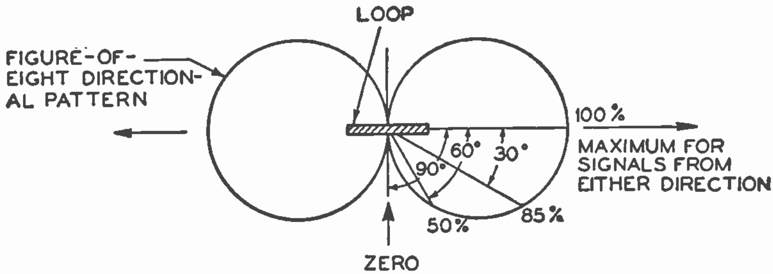


Fig. 6.648. Directional pattern (bilateral) of loop antenna.

Q. 6.649. What is the reception pattern of a vertical antenna?

A. See the figure.

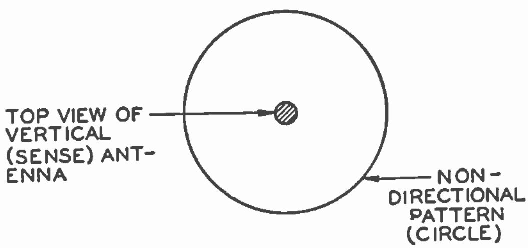


Fig. 6.649. Directional pattern (circular) of vertical antenna.

Q. 6.650. What is the principal function of a vertical antenna, associated with a unilateral radio direction finder?

A. The principal function of a vertical (sense) antenna is to determine from which direction the signal is coming.

D. The normal loop antenna has a bi-directional characteristic (Question 6.648) and it is not possible to determine from which of the two possible directions the signal is arriving. When the sense antenna is connected, using a receiver designed for the purpose, the reception pattern changes to a cardioid (Question 6.652), making it possible to determine which of the two directions is the correct one. (See Appendix IV.)

Q. 6.651. What is the principal function of the vertical antenna associated with the bilateral radio direction finder?

A. The vertical antenna aids in obtaining a sharper "null" indication by balancing out the "antenna effect" of the loop antenna.

D. See Appendix IV.

Q. 6.652. What figure represents the reception pattern of a properly adjusted unilateral radio direction finder?

A. A "cardioid" or heart-shaped figure represents the reception pattern.

D. See the figure.

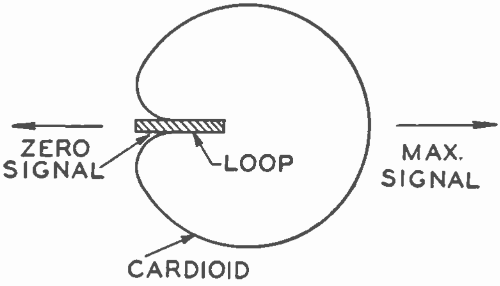


Fig. 6.652. Cardioid reception pattern.

Q. 6.653. From how many simultaneous directions is a direction finder capable of receiving signals if adjusted to take unilateral bearings through 360 degrees?

A. The direction finder is capable of receiving signals from all but one direction. (See Questions 6.652 and 6.650.)

D. See Appendix IV.

Q. 6.654. How is the unilateral effect obtained in a direction finder?

A. The unilateral effect is obtained by combining the reception patterns of the loop antenna and the vertical "sense" antenna to produce a "cardioid" pattern of reception (Question 6.652).

D. See Appendix IV.

Q. 6.655. What is the function of the balancing condenser in a direction finder?

A. The function of the "balancing condenser" is to minimize "antenna effect" and so obtain a sharper null point indication of direction.

D. See Appendix IV.

Q. 6.656. Why are loop antennas, associated with direction finders, metallically shielded?

A. The loop antennas are shielded in order to minimize "antenna effect" and provide a sharper indication of direction. "Antenna effect" causes a broadening of the null points because of the unsymmetrical capacity balance between the loop antenna and ground. The shield must be electrostatic only and, therefore, is electrically broken by a small section of insulating material.

D. See Appendix IV. See also Question 3.373.

Q. 6.657. What is a "compensator" as used with radio direction finders, and what is its purpose?

A. A "compensator" is a mechanical device which is attached to the shaft of the loop antenna. It is individually adjusted for each loop antenna to correct automatically the readings on the compass card for errors introduced by "antenna effect" and by spurious induction fields in the vicinity of the loop. The "compensator" causes the compass card pointer to either lead or lag the actual plane of the loop so that corrected reading will automatically appear.

Q. 6.658. What is indicated by the bearing obtained by the use of a bilateral radio direction finder?

A. The bearing indicates a *line of direction* which passes through the originating station. (Compare Question 6.662.)

D. See Appendix IV.

Q. 6.659. On shipboard what factors may affect the accuracy of a direction finder after it has been properly installed, calibrated, and compensated?

A. The following factors may affect the accuracy of a direction finder:

1. A received wave which has been *bent.*
2. "Night-effect."
3. Any changing of the position of nearby metallic objects.

D. See Appendix IV.

Q. 6.660. Describe the construction and operation of a shielded loop antenna as used with a marine direction finder.

A. See Question 6.656.

D. See Questions 6.648, 6.649, 6.650, 6.651, 6.652, and 6.653. See also Appendix IV.

Q. 6.661. Draw a sketch showing how a "fix" on a ship station can be obtained by taking direction-finder bearings.

A. See the figure.

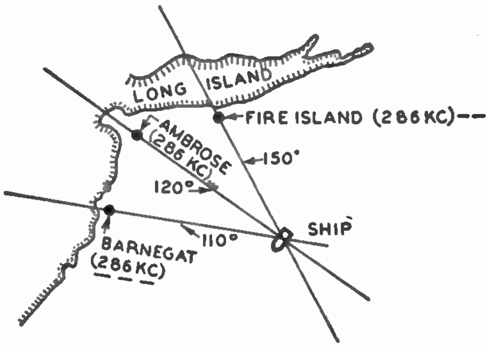


Fig. 6.661. Use of direction-finder bearings to take a "fix."

Q. 6.662. What is indicated by the bearing obtained by the use of a unilateral radio direction finder?

A. The bearing indicates the *sense of direction* of the originating station, or indicates from which of two possible directions the signal emanates. (Compare Question 6.658.)

D. See Appendix IV, and Questions 6.718 and 6.719.

Q. 6.663. Within what frequency-band limits do all United States marine radio-beacon stations operate?

A. From 285 to 315 kilocycles.

Q. 6.664. In what part of the radio frequency spectrum do marine radar systems operate?

A. Marine radar systems operate at frequencies in the order of 10,000 megacycles (wavelength of 3 centimeters) or 3,000 megacycles (10 cm.).

D. One of the primary reasons for the use of such high frequencies lies in the antenna design. In order to obtain accurate bearings, it is quite necessary that the radiation pattern of the antenna be extremely narrow. Such a pattern can be most conveniently obtained by the use of a parabolic reflector of suitable dimensions, which at these frequencies is fed by means of waveguide radiators (Question 6.207). The parabolic reflector focuses the r-f energy into a narrow beam, just as a searchlight reflector provides a narrow light beam from a light source. For the r-f beam to be sufficiently narrow, the dimensions of the parabolic reflector must be in the order of many wavelengths. To accomplish this and yet restrict the overall dimensions of the antenna to a reasonably small size, it is necessary that the operating wavelength be short (3 centimeters; there are 2.54 centimeters per inch). A marine radar antenna has a radiation pattern which is extremely narrow with respect to azimuth (compass) directions, but is relatively broad with respect to vertical directions.

Q. 6.665. Draw a simple block diagram showing the essential components of a radar system. Label the components such as receiver, indicator, etc.

A. See the figure.

D. A general discussion of the radar system is presented below for the benefit of students.

Radar (radio direction and ranging) is a specialized application of the principles of radio which makes it possible to detect the presence of

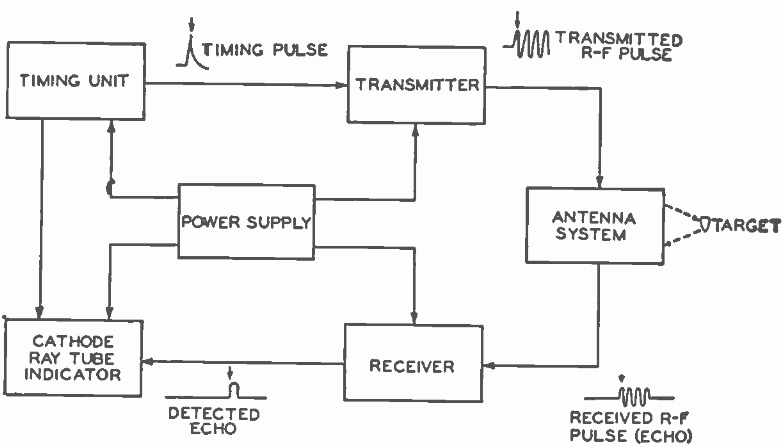


Fig. 6.665. Block diagram of radar system.

near or distant objects regardless of visual or atmospheric conditions; to determine their exact direction and range (distance) and to a limited extent to identify the nature of their character. Basically, a radar set consists of a transmitter and receiver located at the same point, a highly directional antenna system and an indicator (generally a cathode ray tube) to show the presence of reradiated waves and thus of objects. Detection of an object is accomplished by causing a narrow beam of r-f energy to "search" a given area. Whenever the beam strikes a conducting object it causes waves to be reradiated in many directions from the object. A very small fraction of the original radiated energy is returned to the radar set where it is picked up by the same antenna that focused the original radiation upon the object. A receiver of great sensitivity amplifies the received signal (echo) and applies it to a cathode ray tube to provide a visual indication of the presence of the object. The direction of the object will be the same as the direction of the antenna. The range can be determined with great accuracy based upon the fact that radio frequency energy travels at the velocity of light (300,000,000 meters per second, or about 186,000 statute miles per second). Most radar transmitters employ the pulse modulation method. A radio frequency pulse of short duration (about 1 microsecond on the average) and high peak power is transmitted at regular intervals. Between transmitted pulses, the receiver is permitted to operate and to detect the reradiated waves. The receiver output is connected to the indicator where the difference in time between the transmitted and received waves can be measured and the range determined. As an example assume that a pulse is transmitted to an object 18.6 miles away. In one microsecond the pulse can travel .186 miles (328 yards). Therefore, it will require 100 microseconds for the pulse to reach the object. When it strikes the object, it is reradiated without loss of time and returns to the radar set in an additional 100 microseconds, or a total elapsed time of 200 microseconds. Note that the wave actually has to travel twice the distance to the object. Because the range thus provided is twice the actual range, an allowance must be made in the indicator to measure only one-half of the elapsed time, or the true range.

The Indicator: (Discussion of the indicator is here restricted to that type directly applicable to marine radar sets.) The indicator must be a device which can accurately measure the elapsed time between transmitted and received pulses and convert it directly into range. It must also be capable of discriminating against objects with different ranges and the same bearing, and between objects with different bearings and the same range. The P.P.I. (plan-position-indicator) cathode-ray tube admirably fulfills all of the above requirements by providing a polar chart of the immediate area surrounding the ship from a minimum range of about 80 yards to approximately 40 miles. The P.P.I. scope provides a continuous plot of both moving and fixed objects. The sweep (time base) starts at the center of the tube at a time which is directly related to the originating time of the transmitting pulse. It travels radially out to the circumference (like the spoke of a wheel). This sweep line is divided into equal distances by means of range markers which provide indications about a half-mile apart on low ranges, thus affording instantaneous visual checks of the range of objects. Objects are indicated (as well as range markers) by a bright spot upon the P.P.I. tube at a distance from the center corresponding to the range of the object. The radial sweep is caused to rotate (as a wheel spoke would rotate) in exact synchronism with the antenna, so that the object indication upon the P.P.I. tube will be of the same bearing as the antenna. The P.P.I. tube has a relatively long persistence screen, so that as the sweep rotates, a continuous picture of the surrounding area appears on the screen.

The Timer: The timer unit (or synchronizer or Keyer) is generally the most complicated part of the radar and has a number of important functions to perform. A detailed discussion is beyond the scope of this book, but a general list of its functions is as follows:

1. Determines pulse repetition rate.
2. Determines range markers.
3. Provides range markers.
4. Coordinates all operations in the system.
5. Provides sweep, with blanking and unblanking.
6. Specialized functions such as "heading flash" in marine systems.

The Transmitter: The transmitter usually consists of the following units:

1. A pulse shaping circuit, to determine the length of the transmitted pulse.
2. A modulator which applies the pulse (about 1 microsecond, 10,000 to 15,000 volts) to the magnetron, and
3. The magnetron, which is the actual r-f oscillator. (There are no r-f amplifiers.)

The Antenna System: See Question 6.664.

The Receiver: Radar receivers are almost always of the superheterodyne type. The receiver must have great sensitivity in order to receive and amplify the very weak reradiated r-f pulses to a value suitable for use by the P.P.I. scope. Since the input signal may be in the order of one microvolt, the i-f amplifier must have a gain in the order of one or two million to provide sufficient input signal to the second detector (1 or 2 volts). In order to pass the very steep and short-duration pulses, the i-f amplifier must be capable of passing a band of frequencies in the order of 5 to 10 megacycles. The wide band-pass reduces the gain of the individual stages so that the number of stages in the i-f amplifier is often more than six to eight.

There are no r-f amplifiers in the receiver. The input signal is applied directly to a crystal mixer, and the local oscillator is generally of the reflex Klystron type. (See Questions 6.180 and 6.730.)

The intermediate frequencies are in the order of 30 megacycles. Automatic frequency control is often employed, to compensate for frequency drift of the magnetron or local oscillator (reflex Klystron), in order to maintain the proper difference frequency of 30 megacycles, and thus provide the maximum indicated response upon the P.P.I. tube at all times.

Q. 6.666. Approximately at what speed does the antenna of a navigational radar rotate?

A. Navigational radar antennas rotate at speeds ranging from about 6 to 15 RPM. (British radar uses antenna speeds as high as 30 to 50 RPM with shorter persistance PPI tubes).

Q. 6.667. How should a radar set be adjusted by the operator to reduce "sea return"?

A. In order to reduce sea return response in a radar set, the operator should manually adjust the "Suppressor" control (or sensitivity time control, STC) until the solid pattern of sea return is thinned out and stronger ship targets which may be present close-in to the radar set are more easily observed.

D. Sea return response in a radar set is caused by the transmitted pulses striking the tops of waves at such an angle that they are reflected back to the radar antenna and appear on the PPI (Plan Position Indicator) scope as a solid block of interference. Due to the reflection angles involved in sea return, such interference is usually confined to areas within a few miles of the radar set.

It is, therefore, possible to discriminate to some extent against the reception of sea return in favor of targets within the interference area. This can be automatically accomplished by causing the receiver gain to be lower at times representing distances of a few miles from the radar, and automatically restoring the normal gain at times representing greater distances where sea return is not troublesome. A reduction of gain at relatively close distances is effective in this case, since a ship target reflects a signal back to the radar which is considerably stronger than the signal due to sea return. Reducing the gain in sea return areas, reduces the intensity of the PPI display due to sea return to a greater extent than it reduces the display due to target return, and thus the target often can be observed through sea return interference.

(See also Question 6.665 for basic discussion of radar set.)

Q. 6.668. What is the average plate power input to a radar transmitter if the peak pulse power is 15 kilowatts, the pulse length 2 microseconds, and the pulse repetition frequency is 900 cycles?

A. The average plate power input is equal to 27 watts.

D. A radar transmitter operates so as to produce radio frequency pulses of short duration and high peak power, and to be non-radiating between pulses for a comparatively long interval. Since the radar transmitter is "turned off" for a much greater interval than it is "turned on," the average power which is delivered during one operating cycle is much lower than the useful peak power. The average power input can be calculated by multiplying the peak power input by a factor known as the duty cycle. The duty cycle is found from the relationship: $\textit{Duty cycle} = \frac{\textit{pulse length}}{\textit{pulse-repetition time}}$ or $(\textit{pulse length}) \times (\textit{pulse frequency})$. The pulse repetition time is the reciprocal of the pulse repetition frequency or, $T = \frac{1}{F}$. For this example, $T = \frac{1}{900} = .001111$ second, or 1111 microseconds. The duty cycle $= \frac{2}{1111} = .0018$. The average power input equals peak power times duty cycle or: $15{,}000 \times .0018$

= 27 watts. In order to calculate the peak power output (not asked for in this problem), the efficiency of the radar transmitter must be known.

Radar transmitters generally employ magnetrons (Questions 6.179 and 6.180) as the r-f oscillator. Magnetrons operating at moderate power (as in this case) have efficiencies in the order of 30 to 40%. Assuming the figure of 40% to apply in this problem, the actual r-f power output equals 15,000 watts × .40 = 6,000 watts. The average r-f power output equals 6,000 watts × .0018 (duty cycle) or 10.8 watts.

One widely used marine radar set employs a duty cycle of .00075 with a peak d-c power input of 93,000 watts. The duty cycle is obtained by either of two combinations of pulse length and pulse repetition time. One consists of a pulse length of ¼-microsecond with a pulse repetition time of 333 microseconds (short range), and the other combination consists of a pulse length of 1 microsecond with a pulse repetition time of 1340 microseconds (long range).

Q. 6.669. In determining a "fix" position by a marine loran system, what is the minimum number of land transmitters involved?

A. The minimum number of land transmitters involved in determining a "fix" is four; or two pairs of "master" and "slave" stations.

D. See Question 6.671.

Q. 6.670. What is the relationship between a master and a slave station in reference to loran navigation systems?

A. A *master* station originates the r-f pulse which then travels in all directions and is intercepted by the *slave* station. The slave station uses this pulse as a reference to transmit its own pulse at the same rate after a fixed delay which is equal to the sum of the transmit time between master and slave stations, plus a coding delay, plus a delay equal to one-half of the pulse recurrence interval. This total delay is called the "absolute delay."

D. The time difference between master and slave pulses, which is measured by the receiving scope is known as the "Indicated Time Difference" and is equal to the "absolute delay," less one-half the "recurrence interval," less transit time from "master" station to vessel, plus transit time from "slave" station to vessel.

See also Question 6.671.

Q. 6.671. How can the operator of a loran receiver on shipboard identify the transmitting stations that are being received?

A. The operator of a loran receiver can identify the transmitting stations being received, by reference to their frequency of transmission and pulse recurrence rate.

D. (See also Question 6.675.)

A brief description of the loran system follows:

Loran (long range navigation) is a method of navigation which employs highly specialized electronic circuits to provide navigators on the sea or in the air with an accurate and rapid means to determine their position. Position of the vessel is established by determining at least two "lines of position" (Question 6.675) by means of accurately timed radio signals. The intersection of the two "lines of position" upon a special loran chart indicates the geographical location of the vessel. Loran services are available throughout a large part of the major sea lanes for 24 hours each day and provide accurate determination of position at distances from the transmitting stations varying from about 757 miles (nautical) in the daytime to about 1400 miles (nautical) at night. Loran is effective under almost any weather conditions and has an accuracy which compares favorably with good celestial observations, with the additional advantage that loran positions may be determined in only 2 to 3 minutes time.

Basically the system is composed of sets of two transmitting stations each, which are located at fixed points on land, and receiving stations which may be either on ships or in aircraft. Each set of transmitting stations is composed of a "master" station and a "slave" station. The "master" station initiates the transmission cycle by sending out a pulse of r-f energy which travels out in all directions and for great distances. As it travels outward, the pulse is intercepted by the "slave" station which employs the original signal as a timing reference to initiate the transmission of its own r-f pulse after a fixed time interval. The pulse repetition rates of "master" and "slave" stations are exactly the same. The navigator at the receiving station measures the time difference between the "master" and "slave" pulses as received, by means of an accurately calibrated oscilloscope, and uses this information to determine that his vessel lies at some point along a particular line of position. This line of position is determined on the loran chart. Another line of position is then determined by means of a second pair of loran stations, and the intersection of the two lines indicates the true position of the vessel.

Q. 6.672. During daytime hours approximately what is the maximum distance in nautical miles from loran transmitting stations that loran lines of position can be determined?

A. During daytime hours the maximum distance from loran stations that lines of position can be determined is about 750 miles.

D. During nighttime hours the maximum distance is increased to about 1400 miles by the use of "skywaves."

Q. 6.673. Explain why pulse emission rather than continuous waves is used by loran transmitters. Approximately what pulse repetition frequency, pulse duration, and operating frequency are used in loran systems?

A. Pulse emission rather than continuous waves is used in order that the individual transmitting stations may be readily identified, and for the purpose of making time measurements between "master" and "slave" pulses of any particular pair of loran stations.

The pulse repetition frequency at the present time is a slight variation of either one of two so called "base rates" of 25 cycles and 33⅓ cycles. (A new base rate of 20 cycles is contemplated.) The following table lists the pulse rates in use at the present time. Pulse repetition rates are divided into two general groups. These are: Low pulse repetition rate (L), and high pulse repetition rate (H). Each group includes eight station rates, which differ as to recurrence intervals (which is the reciprocal of the repetition rate) by increments of 100 microseconds. The pulse duration is approximately 80 microseconds.

At the present time the following operating frequencies for loran are in use:

1. 1950 kilocycles.
2. 1850 kilocycles.
3. 1750 kilocycles.

TABLE OF LORAN TRANSMISSIONS

Pulse Repetition Rate (PRR)	*Station*	*Recurrence Interval (Microseconds)*	*Repetition Rate (Pulses Per Second)*
L	0	40,000	25.0
L	1	39,900	25.063
L	2	39,800	25.126
L	3	39,700	25.189
L	4	39,600	25.253
L	5	39,500	25.316
L	6	39,400	25.381
L	7	39,300	25.445
H	0	30,000	33.333
H	1	29,900	33.445
H	2	29,800	33.557
H	3	29,700	33.670
H	4	29,600	33.780
H	5	29,500	33.898
H	6	29,400	34.014
H	7	29,300	34.130

Q. 6.674. When several pairs of loran transmitting stations are operating on the same frequency how does the operator at a loran receiver select the desired pair of transmitting stations?

A. The operator selects the desired pair of transmitting stations according to their pulse recurrence rates.

D. As shown in the tables of Question 6.673, there may be as many as 16 pairs of loran stations operating on any given frequency in a particular area. The operator consults a loran chart for the operating frequency, pulse recurrence rate, and station rate for any particular pair of stations and then sets the corresponding controls accordingly on the receiving equipment. For example, the desired stations may have a "PRR" rate of *High*, a frequency of 1850 kilocycles and a station rate of 6. The "PRR" switch is set to position marked "H," the R-F channel switch is set to the channel number corresponding to 1850 kilocycles, and the station rate switch is set to number 6. The desired station pulses should then appear stationary upon the scope with other pulses moving past.

(See also Questions 6.673 and 6.671.)

Q. 6.675. Draw a simple sketch showing relative positions of pairs of master and slave stations of a loran navigation system and indicate lines of position of each pair of stations.

A. See the figure.

D. Note that along a loran line of position such as *XX'* or *YY'*, the time difference between "master" and "slave" stations is always constant. Along line *XX'* the time difference always equals 1500 microseconds, and along line *YY'* the time difference always equals 250 microseconds. It is by measuring this indicated time difference on the receiving scope that the operator is able to identify his lines of position and thus locate himself at the intersection of these lines.

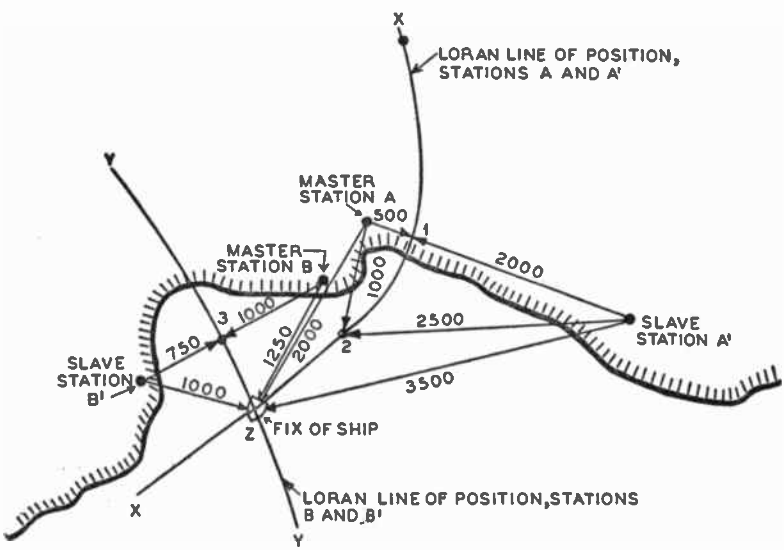


Fig. 6.675. Plan of loran system, master and slave stations and loran lines of position.

Q. 6.676. What is the purpose of "blinking" in a loran navigational system and how is blinking recognized at the receiver?

A. The purpose of "blinking" in a loran system is to warn the receiving operator that difficulty exists at the transmitting stations in maintaining correct synchronization and timing and, therefore, that readings taken during "blinking" are not necessarily correct.

There are two types of "blinking" depending upon the type of equipment at the transmitting station, but both have the same meaning. One type consists of the pulse signal appearing and disappearing at 2 second intervals. The other type consists of a shift of the pulse to the right (about 1000 microseconds) and back at intervals of 2 seconds.

Q. 6.677. What precautions should an operator or serviceman observe when working with cathode-ray tubes and the associated circuits of radar and loran receivers?

A. When working with cathode-ray tubes, great care should be taken not to strike the tube upon any hard surface. If this should happen the tube might *implode* (collapse inward) and the resultant high velocity of glass particles might cause severe injury. Safety goggles and gloves should be worn when handling cathode-ray tubes, particularly those in excess of 7" screen diameter. When working with the associated circuits, care must be taken not to come into contact with high voltage points. Whenever possible, power should be shut off and all condensers discharged manually with a grounding stick, or similar well-insulated device.

Q. 6.678. If the velocity of a radio wave is 186,000 statute miles per second, how many nautical miles does a radar pulse travel in one microsecond?

A. A radar pulse will travel .1614 nautical miles in one microsecond.

D. Since a radar pulse travels 186,000 statute (land) miles in one second, in one microsecond it will travel .186 statute miles. A nautical mile is 1.152 times as great as a statute mile, and, therefore, the number of nautical miles traveled in one microsecond is equal to $\frac{.186}{1.152}$ $= .1614$ nautical miles.

Q. 6.679. What is the primary standard of frequency for radio-frequency measurements for all licensed radio stations?

A. F.C.C. Rules and Regulations, Section 2.1 (effective Feb. 1, 1949) says:

PRIMARY STANDARD OF FREQUENCY: The primary standard of frequency for radiofrequency measurements shall be the national standard of frequency maintained by the National Bureau of Standards, Department of Commerce, Washington, D. C. The operating frequency of all radio stations will be determined by comparison with this standard or the standard signals of station WWV of the National Bureau of Standards.

D. See also Question 4.162.

Q. 6.680. What is the meaning of "frequency tolerance"?

A. "Frequency tolerance" is the allowed deviation in frequency, generally expressed in per cent of the frequency of emission, from the assigned frequency as specified in the regulations governing the class of station concerned.

Q. 6.681. For what period of time must a station log, which contains entries incident to a disaster, be retained?

A. Logs containing distress entries shall be retained by the licensee until specifically authorized by the Commission to destroy them.

Q. 6.682. Under what circumstances may a station be operated by an unlicensed person?

A. The actual operation of all transmitting apparatus in any licensed radio station shall be carried on only by a person holding an operator's license in such station. However, it is provided that the Commission if it shall find that the public interest, convenience, or necessity will be served thereby may waive or modify the forgoing provisions for the operation of any station except (1) stations for which licensed operators are required by international agreement, (2) stations for which licensed operators are required for safety purposes, (3) stations engaged in broadcasting, and (4) stations operated as common carriers on frequencies below 30,000 kilocycles. Further provisions give the Commission power to make special regulations governing the granting of licenses for the use of automatic radio devices and for the operation of such devices.

Q. 6.683. In all cases other than those in which the transmitter output must be maintained at a fixed value, what amount of power should be employed for routine communication?

A. The minimum amount of power necessary to ensure reliable communication should be used at all times.

Q. 6.684. What is the definition of a "station open to public service"?

A. A station open to public service is a station which handles public correspondence, paid or toll messages, or provides radiotelephone facilities for the general public at prescribed rates.

Q. 6.685. If an operator is employed at more than one station, how may he comply with the rule requiring the posting of operator licenses?

A. The holder of a radiotelegraph or radiotelephone first- or second-class license who is employed as a service and maintenance operator at stations operated by holders of Restricted Operator Permits shall post at such stations his operator license or a verified statement from the Commission in lieu thereof.

Q. 6.686. In the transmission of the International Morse code what are the relative time lengths of dashes, dots, and spaces?

A. In the transmission of International Morse code, dashes are about three times as long as dots. Spaces between parts of a letter are equal to the length of a dot, or slightly less. Spaces between letters are equal to the length of a dash, or slightly less; and spaces between words are about five times as long as a dot.

Q. 6.687. Why is the clock on a compulsorily equipped ship radiotelegraph station required to have a sweep second hand?

A. The clock must have a sweep second hand in order to be able to accurately time the dashes and spaces of the auto-alarm signal and also to accurately time the silent periods.

D. See Questions 6.707 (auto alarm) and 6.697 (silent period).

Q. 6.688. Between what points on a ship, compulsorily equipped with a radio-telegraph installation, is a reliable intercommunication system required?

A. Reliable intercommunication is required between the navigating bridge and the radio room.

Q. 6.689. What experience is the holder of a first- or second-class radiotelegraph operator license required to have before he is permitted to act as chief or sole operator on a compulsorily radio-equipped cargo ship?

A. The holder of a first- or second-class radiotelegraph operator license may *not* act as chief or sole operator until he has had at least 6 months' satisfactory service as a qualified radiotelegraph operator on a vessel of the United States.

Note: The holder of a second-class license may not act as chief operator on a *passenger* vessel which is compulsorily radio-equipped.

Q. 6.690. Are there any age requirements that a person must meet before he can be issued a radiotelegraph operator license?

A. The age requirement for a second-class radiotelegraph operator licensee is that the applicant must be at least 18 years of age. To be eligible for a first-class radiotelegraph operator license, the applicant must be at least 21 years of age, except that persons under 21 years of age now holding a radiotelegraph first-class license may renew same without regard to the age limit.

Q. 6.691. What action, if any, should a radio operator take when he observes a ship station flagrantly violating the international radio regulations and causing harmful interference to other stations?

A. The operator should enter the details of the violation in the log, including the time, station involved, type of violation, etc. He should also file a report with the FCC giving a full report of the violation.

Q. 6.692. Upon compulsorily equipped vessels, which are required to have an accurate clock in the radio room, how frequently must this clock be adjusted and compared with standard time?

A. At least once every 24 hours. For this purpose, authentic radio time signals received from land or fixed stations shall be acceptable as standard time.

Q. 6.693. Under what conditions may a mobile station close if its service is not required to be continuous?

A. Ship stations having working hours of limited duration are governed by regulations covered in the International Radio Regulations as follows:

(1) Ship stations whose service is not continuous may not close before they have:

a. Finished all operations resulting from a distress call.

b. Exchanged so far as practicable all radiotelegrams originating in or destined for land stations situated within their range and mobile stations which, being within their range, have indicated their presence before the actual cessation of work.

(2) Any mobile station having working hours must inform the land station with which it has opened communication of the time of closing and the time of reopening its service.

(3) *a.* Any mobile station arriving in port, and whose service is, in consequence, about to close, must notify the nearest land station accordingly and, if necessary, the other land stations with which it generally communicates. It must not close until after the disposal of traffic

on hand, unless the regulations of the country where it is calling do not permit this (*i.e.*, disposal of traffic on hand).

b. On its departure, it must notify its reopening to the land station or stations concerned from the moment when such reopening is permitted by the regulations in force in the country where the port of departure is situated.

Q. 6.694. What exceptions are permitted to the regulation which states that a ship station which has no fixed working hours must advise the land station with which it is in communication of the closing and re-opening time of its service?

A. The exceptions are:

(1) Any mobile station must not close until after the disposal of traffic on hand, unless the regulations of the country where it is calling do not permit this (*i.e.*, disposal of traffic on hand).

(2) On its departure, any mobile station must notify its reopening to the land station or stations concerned from the moment when such reopening is permitted by the regulations in force in the country where the port of departure is situated.

Q. 6.695. How frequently must an entry be made in a ship radiotelegraph log while a radio watch is being maintained?

A. During the time a watch is maintained, an entry shall be made at least every 15 minutes. This is in addition to the entries referring to observance of silent periods.

Q. 6.696. At what time(s) must the international silent period be observed?

A. See Question 6.697.

Q. 6.697. At what time(s) are routine transmissions forbidden in the bands of 480 to 515 kilocycles?

A. Routine transmissions are forbidden during the international silent period.

D. In order to increase safety of life at sea (ships), and over the sea (aircraft), all the stations of the maritime mobile service which normally listen on the waves of the authorized bands between 365 and 515 kilocycles (822 and 583 meters) must, during their working hours, make the necessary provisions to insure the watch on the distress wave, 500 kilocycles (600 meters), twice per hour, for three minutes, beginning at X:15 and at X:45 o'clock, GMT. (See Question 6.699.)

Q. 6.698. Under what circumstances must log entries be made regarding the observance of the international silent period?

A. During the period a watch is maintained by an operator, an entry shall be made twice per hour stating whether or not the international silent period was observed. In addition, entries shall be made indicating any signals or communications heard on 500 kilocycles during this period. If no signals are heard on 500 kilocycles, an entry to that effect shall be made. The use of rubber stamps for making entries to show observation of the silent period is not authorized.

Q. 6.699. What time system shall be used in making log entries with respect to the observance of the international silent period?

A. The time system is Greenwich mean time, and the time is figured according to the 24 hour system.

D. The two international silent periods of 3 minutes each begin at 15 minutes and at 45 minutes past each hour, Greenwich mean time Each sheet of the log shall be numbered and dated and the time used for making an entry in the radio log shall be according to the 24-hour system, starting at midnight of the time at the Meridian of Greenwich. The indication GMT, indicating Greenwich mean time, shall be written at the heading of the column in which the time in four figures is entered. The time is written opposite each entry. The following gives several examples of how time is indicated according to the 24-hour system, bearing in mind that Eastern Standard Time (New York) is five hours earlier, and Pacific Standard Time is eight hours earlier, than Greenwich Mean Time.

E.S.T.		*P.S.T.*		*G.M.T.*
Ordinary	*24-hour*	*Ordinary*	*24-hour*	*24-hour*
12: Midnite	0000 (T)	9:00 P.M.	2100 (M)	0500 (T)
12:45 A.M.	0045 (T)	9:45 P.M.	2145 (M)	0545 (T)
9:00 A.M.	0900 (T)	6:00 A.M.	0600 (T)	1400 (T)
12: Noon	1200 (T)	9:00 A.M.	0900 (T)	1700 (T)
3:00 P.M.	1500 (T)	12: Noon	1200 (T)	2000 (T)
11:59 P.M.	2359 (T)	8:59 P.M.	2059 (T)	0459 (W)

The references M, T, and W represent three consecutive days of the week, to indicate the relation of the time zones to the calendar.

Q. 6.700. What is the international radiotelegraph distress frequency for stations in the mobile service?

A. 500 kilocycles is the international distress frequency.

Q. 6.701. Describe how a distress call should be made.

A. The distress call shall include:

1. The distress signal transmitted three times.
2. The word DE.
3. The call signal of the mobile station in distress transmitted three times.

D. See Questions 6.702 and 6.710.

Q. 6.702. What transmission should precede the transmission of the distress call?

A. The distress call, when sent in radiotelegraphy on 500 kilocycles (600 meters) shall, as a general rule, be immediately preceded by the auto-alarm signal (Question 6.707).

Q. 6.703. What stations shall be in control of distress traffic?

A. The control of the distress traffic rests with the mobile station in distress or with the mobile station which sends the distress call in the event the station in distress is not itself in a position to transmit it. These stations may delegate the control of the distress traffic to another station.

Q. 6.704. During what periods must a distress message be repeated following the initial transmission?

A. The distress message must be repeated at intervals until an answer is received, and especially during the silence periods. The intervals must, however, be long enough to allow stations preparing to reply to start their transmitting equipment.

Q. 6.705. During what periods must the safety signal be transmitted?

A. In the maritime mobile service, apart from messages transmitted according to a schedule, the safety signal must be transmitted toward the end of the first ensuing period of silence, and the message shall be transmitted immediately after the period of silence.

Q. 6.706. How long must mobile stations listen after hearing an urgency signal?

A. Mobile stations which hear the urgency signal must continue to listen for at least 3 minutes. At the end of this period, if no urgency message has been heard, they may resume their normal service.

Q. 6.707. Describe the number of dashes, or dots, and spaces which compose the international auto-alarm signal and indicate the time intervals involved.

A. The alarm signal shall consist of a series of 12 dashes sent in one minute, the duration of each dash being four seconds and the duration of the interval between two dashes, one second. It can be transmitted by hand or by means of an automatic instrument. Any ship station working in the band of 365 to 515 kilocycles (822 to 583 meters), and which is not provided with an automatic apparatus for the transmission of the auto alarm signal must be permanently equipped with a clock distinctly marking the seconds, preferably by means of a moving hand completing one revolution per minute. This clock must be placed at a point sufficiently visible from the keying table so that the operator may, by watching it, easily and correctly time the different elements of the alarm signal.

Q. 6.708. When the auto alarm bell rings, what should the operator do?

A. The operator must immediately proceed to the radio room and press the reset button located on the panel of the auto alarm. If the bells stop ringing, the operator should then plug his headphones into the monitoring jack and listen for further signals which would indicate whether a true or a false alarm signal had been received. In the event of a true signal, the operator must immediately begin a watch on the distress frequency to record the incoming information. (See also Questions 6.709 and 6.710.)

If the bells do not stop ringing when the reset button is pressed, this indicates a defect in the equipment. (See Questions 6.591, 6.592, 6.593, 6.594, 6.595, and 6.596.)

Note: A bell stopped immediately may restart because of continued reception of the auto-alarm signals.

Q. 6.709. Under what circumstances, and by whom, may the international auto-alarm signal be transmitted to announce an urgent cyclone warning?

A. The only purpose of this special signal is to set into operation the automatic apparatus used to give the alarm. It must only be used either to announce that a distress call or message is to follow, or to announce the transmission of an urgent cyclone warning; in the latter case it can only be used by coast stations duly authorized by their government.

Q. 6.710. What space of time should elapse between the transmission of the international auto-alarm signal and the distress call?

A. When circumstances permit, the transmission of the distress call is separated from the end of the alarm signal by an interval of 2 minutes' silence. See also Question 6.712.

Q. 6.711. While a vessel is at sea, how frequently must the auto alarm be tested?

A. While the ship is being navigated outside a harbor or port, the auto alarm shall be tested at least once every 24 hours by means of the testing device supplied as part of the alarm, the timing of the dashes to be made by reference to the second hand of the ship-station clock. A statement that the foregoing requirement has been fulfilled must be inserted in the radio-station log daily.

Q. 6.712. What interval of time must elapse between the end of the auto-alarm signal and an urgent cyclone warning?

A. Two minutes is the time interval which must elapse. See also Questions 6.709 and 6.710.

Q. 6.713. Under what circumstances is a station in the mobile service not required to listen to distress traffic?

A. A station of the mobile service which, while following distress traffic of which it has knowledge, if able to continue its normal service may do so when the distress traffic is well established, on the following conditions:

(a) The use of the distress wave, 500 kilocycles (600 meters), on which the distress traffic is taking place and the use of type B waves are forbidden.

(b) The use of type A1 waves, with the exception of those which might disturb the distress traffic, is permitted.

Q. 6.714. Upon hearing an SOS, what should an operator do?

A. This call shall have absolute priority over other transmissions. All stations hearing it must immediately cease all transmission capable of interfering with the distress traffic, and must listen on the wave used for the distress call. This call must not be sent to any particular station and shall not require an acknowledgment of receipt.

Q. 6.715. What is the purpose of an automatic-alarm-signal keying device on a compulsorily equipped ship?

A. The purpose of an automatic-alarm-signal keying device is to automatically produce the correct auto-alarm signal.

D. See Question 6.707 and also Appendix V.

Q. 6.716. On a vessel of the United States equipped with an approved auto alarm where is the control button, which silences the warning bells, located?

A. Only one switch for stopping the audible warning apparatus from functioning is authorized and this shall be located in the main radiotelegraph operating room and shall be capable of manual operation only.

Q. 6.717. With what type(s) of emission and upon what frequency should a transmitter be adjusted to transmit a distress call?

A. In case of distress, the wave to be used shall be the international distress wave, that is, 500 kilocycles (600 meters); it must preferably be used with type A2 or B emission. Ship stations which cannot transmit on the international distress wave shall use their normal calling wave.

Q. 6.718. If you received a distress call signed by a call signal composed of five letters, could you determine the type of craft which transmitted the signal?

A. Five letter call signals are assigned to aircraft stations.

D. Three letter call signals are assigned to land stations. Four letter call signals are assigned to ship stations.

Q. 6.719. While the vessel is in the open sea, how frequently must the specific gravity of the emergency battery be taken?

A. Once daily.

Q. 6.720. How frequently must the quantity of fuel in the supply tank for use with an oil or gas-driven emergency generator be checked, while the vessel is in the open sea?

A. Once daily.

Q. 6.721. While a vessel is in port, how frequently should the emergency equipment be tested?

A. Tests are required only when the vessel is about to leave port.

Q. 6.722. You intercept "CQ CQ WSV TFC QSY 735 AS." What does this mean?

A. The abbreviations have the following meanings:

CQ = general call "to all stations."

WSV = call letter of a coastal station.

TFC = "traffic."

QSY = "shift to transmission on .... kilocycles (or meters)."

735 = new frequency in meters (735 meters).

AS = "Waiting period" to shift transmission to new frequency (735 meters).

The above communication means the following: A general call is sent to all ship stations from WSV (coastal station). A traffic list will follow giving the call letters of all ship stations for which WSV has traffic. WSV will shift from its present calling wave to the new working wave of 735 meters, which it will use for the transmission of the traffic list. A short waiting period is requested to shift to the working wave (735 meters). (See Appendix III for other abbreviations.)

Q. 6.723. Upon hearing a safety signal, what should the operator at the receiving station do?

A. All stations hearing the safety signal must continue listening on the wave on which the safety signal has been sent until the message so announced has been completed; they must moreover keep silence on all waves likely to interfere with the message.

Q. 6.724. Explain the use and meaning of the following indicators or prefixes on radiotelegrams, and describe the difference in handling of the various types of radiotelegrams: RP, TC, PC, FS, PR, TR, MSG, CDE, OBS, PDH, CODH.

A. 1. The indicator RP ("Reply Paid") indicates that the sender has prepaid a message which is to answer his own message. RP messages are transmitted with the indicator in the preamble and again as the first word in the address followed by the amount prepaid for example: RP $2.10 (entire expression counts as one word.) An operator receiving such a message issues an "RP Voucher" for the amount, to the addressee with the original message. The voucher is valid if presented within 3 months of the date of issue.

2. The indicator TC (Collated radiotelegram) means that the sender has requested that the message be repeated back for verification after having been received. The sender pays an additional charge equal

to one half the charge for an ordinary radiotelegram of the same length for the same destination sent by the same route, and he writes before the address the paid service indicator "TC" or "Collation."

3. The indicator PC (notification of delivery) before the address in a radiotelegram indicates that the sender has paid for an additional six words at domestic rates for a telegram. This will be sent to him immediately upon transmission by the coastal station, notifying the sender of the exact time of transmission to the ship. This service applies only in the case of shore-to-ship service.

4. The indicator FS is a paid service indicator which denotes that the sender wishes the radiotelegram to be forwarded if necessary to reach the addressee. The sender guarantees to pay any additional charges which may arise due to the forwarding. If he so desires, the addressee may pay the additional forwarding charges.

5. The indicator PR indicates that the radiotelegram is to be delivered by registered mail.

6. The indicator TR (Telegraph Restant) is generally used when a radiotelegram is not expected to be delivered personally to the addressee, but is delivered to some place (such as a telegraph office) to await pickup by the addressee.

7. The indicator MSG (Masters Messages) is used when the Master wishes to give information to or obtain information from another ship. (No personal matter allowed.)

8. The indicator CDE (Code Language Radiotelegrams) is used when the radiotelegram is composed either of artificial words, or of real words used with the meaning not normally assigned to them, consequently not forming intelligible phrases in one or more of the languages authorized; or it is composed of a mixture of real words and artificial words. Code words must not contain more than five letters which may be formed in any way. They must not use accented letter 'e'.

9. The indicator OBS (Meteorological Radiotelegrams) denotes a Radiotelegram sent by an official meteorological service or by a mobile station in official relation with such service, and addressed to such a service or to such a station. It consists solely of meteorological observations or meteorological forecasts. These are commonly referred to as 'observers.'

10. The indicator PDH (Franked Radiotelegrams; personal) denotes that the message is "deadheaded" (no charge). Franked messages must be of a social or personal nature. Business or political messages cannot be franked. Only plain language radiotelegrams can be sent. Operators must sign their name in full on their personal PDH messages.

11. The indicator CODH (Franked Company business message) is used to send messages to any service station or District Office requesting information, relief or repairs.

D. The above definitions and handling procedures of the various indicators are made as complete as space allows. Special cases may apply to the use of these indicators, and the operator should consult the International Radio Regulations (or Company Regulations) to ascertain whether or not any special case does exist.

Q. 6.725. Explain cable count and the use of standard service abbreviations, and show the difference between cable count and domestic word count.

A. 1. Cable (or radiotelegram) count is based upon the general fact that with the exceptions noted, everything the sender writes in the address, text, and signature, is counted and charged for in all classes of messages. The exceptions apply to:

(a) *Routing Instructions*: Sender's routing instructions are neither counted nor charged for, except that in the case of messages destined to ships at sea the address must include the name of the coastal station through which the message is to be transmitted to the ship, such name being counted and charged for as one word.

(b) *Paid Service Advices*: In the case of paid service advices only the matter appearing in the text is counted and charged for.

(c) *Dashes*: Dashes written by the sender on his copy, only to separate words or groups contained in the message, are not counted, charged for or transmitted.

2. *ADDRESS*: Except as otherwise indicated in (a) and (b) below, the words in the address of a message of any class are counted at the rate of fifteen, or fraction of fifteen, letters to the word. When any of the following appear in the address, they may in each case be grouped as one word and will be counted at the rate of fifteen, or fraction of fifteen, letters to the word: family names belonging to one person; the full names of places, squares, boulevards, streets and other public ways; names of ships when in port—(for ships at sea, see 3(a) below); names or designations of aircraft or trains when written in words; and house, apartment, room, travel space and similar location numbers when written in words.

(a) *Office of Destination*: The name of the office of destination, including the name of the country or other territorial subdivision when it is necessary, is counted as one word regardless of the number of letters it contains. In the address of messages destined to ships at sea or in the air the name of the ship (including the ship's call letters when necessary but excluding the abbreviation "SS" for steamship) and that of the coastal station are, in all cases and irrespective of their length, each counted as one word.

(b) *Names of Streets, House Numbers, etc.*: The names of streets and house, apartment, room, travel space and similar location numbers, also designations of aircraft or trains when composed of figures and letters, and any figure groups, are counted at the rate of five, or fraction of five, characters to the word. A fraction bar in a group of figures or in a group of figures and letters, forming a house number in the address is not counted even when written by the sender upon the original copy of his message.

3. *TEXT*: The words in the text of a message of any class are to be counted in accordance with the following:

(a) *Plain Language*: Plain language words in plain language messages are counted at the rate of fifteen, or fraction of fifteen, letters to the word. Figures, figure groups, commercial marks, trade marks, abbreviations (see 3(e) below) such as FOB, COD, LCL, etc., are counted at the rate of five, or fraction of five, letters or figures to the word.

(b) *Cipher Language*: In cipher messages, each plain language word and each cipher word as well as each figure group or commercial mark, etc., is counted at the rate of five, or fraction of five, letters or figures to the word.

(c) *Code Language*: Code words, whether real or artificial, are not permitted to contain more than five letters nor may they contain any accented letters. Messages containing code words consisting of more than five letters are subject to cipher count and charge. Messages containing words in code language and words in plain language and/or figures or figure groups are considered for the purpose of charging, as code messages, the plain language words being counted at the rate of five, or fraction of five, letters to the word.

(d) *Words Joined by a Dash or Hyphen*: Words joined by a dash or hyphen, or by a stroke, an apostrophe or other punctuation mark are counted the same as if the words were written separately. In such instance, the punctuation mark, if to be transmitted, is counted as one word; for example, MAY/AUGUST is subject to three word count in a plain language message.

(e) *Abbreviated, Misspelled, Compound or Combined Words*: Abbreviated, misspelled and compound or combined words, contrary to the usage of the language to which they belong, are not admitted in any class of message As an exception, abbreviations in general use in correspondence, such as FOB, CIF, LCL, etc., are admitted and counted at the rate of five, or fraction of five, letters to the word in all classes of messages.

(NOTE—For the purpose of administering the above provision (e) an abbreviation is considered to be "in general use" if it appears with its associated explanation in a standard dictionary of the language in which the message is written, or if it appears in the list of abbreviations shown below.)

(f) *Names, etc.*: Notwithstanding the provisions of the preceding paragraph, the following may be grouped as single words: compound words appearing in the dictionary; the names of cities, countries or other divisions of territory; family names belonging to one person; the full names of places, squares, boulevards, streets and other public ways; the names of ships; names or designations of aircraft or trains when written in words; house, apartment, room, travel space and similar location numbers when composed of figures, or figures and letters, but written in words; whole numbers, fractions, decimal or fractional numbers written in words. In plain language messages, such single word groups are counted at the rate of fifteen, or fraction of fifteen letters to the word as written, and in code and cipher messages they are counted at the rate of five, or fraction of five, letters to the word.

(g) *Numbers Written in Words*: Numbers may be written in words in which each figure is represented separately or in groups; for example, three thousand and thirty or threenaughtthreenaught or thirtythirty; sixhundredandfortysix or sixfoursix or sixfortysix. In plain language messages these expressions are counted at fifteen, or fraction of fifteen, letters to the word as written. In code and cipher messages they are counted at the rate of five, or fraction of five, letters to the word.

(h) *Figures, Figure Groups, Commercial Marks, etc.*; Figures, figure groups, commercial marks, trade marks, abbreviations (see Rule 3(e) above) such as FOB, COD, LCL, etc., and house, room and other location numbers when composed of figures, or figures and letters are counted at the rate of five, or fraction of five characters to the word.

(i) *Ordinal Numbers*: Ordinal numbers composed of figures and letters such as 17th, 21st, 32nd, etc., are counted at the rate of five, or fraction of five, characters to the word.

(j) *Groups of Figures and Letters with Secret Meaning*: The combination, in one group, either of figures and letters, or of figures or letters and signs of punctuation, with a secret meaning is not allowed.

If, however, such groups are discovered in a message subsequent to its acceptance and there is no opportunity to have the sender revise the text to bring it into conformity with this regulation, or if the sender insists upon the acceptance of such a group, the message will be transmitted as a cipher message at the sender's risk of having the message rejected and not delivered by a foreign communications carrier or administration, and each uninterrupted group of figures and each uninterrupted group of letters will be counted at the rate of five or fraction of five characters to the word.

(k) *Isolated Letters and Figures*: Each isolated letter or figure is counted as one word.

(l) *Punctuation*: Signs of punctuation are not transmitted unless the sender specifically requests that they be transmitted, in which case they are charged for. Punctuation signs which may be used in all classes of messages are:

Period, decimal point or full stop	(.)
Comma	(,)
Question (interrogation) mark	(?)
Colon	(:)
Apostrophe	(')
Dash or hyphen	(-)
Underline	(__)
Fraction bar (stroke)	(/)
Parentheses (brackets)	( )

Each sign of punctuation in its customary application, transmitted at the express request of the sender, is counted as one word, except that an underline, regardless of its length, is counted as one word and the two signs ( ) of parentheses (brackets) are counted together as one word. When signs of punctuation, instead of being used separately, are repeated one after another, they are counted and charged for at the rate of five such characters to the word. The decimal point (.), comma (,), colon (:), dash or hyphen (-) and fraction bar or stroke (/) forming part of a group of figures, or a group of letters or a group composed of figures and letters (not having a secret meaning) are each counted as one figure or letter in such group, except as indicated in 2(b) above or in the paragraph below. For example, the following groups count as one word each: 45.48 45,56 12:30 54-32 12/30 or AP/M representing a commercial mark.

If a dash or hyphen is used to separate a whole number from an associated fraction or to separate figures from an associated per cent sign, the dash or hyphen is neither counted nor charged for; for example, 44-½ or 44½ (transmitted 44-½) and 10-0/0 or 10% (transmitted 10-0/0) would each be counted as having five characters and charged for as one word each.

(m) *Multiplication Sign*: The multiplication sign (×) has no equivalent in transmission. It is replaced in transmission by the letter (X) which is counted as a character in the group in which it appears. For examples of counting this sign see Rule 6, "Examples of Count."

(n) *Signs* ($, £, #, %): The dollar sign ($) and the pound sterling sign (£) cannot be reproduced in transmission and therefore messages containing such signs are not acceptable. The sender should substitute the words DOLLARS (or DOLS or DLRS) or POUNDS (or STLG or STERLING) for these signs. Similarly, the number or pound sign (#) cannot be reproduced in transmission and in lieu thereof the sender should use the words NUMBER (or NO), POUND (or LB) or POUNDS (or LBS), as the case may be. If, however, a message subsequent to its acceptance is found to contain a dollar sign ($), pound sterling sign (£) or number or pound sign (#) and there is no opportunity to have the sender make the requisite substitution, such signs will be replaced before transmission from the office of origin by the words, DOLLARS, STERLING, NUMBER, POUND or POUNDS, as the case may be, and such substituted words will be counted in accordance with the class of service. The per cent sign (%) is subject to being transmitted as 0/0 and therefore is counted as three characters in the group in which it appears.

(o) *Other Signs and Expressions*: Quotation marks (" ") and expressions and signs such as X^2 (for X power 2), 30^a (for 30 power a), 1° (for 1 degree), 1′ (for 1 minute or 1 foot), 1″ (for 1 second or 1 inch), @ (for at), ¢ (for cents), etc., cannot be transmitted. Therefore, it is necessary to substitute acceptable equivalents which can be transmitted; for example, QUOTE and UNQUOTE, X POWER 2 (or X 2), 30 POWER A (or 30 A), 1 DEGREE (or 1ST DEGREE) 1 MINUTE (or 1 FOOT), 1 SECOND (or 1 INCH), AT, CENTS, etc. If, however, expressions such as 30^a and 30^b, indicating the number of a house appear in the address, they are transmitted 30/A or 30/B and counted as one word.

4. *SIGNATURE*: Each word, except words with secret meaning which are not registered code addresses, in the signature of a message of any class is counted at the rate of fifteen, or fraction of fifteen, letters to the word. Words with secret meaning which are not registered code addresses are counted at the rate of five, or fraction of five, letters to the word. When any of the following appear in the signature, they may in each case be grouped as one word and will be counted at the

rate of fifteen, or fraction of fifteen, letters to the word: the names of cities, countries or smaller divisions of territory; family names belonging to one person; the full names of places, squares, boulevards, streets and other public ways; the names of ships names or designations of aircraft or trains when written in words; and house, apartment, room, travel space and similar location numbers when written in words. When location numbers and aircraft or train designations composed of figures, or a combination of figures and letters, appear in the signature, they are counted at the rate of five, or fraction of five, characters to the word.

The following are abbreviations in general use:

1. DOLS or DLRS = DOLLARS
2. FOB = FREE ON BOARD
3. CIF = COST, INSURANCE AND FREIGHT
4. CAF = COST AND ESTIMATE
5. ETA = ESTIMATED TIME ARRIVAL
6. ETD = ESTIMATED TIME DEPARTURE
7. EST, CST, MST, PST (abbreviations for Standard Time).
8. EDST, CDST, MDST, PDST (abbreviations for Daylight Saving Time).
9. GMT, G or Z = GREENWICH MEAN TIME
10. SVP = S'IL VOUS PLAIT
11. LCL = LESS THAN CARLOAD LOT
12. STLG = STERLING
13. LB or LBS = POUND OR POUNDS
14. LONG 80.03 W = LONGITUDE 80.03 WEST
15. LAT 37.54 N (irregular combination of LATITUDE 37.54 NORTH).

For additional abbreviatons see Appendix III.

The basic difference between cable count and domestic service count is that in cable count the sender is charged for everything he writes, including address, text and signature, while in domestic service count, he is charged only for the *text.*

Q. 6.726. Construct a plain language radiotelegram and indicate what portions comprise (a) the preamble, (b) the address, (c) the text, and (d) signature.

A. a. Preamble:

Prefix	Sent. No.	Words	Sent to	By
MSG	2	9	WNY	RC

Time Sent	Office of Origin	Date Filed
2200 (GMT)	SS America WEDI	6/25/49

Coastal Station via	Timed filed
WNY	2145

b. Address: UNILINES NEWYORK

c. Text: PASSED AMBROSE 2030 GMT WEATHER CLEAR

d. Signature: MASTER

D. For Prefix, see Question 6.724.

The "sent number" is the serial number of the message, a new series starting each day, with respect to each called station.

The word count is described in Question 6.725. There are two words in the address, six in the text, and one in the signature. "Sent to" is the call of the stations finally receiving the message, whether or not relayed.

"By" is the operator's initials.

"Time sent" is in Greenwich Mean Time, Questions 6.699 and 6.739.

"Office of Origin" is the name (if ship) and call of the station from which the message is being sent.

"Date filed" is self explanatory.

"Coastal station via" is the call of the station through which the message may be relayed. It is the station to which the message is first sent, if relaying is required.

"Time filed" is GMT; it is the time the message was filed at the office of origin.

In the address, "Unilines" is a registered code address, which, by reference to a list, gives the full name and address of the addressee.

Q. 6.727. Upon what band, in addition to the 350-515 kilocycles band, must a main receiver on a United States ship be capable of operation? What is the purpose of this additional band?

A. From 100 to 200 kilocycles. To provide long-wave radiotelegraph long-distance communication.

Q. 6.728. If, upon being called by another station, a called station is unable to proceed with the acceptance of traffic, what should the operator of the called station do?

A. If the station called is prevented from receiving, it shall reply to the call as indicated in the Regulations, but it shall replace the letter K by the signal .—... (wait), followed by a number indicating in minutes the probable duration of the wait. If this probable duration exceeds 10 minutes (5 minutes in the aeronautical mobile service), a reason must be given therefor.

Q. 6.729. After a distress call has been transmitted, every distress-traffic radiotelegram shall contain what symbol in the preamble?

A. Every distress traffic radiotelegram must include the distress signal preceding the call and repeated at the beginning of the preamble.

Q. 6.730. For how long a period of continuous operation should the emergency power supply of a compulsorily equipped ship station be capable of energizing the emergency radiotelegraph installation?

A. The emergency power supply should be capable of energizing the emergency radiotelegraph installation for a period of at least 6 consecutive hours.

Q. 6.731. While the vessel is in the open sea, how frequently must the emergency equipment be tested?

A. Once daily.

Q. 6.732. Indicate the order of priority of the various types of radio communications.

A. The order of priority of radio communications in the mobile service shall be as follows:

1. Distress calls, distress messages, and distress traffic.
2. Communications preceded by an urgent signal.
3. Communications preceded by a safety signal.
4. Communications relative to radio direction-finding bearings.
5. Government radiotelegrams for which priority right has not been waived.
6. All other communications.

Q. 6.733. What is the principal port of the United States, on the Pacific Coast, at which navigation lines terminate?

A. San Francisco.

Q. 6.734. In what city is the major telecommunication center of the United States located?

A. New York City.

Q. 6.735. What is the approximate latitude of Colon, Republic of Panama?

A. Approximately 9.4°N.

D.

	Approximate	
Port	*Latitude*	*Longitude*
Colon, Panama	9.4°N	80°W
Los Angeles, Calif.	34°N	118°W
New Orleans, La.	30°N	90°W
New York, N. Y.	41°N	74°W
San Francisco, Calif.	38°N	122.5°W

Q. 6.736. In what ocean is the island of Guam located?

A. Pacific Ocean.

Q. 6.737. To what continent do the greatest number of telecommunication channels from the United States extend?

A. Europe.

Q. 6.738. What is the principal Atlantic Coast port of the United States at which navigation lines terminate?

A. New York City.

Q. 6.739. What is the GMT time and the day of the week in Shanghai when it is Wednesday noon in New York City?

A. When it is Wednesday noon in New York City, it is 1700 GMT, Wednesday.

D. Since Greenwich Mean Time (GMT) is defined as the local mean time at the meridian of Greenwich, it is the same in all parts of the world. Standard time in New York City is the local mean time of the 75th Meridian, West, and is therefore five hours earlier than Greenwich Mean Time. (Fifteen degrees of longitude represents one hour of time, since a complete revolution of 360 degrees requires 24 hours.) Shanghai takes its time from the 120th Meridian, East, and is therefore eight hours later than GMT. Consequently, local standard time in Shanghai is 13 hours later than in New York; and Wednesday noon (1200) in New York corresponds to 1 A.M. (0100) Thursday in Shanghai.

Q. 6.740. In a ship radiotelegraph station, where may information be found concerning the forwarding charges for radio telegrams?

A. Information concerning such charges are to be found in the I.T.U. book and in the tariff book of the station licensee.

D. The I.T.U. (International Telecommunications Union) book is general in scope and covers charges under all local and foreign conditions. The tariff book of the station licensee covers general charges and in addition, special rates such as for night radiotelegrams.

ELEMENT VII

AIRCRAFT RADIOTELEGRAPH

REGULATION AND TREATY

Question 7.01. Under what conditions is a flight radio operator required aboard scheduled aircraft engaged in flights outside the continental United States?

Answer. A licensed radio operator shall be required for flight over any area, route, or route segment over which the Administrator has determined that radio telegraphy is necessary for communication with ground stations during flight.

Q. 7.02. Under what conditions are flight radio operators required in United States irregular air carrier operation?

A. An airman holding a flight radio operator's certificate shall be required for flight over any area over which the Administrator has determined that radio telegraphy is necessary for communication with ground stations during flight.

Q. 7.03. Is it mandatory that one crew member other than the flight radio operator be capable of operating the radio equipment in an emergency?

A. In all flights requiring only one flight radio operator, one other flight crew member must be capable of operating the equipment in an emergency.

Q. 7.04. What are the Federal Communication Commission's license requirements for an air radiotelegraph operator?

A. The following is quoted from Part 33 CAR:

REQUIREMENTS FOR CERTIFICATE

Issuance. A flight radio operator certificate will be issued to an applicant who meets the following requirements.

Age. Applicant shall be at least 18 years of age.

Citizenship. Applicant shall be a citizen of the United States or of a foreign government which grants reciprocal flight radio operator privileges to citizens of the United States on equal terms and conditions with citizens of such foreign government.

NOTE: At the present time Federal Communications Commission radio operator licenses are issued only to citizens of the United States.

Education. Applicant shall be able to read, write, and understand the English language and speak the same without accent or impediment of speech which would interfere with two-way radio conversation.

Physical standards. Applicant shall meet the physical standards of the third class prescribed in Part 29 of the subchapter of this chapter.

Experience. (a) Applicant shall hold a Federal Communications Commission radiotelegraph operator license of not less than second class. (b) Applicant shall:

(1) Have had at least 12 months of satisfactory experience as a radio operator in aircraft, maritime, or ground stations, commercial or military, including at least 4 months of experience as a radiotelegraph operator; and have had at least 50 hours of experience in the operation of aircraft radio during flight; or

(2) Be a graduate of a flight radio operator course approved by the Administrator.

Knowledge. Applicant shall pass a written examination on the following subjects:

(a) Such provisions of the Civil Air Regulation (Parts 1-99 of this subchapter) as are pertinent to the operation of aircraft radio systems;

(b) Theory and operation of radio communication and radio navigational systems in general use on aircraft;

(c) Radio navigation of aircraft;

(d) Aircraft radio operating procedures.

Skill. Applicant shall:

(a) Pass a practical examination on the operation, adjustment, and routine repair of aircraft radio communication and radio navigational equipment;

(b) Demonstrate his ability to send and receive International Morse Code at a speed of 20 words per minute code groups, and 25 words per minute plain language.

CERTIFICATION RULES

Application. Application shall be made on a form and in the manner prescribed by the Administrator.

Duration. A flight radio operator certificate shall remain in effect unless it is suspended, or revoked, or a general termination date for such certificate is fixed by the Board.

Temporary certificates. The Administrator or his authorized representative may issue a temporary flight radio operator certificate for a period of not to exceed 90 days, subject to the terms and conditions specified therein by the Administrator.

Reexamination. Applicants who have failed in any examination may apply for reexamination on the part failed after 30 days from the date of such failure.

Certificate. No individual shall serve in the flight crew as a flight radio operator unless he has in his personal possession while so serving a valid flight radio operator certificate issued by the Administrator.

Medical certificate and renewal. No individual shall exercise the privileges of a flight radio operator certificate unless he has in his personal possession while so serving a medical certificate or other evidence satisfactory to the Administrator showing that he has met the physical requirements appropriate to his certificate within the preceding 12 calendar months.

Certificate display. A flight radio operator shall, upon request, present his airman and medical certificates for examination by any representative of the Civil Aeronautics Board or Administrator or by any State or local law enforcement officer.

Operation during physical deficiency. No flight radio operator shall exercise the privileges of his airman certificate during any period of known physical deficiency or increase in physical deficiency which would render him unable to meet the physical requirements prescribed for the issuance of his currently effective medical certificate.

Change of address. Within 30 days after any change in the permanent mailing address of a holder of a flight radio operator certificate, the holder shall notify the Administrator in writing of such change. Such notice shall be mailed to the Administrator of Civil Aeronautics, attention Airman Records Branch, Washington 25, D.C.

Q. 7.05. What is meant by "long distance" operation in scheduled air carrier flights outside the continental United States?

A. A "long distance" operation is one in which the time interval between stops is of sufficient duration to require that the dispatch be based entirely on forecasts of weather expected at the intended destination and alternates.

Q. 7.06. An aircraft is engaged in "long distance" operation. What radio equipment is required aboard for this type of operation?

A. Each aircraft shall be equipped with such radio facilities as are necessary to accomplish the following:

(a) By either of two independent means, transmit communications and meteorological information to at least one ground station from any point on the route and transmit, from a distance of not less than 25 miles, to airport traffic control towers located at airports approved for the route;

(b) By either of two independent means, received communications at any point on the route;

(c) By either of two independent means, receive meteorological information at any point on the route and receive instructions from airport traffic control towers located at airports approved for the route;

(d) By either of two independent means, satisfactorily receive radio navigational signals from any radio aid to navigation required by §41.13 (b).

If appropriate, equipment provided for compliance with paragraph (c) of this section may be employed for compliance with either paragraph (b) or this paragraph.

D. See Question 7.07 for the text of section 41.13 (b) referred to above.

Q. 7.07. For "long distance" operation outside the continental United States, what ground radio navigational aids are required at scheduled stops and alternate airports?

A. Each route shall be equipped with radio navigational facilities so located as to permit the obtaining of reliable radio bearings when within 200 miles of any regular or approved alternate airport and a facility shall be so located with respect to each such airport as to provide adequate means for making an instrument approach: *Provided,* That, the Administrator, at particular airports, may approve facilities which provide less coverage than that required in this section if he finds that adequate safety is provided.

Q. 7.08. What are the requirements for a two-way air-to-ground communications system in schedule air carrier operations outside the continental United States?

A. A two-way ground-to-aircraft radio communication system shall be available at such points as are necessary to ensure adequate communication between plane and ground over the entire route.

Q. 7.09. For "long distance" scheduled air carrier operations outside the continental United States, what is the required communications range from aircraft to airport traffic control towers at airports approved for the route?

A. See Question 7.06 (a).

Q. 7.10. For "long distance" scheduled aircraft operations outside the continental United States, what are the aircraft receiver requirements for receiving communications, meteorological, and navigational information?

A. See Question 7.06.

Q. 7.11. For "long distance" scheduled air carrier operations outside the continental United States, what aircraft transmitting equipment is required and over what distance should this equipment operate?

A. See Question 7.06 (a).

Q. 7.12. What radio equipment is required aboard foreign flag aircraft operating into the United States and outlying possessions?

A. Each aircraft shall be provided with such radio equipment as is necessary to make use of the air navigation facilities along or adjacent to the route to be flown within the United States and to maintain communication with ground stations along and adjacent to such routes.

Q. 7.13. Discuss the requirements for electrical power and radio equipment required for continuance of flight.

A. 1. One or more storage batteries or other source of electrical supply adequate to operate all radio and electrical equipment necessary for the flight.

2. Two of the following three units of radio equipment:

a. One transmitter for two-way communication.

b. One receiver for two-way communication.

c. One receiver capable of receiving navigational signals.

3. In addition to the instruments named, one of the radio navigational systems, if navigational facilities on the route are required. (See Question 7.06.)

4. Three spare fuses of each capacity, or 25 percent of the number of each capacity, whichever is the greater.

Q. 7.14. An aircraft is at mid-ocean and experiences a communication failure. What procedure would the pilot follow after being advised by the flight radio operator that the aircraft is out of communication?

A. In the event of inability to maintain two-way radio communication, the pilot in command shall observe one of the following procedures in the order listed:

(a) Proceed according to current flight plan, maintaining the minimum instrument altitude or the last acknowledged assigned altitude, whichever is higher, to the airport of intended landing and commence descent at approach time last authorized or, if not received and acknowledged, at the estimated time of arrival specified in the flight plan; or

(b) If weather conditions permit, proceed in accordance with contact flight rules; or

(c) Land as soon as practicable.

Q. 7.15. Define the point-of-no-return as used in air carrier operations.

A. The term "point-of-no-return" means that point at which the aircraft no longer has sufficient fuel, under existing conditions, to return to the point of departure or any alternate for that point.

Q. 7.16. If a flight operator noted an irregularity or hazard which, in his opinion, made for unsafe operation, to whom should he report such hazard or irregularity?

A. All airmen, including flight and ground personnel, shall immediately report to the operations manager any irregularity or hazard which, in their opinion, makes for unsafe operation. If such report is found to be justified, notice of the irregularity or hazard must be submitted to the Administrator at once.

Q. 7.17. With regard to air-to-ground communication, what is the order of priority for communications on a channel that is used in point-to-point as well as air-to-ground contacts?

A. Where a communications channel serves point-to-point contacts in addition to ground-to-plane contacts priority shall be given to plane-to-ground and ground-to-plane communications.

Q. 7.18. What is meant by "type certification" of radio equipment on United States scheduled air carrier aircraft?

A. "Type certification" is an approval bestowed by the CAA upon certain aircraft and their equipment when they meet the CAA requirements. To be eligible for type certification, aircraft radio equipment must be so designed and constructed that it will satisfactory perform the function or functions for which it is intended to be used in aircraft under all flight conditions which may be met in regular service and must:

(a) Be free from hazard both in itself and in its method of operation;

(b) Be constructed of suitable and dependable materials:

(c) Satisfactorily pass a visual inspection of the construction, layout, and electrical arrangement of all components of the particular aircraft radio equipment and such electrical, humidity, temperature, pressure, vibration, drop, and other tests as the Administrator may prescribe.

Q. 7.19. What is an air carrier operating certificate and by whom is it issued?

A. A certificate prescribing the type of operation, the routes over which such operation may be conducted, the airports which may be used, and other specifications and restrictions as may reasonably be required in the interest of safety, shall be issued by the Administrator.

Q. 7.20. What are the requirements regarding marker beacon receivers on United States irregular air carrier aircraft operating outside the continental United States?

A. The following are required:

At least one marker beacon receiver and such radio equipment as are necessary to receive satisfactorily, by either of two independent means, radio navigational signals from any other radio aid to navigation intended to be used.

Q. 7.21. Is it mandatory that United States irregular carriers operating outside the continental United States maintain a ground communication system to provide radio contact at all times with their aircraft?

A. Yes. See Question 7.06 (b).

Q. 7.22. When a United States irregular air carrier aircraft is operating outside the continental United States on long distance flights over water or uninhabited terrain, what transmitting means are required?

A. 1. For day VFR operations over routes on which navigation can be accomplished by visual reference to landmarks, each aircraft shall be equipped with such radio equipment as is necessary to accomplish the following:

(a) Transmit to at least one appropriate ground station from any point on the route and transmit to airport traffic control towers, from a distance of not less than 25 miles,

(b) Receive communications at any point on the route,

(c) By either of two independent means, receive meteorological information at any point on the route and receive instructions from airport traffic control towers.

2. For day VFR operations over routes on which navigation cannot be accomplished by visual reference to landmarks, for night VFR, or for IFR operations, each aircraft shall be equipped as specified, and in addition shall be equipped with at least one marker beacon receiver and with such radio equipment as is necessary to receive satisfactorily, by either of two independent means, radio navigational signals from any other radio aid to navigation intended to be used. For operations outside the United States each aircraft operated for long distances over water or uninhabited terrain shall be equipped with two independent means of transmitting to at least one appropriate ground station from any point on the route.

Q. 7.23. Define a "route segment" as used in scheduled air carrier operations.

A. A route segment is a portion of a route, the boundaries of which are identified by:

(1) A continental or insular geographic location;

(2) A point at which some specialized aid to air navigation is located; or

(3) A point at which a definite radio fix is located.

Q. 7.24. When an aircraft is in distress upon what frequency or frequencies should the first radio transmission of distress call and message be made?

A. The first transmission by the aircraft shall be on the designated air-ground route frequency. If the aircraft is unable to establish communication on the designated air-ground route frequency, any other available frequency shall be used in an effort to establish contact with a ground or ship station.

Q. 7.25. In event of an aircraft in distress, how often should the distress message be repeated?

A. The distress message should be transmitted at intervals until an answer has been received.

Q. 7.26. Under what condition should an aircraft, becoming aware that another aircraft is in distress, transmit the distress call and message?

A. An aircraft becoming aware that another aircraft is in distress may transmit the distress call or message when:

(1) The aircraft in distress is not itself in a position to transmit it; or

(2) The person in command of the aircraft which intervenes believes that further help is necessary.

Q. 7.27. What is the distress signal used on vhf A3 emission?

A. When vhf radio-telephony is used, transmit the distress signal MAYDAY (three times), the words THIS IS, followed by the identification of the aircraft (three times), the distress message, and the word OVER.

Q. 7.28. List the order of priority in the establishment of communications in aeronautical mobile radio service.

A. The order of priority in the transmission of messages in the aeronautical service is as follows:

(1) Messages bearing the priority prefix SOS . . . .
(2) Messages bearing the priority prefix SVH . . . .
(3) Messages bearing the priority prefix URGENT . . . .
. . . . to be followed, if necessary, by the service suffix.
(4) Messages bearing the service prefix EXC.

(5) Messages bearing the service prefix CTL.
(6) Messages bearing the service prefix AMT.
(7) Messages bearing the service prefix DEP.
(8) Messages bearing the service prefix CHG.
(9) Messages bearing the service prefix OBS.
(10) Messages bearing the service prefix NOTAM.
(11) Messages bearing the service prefix PLN.
(12) Messages bearing the service prefix ARR.
(13) Messages bearing the service prefix CNL.
(14) Other messages (OPN, MET, DEL, RES, etc.).

Q. 7.29. A control station receiving a distress message from an aircraft shall forward the information immediately to what offices?

A. A radio station receiving a distress message relating to an aircraft in distress shall forward the information immediately to the area traffic control center or flight information center. The radio station shall take further immediate action as follows:

(1) Continue to guard the aircraft frequency last used and, as far as possible, any other frequencies which may be used by that particular aircraft. Under no circumstances, shall the frequency last used by the aircraft be left unguarded. A continuous watch shall be established immediately on the authorized international distress frequencies.

(2) Notify any D/F station with which the control station can communicate.

(3) Handle distress traffic to, or from, the station which transmitted the distress call, and control all such traffic when authority to do so has been delegated by that station or when it has reason to believe that the aircraft in distress is not in a position to make any delegation of responsibility.

Q. 7.30. In aircraft distress communications, what is the normal speed of radiotelegraph transmission?

A. In handling distress traffic the speed of telegraphy should not normally exceed sixteen words per minute, unless positive accuracy can be maintained at higher speed.

Q. 7.31. List the information that should be transmitted, if time permits, from an aircraft in distress.

A. If time permits, the following information shall be transmitted:

(1) estimated position and time thereof;

(2) true heading and indicated air speed;

(3) altitude;

(4) type of aircraft;

(5) nature of distress;

(6) intention of person in command (such as forced alighting on the sea or crash landing).

Q. 7.32. What action should be taken by the flight radio operator immediately prior to ditching or crash landing?

A. Immediately prior to a forced or crash landing, the telegraph key shall be closed. If the aircraft is equipped with radio-telephone, any means available shall be used to obtain continuous transmission.

Q. 7.33. List the distress frequency for aircraft in the MF band.

A. The distress frequency for aircraft in the MF (300-3000 kc.) band is 2182 kilocycles.

Q. 7.34. What is the international frequency in the high-frequency band for use by life rafts for search and rescue communication with stations of the maritime mobile service? (R & R 9.312)

A. This is 8364 kilocycles.

Note: Prior frequency of 8280 kilocycles is no longer in use.

Q. 7.35. What is the common VHF aircraft emergency frequency?

A. 121.5 megacycles.

Q. 7.36. How would a flight radio operator alert the search and rescue facilities in his particular area?

A. When an aircraft is threatened by serious and imminent danger, and requires immediate assistance, the person in command of the aircraft will direct appropriate action as follows:

1. Turn on automatic emergency equipment if so provided.

2. When radio-telegraphy is used, transmit the distress signal SOS (three times), the word DE, followed by the call sign of the aircraft (three times), the distress message, a twenty-second dash, the call sign of the aircraft once, and the signal K.

3. When VHF radio-telephony is used, transmit the distress signal

MAYDAY (three times), the words THIS IS, followed by the identification of the aircraft (three times) the distress message, and the word OVER.

4. When MF and HF radio-telephony is used, transmit the distress signal MAYDAY (three times), the words THIS IS, the identification of the aircraft (three times), the distress message followed by a twenty-second period during which the microphone button remains depressed, the identification of the aircraft once, and the word OVER.

5. When modulated telegraphy (MCW) is available on radio-telephone frequencies, the distress signal SOS may be transmitted prior to the procedures specified in 3. or 4., or any other available methods may be employed to call attention to the distress.

Q. 7.37. What procedure is used by an aircraft to cancel a distress message?

A. If the aircraft is no longer in distress, it must transmit, on the same frequency, a message cancelling the state of distress. When it is no longer necessary to observe silence, or when the distress traffic is ended, the station which has controlled the traffic shall send on the distress frequency, and on the frequency used for the distress traffic, a message addressed "to all stations" (CQ) indicating that the distress traffic is ended and shall so inform the area traffic control center and the flight information center. This message shall take the following form:

1. In radio-telegraphy: the distress signal, the call to all stations CQ (three times), the word DE, the call sign of the station transmitting the message (once), time of handing in (filing) of the message, name or call sign of the aircraft station which was in distress (once), and the abbreviation QUM.

2. In radio-telephony: the word MAYDAY, the words THIS IS, the identification of the station transmitting the message (once), name or identification of the aircraft station which was in distress, and the words DISTRESS TRAFFIC ENDED.

3. Should facilities for transmission on the international distress frequency not be available at the air-ground control radio station, the rescue service, or other agency having the frequency available shall be requested to transmit the message relative to cessation of distress traffic.

Q. 7.38. What is the meaning of: (a) air carrier aircraft station, (b) airdrome control radio station, (c) aeronautical station, (d) aeronautical fixed station, (e) radio beacon station, (f) radio range station,

(g) localizer station, (h) glide path station, (i) aeronautical marker beacon station, (j) surveillance radar station, and (k) aeronautical public service station?

A. (a) A radio station aboard an aircraft engaged in, or essential to, transportation of passengers or cargo for hire.

(b) A radio station providing communication between an airdrome control tower and aircraft or aeronautical mobile utility stations.

(c) A land station in the aeronautical mobile service service carrying on a service with aircraft stations, but which may also carry on a limited communication service with other aeronautical land stations.

(d) A radio station used in the fixed service for the handling of communications between fixed points relating solely to actual aviation needs.

(e) A special radio station, the emissions of which are intended to enable an aircraft to determine (1) its radio bearing or direction with reference to the radio beacon station, or (2) the distance which separates it from the latter, or (3) both of these.

(f) A form of radio beacon, the emissions of which provide definite track guidance.

(g) A directional radio beacon normally associated with an instrument landing system which provides guidance in the horizontal plane to an aircraft for purposes of approach in landing.

(h) A directional radio beacon associated with an instrument landing system which provides guidance in the vertical plane to an aircraft for purposes of approach in landing.

(i) A radio station marking a definite location on the ground as an aid to navigation.

(j) A radionavigation land station in the aeronautical radionavigation service employing radar to detect the presence of aircraft within its range.

(k) A radio station, ground or aircraft, operated in the aeronautical public communication service.

Q. 7.39. In general, what language shall be used in radiotelephone communications between aircraft and aeronautical stations in the international service?

A. In general, radiotelephone communications between aircraft and aeronautical stations shall be conducted in the language of the ground station. The English language shall also be used, on request from the aircraft station. In English-speaking countries the first alternative language shall be French or Spanish, the selection to be made regionally.

Q. 7.40. In event of noncommunication with an aircraft what offices should be advised immediately by the control station operator?

A. The control station shall notify the Air Traffic Control Office and the airline operating agency, as quickly as possible, of any failure in air-ground communication.

Q. 7.41. In communications between aircraft radio stations, what station controls the duration of continuous work?

A. In communications between aircraft stations, the duration of continuous work is controlled by the aircraft station which is receiving, subject to the intervention of a communication station.

Q. 7.42. How should an aircraft flying over the sea signal its position?

A. As a general rule, an aircraft over the sea shall signal its position in latitude and longitude (Greenwich), but may give the true bearing and distance in nautical miles (unless otherwise indicated in the message) from some known geographical point. When the position is expressed in latitude and longitude, a group of four figures followed by the letter N or S shall be used for latitude and a group of four figures followed by the letter E or W for longitude. In radio-telephony the words North, South, East and West shall be used.

Q. 7.43. How should an aircraft flying over land signal its position?

A. An aircraft flying over land shall signal its position by the name of, and approximate distance and direction from, the nearest reference point. The direction shall be indicated by the letters N, S, E, W, or the letters appropriate to the sixteen points of the compass. In radio-telephony, the words North, South, East, West, or words appropriate to the intermediate directions shall be used.

Q. 7.44. What procedure should an over-ocean aircraft follow if it is unable to establish communications for any reason other than transmitter failure?

A. Should an aircraft station, for any reason other than failure of its transmitter, be unable to establish communication, it shall transmit periodic reports at scheduled times, or positions, on the assigned frequency.

Q. 7.45. In air-to-ground radiotelephone communications, how is the "invitation to reply" spoken in standard voice procedures?

A. The word OVER is given to invite a reply.

Q. 7.46. What is meant by the priority prefix SVH?

A. Messages for the safety of human life, in the aeronautical service, are preceded by the priority prefix SVH and comprise the following:

1. Urgency messages (XXX or PAN).
2. Safety messages (TTT or SECURITY).
3. Other messages concerning the safety of human life.

Q. 7.47. After communication has been established between an aircraft and its control station, is it permissible to dispense with the radio call letters in subsequent communication?

A. In establishing communication by means of radio-telegraphy the full call sign of the aircraft radio station shall be used. After communication has been established, an abridged call consisting of the first letter and the last two letters of the call sign may be used, provided that no confusion will result.

Q. 7.48. Is it mandatory that an aircraft maintain continuous watch in flight on the air-to-ground route frequency?

A. During flight, aircraft shall maintain continuous watch on the ground-to-air route frequency, and shall transmit on the air to ground route frequency assigned by the air-ground control station. The aircraft station shall not abandon watch on the ground-to-air route frequency in use, without the concurrence of the air-ground control station.

Q. 7.49. In radiotelephone communications what word is spoken to denote that an error has been made in transmission?

A. The word CORRECTION is used.

Q. 7.50. In radiotelephone communication, how is termination of communication indicated by the receiving station?

A. Termination of communication: A radiotelephone contact shall be terminated by the receiving station using the phase ROGER OUT (with a slight pause between the two words).

Q. 7.51. With which station should an aircraft normally communicate when flying over a particular route?

A. An aircraft station shall normally communicate with the control station which exercises control in the area in which the aircraft is flying. An aircraft station may communicate with other aeronautical telecommunication stations on the same route when traffic can be handled better than through the control station.

Q. 7.52. What is the radiotelephone spoken equivalent of radiotelegraph signal IMI?

A. The word REPEAT.

Q. 7.53. What is the radiotelephone equivalent of the radiotelegraph signal R?

A. The word ROGER.

Q. 7.54. What is meant by break-in procedures in aircraft radiotelegraph communications?

A. "Break-in" is defined as the process of interrupting or attempting to interrupt the transmissions of another station. Break-in shall be accomplished by transmitting the signal BK followed by a short listening period to determine whether interruption has been accomplished. If three attempts to break-in do not accomplish the desired interruption, the breaking operator should refrain from further attempts until the message being transmitted has been completed.

Q. 7.55. What type of information is generally included in a broadcast service known as NOTAMS?

A. These notices contain general information (except meteorological information) of an urgent nature, affecting the safety of air navigation. They should be made known over a wide area as rapidly as possible.

Q. 7.56. Describe the structure of the NOTAM code as used in international flight operations.

A. 1. The NOTAM Code is provided to enable information regarding radio aids, aerodromes and lighting facilities, dangers to aircraft in flight or landing, or action regarding search and rescue, to be coded. The coding facilitates the transmission of NOTAMS over telecommunications channels. Plain language shall be used in the composition of a notice to airmen in cases where the NOTAM Code cannot convey the meaning.

2. All NOTAM Code groups shall contain a total of five (5) letters. NOTAM messages shall always commence with the service prefix NOTAM. This service prefix shall in all cases be immediately followed by the place name abbreviation.

3. *The first letter* of the code group will always be the letter Q to indicate that it is a code abbreviation for use in the composition of NOTAMS. The letter Q has been chosen to avoid confliction with any assigned radio call or other code abbreviations. Five letter groups have been chosen to avoid confusion with three and four letter Q signal abbreviations.

4. *The second letter* shall in all cases be a vowel. This makes it possible to pronounce the NOTAM Code abbreviations, which facilitates remembering those most frequently used. In making up the Q letter groups the vowels have been assigned as follows:

A Radio Aids.
E Radio Aids.
I Lighting Facilities.
O Aerodromes; Search and Rescue.
U Aerodromes; Search and Rescue.

5. *The third letter* may be any letter of the alphabet. Examples of second and third letters:

AR Radio Range.
ER Telegraph transmitting facility/ies.
IR Runway lights No. . . .
OB Beaching facilities.
UR Runway No. . . . .

6. *The fourth letter* shall in all cases be a vowel.

7. *The fifth letter* may be any letter of the alphabet. Examples of fourth and fifth letters:

EN Not operative until further notice.
OK Resumed operation.
UJ Closed until further notice due to repairs or construction.
UN Hazardous due to flood.
AU Appears unreliable.
ER Burning but not revolving until further notice.

8. Supplementary information regarding positions, sources, or frequencies is given in figures or plain language. The complementary ab-

breviations normally associated with the Q Code may also be used. Examples of supplementary information:

QAREL 332 BN 1000 — 1200 DAILY kc/s.

Meaning:—Radio range on 332 will not be operative between 1000 and 1200 hours daily.

QURUJ 22.

Meaning:—Runway No. 22 closed until further notice, due to repairs or construction.

9. The code groups need not be pronounced as they are never used in voice communications. Example:

Telegraph or teletypewriter transmission

NOTAM..QAREN 151600.

(*Place name identification*)

Voice Communications

NOTICE TO AIRMEN (place name) RADIO RANGE NOT OPERATIVE ONE SIX ZERO ZERO, UNTIL FURTHER NOTICE.

SECOND AND THIRD LETTERS

RADIO AIDS

AA ATC aerodrome control receiver (frequency/ies) . . .

AB Boundary marker, instrument landing system.

AC ATC aerodrome control transmitter (frequency/ies) . . .

AD Middle marker.

AE Outer marker.

AF Fan-type marker.

AG Glide path, instrument landing system.

AH Radiobeacon homing facility.

AI Instrument landing system.

AJ Radio range and voice communications.

AK Radio receiving facilities.

AL Localizer, instrument landing system.

AM Compass locator, inner, instrument landing system.

AN ATC approach control receiver (frequency/ies) . . .

AO Compass locator, outer, instrument landing system.

AP ATC approach control transmitter (frequency/ies) . . .

AQ Radar ground equipment—(GCA, ACR, etc.)

AR Radio range.

AS Radio range leg.

AT Attention signal.

AU Meteorological communications (frequency/ies) . . .

AV Voice communications (frequency/ies) . . .

AX Radiobeacon homing and voice facility.
AY Responder beacon.
AZ Station location marker VHF.
EC Consol station (position).
ED Decca chain.
EG Gee chain.
EH HF DF.
EJ Telecommunication facilities.
EL Loran chain.
EM MF DF.
EP Power supply.
ER Telegraph transmitting facility/ies.
ET Teletypewriter transmitting facility/ies.
EV VHF DF.
EW Lorenz/S.B.A. system.
EX Lorenz/S.B.A. system localizer.
EY Lorenz/S.B.A. system boundary marker.
EZ Lorenz/S.B.A. system outer marker.

LIGHTING FACILITIES

IA Boundary lights.
IB Aerodrome beacon light.
IC Contact lights.
ID Channel lights.
IE Beacon at (location).
IF Flood lights.
IG Glide-path lights.
IH Taxyway lighting.
IJ Threshold lighting.
IK Flares.
IL All landing area lighting facilities.
IO Obstruction lights.
IP Approach lights (No. of approach . . . .)
IR Runway lights (No. . . . . . .).
IS Strip lights.

AERODROMES; SEARCH AND RESCUE

OA Land aerodrome.
OB Beaching facilities.
OC Water aerodrome.
OF Fire-fighting equipment.
OG Crash vehicle.

OL Landing area.
OM All runways.
OQ Ocean weather station.
OR Refuelling facilities.
OS Rescue search aircraft.
OT Tug.
OU Rescue boat.
OV Rescue heliocopter.
OW Merchant ship.
OX Rescue land unit.
OY Rescue vehicle.
OZ Warship.
UB Mooring buoys.
UF Fixed balloons.
UL Landing direction indicator.
UM Mooring and docking facilities.
UQ Apron.
UR Runway No. . . . . .
UT Turf landing area.
UW Wind direction indicator.

FOURTH AND FIFTH LETTERS

HAZARD OR STATUS OF OPERATION

AB Cleared of snow and serviceable for width of . . . . .
AC Covered by snow to a depth of . . . . .
AF Braking action poor.
AG Braking action fair.
AH Braking action good.
AM Snow clearance in progress.
AN Grass cutting in progress.
AP Work is in progress.
AQ Work in progress now completed.
AU Appears unreliable.
EC Characteristics changed to . . . . .
EF Burning but not flashing until further notice.
EH Not heard.
EK Completely withdrawn.
EL Will not be operative until further notice.
EN Not operative until further notice.
EP Available on prior permission only.
ER Burning but not revolving until further notice.
EW Was not operative.

IC Report of apparent unreliability or course displacement hereby is cancelled.
ID Availible on request to . . . . . (Named radio station).
IK Is available on request immediately or at . . . . minutes notice.
IL Hours of service are now . . . . .
IM Serviceable but not flight checked.
IN Will be operative from . . . . .
IO Operating normally.
IP (Course/s) reported to be displaced (degrees) (direction) of published bearing, other courses probably have shifted.
IT Keep to runways and taxyways.
IU Unserviceable for aircraft heavier than . . . . . tons.
IV Unserviceable until further notice.
IW Unserviceable from . . . . to . . . .
IX Partially obstructed. Exercise care in landing.
OA Available for dispatch to scene of distress incident.
OB Partially or wholly obscured.
OK Resumed normal operation.
OM Shut down for maintenance until further notice.
ON Will be shut down for maintenance until further notice.
OO Was shut down for maintenance.
OP Conducting operations at scene of distress incident.
OS Out of service until further notice.
OU Operating without interruption for voice transmissions until further notice.
OW En route to scene of distress incident.
OX Exercising at. (Time, location, height.)
UA Closed to all operations for (period of time).
UB Closed to all operations until further notice.
UC Closed to all operations except scheduled air-lines operations.
UD Closed to all night operations until further notice.
UE Closed to all landings until further notice.
UF Closed until further notice due to flood.
UG Closed until further notice due to ice or snow.
UH Closed until further notice due to thaw.
UI Closed until further notice due to obstruction.
UJ Closed until further notice due to repairs or construction.
UK Closed until further notice due to special conditions.
UL Closed until further notice due to dust.
UM Closed until further notice due to fog.
UN Hazardous due to flood.
UO Hazardous due to ice or snow.

UP Hazardous due to thaw.
UQ Hazardous due to repair or construction.
UR Hazardous due to obstruction.
US Hazardous due to rough water.
UT Hazardous due to special conditions.
UU Hazardous due to dust.
UV Hazardous due to fog.

Q. 7.57. What is meant by the ICAO abbreviations such as: CNL, ARR, DEP, PLN?

A. CNL —Cancellation message.
ARR —Arrival message.
DEP —Departure message.
PLN —Flight plan message.

Q. 7.58. How are the ICAO complimentary code groups used in air-to-ground communications?

A. The complimentary code groups are abbreviations to be used in conjunction with Q signals to reduce the length of transmissions. Some typical examples are as follows:

ADC—Aerodrome control
ADZ—Advise
GND—Relative to ground
RNG—Radio range

Q. 7.59. What radio information is contained in the IFR flight plan of scheduled air carrier operation outside the continental limits of the United States?

A. The information relating to radio includes: aircraft identification (radio call letters), and the transmitting and receiving frequencies to be used.

Q. 7.60. What is the intermediate frequency reserved for aircraft flying over the seas?

A. 457 kilocycles.

Q. 7.61. Is it mandatory that U.S. air carrier aircraft operating

within the United States and overseas be equipped with a radio altimeter?

A. The regulations do not indicate that a radio altimeter is mandatory.

Q. 7.62. What are the requirements regarding a master switch in an aircraft electrical installation?

A. If electrical equipment is installed, a master switch arrangement shall be provided which will disconnect all sources of electrical power from the main distribution system at a point adjacent to the power sources.

The master switch or its controls shall be installed so that it is easily discernible and accessible to a member of the crew in flight.

Q. 7.63. Air carrier aircraft electrical installations incorporate storage batteries in the primary systems. Discuss the requirements for battery vents, cooling, containers, and protection against acids.

A. 1. *Battery vents.* The battery container or compartment shall be vented in such a manner that gases released by the battery are carried outside the airplane.

2. *Battery cooling.* Battery cooling shall be provided, if necessary, to keep the battery temperature wihin the limits specified by the battery manufacturer.

3. *Battery containers.* Batteries shall be completely enclosed in a container or compartment and shall be easily accessible for servicing and inspection on the ground.

4. *Protection against acid.* Means shall be provided to prevent corrosive battery substance from coming in contact with other parts of the airplane during servicing or flight.

Q. 7.64. With reference to aircraft generators, what are the requirements concerning generator capacity, generator switch, generator rating, generator controls, and a reverse current cut-out?

A. 1. Capacity. The capacity necessary shall be determined initially from an electrical load analysis and its adequacy shall be demonstrated during flight test.

2. A switch shall be provided for each generator to permit its output to be interrupted.

3. Generator rating. Individual generators shall be capable of delivering their continuous rated power.

4. Generator controls. Generator voltage control equipment shall be capable of dependably regulating the generator output within rated limits.

5. Reverse current cut-out. A generator reverse current cut-out shall disconnect a generator from the battery and other generators when that generator is developing a voltage of such value that current sufficient to cause malfunctioning can flow into the generator.

RADIO THEORY

Q. 7.65. What type of radio waves is the most suitable for aircraft radio direction-finding, vertically or horizontally polarized waves?

A. Vertically polarized waves are most suitable for direction-finding. (See also Question 3.490.)

D. One of the reasons for the preference for *vertical* polarization is the ease in obtaining the desired *nondirectional* transmitting pattern which is required from a ground transmitter. (See Q. 3.252-b and 6.649.) A single vertical antenna transmits a nondirectional radio wave, which means that the energy from the antenna goes out with equal strength in all compass directions. This is very important from the point of view of aircraft involved in taking bearings, since it is obvious that such aircraft may be utilizing the radio waves from *any* compass point. Other reasons are, the reduced reflection from vertical surfaces, and the low angles of concentration of radio-frequency energy.

Q. 7.66. Explain the term "quadrantal or aircraft error," and what is done to counteract this error in modern aircraft radio installations. How does quadrantal error vary with frequency?

A. "Quadrantal error" is an *apparent deviation* in the direction of arrival of the radio wave, as picked up by the loop antenna. The error may be counteracted by an adjustable cam, which is calibrated for each installation. Quadrantal error increases when the object (or objects) causing this error receives a frequency approaching the object's own natural resonant frequency. Quadrantal error is greatest for signals arriving at angles of approximately 45° and least at 0°, 90°, 180°, and 270°.

D. The modern airplane is a nonuniform metal structure. It picks up radio energy and also acts as a *shield* for it. Because of this, the signal picked up by the loop antenna, in certain positions, will be greater or less than the *normal* signal. This effect produces an error in the readings which must be compensated for by some means. This error is known as the "quadrantal error."

Loop antennas on aircraft are usually mounted either above or below the fuselage. Both positions give about the same amount of "quaddrantal error."

Before quadrantal error can be counteracted, it must be accurately determined. This must be done with the airplane in normal flight. The plane circles a known point, during which time radio bearings are taken and compared with those from a directional gyro. On the basis of this comparison, an error chart can be constructed. The error chart is used to determine the desired compensation. One method used to counteract the quadrantal error is to plot the errors on a so-called "Radio Compass Calibration Chart," as shown in the figure. This system has the disadvantage of requiring addition or subtraction for each reading. A better solution is a cam arrangement in the loop-rotating mechanism which automatically advances or retards the bearing pointer to give the corrected reading. One such cam consists of a spring which is properly shaped by means of a large number of adjusting screws.

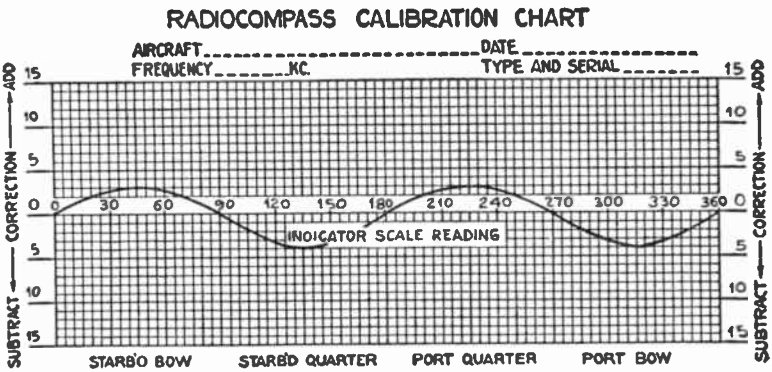


Fig. 7.66. Radiocompass calibration chart.

Frequency has an effect upon the quadrantal error. This is due to the fact that the largest induced currents will flow in various parts of the aircraft structure when the incoming waves have a frequency approaching the natural resonant frequency of the structure. The largest currents will cause the greatest amount of reradiation and therefore will produce the most error when picked up by the loop.

Q. 7.67. Normally, what are the maximum and minimum frequencies upon which a standard transport aircraft D/F loop will give satisfactory operation?

A. A standard D/F loop will usually give satisfactory operation between the frequencies of 100 kc and 1800 kc.

D. See Questions 7.68 through 7.72.

Q. 7.68. An aircraft loop antenna is influenced by the field of a

vertically polarized wave front. Will the magnetic lines of force cut the loop from top to bottom or from side to side?

A. The magnetic lines of force will cut the loop from side to side.

D. The polarization of a radio wave is determined by the plane of its *electric* component. Therefore, in a vertically polarized wave, the electric lines of force are oriented up and down. The magnetic lines of force are always at right angles to the electric, and therefore, will cut the loop from side to side. (Provided, of course, that the loop is broadside to the transmitting station.) See also Question 3.490 and Question 6.648.

Q. 7.69. It is common practice to employ plastic housing to streamline electrostatically shielded loop antennas on air carrier aircraft. Do these housings have a conductive or nonconductive surface?

A. The housings have a partially conductive surface (see figure).

D. The surface of the housing *must* be essentially nonconductive if the loop antenna is to be permitted to function. Otherwise, the housing would act as a magnetic and electrostatic *shield*, and radio waves would not penetrate the housing and reach the loop. However, the plastic housing must be sufficiently conductive over its surface to prevent the building up of static charges. If the housing were completely nonconductive, it would be possible to build up a static charge of high potential. This would cause serious interference with loop operation, mostly due to corona discharge. The resistance of the conductive material is fairly critical. It must be high enough to prevent strong currents from flowing in it, and thus acting as a magnetic shield.

At the same time, it must be sufficiently low to permit rapid discharge of static charges. In practice the plastic housing may be impreg-

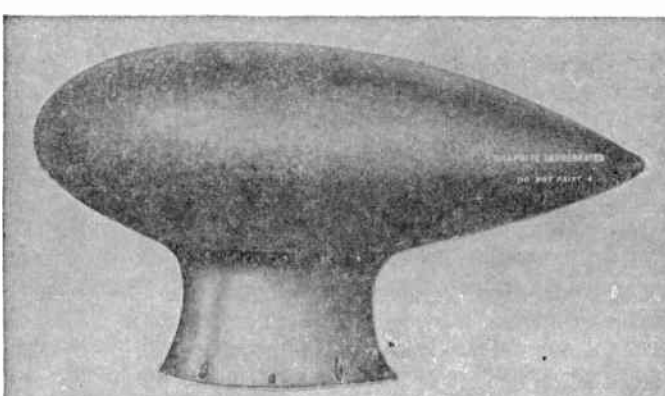


Fig. 7.69. Graphite impregnated cover for shielded ADF loop.

nated with graphite. The resistance of the conductive material is such that when measured from any square inch area of the housing to the metal aircraft frame, it is of the order of 10 megohms. (See also Questions 3.373, 6.656, and Appendix IV.)

Q. 7.70. Explain how aircraft D/F loops are constructed so that they intercept electromagnetic waves and reject electrostatic charges?

A. Electrostatic charges are rejected on aircraft D/F loops because the loops are shielded by a grounded aluminum housing.

D. The electrostatic loop shield is broken by the insertion of a small insulated segment. This prevents the shield from acting as a *shorted* turn and thus rejecting the *magnetic* component of the radio waves. (See also Question 7.69.) If the loop shield were completely shorted, the loop itself would receive no energy from the waves.

Q. 7.71. When using a manual direction finder on a housing station, how should the D/F loop and the associated receiver be adjusted?

A. In "homing," the plane of the loop antenna is rotated until the indicating needle on the loop azimuth scale points to zero. The receiver should be accurately tuned to the station, and the volume level kept to the minimum consistent with good reception.

D. The plane is flown so that a *null* is maintained in the earphones, or if a visual indicator is used, the needle is kept in the center position. As long as the proper null indication is present, the plane's nose will always be pointed toward or away from the station. If it is pointed toward the station the reception will get progressively *stronger*; otherwise it will become weaker. The volume control should not be radically reduced as the station is approached, because there will be a large increase in signal strength when close to the station, after which the null disappears. This usually indicates that one is in the immediate vicinity of the homing station.

Actually, when homing, the directional gyro is set on zero when the null has been obtained, and the pilot flies the gyro setting. Periodic investigations of the null are made and corrections in heading are made from time to time, if required.

Q. 7.72. In an aircraft D/F installation, is the loop calibration curve considered accurate for any frequency between 200 and 1800 kc?

A. It is not considered accurate for any frequency between 200 and 1800 kc.

D. As was pointed out in Question 7.66, quadrantal error varies with frequency, and therefore, we cannot expect a calibration curve which may have been made up at say, 200 kc, to hold at 1800 kc. This is a 9 to 1 ratio of frequencies, and any number of aircraft structure elements could go in and out of resonance in this frequency sweep and cause deviation from the 200 kc calibration curve. If one calibration curve is used, it is generally made at (or very near) the frequency at which it is to be used. If it is expected that a wide range of frequencies will be utilized for direction finding, calibration should be carried out at a *number* of frequencies distributed throughout the direction finder band.

Q. 7.73. What effect does a coast line have upon radio bearings taken aboard an aircraft flying off shore?

A. A coast line causes errors in radio bearings, when such bearings are taken aboard an aircraft flying off shore, on a station located on land.

D. When radio waves travel from a terrain of one particular conductivity and dielectric constant, to another terrain having a different conductivity and dielectric constant, refraction (bending) of the waves takes place. The abrupt change which occurs in the conductivities of coast land and ocean water is a condition which produces bending of the radio waves. Because of this effect, an aircraft flying off shore, taking bearings on a land station, will find that such bearings will be erroneous. No set rule or correction can be made for refraction errors, each type of coast line having its own peculiar characteristics. Any correction will have to be determined at the operating frequency of the land station and must take into account the terrain characteristics of each individual station.

Q. 7.74. In aircraft D/F work, is the minimum or maximum signal used to observe bearings? Explain.

A. The minimum (or null) position is used to observe bearings. This is due to the fact that the indication of minimum signal is much sharper and therefore more accurate, than the maximum position.

D. See Question 6.648 for directional pattern of loop antenna, and Appendix IV for explanation of loop operation.

Q. 7.75. In aircraft radio navigation, what is meant by a "reciprocal"?

A. A "reciprocal" is a bearing which is 180° away from the true bearing.

D. As shown in the figure for Question 6.648, a loop antenna will produce *two* nulls 180° apart, due to the characteristic of the loop antenna. Thus, unless some additional device is used in conjunction with the loop, it is not usually possible to tell which of the two possible bearings is correct. One way to remove this 180° ambiguity is by using a separate "sense" antenna, together with the loop. (For an explanation of the sense antenna operation, see Question 6.650 and Appendix IV.)

Q. 7.76. Is quadrantal error in a loop installation, aboard an aircraft, maximum or minimum at the cardinal points of the azimuth?

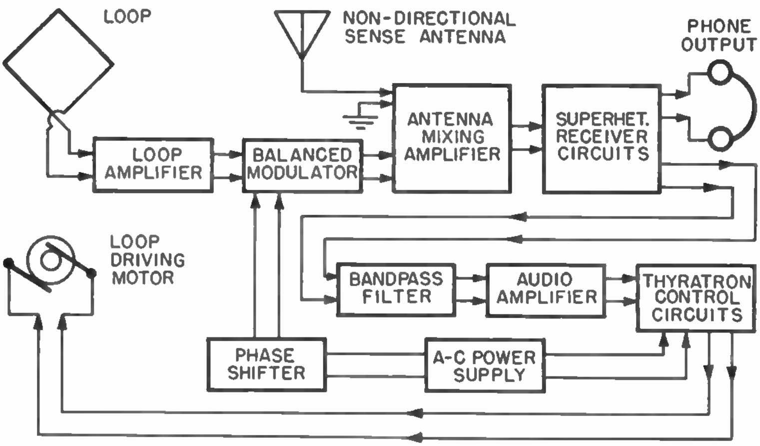
A. Quadrantal error is minimum at the cardinal points of the azimuth. (The cardinal points are: 0°, 90°, 180°, and 270°.)

D. For purposes of explanation we may consider that the fuselage, tail fin and the various receiving antennas form a closed loop whose plane lies in the same plane as the fuselage (front-to-back). This closed loop reacts to the radio waves in the same way as a regular loop antenna. Pickup in the closed loop is maximum from a station dead ahead (0°) or dead astern (180°). However, the regular loop antenna will be at right angles to the closed loop when taking a bearing either dead ahead or dead astern, and there will be no coupling between the two loops (no deviation error). If the radio waves are arriving at right right angles (angles (90° and 270°) to the fuselage, the pickup in the closed loop is zero (practically) and, again, there is no interaction between the closed and regular loops. At some intermediate angle in each of the four quadrants, the quadrantal error attains its maximum value.

Q. 7.77. Describe the function of the sense antenna used in conjunction with an aircraft ADF installation.

A. The sense antenna provides a carrier wave to the loop receiver to replace the carrier picked up by the loop which was previously removed in the receiver. It also assists in preventing 180° ambiguity.

D. A brief discussion of a typical ADF is presented below in order to clarify various details of the system. Refer to the figure, which shows the typical elements of an ADF system. Let us begin with the Balanced Modulator #1. It will be noted that there are two inputs to this circuit. One input consists of the signal picked up by the loop antenna and amplified by the loop amplifier. The other input is a large amplitude locally generated low frequency a-c signal. This may be developed by a separate audio oscillator or taken from the a-c power supply. This low frequency signal is on the order of 50 to 100 cycles, and is applied to the grids of the balanced modulator through a phase shifting network. The operation of the balanced modulator (#1) is such that it suppresses the carrier from the loop and provides double sidebands due to the low frequency a-c signal. The double sidebands are then fed into the Antenna Mixing Amplifier, where they are combined with the carrier from the nondirectional sense antenna. The resultant wave, with its new carrier and phase-shifted double sidebands, is fed into the superheterodyne receiver circuits. The output signal from the receiver goes into two channels. One is the headphone channel, where any speech components present on the original carrier may be heard. The other is the motor channel. The first element of the motor channel is a bandpass filter, where the local low-frequency modulating signal is filtered out and the remainder passed on and amplified by the audio frequency amplifier. This is not a conventional audio frequency amplifier, but is a thyratron-controlled circuit which accom-



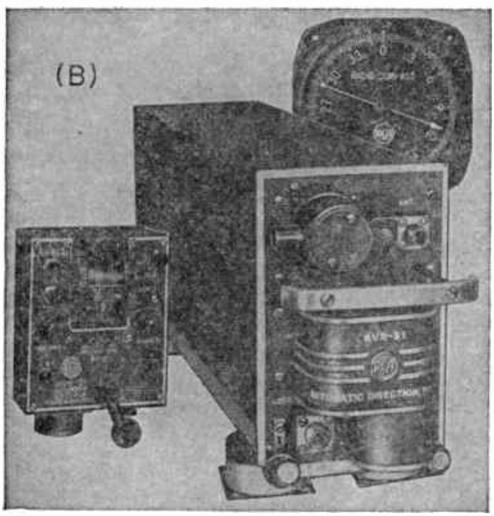


Fig. 7.77. (A) Block diagram of automatic direction finder. (B) RCA Model AVR-21 automatic direction finder.

Courtesy RCA

plishes the desired results at a much higher power efficiency. The thyratron circuit receives an amplified low frequency modulation signal from the receiver. The phase of this modulation voltage reverses when the null position of the loop reverses. The loop motor receives two phases of the modulating voltage. One comes directly from the low frequency modulation source in its original phase, while the other comes through the complete loop and receiver channel, and has a variable phase. The phase of this latter signal determines which of the two thyratrons will conduct and this, in turn, causes motor action to take place in such a manner that the loop will automatically rotate toward the null position. When the loop is at the null position neither of the two thyratrons can conduct and the loop remains stationary until it is again removed from the null. The reversible motor circuit always acts to drive the loop towards the 0° null, so that there is no 180° ambiguity present in this system, and therefore, no "reciprocal" bearing to worry about.

Q. 7.78. What is the purpose of the threshold sensitivity control on an aircraft ADF unit?

A. The purpose of the threshold sensitivity control is to adjust the bias of the motor control thyratrons.

D. (See also Questions 7.77 and 7.82.) The two thyratrons are responsible for the activation of the loop driving motor. Consequently the thyratron bias will determine how much control signal is needed to fire each thyratron. If the bias is too small, the system will tend to become unstable, since any small random impulse might then be capable of firing a thyratron. On the other hand, too much bias will tend to render the system insensitive to small changes of null indication and may cause erratic operation. The control itself is a slotted shaft potentiometer (screwdriver adjustment) located on the rear of the loop motor control unit. This control is preset at the factory but may require occasional adjustment due to aging of tubes and components.

Q. 7.79. What circuits of an aircraft ADF use thyratron tubes?

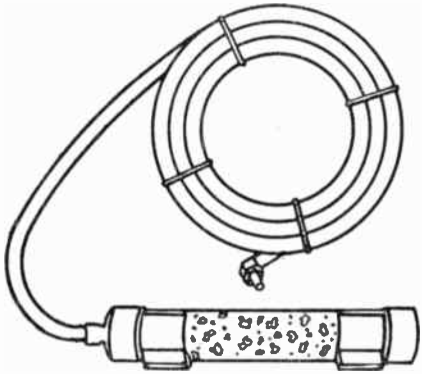
A. The loop motor control circuits use thyratron tubes.

D. See Question 7.77 for a discussion.

Q. 7.80. What is the purpose of the silica gel crystals in an aircraft ADF unit?

A. The purpose of the silica gel crystals is to absorb the moisture in the loop housing and thereby protect the loop rotating equipment.

Fig. 7.80. Loop dehydrator.



Courtesy Bendix

D. The silica gel crystals are shown in the figure in the loop dehydrator. The loop dehydrator usually consists of a transparent housing containing a number of crystals. The dehydrator is connected into the loop housing through a tube. The loop housing is air-tight and any moisture which tends to form in the housing is absorbed by the silica gel crystals. The crystals have to be replaced from time to time and one way of determining this is by observing their color. The crystals are dark blue when dry, but change to a pinkish or light-blue color when they have absorbed considerable moisture, and require reactivation.

Q. 7.81. With reference to ground direction finder stations, what is the principal advantage of the ADCOCK station over the early loop direction finder stations?

A. The principal advantage of the ADCOCK station over the early loop direction finder stations is the great reduction in errors in bearing due to the so-called "night effect."

D. (See Question 6.659 and Appendix IV.) One of the causes of serious errors in bearing is the so-called "night effect" or *polarization error*. In the case of the simple loop antenna, which utilizes vertical polarization, bearings can only be considered reasonably accurate as long as the radio wave arrives at the loop with its normal (vertical) polarization. However, radio waves (particularly above 2,000 kc) may be refracted and reflected back to the earth from the transmitter and so arrive at the ground direction-finding station with a polarization having a *horizontal* as well as a vertical component. In the case of the simple loop, the horizontal component of polarization induces currents in the *horizontal* sections of the loop, and thus makes it impossible to obtain a *true* null signal. From this we can conclude that a simple loop antenna is practically *useless* in the presence of waves having a horizontal component. With waves having a frequency above 2,000 kc, polarization error can always be expected. In the case of lower frequency waves, serious polarization errors usually occur only at night, hence the term "night effect."

Since the polarization errors are due to the horizontal component of the wave only, an antenna which is insensitive to this component will be free (theoretically) from such errors. This is the principle upon which the ADCOCK antenna is based. One form of the ADCOCK antenna is shown in the figure. It will be noted that there are no *horizontal* members in the antenna, all elements being vertical. This antenna produces the familiar "figure 8" pattern shown in Question 6.648. It must not be supposed that the ADCOCK antenna completely eliminates polarization error. However, it does reduce such errors to a considerable degree.

NOTE: The basic ADCOCK antenna is very little used in the

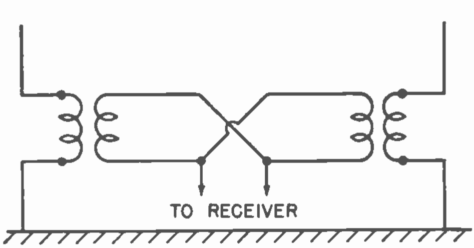


Fig. 7.81. Adcock antenna.

United States, but its principles are used in the design of the so-called "transmission-line" antenna (TL) used with radio-range beacons.

Q. 7.82. What is meant by the term "hunting" in an ADF system?

A. The term "hunting" refers to the tendency of the loop to overshoot the null position and oscillate back and forth around the null point before coming to rest.

D. Due to the inertia of the loop and drive motor, there is a natural tendency for the loop to overshoot the exact null point and to oscillate before coming to rest. This "hunting" is undesirable because it tends to make the system unstable. In order to counteract hunting and thus obtain smooth operation, an antihunt circuit is provided. A description of one type of antihunt circuit follows. An antihunt generator is mounted on the same shaft as the loop drive motor. This generator develops a voltage at the same frequency as the low-frequency modulation signal. Its phase reverses with reversal of rotation of the loop, and the amplitude of its output voltage is a function of the *speed* of rotation. When the loop rotates, an antihunt voltage is developed by the antihunt generator which is always in direct opposition to the original motor control modulating signal. The original modulating signal overrides the small bucking antihunt voltage until the loop is about 2° off the null position. At this time, the antihunt voltage overrides the original modulating signal and fires the reverse thyratron which slows down the loop motor. As the motor slows down, the antihunt voltage decreases and the original signal voltage continues to drive the motor so that the loop comes smoothly to rest at the null.

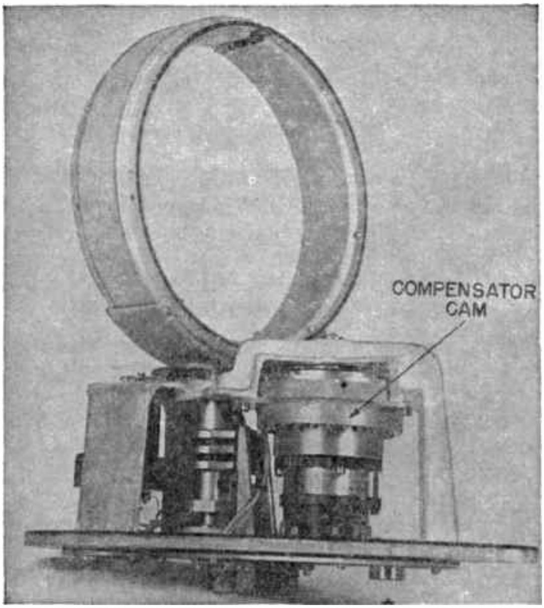
Q. 7.83. Will static crashes affect the operation of an aircraft ADF?

A. Occasional static crashes will have no appreciable effect on an aircraft ADF, but continuous static such as is due to rain, snow, dust, or thunderstorms will have an adverse effect on the ADF operation.

D. Continuous static which is usually due to precipitation or dust will render an unshielded sense antenna unusable. Thus an ADF which depends upon reception from the sense antenna for automatic operation will have to go on manual operation. One type of ADF incorporates an auxiliary, or sense, shielded loop which is substituted for the unshielded normal sense antenna under conditions of continuous static. This permits automatic operation of the direction finder, but at the sacrifice of its unidirectional characteristics. That is to say, when using the shielded loop auxiliary sense antenna there are two null points 180° apart at which the bearing indicator may come to rest. When flying in the vicinity of severe electrical storms or thunderstorms, the ADF may attempt to take bearings on the electrical discharges. The loop operation under such conditions will be somewhat erratic, since it will tend to oscillate between the storm and the desired D/F station.

Q. 7.84. What is the purpose of a compensator cam in an aircraft ADF installation?

A. A compensator cam is used to counteract bearing errors due to the aircraft structure (quadrantal error).



Courtesy RCA.

Fig. 7.84. Loop assembly of ADF.

D. See Question 7.66 and the figure.

Q. 7.85. What is an autosyn as used with ADF systems and what device furnishes power to the autosyn?

A. An autosyn (or selsyn) is one of a pair (or more) of self-synchronized motor type transmitters. Autosyns are used to transmit pointer information from the source (loop) to some remote indicator, electrically. The autosyn receives its power from the 400-cycle inverter.

D. A typical autosyn (or selsyn) self-synchronized transmission system is shown in the figure. The transmitter and repeater autosyns are identical except that in cases where more than one repeater is desired, the transmitter autosyn may have a higher power rating. As can be seen in the diagram, each autosyn resembles a three-phase motor. Both rotor windings are excited from the 400 cycle single phase supply, and are tied in parallel. The three-phase windings of each autosyn are also connected in parallel and receive their energy by induction from the rotors. If the two rotors do not occupy the same relative angular position, currents will be set up in the three-phase windings in such a way as to develop a restoring torque and bring the repeater (indicator) autosyn back to the correct relative position with respect to the transmitter autosyn. The transmitter autosyn is mechanically coupled to the loop, so that any loop bearing will be transmitted to the remote

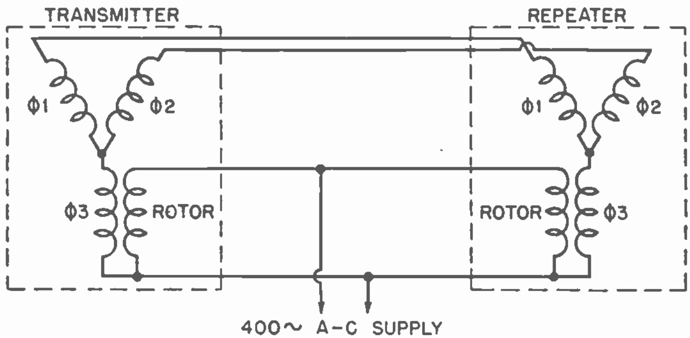


Fig. 7.85. Schematic of an autosyn system.

indicator, which has an azimuth scale on it. An advantage of this system is that several remote indicators may be connected, if desired, to one transmitting autosyn without any cumbersome mechanical coupling.

Q. 7.86. What type of radio range gives satisfactory ADF operation? What type gives unsatisfactory operation?

A. The Adcock type usually gives satisfactory ADF operation. The older loop type may be unsatisfactory due to the transmission of a considerable horizontal component.

D. See Question 7.81.

Q. 7.87. Why is it inadvisable to take ADF bearings on synchronized broadcast stations?

A. It is inadvisable to take ADF (or manual D/F) bearings on synchronized broadcast stations because no true indication of a null can be obtained under such conditions.

D. In certain localities, broadcast stations may be operating with synchronized carrier frequencies. This may be true in the case of two or more broadcast stations, which are located 100 to 200 miles apart and operate on the same *assigned* carrier frequency. Synchronization of the carriers of such stations is desirable to remove the heterodyning whistle from receivers located so as to receive the two (or more) stations with appreciable strength. While this is fine for broadcast reception, it is extremely detrimental from the standpoint of direction finding. Since the two carriers are on exactly the same frequency, their energies add in space in such a way that a *maximum* energy point will be found in *space* somewhere between the two antenna towers. To make it worse, this point of maximum energy is not fixed, but moves back and forth due to changes in radio wave propagation. Thus it is virtually impossible for an ADF, or any other D/F, to utilize signals emanating from synchronized carrier stations in order to obtain useful bearings.

Q. 7.88. In reference to an ADF system, explain why the position of the loop determines when power will be delivered to the loop motor control circuit.

A. The position of the loop determines the amount of signal pickup from a given station. These varying amounts (and phases) of loop signal pickup are eventually fed to the loop motor control circuit which positions the loop to the null point. If the loop is not at the null point, there will be enough signal fed to the motor control circuit to bring it back there.

D. See Questions 7.77 and 7.82.

Q. 7.89. Why is a low-inertia type motor used as the loop control motor in an ADF system?

A. A low inertia type motor is used to provide smooth bearing indications and to minimize hunting.

D. It is necessary in an ADF to provide bearing indications that respond quickly and smoothly to null indications. Another requirement of an ADF is that there be a minimum of *hunting*. (Q. 7.82.) A high-inertia motor tends to defeat both of these requirements because it is slow getting started and just as slow in stopping. Therefore, if a high-inertia motor were used to control the loop, it would tend to make the bearing indicator (and loop) erratic in operation, since the loop would tend to oscillate around the null point instead of approaching it smoothly.

Q. 7.90. When using the aircraft ADF receiver for aural flying of a low frequency radio range, the function switch should be in the "ANTENNA" position instead of the "COMPASS" position. Explain.

A. The function switch should be in the "ANTENNA" position in order to provide maximum signal pickup and nondirectional reception with the use of the sense antenna.

D. With the function switch in the "COMPASS" position, the loop antenna is connected to the receiver for directional reception. Thus, when flying the range and changing from one range to another, the pilot would have to be concerned with the orientation of the loop antenna which would have to be oriented for *maximum* reception. This is obviously undesirable from the pilot's point of view, and is not possible on automatic operation of the ADF. Another very important factor is that the nondirectional sense antenna has a *greater* signal pickup than the loop and can be used satisfactorily for range flying at greater distances.

In cases of extreme precipitation static, it might be desirable to use the shielded loop, should reception prove impossible on the unshielded sense antenna. In this case the ADF would have to be switched to manual D/F operation.

Q. 7.91. What is the purpose of the rotatable scale on the aircraft ADF azimuth indicator?

A. The purpose of the rotatable azimuth scale is to permit the bearing indications to be read directly in terms of the *magnetic* course of the airplane, rather than its *relative* bearing.

D. Unless a rotatable scale were provided, the bearing indication from a radio compass would always read a *relative* course. For example, assume a plane to be flying a *magnetic* course of 90°. If a bearing were taken on a station dead ahead, the bearing indication of the D/F would be 0°. This is a relative bearing. To find the *magnetic* bearing by means of the D/F we would have to add 90° to the D/F reading. Rather than do this, a rotatable azimuth scale is provided, so that it can be set to correspond with the airplane's magnetic course. In this example, the azimuth scale is rotated to read 90° instead of 0°. This eliminates the necessity for constantly having to compute the magnetic bearing from the relative bearing.

Q. 7.92. Why is it important that an aircraft employ bonding and shielding of various radio and electrical units?

A. Bonding and shielding are extremely important because it greatly reduces the effect of locally generated electrical interference upon the operation of the aircraft receiver(s).

D. BONDING.—The term "bonding" designates the electrical interconnection of all metal parts of an aircraft (including all components therein) by means of low resistance conductors. If such bonding were not present it might be possible for various metal sections of the plane to assume different static potentials. This effect would be particularly severe while the plate was in the vicinity of an electrical storm or passing through snow, hail, rain or dust. Any potential differences would tend to become equalized and this might result in arcing between various component parts. Any such arcing, or corona, would set up severe radio interference due to its proximity to the receiving antenna and the inherent sensitivity of the aircraft receiver.

SHIELDING.—There are several sources of radio interference in an aircraft. Generally speaking, such interference is due to any and all sparking-producing devices in the aircraft. The most important of these are: (1) the aircraft ignition system, and (2) the aircraft generator. Whenever a spark discharge occurs, oscillations may be set up in the wiring associated with the sparking device and the stray capacities. This occurs in the form of shock-excited damped oscillations covering an extremely wide frequency range, and having relatively high field strengths in the vicinity of the receiving antenna. The ignition system is the worst offender in producing this type of interference. Its shielding must be made unusually complete, encasing the ignition system in one continuous metallic case from the magneto to and including the spark plug. Generator commutator sparking is another important source of interference, and may cause radiation by means of the low tension wiring. The only satisfactory solution in this case is to completely shield all electrical equipment and all wiring in the aircraft. The shielding is grounded at short intervals to the same common ground as the bonding.

Q. 7.93. In bonding aircraft radio and electrical units on an aircraft, should the resistance of the bond be of a high or low value?

A. The resistance of the bond must be kept very low, to prevent potential differences from being maintained.

D. See Question 7.92.

Q. 7.94. In a carbon-pile voltage regulator, is the carbon-pile connected in series or in parallel with the shunt field of the generator?

A. The carbon-pile is connected in series with the shunt field of the generator.

D. A carbon-pile voltage regulator consists of a series of carbon rings which are piled one on top of another. The pressure, and therefore the resistance, of the pile is controlled by a solenoid, which in turn is controlled by the generator output voltage. For example, assume that the generator voltage tends to go up. The solenoid then reacts on the carbon-pile in such a way as to *reduce* the pressure on the rings. This *increases* the resistance of the pile, decreases the field current, and thus reduces the generator voltage to the correct value. The reverse action is also true.

Q. 7.95. In the resistance element of the carbon-pile voltage regulator, does the resistance vary inversely or directly with the amount of pressure on the carbon?

A. The resistance varies inversely with the pressure on the carbon (the same as in a carbon microphone).

D. See Question 7.94.

Q. 7.96. What operating characteristics of the carbon-pile voltage regulator makes it well suited for aircraft use?

A. The following are desirable characteristics of the carbon-pile regulator:

1. It is practically trouble-free.
2. It provides good voltage regulation.
3. It has less sparking than relay contacts.
4. It is practically immune to vibration and shock.
5. It is relatively unaffected by wide temperature variations.
6. It is effective over a wide range of variations.
7. It can handle heavy currents without damage.

D. See Questions 7.94 and 7.95.

Q. 7.97. What is the purpose of the equalizer circuit in a parallel generator system using a carbon-pile voltage regulator?

A. The equalizer circuit causes the voltage output of the parallel generators to be the same.

D. When parallel generators are used for battery charging, it is essential that they all have the same voltage output. This is necessary to prevent wasteful currents from flowing between the individual generators. The equalizer circuit automatically acts upon the carbon-pile regulators to provide equal voltage output from all parallel generators.

Q. 7.98. At what speed of the aircraft engine should the generator develop its normal voltage?

A. The normal generator voltage should be developed at the cruising speed of the engine.

D. The cruising speed, of course, depends upon the particular engine and also to some extent upon the aircraft in which it is to be used. Thus the cruising speed may range from 1500 to 2400 or more rpm. The generator may be geared to the engine with a step-up ratio of about 1.5 to 1. Thus, with an engine whose cruising speed is 2000 rpm, the generator speed will be 3000 rpm. This gear ratio is not necessarily standard and some aircraft may utilize ratios as high as 3 to 1.

Q. 7.99. How is the rating of an aircraft generator usually stated?

A. The rating of an aircraft generator is usually stated in terms of the following:

1. Minimum and maximum rpm.
2. D-c voltage output.
3. D-c current output.
4. Power output.

D. See also Questions 7.94, 7.95, 7.96 and 7.97.

Q. 7.100. List at least two sets of figures for generator ratings on present-day transport aircraft.

A. The following are two sets of typical generator ratings:

Generator #1: d-c voltage output, 30 volts; maximum d-c current, 50 amperes; power output (max), 1500 watts; speed, 2400-3600 rpm.

Generator #2: d-c voltage output, 30 volts; maximum d-c current, 150 amperes; power output (max), 4500 watts; speed, 2400-4400 rpm.

Q. 7.101. What is the purpose of employing differential voltage reverse-current relays in aircraft generator systems?

A. The purpose of such relays is to prevent the battery from discharging through the generator.

D. These relays operate so that they close only when the generator voltage output exceeds the battery voltage by some predetermined amount. When the generator output voltage is lower than the battery voltage, the relays open and prevent the battery from discharging through the generator. Similar relays are found in automobiles where they are usually called "cutout" relays.

Q. 7.102. Discuss air carrier aircraft electrical systems with regard to general wiring (single-wire, two-wire).

A. The single-wire system is the simplest and least expensive of the two. A bus bar is attached to the aircraft structure and acts as the second wire of the system. Although relatively inexpensive, this system has a disadvantage in that currents flowing through the separate wiring and bus set up magnetic fields, which may affect the operation of magnetically operated equipment, such as the magnetic compass. Wiring is generally made up in harnesses or cables which are completely shielded. These terminate in junction boxes to permit replacement of individual sections.

The two-wire system, as the name implies, utilizes two distinct wires for the conduction of current. It is more expensive, heavier, and more complicated than the single-wire system. However, it does have the advantage that magnetic fields are largely canceled by the proximity of two wires carrying currents in opposite directions.

Q. 7.103. Describe the operational characteristics of "trip-free" and "non-trip-free" circuit breakers as used in aircraft radio and electrical installations.

A. A "trip-free" circuit breaker is one which cannot be closed after tripping if the overload still remains. It will just keep tripping until the overload is removed. Such circuit breakers are utilized in circuits not required for emergency operation.

A "non-trip-free" circuit breaker is one which can be re-set even though the overload persists. It is used in circuits required for emergency operation of aircraft. These circuits utilize flame-resistant insulation on cables to minimize danger of fire due to electrical overload.

D. See Questions 7.94 through 7.99.

Q. 7.104. Name one important reason why alternating current is not used for the primary power source on transport aircraft.

A. One very important reason for not using a-c as a primary power source is that it lacks the power-storing ability of a d-c battery-generator system.

D. This storage ability is very important in aircraft as a safety feature. In the event of generator failure, the batteries will still provide power for a considerable time. In starting the engines (particularly from a non-serviced field) the batteries must be used. An a-c system is obviously unsatisfactory here, since it would require that the engines were already running. Another difficulty in using a-c as primary power is the difficulty in providing a practical prime mover for the alternator(s).

Q. 7.105. Explain how transport aircraft generators are driven.

A. Aircraft generators are driven from the aircraft engines through a gear system. The gear ratios may vary from 1.5 to 1, to 3 to 1, with the generators rotating faster than the engines.

D. See Question 7.98.

Q. 7.106. What particular electrical system on an aircraft is difficult to shield by the use of filters?

A. The ignition system.

D. This question is a little confusing, since you do not shield by the use of filters, but by the use of *shields*. However, it undoubtedly means, "from what part of the aircraft electrical system is it difficult to prevent radiation of interference by means of filters." This, of course, would be the ignition system. The ignition system cannot be filtered since it radiates from the wiring and so must be completely shielded. (See also Question 7.92.)

Q. 7.107. Polyethylene-covered antenna wire is being used on transport aircraft installations. What is the advantage of this type of antenna over the small diameter braided copper wire? Over solid copper wire?

A. The advantage of polyethylene-covered wire over small diameter bare braided copper wire is that the insulated wire will prevent corona discharge, while the braided wire will induce corona due to the sharp points formed. The polyethylene-covered wire has the advantage over solid copper wire in that it offers greater resistance to corona discharge and is more flexible than a heavy solid wire.

D. One of the important sources of static is the corona discharge from the aircraft antenna(s). Corona discharge takes place most easily from uninsulated wires (or braid) of relatively small diameter wire. Braid is especially poor for antennas, since many sharp points may exist on the braid, permitting corona discharge to occur at relatively low potentials. Modern aircraft antennas are either made up of insulated wire (polyethylene) or of large diameter (.18 inch) bare aluminum wire. Both of these types resist corona discharge to a great degree. When insulated wire is used, all fittings and joints must also be insulated, and exposed metal parts shoud be wrapped with polyethylene or vinylite tape.

Q. 7.108. Name one advantage of using large-diameter bare aluminum wire for antennas on transport aircraft.

A. One advantage of using this wire is its great resistance to corona. Another advantage lies in its lighter weight (about 1/3) as compared to the same diameter copper wire.

D. See Question 7.107.

Q. 7.109. What is the purpose of using trailing wicks on the wing tips and tail surfaces of transport aircraft?

A. The purpose of the trailing wicks is to reduce corona discharge from relatively sharp surfaces of the aircraft.

D. After the corona discharge from the antenna has been taken care of, it becomes important to reduce corona due to parts of the aircraft. One method of doing this is to attach a number of trailing cotton wicks at strategic points. The wicks act as an impedance matching device between the aircraft and the atmosphere and thus permit slow discharges, with little or no corona. About 30% of the wicks should be on the trailing edge of each wing tip, starting about 1 to 3 feet inboard and spaced about 30 inches apart. About 40% should be distributed at the extremities of the trailing surfaces of the elevators and rudder. The remainder are appropriately distributed as needed.

Q. 7.110. With reference to electrostatic charging on transport aircraft, which will produce the higher charging rate, dry snow and ice crystals, or wet snow and rain?

A. Dry snow and ice crystals will produce the higher charging rate.

D. See Questions 7.107, 7.109, 7.111, and 7.112.

Q. 7.111. Which one of the two, air speed or ground speed, is a contributing factor in the build-up of high electrostatic potential on an aircraft flying through sleet, snow, or dust?

A. The air speed and *not* the ground speed is the contributing factor.

D. The build-up of high electrostatic potential is a function of the velocity of the sleet, snow, or dust relative to the aircraft. This depends only on *air* speed. For example, an aircraft could be flying at 100 mph air speed against a 100 mph wind. The *ground* would be *zero*, but the particles would still be bombarding the pane at 100 mph.

Q. 7.112. Discuss the progress that has been made in recent years toward the elimination of precipitation static on aircraft.

A. The first step taken in the fight against precipitation static was in 1936, when electrostatically shielded loop antennas were first installed. It has been found that wire aircraft antennas are a major cause of precipitation static. Steps taken to reduce this are the use of insulated antenna wire, and of large diameter bare wire. (See Questions 7.107, 7,108.) Another source of precipitation static is corona discharge from the airplane itself. This static is reduced by the use of soft impregnated cotton trailing wicks.

D. See Questions 7.109, 7.110, and 7.111.

Q. 7.113. Under conditions of severe precipitation static, why is a loop antenna superior to a fixed antenna in receiving radio signals?

A. A shielded loop antenna is superior to an unshielded fixed antenna, because the electrostatic shielding is offensive in eliminating a considerable amount of the static.

D. When corona discharge occurs, electromagnetic radiation is propagated. The radio field will be very weak due to the low current and small radiator height, and so is not usually a source of trouble. The *induction* field however, is very strong, because it depends mainly upon the voltage, which may reach several thousand volts. The effect of the induction field is felt only in the immediate vicinity of the corona discharge, but it does affect the antennas to a great extent. By shielding the loop antenna and *grounding* the shield, the electric induction field is prevented from reaching the wires of the loop, and only the magnetic induction field is accepted. It the discharge rate is low, this magnetic field will be below the level of receiver sensitivity and no static will result from this cause. To reduce the charge on the aircraft, a discharge wire and suppressor may be released as a trailing device. (See also Question 7.70.)

Q. 7.114. What is meant by corona, or St. Elmo's fire? What design in aircraft antennas aids in preventing corona?

A. The visible electrical arcing, which may be seen on certain portions of the aircraft, during periods of precipitation static, is known as St. Elmo's fire (corona). Aircraft antennas may be insulated with polyethylene or they may be made of large diameter in order to reduce corona from the antenna.

D. Investigation has shown that the chief cause of precipitation static is the discharge of the accumulated aircraft charge, mostly from the trailing edges of the wings and tail surfaces, and partially from the sharp points such as propellor tips and windshield corners. Under severe precipitation static conditions, this discharge may become visible, and has been given the name of St. Elmo's fire by pilots. The technical term for such discharges is "corona." (See also Questions 7.107 through 7.113.)

Q. 7.115. What is the advantage of the SBRA-type range station over the MRL-type range station when using the aircraft D/F for bearing?

A. The SBRA uses an Adcock antenna, which has very little horizontal transmitted wave component and provides more accurate bearings than the MRL which utilizes a loop antenna.

D. (See Question 7.81.) The meaning of SBRA is as follows:

S = simultaneous transmission of range signals and voice

B = scheduled broadcast station

RA = Range (Adcock, vertical radiators) power greater than 150 watts.

The meaning of MRL is as follows:

MRL = Range (Loop radiators) power 50 to 150 watts.

The higher power output of the SBRA may make it possible to take bearings at greater distances than with the MRL.

Q. 7.116. What are the principal advantages of the Adcock radio range over the loop-type radio range?

A. The principal advantages of the Adcock over the loop-type range are:

1. The Adcock uses vertical antennas and transmits very little horizontal component, which results in more accurate bearings.
2. There is a well defined "cone of silence" over the Adcock range, indicating the position of the transmitting antenna.

D. See Questions 7.81 and 7.115.

Q. 7.117. Explain the principle of operation and the type of emission obtained from an aerophare.

A. An aerophare is a transmitting station which sends out continuous waves in all directions for direction finding purposes for aircraft. Aerophares operate in the range of frequencies from 200 to 400 kilocycles, and are identified by dots and/or dashes followed by a silent period. The keying is modulated at 1,020 cycles.

D. Generally speaking, aerophare is an international designation for any nondirectional aeronautical radio-beacon station. Thus, in general terms, it could refer to any one of several types, such as MOR, VOR, or RACON.

However, the meaning of aerophare, as commonly used, is that given in the answer above.

Q. 7.118. What is the general shape of the radiation pattern of an aerophare?

A. The general shape of the radiation pattern of an aerophare is circular. That is, the effective pattern is nondirectional.

D. See Question 7.117.

Q. 7.119. What aircraft equipment is necessary to make use of the service of an aerophare?

A. To make use of the service of an aerophare, the aircraft must utilize an aircraft receiver with loop and sense antennas.

D. See Questions 7.117 and 7.118.

Q. 7.120. Explain the principle of operation of the omni-directional range.

A. The omni-directional range produces a theoretically infinite number of flight courses. This is provided by means of a rotating antenna pattern (1800 rpm). An indication of the *magnetic* heading of the aircraft is obtained by measuring the phase difference between a transmitted *reference* signal and a *variable* signal.

D. The following is a general discussion of the omni-directional radio range:

The conventional low-frequency and visual-aural ranges are limited in utility because they provide a maximum of only *four* courses. For a pilot to make use of such a range, he must accurately orient himself with respect to one of the four "legs." Various difficulties are encountered by the pilot in finding the leg and in orienting himself properly to whichever leg he is actually flying. Another disadvantage is the fact that unless the pilot has a direction finder aboard, the only time he can determine his exact direction from the range station is when he is actually on one of the legs.

The omni-directional range eliminates these difficulties by providing the pilot with a theoretically infinite number of courses, and making unnecessary the complicated orientation procedures needed with the four-course ranges. With these advantages, the pilot can spend more time flying the airplane and less time trying to figure out where he is and where he is going.

TRANSMITTING EQUIPMENT. The transmitting antenna of the VOR (VHF omnirange, 112 to 118 mc.) is shown in (A) of the figure. This actually consists of five separate antennas. The center (highest) antenna radiates a nondirectional signal. It has a constant phase throughout its 360 degrees of azimuth, and is designated as the REFERENCE phase. The reference signal is used to modulate a 10 kc FM subcarrier with

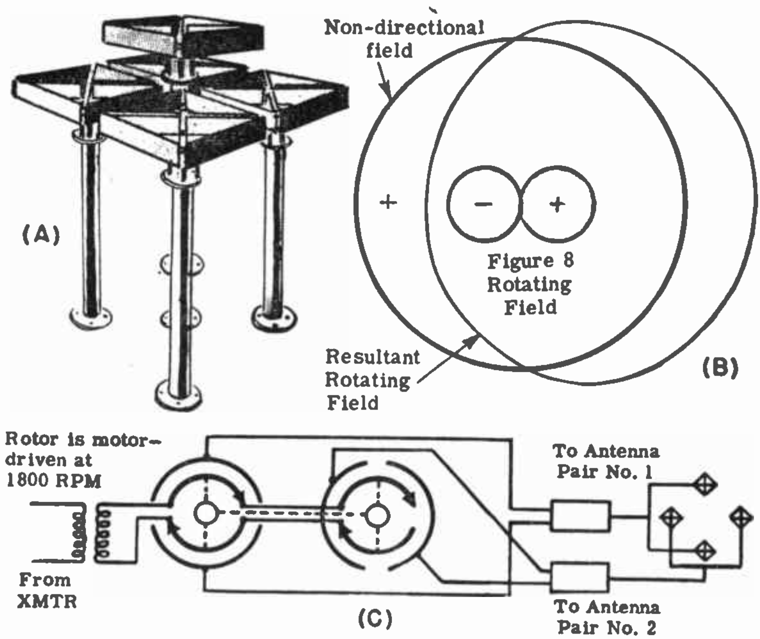


Fig. 7.120. (A) VOR antenna array. (B) Simplified drawing of omnirange transmitting system. (C) Radiation fields from omni-directional transmitting antenna.

30 cycles and this, in turn, modulates the main carrier. This is done for the benefit of receiving equipment, described later. The other four antennas are arranged in a square. These antennas radiate a signal *rotating* at 1800 rpm. This signal varies in phase with azimuth and is designated as the VARIABLE phase. The rotating signal is produced by connecting the antennas in pairs to a motor-driven goniometer as shown in (C) of the figure. The antenna field pattern produced by the four antennas alone is a figure 8, rotating at 1800 rpm. The resultant field pattern of the five antennas is a rotating eccentric pattern as shown in (B) of the figure.

The rotating signal is set so that when sweeping through magnetic north, it is in exact phase with the reference signal. In all other directions the two signals are out of phase by some fraction of a cycle and it is this phase difference which is used to determine the azimuth angle at any particular point. The method of utilizing the transmitted signal will now be discussed.

RECEIVING EQUIPMENT. A simplified block diagram of a VHF omnirange receiver is shown in (D) of the figure. The receiver may be broken down into three basic sections as follows:

1. Superheterodyne receiver circuits (including special antenna).
2. Navigation circuits.

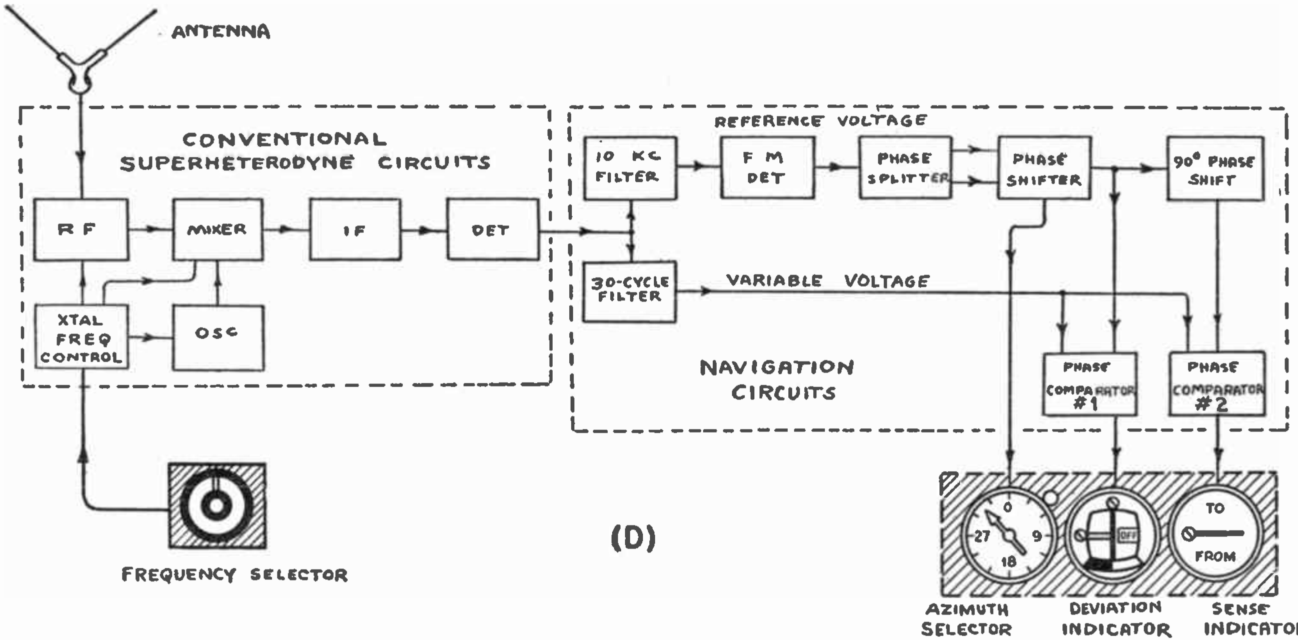
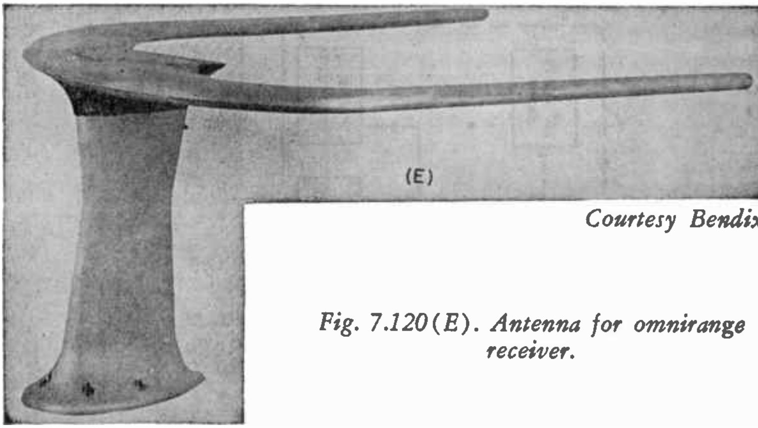


Fig. 7.120(D). Block diagram of VHF omnirange receiver. *Courtesy CAA*



Courtesy Bendix

Fig. 7.120(E). Antenna for omnirange receiver.

3. Deviation and sense indicators and azimuth selector.

A special antenna is required, which covers the band 108-118 mc. This includes the localizer band (108-112). A picture of this antenna is given in (E) of the figure.

A typical VHF range receiver covers the band 108-136 mc. on the basis of 100 kc channels. This provides a total of 280 channels, any one of which may be selected by the pilot by means of a rotary switch in the cockpit. All tuning is done automatically and is governed by high-stability crystals. The output of the superheterodyne circuits is taken from the detector and fed to the navigation circuits. Part of this output goes to the REFERENCE voltage section, and part to the VARIABLE voltage section. Let us take the REFERENCE section first. The detector output goes to a 10 kc filter. This has the effect of selecting the REFERENCE signal and rejecting the VARIABLE signal since the REFERENCE signal is on a 10 kc FM subcarrier. The 10 kc filter rejects the variable signal, since it is varying at 1800 rpm, which is equivalent to 30 cycles per second. After passing the 10 kc filter the REFERENCE signal is detected by an FM discriminator where the ominidirectional range reference phase modulation frequency, 30 cycles, is removed from the 10 kc subcarrier. This reference modulation frequency (30 cycles) is then fed into a phase splitting network and amplifier which provides two-phase voltage to a phase shifting device (Resolver). This Resolver is coupled to the omni-bearing selector, and its phase output is governed by the manual setting of the desired magnetic bearing on the omni-bearing selector. Another output of the Resolver feeds into Phase Comparator #1, where it is compared to the Deviation Indicator (vertical pointer). This indicator shows in terms of "Right" and "Left" the direction in which the aircraft must be steered to make good the desired magnetic heading. The REFERENCE voltage then undergoes a 90° phase shift and is then again compared to the phase of the VARIABLE signal in Phase Comparator #2. The resultant signal is fed to the sense (or ambiguity) indicator.

This indicator will show the pilot which side of the station he is on and reads "TO" and "FROM." Thus, if the pilot is flying *towards* the station, the indicator reads "TO." If he is flying *away* from the station, the indicator reads "FROM."

Q. 7.121. How is the rotating signal in an omnirange initially set, with respect to true north or magnetic north?

A. The rotating signal is set to be in phase with the reference signal in the direction of magnetic north.

D. See Question 7.120.

Q. 7.122. Upon what frequencies do marker beacon receivers operate?

A. Marker beacon receivers operate at 75 mc.

D. See Questions 7.132, 7.133, 7.134, and 7.135.

Q. 7.123. What is the purpose of the "HIGH-LOW" switch used in conjunction with the aircraft marker beacon receiver?

A. The purpose of the "HIGH-LOW" switch is to select either of two corresponding values of receiver sensitivity in order to provide the sharpest indication of the marker.

D. When flying over a marker it is desirable to utilize the least amount of receiver gain consistent with good reception, thus providing the sharpest indication of the location of the marker. This may be accomplished to some extent by the use of the "High-Low" switch. The marker transmits only in the vertical direction. Thus, aircraft flying at high altitudes would probably want the switch in the "High" position, while aircraft operating at comparatively low altitudes would have the marker receiver operating at reduced sensitivity and the switch would be in the "Low" position.

Q. 7.124. Explain how overloading in a radio range receiver may cause apparent reversal of quadrant signals of a low-frequency range.

A. When an aircraft is flying in the twilight zone of a radio range, either the A or the N signal will be much weaker than the other, depending upon which side of the leg it is being flown. If the receiver sensitivity is too high, it is possible for the stronger (desired) signal to overload the i-f amplifiers and block the receiver, while the weaker (undesired) signal will not block, and will come through normally. Thus, the desired signal will come through very weak while the undesired signal will be amplified and appear louder. This causes an apparent reversal of the A and N signals and makes it impossible for the pilot to orient himself properly.

D. One method of preventing the pilot from operating the receiver under overloading conditions is to provide a large amount of audio power. This forces the pilot to reduce the receiver sensitivity to a safe value because if he doesn't, the audio output becomes excessive and extremely uncomfortable (if not painful). Under any reasonably comfortable listening levels the receiver cannot overload and thus produce the apparent reversal of A and N signals.

Q. 7.125. Explain the principle of operation of the radio range filter as used on U.S. aircraft radio installations.

A. The radio range filter as used with the Simultaneous Radio Range makes it possible to transmit weather and other broadcasts simultaneously with the range (A and N) signals so that they can be received on a single setting of the receiver simply by operating a filter switch.

D. The radio range signal is the resultant of the transmissions of two independent transmitters. One transmitter (range) transmits the A and N signals, but they are not tone modulated. This transmitter feeds the conventional four corner tower radiators. The other transmitter transmits continuously and, from time to time, weather broadcasts by voice. The voice transmitter has a transmitting tower which is centrally disposed with respect to the other four towers. It has a carrier frequency which is exactly 1,020 cycles lower than the range transmitter. The beat frequency (1,020 cycles) produced by the two transmissions is utilized in the receiver to provide the aural tone for the A and N characters.

There are two filters provided in the range receiver. One filter passes only 1,020 cycles for range information (A and N), the other filter excludes 1,020 cycles but passes frequencies around it for voice broadcasts. By means of a three position switch it is possible to listen to range signals only, weather signals only, or both simultaneously, if desired.

Q. 7.126. What types of aircraft antennas are used for radio range flying?

A. Various types are in use depending on the frequencies employed and the particular aircraft. Three common types are:

1. The inverted L type (low and medium frequency).
2. The inverted T type (low and medium frequency).
3. The V type dipole (VHF).

D. See Questions 7.65, 7.107, and 7.108.

Q. 7.127. What are compass locator stations and on what frequencies do they operate?

A. Compass locator stations are low-powered, nondirectional radio beacons which operate in the band 200-400 kilocycles.

D. When used in connection with ILS (Instrument Landing System), compass locators are installed at the outer and/or middle marker sites. They are designed for use with automatic direction finding equipment in the aircraft. Such stations are identified by a single code letter which is transmitted at intervals on the carrier utilizing a 1,020 cycle modulating tone.

Q. 7.128. List three disadvantages of the conventional low-frequency radio range.

A. The main disadvantages are:

1. Bending and swinging of the beam.
2. Possibility of multiple courses.
3. Only 4 courses (maximum) provided by any one station.
4. Complicated orientation procedures needed for pilot to identify proper quadrant.
5. Pilot does not know exact angle from station unless he is on a "leg" or has D/F equipment.
6. Static interference is very serious at the low frequencies.
7. Long receiving antenna is required.

D. See Question 7.120 for comparison with omnirange.

Q. 7.129. In actual flying practice, how many visual courses does VOR offer simultaneously at any given altitude level—(1) 4, (2) 16, (3) 90, and (4) 360?

A. VOR offers 90 courses.

D. Although an infinite number of courses are theoretically offered by VOR, in practice, there is a very definite number of courses which can be flown. This results from the fact that there are inaccuracies in reading bearings. These inaccuracies are the total of the ground and aircraft equipment and are to some extent a function of the angle of elevation between the aircraft and ground station. For example, at elevation angles in excess of about 8°, the error may be plus or minus 2° (total 4°). The practical number of courses at this elevation is then $\frac{360}{4}$ or 90 courses. At elevation angles in the neighborhood of 8° or less, the error is usually plus or minus 3° (total 6°). The practical number of courses at such elevations is $\frac{360}{6}$ or 60 courses. It is expected that future developments will materially reduce these errors and provide additional practical courses.

Q. 7.130. What is the frequency of the keyed tone producing the VOR station identification signal—(1) 500 cps, (2) 1,020 cps, (3) 3,010 cps, (4) 3,000 cps, and (5) 6,210 cps?

A. The tone frequency is 1,020 cps.

D. See also Questions 7.117, 7.120, and 7.125.

Q. 7.131. What is meant by the term MOR with respect to radio aids to air navigation?

A. MOR is an omnirange operating on a low frequency. The recommended operating frequencies lie in the band 365 to 415 kc.

D. The VOR is designed to operate in the 112- to 118-mc band, it is relatively free from static interference. At minimum instrument altitudes, the operating range is less than 150 miles, and VOR facilities are spaced approximately 100 miles apart.

The MOR is designed primarily for long-distance transoceanic and transcontinental flights and may have a power output of 10,000 watts, as compared with the 200-watt output of VOR. The MOR is expected to give a dependable operating radius of over 500 miles, and a still greater range over water and flat terrain. The MOR course will be somewhat sharper than a VOR course having an error of only about plus and minus 1°. MOR stations will not be equipped for voice broadcasts and will be identified by a 1,020-cycle keyed tone.

Q. 7.132. How does the "Z" marker provide a definite means for the aircraft determining its position over the cone of silence?

A. The "Z" marker (Station Location Marker) helps the pilot to positively identify his position over a range station by the flashing of a white light on the instrument.

D. The "Z" marker transmits a pattern which is basically conical in shape, and fits into the space where the "cone of silence" would normally occur. The operating frequency is 75 mc and it is modulated by a 3,000-cycle tone. There is no identification keying. Prior to the advent of the "Z" marker, the pilot had to rely on the "cone of silence" to establish his position over the station. This method was proved to be unreliable due to the irregular shape, and difficulty in distinguishing the true cone from a false one.

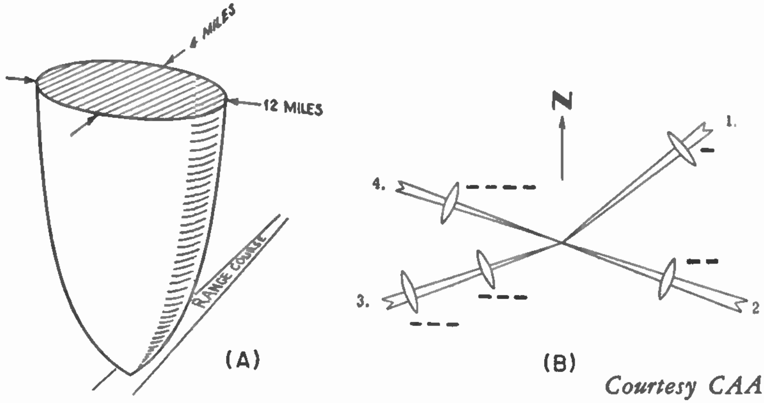
Q. 7.133. What audio frequencies are associated with "Z" markers, fan markers, and inner and outer markers?

A. "Z" markers and fan markers are modulated at 3,000 cycles. Inner markers (ILS), otherwise called "middle" markers are modulated at 1,300 cycles. Outer markers (ILS) are modulated at 400 cycles.

D. For a discussion of the "Z" marker see Question 7.132. For a discussion of the ILS markers, see Question 7.147. The following is a discussion of the fan markers.

A fan marker is a location marker which is located at strategic points along an airway and on one or more courses of a range station. These markers make it possible for the pilot to check his distance from the station. They operate continuously on a frequency of 75 mc and are tone-modulated at 3,000 cycles. There are two general types of fan markers, both having a pattern as shown in part (A) of the figure.

The high-power marker (FM) has a power output of 100 watts. This radiates a "fan" pattern which, at about 3,000 feet above the transmitter, is about 2 to 4 miles deep *along* the range course and about 12 miles long across the range course.



Courtesy CAA

Fig. 7.133. (A) Cross section of standard fan-marker pattern at 3,000-foot level. (B) Marker identification of range legs.

The low-power marker (LFM) has a power output of 5 watts and radiates a pattern which is smaller than, but of the same basic shape as the FM. LFM markers are usually located within 5 miles of a range station.

The coding procedure for the marker identification signals may be understood with the aid of part (B) of the figure, starting at *true* north, and proceeding in a clockwise direction, the range courses are numbered *1*, *2*, *3*, and *4*. The marker on each course is identified by a system, the number of dashes corresponding to the course number. In the event that there are two fan markers on a single range course, the marker which is *farthest* from the range station would have its dash coding preceded by two dots.

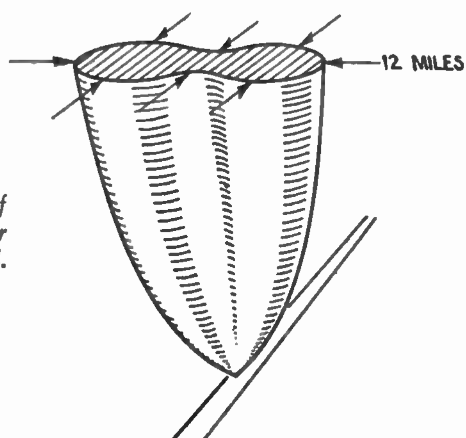


Fig. 7.134. Cross section of bone-shaped fan marker pattern at 3,000-foot level.

Courtesy CAA

Q. 7.134. What advantage, with respect to approach control, does the new bone-shaped marker offer over the standard fan-shaped marker?

A. The bone-shaped marker has a considerably narrower pattern, and thus enables the pilot to determine much more accurately, the time that he is over the marker site.

D. The older conventional type of fan marker is approximately 4 miles in width (at 3,000 feet) (Question 7.133). It takes the pilot an appreciable time to fly through this and makes it difficult for him to determine his exact position over the marker. The latest fan-marker design incorporates a bone-shaped pattern as shown in the figure. The thickness of the bone-shaped marker is only 1½ miles (at 3,000 feet) and this enables the pilot to determine more precisely, the exact time that he is over the site of the marker. When the fan marker is being used as an approach control holding fix, this narrower pattern assumes great importance. In approach control to an airport, delays may be cut down by assigning, in advance, a time for each holding aircraft to leave the marker. If the pilot has a more precise starting point, it is possible for him to vary his holding flight pattern in such a manner that he can be over the marker and inbound to the range station at the exact specified time.

Q. 7.135. If the marker light indicator in the cockpit failed, would the flight personnel have available any other indication that signals from a marker were being received?

A. Yes. The markers may be identified by means of their characteristic audio-modulating frequencies heard in the pilot's headphones.

D. See Questions 7.132, 7.133, and 7.134.

Q. 7.136. What is the signal called that is radiated from the center loop of a VOR radio facility?

A. This is called the "reference" signal.

D. See Question 7.120.

Q. 7.137. What may be considered as the normal reliable service radiation of the VOR radio facility—(1) 50 miles, (2) 2.5 miles, (3) 3 miles, (4) 3.5 miles, and (5) 100 miles?

A. The normal reliable service radiation is about 50 miles (at 1,000 feet altitude).

D. Due to the high frequencies employed (112 to 118 mc), VOR transmissions are largely confined to line-of-sight distances. Because of this, the reliable transmission distance varies with the height of the aircraft. For example, at 10,000 feet, the coverage is 150 miles and, at 1,000 feet, the coverage is 50 miles. Present plans called for VOR stations to be spaced about 100 miles apart in order to give continuous coverage to aircraft flying at 1,000 feet and higher.

Q. 7.138. What are the three main advantages of the VAR radio facility?

A. As compared to the conventional low-frequency ranges, the advantages of the VAR radio facility are:

1. It is not subject to static interference due to the high frequencies used (108 to 112 mc).
2. It is not subject to multiple-course effects.
3. It is not subject to bent-beam or night effects.
4. The pilot may instantaneously identify the quadrant he is flying in.

D. The Visual-Aural Range (VAR) was designed to counteract some of the more serious disadvantages of the conventional low-frequency range. The development of the omnirange has pushed the VAR into the category of "interim facilities." VAR will, in the future, be replaced by VOR. At present, there are 70 VAR stations being operated and no additional installations are planned.

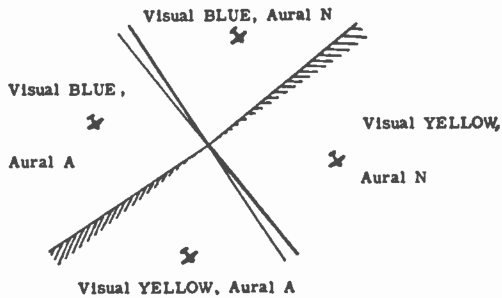


Fig. 7.138. Visual-aural range.

Courtesy CAA

The Visual-Aural Range has a total of four courses. Two of these are *visual* courses and the other two are *aural* courses. VAR is intended primarily to be flown by reference to the visual courses and these are aligned with the airway on which the range is located. The main function of the aural part of the system is to serve as an instantaneous means of quadrant orientation, for the pilot. This may be seen with the aid of the figure. It is seen that any one quadrant will not give the same combinations of visual and aural signals as any other quadrant. By identifying the visual signal (BLUE or YELLOW) by pointer indication, and the aural signal (*N* or *A*) in the headphones, the pilot is assured of positive, instantaneous identification of the quadrant, thus eliminating intricate orientation procedures.

Q. 7.139. What is the average usable range of the VAR facility?

A. The over-all reliable range is about 50 miles.

D. The range is governed by the same factors as in the case of VOR. See Question 7.137.

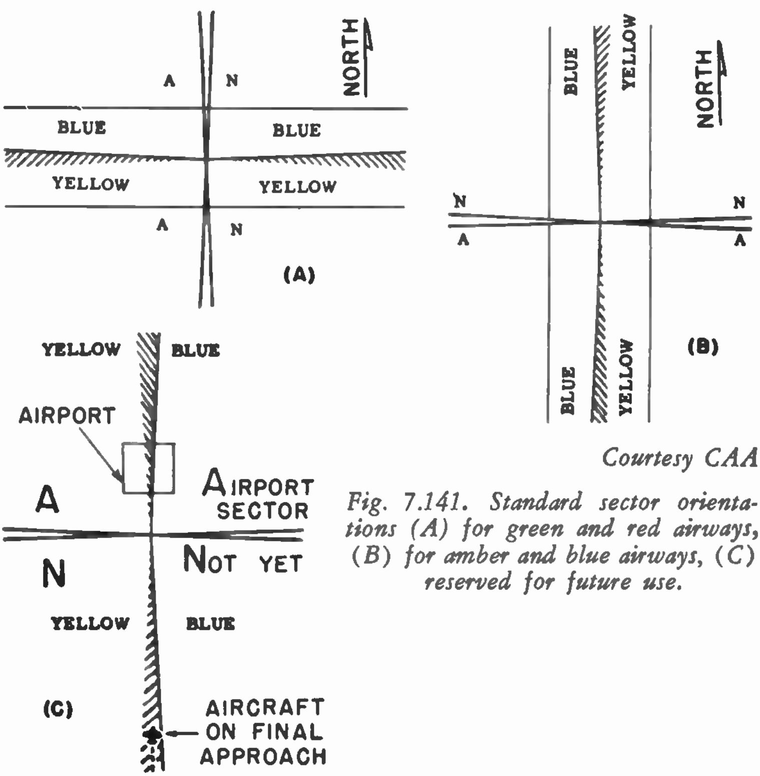
Q. 7.140. Why are the BLUE and YELLOW visual, and the A and N aural areas of a VAR referred to as sectors rather than quadrants?

A. These are referred to as sectors because they are effective for an angle other than 90° (actually for 180°). A quadrant is a sector of exactly 90°.

D. This is strictly a matter of definition. A quadrant must be bounded by an angle of 90°, while a sector may be bounded by any angle. The sectors in the conventional low-frequency range are 90° sectors and so by definition are "quadrants." The sectors in the VAR are 180° sectors and so are called simply "sectors." See Questions 7.137 and 7.142 for comparison of the courses of the two systems.

Q. 7.141. Describe the method of orientation used in the VAR.

A. The pilot may orient himself instantaneously by observing the combination of visual and aural signals. (See Question 7.138.)



Courtesy CAA

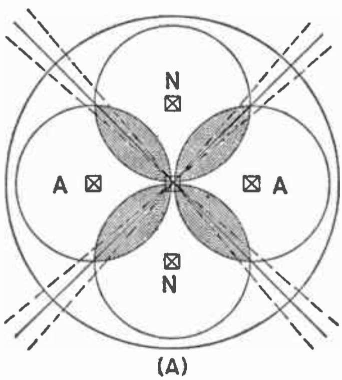
Fig. 7.141. Standard sector orientations (A) for green and red airways, (B) for amber and blue airways, (C) reserved for future use.

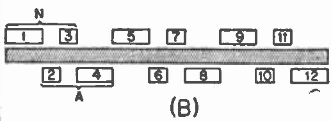
D. It is not too clear from the question whether orientation refers to the aircraft or to the actual pointing of the beams in magnetic directions. The aircraft orientation has already been described. The sector orientation is determined by one of the following three diagrams, parts (A), (B), and (C) of the figure.

Q. 7.142. How is the "on-course" signal produced in a low-frequency radio-range station?

A. The "on-course" signal is produced by a blending of the *A* signal of one antenna and the *N* signal of the other antenna into a continuous tone.

D. The low-frequency range station is made up of five antenna towers. Four of these towers are arranged to form a square. These are the range signal towers. The fifth tower is in the center of the other four. This radiates a continuous transmission and has a nondirectional pattern. The range towers form a double figure-eight pattern. This is shown in part (A) of the figure. The range towers form a double figure-eight pattern. This is shown in part (A) of the figure. The range transmitter is alternately connected first to one set (2) of range towers and then to the other set (2). It is connected to one set for 3 seconds, to the second set for 1 second, back to the first set for 1 second, and then back again to the second set for 3 seconds. If a listener were situated to receive maximum signal from the first set he would hear a 3-second dash followed by a pause and a 1-second dot *N*. If he were receiving maximum signal from the second set, he would hear a 1-second dot, followed by a 3-second dash *A*. However, if the listener were situated at an angle of 45° from any *maximum* point, he would hear the signal from *both* sets of antennas with equal intensity. The *A*'s and *N*'s would blend together to form one continuous tone, which is the "on-course" signal. Should the listener be off to the side of the on-course signal, he would hear both the *A* and the *N* signals, with one predominating depending upon which side of the course he





Courtesy CAA

Fig. 7.142. (A) Radiation pattern of low-frequency range. (B) Sequence of dots and dashes in low-frequency radio range.

was on. The blending of signals may be more clearly understood by studying part (B) of the figure. The numbers in the dots and dashes indicate the sequence of switching antennas. The range transmitter is unmodulated. The tone frequency of 1,020 cycles is produced in the receiver by the "beat" due to the difference frequency of 1,020 cycles between the range transmitter and the voice transmitter. The voice transmitter is used for weather broadcasts and other important announcements.

Q.7.143. What is meant by the "twilight" zone in radio-range flying?

A. The "twilight" zone is a zone on either side of the "on-course" area, where a weak opposite *A* or *N* will always be heard. Aircraft flying the beam are required to keep to the right of the "on course" in the twilight zone to avoid head-on collisions.

D. See Question 7.142.

Q. 7.144. How is the cone of silence produced over a low-frequency radio-range station?

A. The cone of silence is produced by virtue of the fact that the transmitting and receiving antennas are both vertically polarized (practically) and thus, when the receiving antenna is directly above the transmitting antennas, little or no reception will occur.

D. The cone of silence as such, no longer exists. It is "filled" in by a marker, such as a "Z" marker to provide more reliable and accurate identification. (See also Question 7.132.)

Q. 7.145. In radio-range flying, what is meant by "multiple courses?"

A. "Multiple courses" is the splitting of a single "on-course" indication two or more apparent courses.

D. Multiple courses are due to the presence of vertical surfaces in the vicinity of a radio range. This indicates that, in mountainous regions, multiple courses may be prevalent. When vertical surfaces are present, reflections take place from them in such a way that false indications of "on-course" signals are received. This effect may be very dangerous to the aircraft if it is flying below the level of high mountain peaks under conditions of poor visibility. The effects of multiple courses are made negligible when vhf is used. A pilot may detect a multiple beam by the fact that he goes from an on-course zone into an *A* or *N* zone, back into an on-course, then into the *N* or *A* zone without passing through any twilight zones.

Q. 7:146. If an aircraft is flying at right angles to a range leg affected by multiple courses, what signals would be heard in the radio-range receiver?

A. See last part of Discussion for Question 7.146.

D. See Questions 7.142 through 7.146.

Q. 7.147. Explain the operation of the ground portion of an ILS.

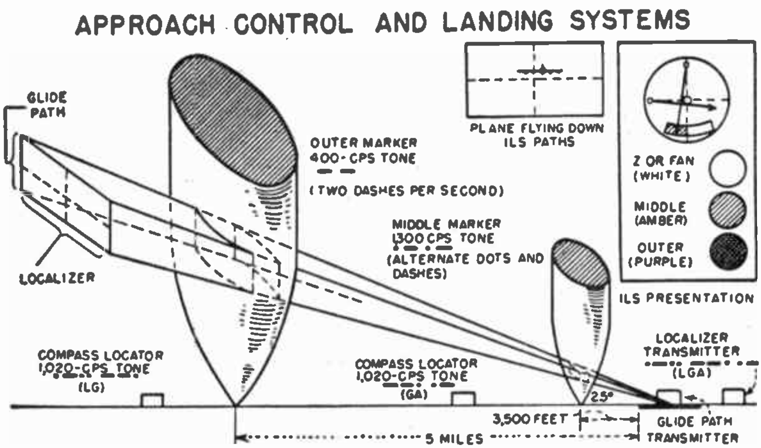
A. The ground portion of an ILS consists of three basic sections, as follows:

1. A "localizer" transmitter (108 to 110 mc)
2. A "glide-path" transmitter (332 to 335 mc)
3. A system of fan markers.

The localizer and glide-path transmitters produce an accurately oriented radio beam which the pilot may follow right down to the runway. The fan markers furnish the pilot with definite fixes on the approach path.

D. A sketch showing the location of the various units of the ILS is shown in the figure.

Lateral (azimuth) course guidance is provided by a beam radiated from the antenna of the "localizer" transmitter. This unit is located in line with the instrument runway, and at the end opposite the approach end. It is far enough away from the end of the runway to prevent its being a collision hazard. The localizer radiates a field pattern directly down the center of the runway, toward the fan markers. This is called "the front course." It also has another pattern directly to the rear, which is called "the back course." The front course is the one normally used, although under certain conditions, the back course may be used. The localizer transmitter will produce a usable on-course (lateral) signal at least 25 miles from the runway at a minimum altitude of 2,000 feet. The on-course signal is produced by modulating the transmitted radiation at two different frequencies. The right side, looking down the front course toward the transmitter, is modulated at 150 cycles. This is called the "blue" sector and is so



Courtesy Electronics

Fig. 7.147. Instrument landing system.

identified on maps, charts, and the cross-pointer indicator of the aircraft. The left side is modulated at 90 cycles and is called the "yellow" sector. The "on-course" signal is the point of equi-signal between the two modulated sides. The localizer beam is about 70 feet wide at the landing point and spreads to a width of about 5,520 feet ten miles from the transmitter.

The localizer is identified by a 3-letter code signal. A voice facility is usually provided for the transmission of approach control instructions from the airport control tower.

Vertical (altitude) course guidance is provided by a beam radiated from the antenna of the "glide-path" transmitter. This unit is located about 1,000 feet from the approach end, and 400 feet off to the side of the center line of the instrument runway. The glide-path transmitter radiates a beam which is basically the same as the localizer except that it has been turned 90°. The upper side of the beam is modulated at 90 cycles and the lower side at 150 cycles. These vertical sectors are not identified by colors. The glide-path beam is extremely narrow at the landing point, being only about 1°. Ten miles away, it is about 1,380 feet thick.

There are generally two fan markers employed. These have about 2 watts output on 75 mc and have the standard fan-shaped pattern. (See Question 7.132.)

One of these is designated the "outer marker." It is located about 4.5 miles from the approach end of the runway, and is aligned with the "front course." It emits two dashes per second, modulated at 400 cycles.

The second marker is the "middle marker." It is located about 3,500 feet from the approach end of the runway, and is aligned with the "front course." It emits alternate dots and dashes, and is modulated at 1,300 cycles.

Compass-locator stations may also be employed and are described in Question 7.127.

Boundary markers were installed by the CAA for the United States Army in certain airports. These markers are located about 300 feet from the approach end of the instrument runway, and 200 feet off to the side of the center line of the runway. It emits a continuous stream of dots, at 6 dots per second, and is modulated at 3,000 cycles.

Q. 7.148. In the ILS, which is the sharpest course, the localizer or glide path?

A. The glide path is considerably sharper than the localizer.

D. See Question 7.147.

Q. 7.149. On what frequency do marker beacons used in conjunction with ILS operate?

A. The carrier frequency is 75 mc.

D. See Question 7.148.

Q. 7.150. What aircraft radio equipment is necessary to make use of all units of ILS?

A. The following aircraft radio equipment is necessary:
1. Special localizer and glide-path antennas
2. Localizer and glide-path receivers
3. A cross-pointer indicator, for on-course, and off-course indicators
4. Fan-marker receiver, with modulation filters
5. Fan-marker light panel.

D. Two special antennas are required for the ILS receiving equipment. The localizer antenna consists of a dipole which is bent into a "U" shape to provide better streamlining and a circular pattern. The glide-path antenna is a straight dipole. The two antennas are usually mounted as a single unit, well forward on the fuselage.

The localizer and glide-path receivers are remotely controlled from a control panel near the pilot's seat. Each localizer frequency has a corresponding glide-path frequency. The channel selector switch is so arranged that it automatically switches in the correct glide-path frequency when the pilot selects the desired localizer frequency.

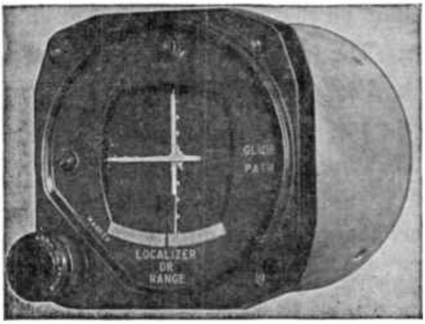


Fig. 7.150. Cross pointer indicator.

Courtesy Bendix

The cross-pointer indicator, shown in the figure, actually contains four meters within the one case. Two of these meters are microammeters, mounted so that their needles are normally vertical and horizontal. These are normally in view and are centered over the target when the pilot is making the correct approach. The vertical needle is the localizer (azimuth) pointer and the horizontal needle is the glide-path (vertical) pointer. These needles will aways deflect in such a manner as to indicate to the pilot the area of the beam is which he is flying. For example, if a pilot is flying above and to the *right* of the center beam, the localizer (vertical) pointer will deflect to the left. This is Blue on the meter and corresponds to Blue as the right side of the course. The localizer needle at the *left* tells the pilot to turn to the left until the needle is centered. At the same time, the glide-path (horizonal) pointer will point down, telling the pilot that he must lose altitude until the pointer is centered. In other words, the position of the pointers is an indication of which way to maneuver the ship to reach the center of the beam.

The other two meters in the cross-pointer indicator are voltmeters which are used as "flag alarms." Instead of the conventional pointers, each meter has a small red metal flag bearing the word "off." If insufficient signal is being received from one or both receivers, the appropriate flag will stick out across either the localizer or glide-path pointer. This indicates to the pilot that insufficient signal is being supplied for reliable use of the ILS.

The fan-marker receiver operates on the standard 75-mc frequency, but is equipped with a system of three filters, and three lights to indicate which of the ILS fan markers the pilot is flying over. There is a 400-cycle bandpass filter which actuates the purple light when the outer marker is being received. A 1,300-cycle filter actuates the amber light when the middle marker is being received. A 3,000-cycle filter actuates the white light whenever the aircraft is over either a boundary, station location "Z" or airway fan marker.

Q. 7.151. What type of instrument is used for the cross-pointer indication on the instrument panel of an aircraft when using ILS?

A. The instrument used is a "cross-pointer indicator."

D. For a description of this, see Question 7.150.

Q. 7.152. What is the purpose of the aircraft flag warning used with the ILS indicator?

A. The purpose of the flag warning is to inform the pilot that either the ground or aircraft portion of the ILS is malfunctioning.

D. For a description of this, see Question 7.150.

Q. 7.153. Is the following statement TRUE or FALSE? "In the ILS, regardless of the position or heading of an aircraft, the localizer needle will always be deflected in that color area in which the aircraft is flying."

A. This statement is absolutely TRUE.

D. See Questions 7.150, 7.151, and 7.154.

Q. 7.154. In flying the ILS, when the aircraft is above the glide path, will the horizontal needle be deflected UP or DOWN?

A. The horizontal needle will be deflected DOWN. It always points toward the direction the pilot must fly to reach the center of the glide path.

D. See Questions 7.147, 7.150, 7.151, and 7.153.

Q. 7.155. If noise breaks through in the headset on a vhf communications unit, what adjustment can be made?

A. The threshold adjustment of the squelch circuit may be adjusted, if noise breaks through in the absence of a carrier.

D. It is not entirely obvious from the question whether or not a carrier is being received at the time the noise breaks through. If a carrier is *not* being received, the bias on the squelch circuit may be increased so that noise pulses alone will not permit the audio amplifier to function. In the event that noise breaks through when a carrier *is* being received, it may be due to malfunctioning of the noise-limiter circuit. If the receiver is equipped with any adjustment for setting the clipping level of the noise limiter, this may be set to reduce noise output from the receiver. (See also Question 3.496 for discussion of squelch circuit.)

Q. 7.156. Certain aircraft communications receivers have an antenna aligning control on the panel. Electrically, what is accomplished when this control is adjusted?

A. The antenna aligning control tunes the antenna input circuit to the receiver in order to effect the maximum transfer of signal from the antenna to the receiver.

D. Aircraft antennas may have different input impedances depending upon their type, location, and frequency of operation. Maximum signal will be accepted by the input circuit of the receiver when the input circuit impedance most closely approaches the antenna impedance. In order to bring about a condition of impedance watching, the input circuit of the receiver is sometimes made tunable.

Q. 7.157. What are the approximate CW, MCW, and VOICE power ratings of transmitters used in United States air carrier operating overseas?

A. The approximate CW power is 85 watts. The approximate MCW and VOICE power is 125 watts.

D. The above ratings are given on the basis of a large percentage of aircraft operations. It must be realized that these figures may vary with individual types of equipment. For example, the VOICE power rating of certain aircraft may be only 75 watts.

Q. 7.158. What is the purpose of an isolation amplifier in an aircraft radio installation?

A. The purpose of an isolation amplifier is to permit one of the crew members to listen to a particular desired combination of signals without interfering to any appreciable extent, with the reception desired by other crew members.

D. In a transport aircraft, there may be nine or more audio-output producing units. These may include receiving and interphone systems. Several of the crew members, including the pilots, may desire to listen to various individual combinations of audio output. This must be done, in each case, without interference between the different outputs. In order to prevent such interference (or cross-talk), isolation amplifiers as well as other isolating devices (resistance networks) are emlpoyed.

Q. 7.159. What is the purpose of the sidetone feature in an aircraft radio installation? How is sidetone obtained?

A. The purpose of the sidetone feature is to permit the pilot or radio operator to monitor his own audio transmissions. Sidetone may be obtained in any one of several ways, which sends the audio signal from the microphone back into the headphones of the speaker.

D. Sidetone is merely an audio monitor signal, which permits the pilot to regulate the loudness of his voice while speaking over the microphone. The pilot's ears are normally covered by headphones and this, plus the engine noises, make it very difficult for him to judge the loudness of his own voice. Under such conditions, he has a tendency to shout and thus may overmodulate the transmitter. By returning some of the audio power to his own ears, the pilot tends to speak at a level which is comfortable to him. Thus, sidetone acts as a sort of automatic input-level control for the speaker. There are various methods of obtaining the sidetone. The more desirable methods at present are to secure sidetone from an audio amplifier in the transmitter, or by an amplifier in the interphone system.

Q. 7.160. What may cause severe arcing in aircraft transmitters at high altitude?

A. Severe arcing at high altitude may be caused by a decrease of ionization potential of the air, due to the decreased pressure.

D. Within the altitude limits that modern aircraft are capable of operating at, the potential required to ionize the air *decreases* as the air pressure decreases (as it does with high altitudes.) Therefore, equipment which is free from arcing at sea-level pressure, may arc after a certain *mininum* pressure is reached (about 0.6mm Hg) the ionization potential begins to *increase* and becomes very great as a vacuum is approached.

Q. 7.161. In tuning an aircraft transmitter, can it always be expected that the same antenna current will be secured at all frequencies?

A. It can not be expected that the current will be the same at all frequencies.

D. At different frequencies, the antenna represents different portions of a wavelength. Thus, its radiation resistance changes, as well as its input impedance, and this causes changes in antenna current.

Q. 7.162. In aircraft communications, how does the line-of-sight communication range vary with the altitude of the aircraft? At an al-

titude of 5,000 feet over level terrain, what maximum line-of-sight vhf communication range may be expected from the aircraft to a ground station?

A. The line-of-sight communication range increases as the altitude increases. At 5,000 feet, the line-of-sight range is 86.961 miles.

D. The line-of-sight range (or distance to horizon) may be found from,

$$D = 1.23 \sqrt{h}$$

where

$D =$ distance in miles
$h =$ height in feet.

The line-of-sight distance from 5,000 feet is,

$$D = 1.23 \sqrt{5{,}000} = 1.23 \times 70.7 = 86.961 \text{ miles.}$$

The actual *communications* range may be somewhat greater than line-of-sight due to refraction (bending) of the waves at the surface of the earth.

Q. 7.163. When using automatic keying or the AN/CRT-3 (modified Gibson girl life-raft transmitter), what signals are transmitted and upon what frequencies?

A. The following signals are transmitted: A 500-kc carrier modulated with a 1,000-cycle tone transmits six groups of SOS, followed by a dash (for D/F) not exceeding 20 seconds in length. The frequency then shifts to 8,280 kc and six groups (unmodulated) of SOS are transmitted followed by a dash (for D/F) not exceeding 20 seconds in length.

Q. 7.164. Discuss the advantages and disadvantages of the following aircraft antennas: fixed, trail, whip, stub mast, and loop.

A. 1. The fixed antenna extends from nose to tail, and because of its length is particularly useful for transmission and reception on low and medium frequencies. A disadvantage of this antenna is that it is capable of piling up considerable ice loading due to its length. This type of aircraft antenna is in fairly common use today.

2. The long-wire trailing antenna had the advantages of long length for low-frequency transmission and reception, and of tunability to various operating frequencies by a change of length (by reeling out wire). It had, however, several serious disadvantages. First, it required a heavy (10 lb.) trailing weight, and heavy associated mechanical equipment. Its aerodynamic drag was high, slowing down the aircraft. Also, the pilot frequently forgot to reel in the antenna before landing creating hazards and a prominent maintenance problem. This antenna is no longer in general use.

3. The whip antenna is vertically polarized in level flight and is short and light in weight. It cannot accumulate much ice loading be-

cause of its length. However, this short length greatly limits its pickup, especially on the lower frequencies, and therefore, limits the communication range to a greater extent than longer antennas. The whip antenna also tends to change polarization when the ship is turning.

4. The stub mast was made of streamlined aluminum alloy tubing. Some masts were as high as 7½ feet and were guyed by 3 long wires. This antenna was fairly efficient electrically, but had several important disadvantages. It had excessive drag, size, and bulk. Due to its large total area it was subject to severe ice loading. The mast was vertically polarized during level flight but changed polarization whenever the plane turned, and thus subjected the receiving equipment to possible loss of signal.

5. The loop antenna has the advantages of shielding and a bidirectional pattern for direction finding. However, its pickup is relatively small.

D. See Question 7.65 through 7.70 and 7.165. (See also Index under Antennas.)

Q. 7.165. What type of aircraft antennas permit maximum radiation on such medium frequencies as 333 and 500 kc?

A. The type with the greatest physical length. For modern aircraft, this would usually mean a fixed-type nose-to-tail antenna.

D. See Question 7.164.

Q. 7.166. Explain the principle of operation of the antenna change-over relay in an aircraft radio installation. What is a vacuum antenna relay?

A. The antenna change-over relay functions to switch the antenna from receiver to transmitter when the aircraft is engaged in a transmission. A vacuum antenna relay is one in which the contacts are enclosed in an evacuated structure. This protects the contacts from arcing, dirt, and oxidation.

D. In aircraft radio installation, the transmitting antenna is invariably used also for receiving. In order that calls to the aircraft from the ground be heard, it is essential that the receiver be in almost continuous operation. This, of course, requires that the antenna be connected to the receiver at all times except when the plane is actually making a transmission. In order to provide efficient communication, it is necessary to restore the antenna to the receiver immediately upon termination of a communication. This requirement is met by a special relay which can be operated by a button on the microphone or other convenient point. In radiotelegraph operation, the relay follows the keying.

The change-over relay performs several functions as follow:

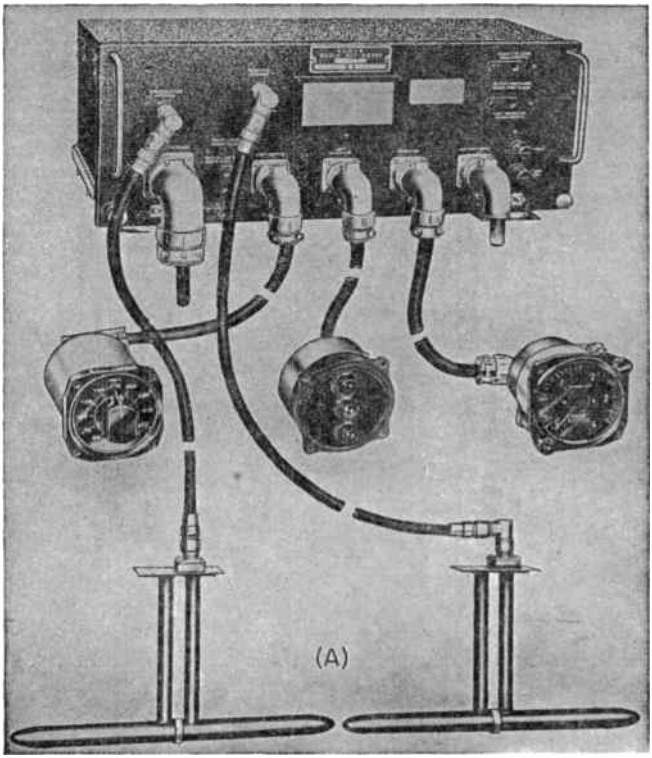
1. Switches the communications antenna from receiver to transmitter
2. Grounds the receiver's antenna connection
3. Increases transmitter filament voltage to normal
4. Supplies primary power to the transmitter dynamotor.

Q. 7.167. How may an aircraft D/F loop be utilized for antistatic reception of radio-range signals?

A. A shielded D/F loop may be switched into the receiver input in place of the regular unshielded antenna. The electrostatic shielding greatly reduces the effects of precipitation static.

D. See Question 7.113.

Q. 7.168. Describe the physical construction of antennas used with the aircraft radio altimeter.



Courtesy RCA

Fig. 7.168. (A) RCA radio altimeter.

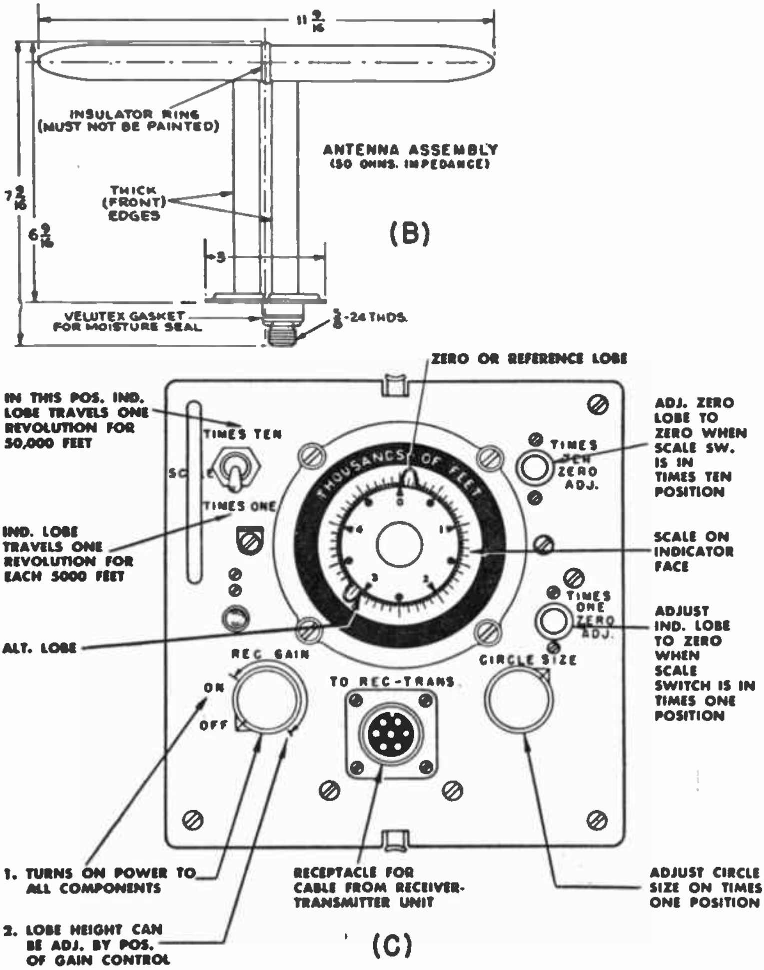


Fig. 7.168. (*B*) *Radio altimeter antenna.* (*C*) *Radio altimeter indicator.*

A. There are two antennas used with an aircraft radio altimeter. One is for transmitting and the other for receiving (See part (A) of the figure). These are each dipoles, approximately one-half wavelength long, and each have an input impedance of about 50 ohms. A sketch showing all the important physical dimensions is given in part (B) of the figure. A mounting bracket is provided which places the dipole approximately one-quarter wavelength from the body of the aircraft.

D. The aircraft radio (or radar) altimeter consists of a transmitter, a receiver, and antennas operating at 440 mc (RCA AVQ-9). This particular unit is a high-altitude altimeter which indicates the height of aircraft above terrain. It has a nominal operating range of 0 to 40,000 feet. The unit operates briefly as follows. The transmitting antenna sends pulses of radio-frequency energy earthward. When these pulses reach the terrain below, they are reflected and picked up by the receiving antenna. The travel time of the signals from plane to earth and return is directly proportional to the altitude of the plane over the terrain. The receiving antenna passes the received signal (both direct and reflected) through a high-frequency receiver and into a cathode-ray indicator. This is shown in part (C) of the figure.

Two indications (or lobes) appear on the face of the cathode-ray indicator, which has a circular time base. One lobe always appears at zero and corresponds to the original transmitted pulse as it leaves the aircraft. The other lobe is that corresponding to the reflected signal. The reflected lobe will be indicated at a point on the indicator scale which represents the actual distance of the aircraft above the terrain in feet.

Another unit (RCA AVQ-6) is specifically designed for low-altitude measurement. Two ranges are provided, one extending from 0 to 400 feet and the other from 400 to 4,000 feet. The unit operates in the vicinity of 440 mc but is frequency-modulated between the ranges of 420 to 460 mc. The detector in the altimeter compares the direct transmitter signal with the reflected signals, and produces a resultant audio signal. The frequency of the audio signal is proportional to the height of the aircraft above the reflecting surface. Altitude indications are read directly on a meter type of indicator.

Q. 7.169. Explain the principle of operation of the flux-gate-compass system.

A. The explanation which follows is based upon the block diagram as shown in the figure.

The flux-gate compass is a remote indicating earth inductor compass. It is located in the aircraft in a position where it is least affected by the aircraft's magnetic field. The magnetic element is stabilized in the horizontal plane by the use of a gyroscope. This results in the presentation of continuous magnetic reading on all headings, which are unaffected by turns, banks, climbs, yawing about a given course, or bumpy weather. The flux-gate compass consists basically of the following:

1. A "transmitter," containing the flux gate, a gyroscope, a caging mechanism, and an erection mechanism

2. A "master indicator," consisting of an autosyn, a low-inertia motor, and a magnesyn, together with an indicator dial and correction mechanism

3. "Repeater" indicators (up to six), containing a receiving magnesyn, dial, and pointer

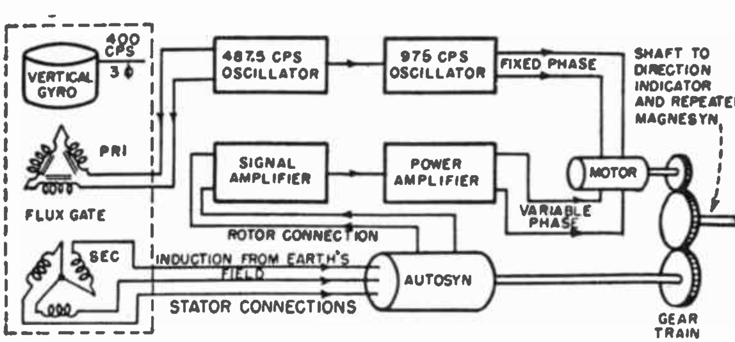
4. An amplifier unit containing a 400-cycle power supply, a 487½-

cycle oscillator section, a 975-cycle oscillator section, and an autosyn signal amplification system.

A discussion of the functioning of each of these basic sections is necessary for an understanding of the operation of the flux-gate compass, and this follows.

TRANSMITTER UNIT. The flux gate is the sensitive compass element. It is mounted on the bottom of the gyro frame and is stabilized by the gyro. The flux gate is triangular and each leg contains a laminated core of magnetic alloy. The primary exciting coil is wound in series around the three cores, and the secondary coil is delta wound around the same three cores. The primary coil is so wound that the exciting currents from the 487½-cycle oscillator do not induce currents into the secondary. The flux gate is so designed that the core will be completely saturated whenever the current from the 487½-cycle oscillator rises to a peak (twice per cycle). Between peaks, the core is no longer saturated and the earth's magnetic field affects the core and induces voltages in the secondary. These voltages rise and fall twice each cycle producing a signal frequency of 975 cycles. The magnitude of the signal voltages across each leg differ, and are dependent upon the position of the flux gate with respect to the earth's magnetic field.

The function of the gyroscope is to keep the flux gate horizontal with respect to the earth's surfaces at all times. The gyro consists of a 2-phase, 4-pole condenser-type induction motor operated from a 115-volt, 400-cycle, single-phase source. It rotates at 10,500 rpm. The "caging" mechanism of the gyro is a mechanical arrangement which erects the gyro to an approximately correct operating position after the gyro motor is started. The "erection" mechanism is a mechanical arrangement which keeps the axis of the gyro parallel to the earth's gravitational field at all times.



Courtesy Electronics

Fig. 7.169. Block diagram of flux-gate compass.

MASTER INDICATOR. The output of the flux gate is fed to the autosyn of the master indicator. The autosyn consists of a single-phase, 2-pole rotor which revolves within a 3-phase, 2-pole *Y*-connected stator. The secondary coil of the flux gate connects to the stator. There is induced in the rotor, a signal voltage whose value is a function of the position of the rotor with respect to the field produced by the stator. The voltage induced in the rotor is fed to the input of the signal amplifier and power amplifier. The amplified voltage is then fed to one phase of the 2-phase low-inertia induction motor. This is a variable phase voltage. The other phase (fixed phase) is continuously excited by the 975-cycle oscillator. The rotor of the low-inertia motor is connected to the rotor of the autosyn through a gear train. When voltage is applied to both phases of the low-inertia motor, it will rotate, driving the autosyn to its null point. An indicating pointer is geared to the autosyn. This pointer always indicates the direction in which the aircraft is headed with respect to the earth's magnetic field, regardless of the orientation of the aircraft.

The magnesyn is geared to the indicating mechanism and transmits information concerning the compass reading from the master indicator to the repeater indicators.

REPEATER INDICATORS. These each contain a receiving magnesyn, dial and pointer. There may be as many as six repeaters located at different points in the aircraft, permitting the compass reading to be determined at any of these points in addition to the master indicator.

D. See Questions 7.170 through 7.176.

Q. 7.170. What type of power supply is used in the flux-gate-compass system?

A. The flux-gate-compass system uses a 115-volt, 400-cycle inverter operated from the aircraft's batteries.

D. Other 400-cycle voltages are required for the operation of the equipment, such as: 24, 26, 28, 105, and 125 volts. These are obtained by the auto-transformer action of the tapped primary of the power transformer.

Q. 7.171. Explain the purpose of the gain control on the amplifier unit of the flux-gate-compass system.

A. The purpose of the gain control is to increase or decrease the sensitivity of the compass system.

D. The horizontal component of the earth's magnetic field varies widely in strength at different points on the earth's surface. By means of this control, the sensitivity of the flux-gate compass may be adjusted to give satisfactory performance under widely different magnetic conditions. In practice, the gain control is set to give the maximum sensitivity consistent with stable performance of the indicator dials.

Q. 7.172. What functions are performed by the amplifier unit of the flux-gate compass?

A. The amplifier unit provides a 487½-cycle and a 975-cycle output. It also provides amplification for the autosyn signal.

D. These functions are described in detail in Question 7.169. (See also Question 7.170.)

Q. 7.173. Why is the sensitive compass element in the flux-gate system usually located in a remote spot such as the aircraft wing tip?

A. The flux gate is remotely located to avoid magnetic disturbances which might be caused by the engine(s) and other ferromagnetic materials. These disturbances might cause erroneous readings.

D. See Question 7.169.

Q. 7.174. In what portion of the flux-gate-compass system is a low-inertia motor used?

A. The low-inertia motor is connected mechanically to the autosyn and indicator dial and electrically to the 975-cycle oscillator and the power amplifier.

D. See the figure and text of Question 7.169 for further discussion.

Q. 7.175. In the flux-gate-compass system, the gyro is a self-erecting vertical gyro. Explain the function of the gyro.

A. The function of the self-erecting vertical gyro is to maintain the flux gate horizontal with respect to the earth's surface at all times.

D. See Question 7.169.

Q. 7.176. What is meant by "caged" and "uncaged" in a flux-gate compass?

A. The flux-gate gyro is "caged" when it is positioned and *held* mechanically by the caging mechanism in the approximately correct operating position. It is "uncaged" when the caging mechanism releases the gyro, whereupon it is under the influence of the erection mechanism.

D. See Question 7.169.

Q. 7.177. In Loran terminology, what would be indicated by the legend 1L3-2120?

A. The first three symbols (1L3) identify the station pair for tuning purposes. The figure "1" represents frequency channel No. 1, or 1,950 kc; "L" indicates a basic pulse rate of "Low" (25 pulses per second); the figure "3" indicates specific repetition rate No. 3 (25 3/16 pulses per second). The figure "2120" indicates the absolute time difference (2,120 microseconds) between the arrival of master and slave pulses from the 1L3 station pair.

D. See Questions 6.669 through 6.676.

Q. 7.178. How is a Loran fix indicated on a Loran navigation chart?

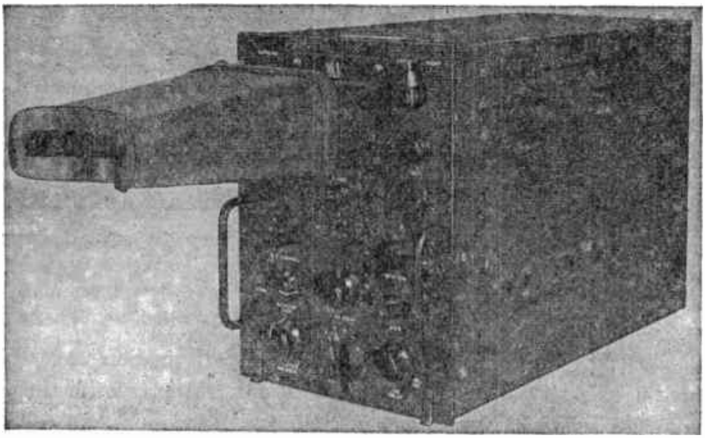
A. A Loran fix on a Loran navigation chart is indicated by the intersection of at least two Loran lines of position.

D. See Questions 6.669 and 6.675.

Q. 7.179. Does precipitation static affect operation of the Loran receiver-indicator?

A. Yes. Loran operates in the frequency range 1,700 to 2,000 kc and is subject to precipitation static interference, the same as other radio equipment operating on these frequencies.

D. See Questions 6.669 through 6.676.



Courtesy RCA

Fig. 7.179. RCA Loran receiver.

Q. 7.180. What is the approximate usuable over-water range in nautical miles of the Loran system in both day and night operation?

A. The daytime range, over water, is about 700 nautical miles. The nighttime range, over water, may be as great as 1,400 nautical miles by utilizing reflected sky waves. These sky-wave readings require corrections which are shown on Loran charts.

D. Over land areas, the daytime range is 250 miles at high altitudes and about 100 miles at ground level.

Q. 7.181. To what reading, or indication, is sky-wave correction applied in Loran navigation?

A. Sky-wave correction is applied to Loran readings which are taken by utilizing sky-wave reflections to obtain lines of position.

D. If sky waves are used to permit reception at great distances (up to about 1,400 miles) from the Loran transmitters, a time correction must be applied. This compensates for the greater distance of travel of the radio wave resulting from the reflected path. Sky-wave corrections will be found on Loran charts and tables. (See also Question 7.180.)

Q. 7.182. What frequency channels are used in the present Loran system?

A. At the present time, channel frequencies of 1,850 and 1,950 kc are in use.

D. See Questions 6.669 through 6.676, and 7.177 through 7.181.

Q. 7.183. What type of power supply is used with the Loran receiver aboard aircraft?

A. Most Loran receivers operate at 117 volts (approximately), 400 to 2,400 cycles. The primary source of power is a 28-volt battery system which operates an inverter to produce the required power voltage and frequency.

D. See Question 7.182 for references.

Q. 7.184. Consol is a long-range radio aid to navigation undergoing considerable practical use in certain sections of the world. Explain briefly, the principle of operation of the consol system.

A. A consol station consists basically of a medium-frequency transmitter, operating at the present time on frequencies within the band

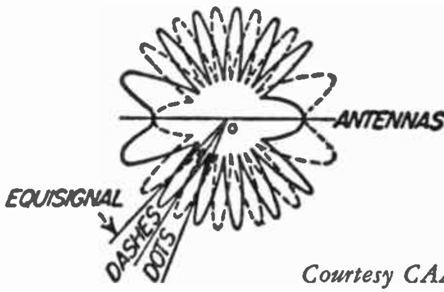


Fig. 7.184. Radiation patterns of Consol systems.

Courtesy CAA

263 to 319 kc. A special directional antenna is used which consists of 3 antennas in line. The radiation pattern of each of the two coverage areas (120° each) is made up of 15° sectors which have alternate dot-and-dash signals. This is shown in the figure. Between the dot-and-dash sectors is an equisignal region. The radiation pattern rotates so that during the period of one keying cycle, the equisignal moves through the width of one sector (15°). This rotation is stopped at the end of one keying cycle, after which the pattern returns to its original position.

Because of this rotation, a listener will hear the equisignal once in each keying cycle. He may determine his angular position in the pattern sector by the number of dots or dashes heard before the equisignal. Between keying cycles, a continuous note and the call sign of the station are transmitted.

The range in daylight is about 1,000 miles over water and 800 miles over land, with greater ranges being possible at night.

D. There are four stations operating at present, as follows:

1 Bushmills, North Ireland, (MWN) frequency 263 kc, A1
2. Stavanger, Norway, (LEC) frequency 319 kc, A1
3. Otero del Rey, Spain, (LUGO) frequency 303 kc
4. Sevilla, Spain, frequency 311 kc.

A 60-second keying period is used in most cases although a 40-second keying period is undergoing tests at Bushmills. The 40-second cycle details are as follows:

1. 60 dot-and-dash cycle	30	seconds
2. Silent period	2⅓	seconds
3. Call sign "MWN'	2½	seconds
4. Silent	½	second
5. Continuous note	4	seconds
6. Silent	1⅓	seconds
Total period	40⅔	seconds

Q. 7.185. What aircraft radio equipment is necessary to make use of Racon beacons?

A. The required aircraft radio equipment consists of a primary radar transmitter and receiver.

D. The Racon (Radar beacon) is a secondary radar which is triggered by impulses from the primary radar located in the aircraft. The Racon consists of a receiver, time-delay device, and transmitter. Some means of coding is also provided. This system permits operation at much greater distances than could be furnished by radar alone. An example of Racon operation is as follows. An aircraft flying in a certain sector wishes to learn his position. He turns on hs aircraft radar and challenges the Racon. This, in turn, is triggered and sends back information to the aircraft indicating identity, azimuth, and distance.

OPERATING PROCEDURES

Q. 7.186. In air-traffic control procedures, what is meant by a service known as an "approach control?" How are communications handled between aircraft and approach control?

A. "Approach control" is a service established to control IFR (instrument flight rules) flights arriving at, departing from, and operating in the vicinity of airports.

Communications are handled by means of direct and instantaneous means (radiotelephone) between "approach control" personnel and all aircraft operating under their control.

Q. 7.187. A Constellation aircraft of Midway Airways, Trip 14, with radio call KHCBX, licensed as NC 18947, is entering the traffic pattern at a particular airport. What is the correct procedure to be followed by the air-traffic control tower in establishing radiotelephone communication with this aircraft?

A. The tower may call the aircraft as follows:

Item	*Example*
1. Designation of the aircraft called (Name of company and trip number)	Midway 14
2. Geographical location of aircraft and altitude	3 miles west of field at eight hundred (feet)
3. Landing clearance	Cleared to land, make right turn in

If one or more preceding aircraft are in the traffic pattern, waiting for landing instructions, a sequence number will be issued in lieu of the instruction "cleared to land." Example: "You are number two to land."

D. Since the aircraft is *entering* the traffic pattern, it must have previously been given *clearance* to enter the pattern. This communication may have been as follows. Example; "Midway 14, three thousand. Cleared to enter traffic pattern. Wind South, one four (14), runway one eight (18). Over."

Q. 7.188. Certain United States Coast Guard radio beacons have undergone modifications to permit satisfactory use with aircraft ADF. Describe.

A. Many marine radio beacons have been modified to transmit a continuous carrier signal during the radio beacon transmitting minute. Characteristic signals are provided by keying the *modulation.*

D. Such marine radio beacons operate continuously 24 hours a day and transmit according to a cycle consisting of 1 minute of transmission and 2 minutes of silence. Before modification, characteristic signals were transmitted by interrupting the carrier during the 1-minute transmission time. This would be unsatisfactory for ADF operation, since the loop might tend to jump around between dots and dashes.

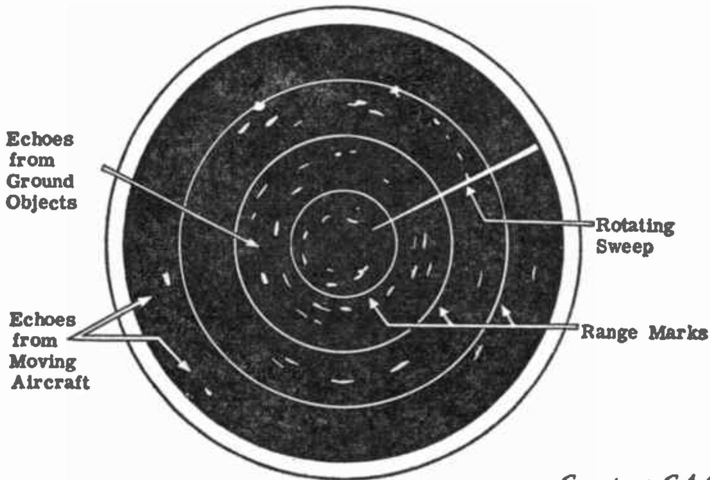
Q. 7.189. What aircraft radio equipment is needed to carry out a GCA (Ground Controlled Approach) problem?

A. The standard communications receiver is the only aircraft radio equipment needed to carry out a GCA problem.

D. GCA is a precision approach system using radar principles. Its basic function is to guide an aircraft to a landing during conditions of poor visibility. Basically, this is done by transmitting information on radiotelephone from the GCA station to the pilot. The GCA operator literally "talks the aircraft down" onto the runway. The equipment consists of two microwave radar sets which are placed adjacent to the runway in use. One set, the "surveillance" radar (10 cm) continually surveys the air space around the radar site. This set is designed to detect an aircraft flying at a minimum altitude of 3,000 feet, at a distance of at least 30 miles. Any aircraft within a radius of 30 miles (minimum) will be indicated on a PPI (Plan Position Indicator) scope as shown in the figure. This scope provides a running record as to the range and azimuth of aircraft in the vicinity of the airport. The aircraft is guided by means of the surveillance radar to within range of the second radar set, the "precision approach" radar (10 cm). This has a range of only about 10 miles and its antenna scans are limited to a total of 20° of azimuth and 7° of elevation. This radar set is extremely accurate in its indications and, therefore, is capable of providing guidance for the aircraft, practically down to the runway.

A later development, the automatic radar landing system, automatically translates azimuth and elevation information into artificial ILS localizer and glide-path signals which are transmitted, on different frequencies, to the aircraft being tracked. These simulated ILS signals are used to actuate the ILS cross-pointer indicator to guide the aircraft down the approach path to the runway.

Another use of the GCA is to monitor the approach of aircraft on ILS. This checks the accuracy of the ILS and provides an additional safety feature for the aircraft.



Courtesy CAA

Fig. 7.189. A PPI presentation.

Q. 7.190. Define the following terms as used in air-traffic control procedures; approach clearance, approach sequence, approach time, control area, control zone, control altitude, essential traffic, local traffic, traffic pattern, IFR, VFR, downwind leg, base leg, and final approach.

A. *Approach clearance*: A clearance given by air control to the pilot of an aircraft under IFR, which authorizes the aircraft to enter into an approach for a landing.

Approach sequence: The sequence in which aircraft are given an approach clearance. Usually, the first aircraft to arrive over the holding point will be the first aircraft cleared to approach.

Approach time: The time at which it is expected that an arriving aircraft will be cleared to commence approach for a landing, if any portion of the approach may be conducted in IFR conditions.

Control area: An air space of defined dimensions, designated by the Administrator, extending upward from an altitude of 700 feet above the surface, within which air-traffic control is exercised.

Control zone: An air space of defined dimensions, within which rules additional to those governing flight in control areas apply for the protection of air traffic.

Control altitude: An altitude assigned to an aircraft by the controlling authority when the aircraft is operating under IFR.

Essential traffic: Aircraft on IFR under the following conditions:

1. Same direction IFR traffic on same or converging courses, if aircraft is separated by 1,000 feet or less vertically and with less than the minimum longitudinal separation (5-minute separation).

2. Opposite-direction IFR traffic on reciprocal or converging courses, if aircraft are separated by less than the minimum time separation for altitude changes (5 minutes), and occupying or passing through the same flight levels or within 1,000 feet of each other.

Local traffic: Aircraft operating in the vicinity of an airport, in the traffic pattern, or within about a 3-mile radius of the airport.

Traffic pattern: The route of aircraft operating in the vicinity of an airport, as determined by the controlling authority. (Usually terminates in a landing.)

IFR: The symbol for Instrument Flight Rules.

VFR: The symbol for Visual Flight Rules.

Downwind leg: That portion of the landing approach, parallel to, but opposite in direction to the actual landing. (See the figure.)

Base leg: That portion of the landing approach at right angles to the direction of landing, and just preceding the final approach to ground contact. (See the figure.)

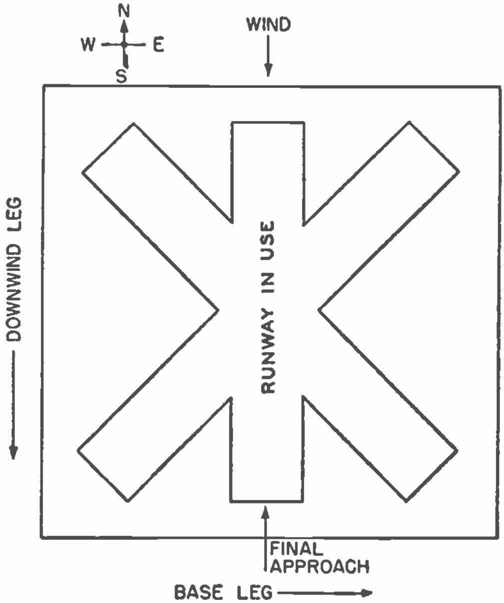


Fig. 7.190. Identification of legs of traffic patterns.

Final approach: That portion of the landing approach which is straight into the runway and terminates in ground contact. (See the figure.)

Q. 7.191. Is it possible for an aircraft to contact United States radio-range stations by using A-2 emission?

A. It is possible in an emergency. However, contact with range stations is customarily carried on by A-3 emission.

D. Many *radio beacons* may be contacted upon request using A-2 emission on the following frequencies; 3,105 kc, 4,495 kc, 6,210 kc, and 3,117.5 kc.

Q. 7.192. What is the "attention" signal used on United States radio-range station transmissions?

A. The "attention" signal consists of a series of dots sent for 1 second followed by a 5-second silent interval after which the communication commences.

D. One major purpose served by the "attention" signal is to give pilots a chance to switch in the voice filter on the range receiver. See also Question 7.125 for operation of radio-range filter.

Q. 7.193. Explain how marker beacons identify the legs of a four-course radio-range station. If the legs of a radio-range station are spaced at 040°, 140°, 230°, 320°, respectively, what range leg would an approaching aircraft be on if a marker beacon identification of two dashes (— —) were intercepted?

A. The legs are identified by the number of dashes transmitted by the marker beacon transmitter. The first leg clockwise has one dash, the second, two dashes, the third, three dashes, and the fourth, four dashes. This is shown in part (B) of the figure for 7.133. In this example, two dashes would identify the 140° leg.

D. If two markers are provided on a leg, the *outer* marker will be identified by two dots (. .) preceding the dash identification. See the figure. (See also Questions 7.132, 7.133, 7.134, and 7.147.)

Q. 7.194. Explain the method of determining "overhead" on a radio beacon using the aircraft manual D/F loop.

A. There will be a strong build-up of signal when close to the station, after which the null disappears.

D. When using the loop antenna, there will be no "cone of silence" when directly over the station. This area is then simply referred to as the "overhead." The loop is not recommended for determining the location of the "overhead" since other effects may give false indications which are similar to the desired indication.

Q. 7.195. What United States Government document gives the location, frequency, identifier, and hours of operation of all marine radio beacon stations?

A. The document is entitled "Radio Navigational Aids." It is designated H. O. (Hydrographic Office) Publication No. 205.

D. This document contains much useful information, some of which follows:

1. Table of radio services by countries
2. List of D/F stations by countries
3. List of radio beacon stations by countries
4. Aeronautical radio aids
5. Radio time signals
6. Long-range navigational aids
7. Loran and Consol.

This volume may be obtained locally from Marine supply stores or by writing to the U.S. Navy Department, Hydrographic Office, Washington 25, D.C.

Q. 7.196. What agency of the United States Government may be called upon to render emergency direction-finding aid to aircraft? How is this agency contacted?

A. Any agency which is equipped to render this service, such as, Coast Guard, Army, Navy, Marine, CAA, or FCC Services. The agency is contacted on a frequency on which the station normally keeps watch.

D. The calling frequencies are listed on maps, charts, and tables normally used. In emergency, aircraft may also ask for GCA assistance from any stations so equipped.

Q. 7.197. A control-station operator desires to determine whether or not an aircraft is flying in accordance with VFR. What is the appropriate signal to use?

A. The appropriate signal to use is "QDT" which means: "Are you flying in accordance with Visual Flight Rules?"

Q. 7.198. An aircraft is approaching its point-of-no-return and desires amendments to the flight forecast. What is the correct signal?

A. The correct signal is "QMZ" which means: "I am approaching my point-of-no-return. Have you any amendments to the flight forecast in respect of section of route yet to be traversed?"

Q. 7.199. An aircraft is preparing to make a QDM approach at a foreign terminal. What signals are used to request a series of QDM's from the ground D/F station?

A. The signal used is "QDL QUX."

D. The signal "QDM" means: "What is the magnetic course to steer with zero wind, to reach you." The request is "QDL QUX" which means: "I intend to ask you for a series of bearings," and "What is the magnetic course for me to steer towards you with no wind?"

Q. 7.200. An over-ocean aircraft desires to check its distances out from an OSV by using the vessel's radar equipment. What signals are used to obtain this information?

A. The signals are "QGE NLM" which means: "What is my distance to your station in nautical miles?"

D. A bearing indication Q signal is usually sent at the same time. The message might read "QGE NLM QTE." This signal "QTE" means: "What is my true bearing from you?"

Q. 7.201. A flight radio operator copies the following signals from the control station: QAK QAH 8,500 FT IMT. The pilot should be advised immediately. Why?

A. There is a risk of collision.

D. The symbol "QAK" means: "There is risk of collision." This signal is followed by instructions for avoiding collision. In this example, "QAH 8,500 FT IMT." This means: "Arrange your flight so as to reach altitude 8,500 feet immediately."

Q. 7.202. What signal would the flight operator transmit to request the surface wind at a particular airport?

A. The signal "QAN."

D. This signal means: "What is the surface wind at........(place)?"

Q. 7.203. An aircraft is estimated to be within D/F range of a certain radio beacon, but the signals cannot be heard on the aircraft. To request information as to whether or not the radio beacon is in operation, the "Q" signal ______ should be transmitted.

A. The "Q" signal "QFS" should be transmitted.

D. This signal means: "Is the (beacon) radio facility at........(place) in operation?"

Q. 7.204. An aircraft cleared to cruise at 12,000 feet is climbing on course under IFR conditions. OATC, through the control station, requests the aircraft to report immediately upon reaching cruising altitude. What are the correct "Q" signals?

A. The aircraft will transmit "QBV."

D. This symbol means: "I have reached the altitude of (12,000) feet. When transmitted by the control station, the same signal "QBV" means: "Report reaching the altitude of (12,000) feet."

Q. 7.205. What is meant by the terms POMAR, METAR, NAREPS, RAWIN, PIBALS, PIREPS?

A. *POMAR*: Observations of position and weather from international overseas flights.

METAR: Hourly weather broadcast transmitted on CW.

NAREPS: Navy aerological reports.

RAWIN: Winds aloft information obtained by tracking reflecting balloons by means of radar.

PIBALS: Winds aloft information made by visual (theodolite) observation of pilot balloons.

PIREPS: Weather reports from itinerant (private) aircraft.

Q. 7.206. What is the meaning of the following signals? QAA through QAZ, QBC (used with QMI, QFT, QBJ, QMZ, and QTH), QBF, QBG, QBH, QBI, QBS, QBX, QCB, QCE, QDR, QDX, QFE, QFG, QFH, QFM, QGJ, QGZ, QHH, QJD, QLH, QMH, QNI, QNT, QUG, QUO, QUR, QUS, QUU, QUV, QUX, and QRF.

A.

Abbreviation	*Meaning*
QAA	No definition yet assigned.
QAB	What is your DESTINATION? or IS your DESTINATION . . . .(place)? or AM I CLEARED TO. . . .(place and/or control)?
QAF	At what time were you OVER. . . .(place)?
QAG	Lose time to ARRIVE OVER. . . .(place, at. . . .hours or I am arranging my flight in order to ARRIVE OVER. . . .(place) at. . . .hours.
QAH	What is your ALTITUDE?

QAK	Is there any risk of COLLISION?
QAL	Are you going to LAND at. . . .(place)? or Has aircraft. . . . LANDED at. . . .(place)? (See also QTP.)
QAM	What is the latest available meteorological OBSERVATION for. . . .(place)?
QAN	What is the SURFACE WIND at. . . .(place)?
QAO	What are the WINDS at. . . .(position or zone) at the following heights above MEAN SEA LEVEL. . . .?
QAP	Shall I LISTEN for you (or for. . . .) on. . . .kc (mc)?
QAQ	Am I NEAR a PROHIBITED AREA [or. . . .prohibited area (name of prohibited area)?]
QAR	May I STOP LISTENING on the watch frequency for. . . . minutes?
QAS	You are flying OVER a PROHIBITED AREA [or. . . .prohibited area (name of prohibited area)].
QAU	I am about to JETTISON fuel.
QAV	Are you able to HOME on your D/F equipment?
QAY	Will you advise me when you are. . . . 1. AT 2. OVER } . . . .(place)? 3. ABEAM OF
QAZ	Are you flying in a STORM?
QBC	What are the present METEOROLOGICAL CONDITIONS as observed from your aircraft?
QBF	Are you flying IN CLOUD?
QBG	Are you flying ABOVE CLOUD?
QBH	Are you flying BELOW CLOUD?
QBI	Is flight under INSTRUMENT FLIGHT RULES COMPULSORY at. . . .(place) [or from. . . .to . . . .(place)]?
QBS	Ascend or descend to an altitude of. . . .(height) BEFORE ENCOUNTERING INSTRUMENT FLIGHT RULES conditions or if visibility falls below. . . .(distance) and advice.
QBX	Have you LEFT the ALTITUDE of. . . .(height) [or. . . . (area or place)]?
QCB	You are CAUSING DELAY by answering out of turn.
QCE	When may I expect APPROACH CLEARANCE?
QDR	What is my MAGNETIC BEARING FROM YOU (or from . . . .)? (See also QUV.)
QDX	I have ACCEPTED CONTROL (or responsibility) of (for) . . . .
QFE	What is the present BAROMETRIC PRESSURE at official AERODROME LEVEL at. . . .(place)?

QFG Am I OVER the AERODROME?
QFH May I DESCEND BELOW the clouds?
QFM What ALTITUDE should I maintain? or What ALTITUDE are you maintaining?
QGJ REDUCE your COMMUNICATIONS to strict minimum; I have to communicate with other aircraft.
QGZ HOLD on. . . .direction of. . . . facility
QHH Are you making an EMERGENCY LANDING?
QJD Not assigned yet.
QLH Will you use SIMULTANEOUS KEYING on. . . .frequency and. . . .frequency?
QMH SHIFT to transmit and receive on. . . .frequency; if communication is not established within 5 minutes, REVERT to present frequency.
QNI What is the present ALTIMETER SETTING at. . . .(place)?
QNT What is the maximum GUST SPEED of the surface wind at . . . .(place)?
QUG Will you be FORCED to ALIGHT (or LAND)?
QUO Shall I SEARCH for. . . .

1. AIRCRAFT
2. SHIP
3. SURVIVAL CRAFT

in the vicinity of. . . .latitude. . . .longitude (or according to any other indication)?

QUR Have SURVIVORS. . . .

1. received survival equipment?
2. been picked up by rescue vessel?
3. been reached by ground rescue party?

QUS Have you SIGHTED SURVIVORS or WRECKAGE? If so, in what position?
QUU Shall I HOME SHIP or AIRCRAFT to my position?
QUV What is my MAGNETIC BEARING FROM YOU (or from . . . .)?
QUX Will you indicate the MAGNETIC COURSE for me TO steer toward YOU (or. . . .)with no wind?
QRF Are you RETURNING to. . . .(place)?

Q. 7.207. What is an ocean station vessel (OSV)?

A. An ocean station vessel is a ship operating in the maritime service which provides radio-beacon service and meterological data on a 24-hour basis at 5, 20, 35, and 50 minutes past each hour for 3 minutes duration.

D. The ocean station vessels normally are under way around a 10-mile square, the center of which is the geographic position assigned to the stations.

Q. 7.208. How are radio-beacon transmissions from ocean station vessels identified?

A. The identification signal consists of four letters; the first 2 comprise the characteristic signal, the last 2 indicate its postion within the 10-mile square, as indicated on a grid.

D. A typical OSV identification and characteristics are as follows:

1. Ocean station Vessel A
2. Latitude 62° 00′ north, longitude 33° 00′ west.
3. Frequency: 414 kc
4. Characteristic signal: CB (— • — • — • • •)
5. The characteristic signal is followed by 2 letters indicating the ship's location on the grid. (See also Question 7.212 for grid.)

Q. 7.209. What type of radio-beacon service is maintained by an ocean station vessel when it is driven off station with position unknown?

A. No beacon service will be given except when requested for homing purposes.

D. If a station vessel is off its grid entirely, such as when on a distress mission, no normal beacon service will be given except by request, for homing. In such a case, the station's international radio call is used. The collective call for all OSV is NMMZ. These vessels guard 500 kc and 8,280 kc continuously.

Q. 7.210. What radio-beacon service is maintained by an ocean station vessel when it is off station proceeding on a distress mission?

A. See Question 7.209.

Q. 7.211. How does an ocean station vessel indicate "on station;" "off station?"

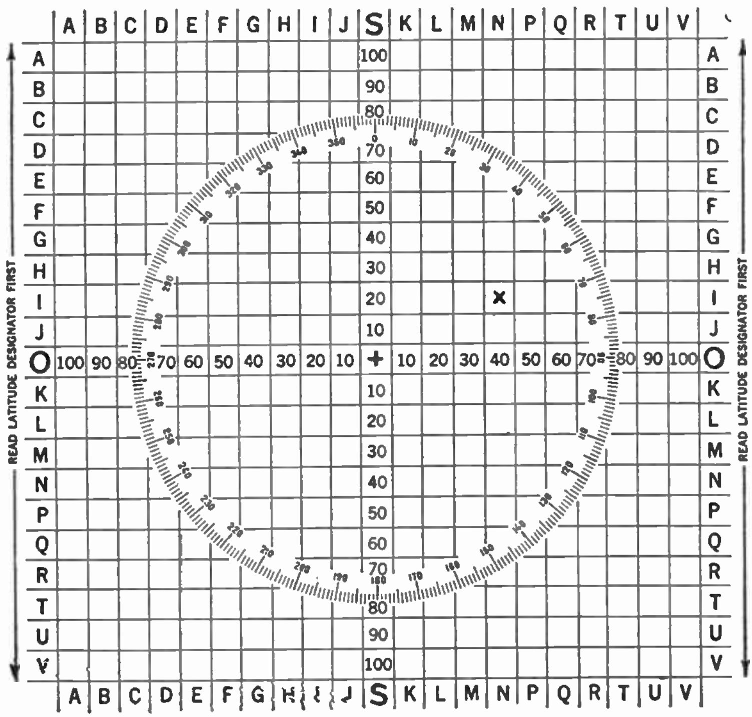
A. When "on station" the vessel will transmit "OS" as the last two letters of the identifying signal. When "off station," the vessel will transmit two other letters identifying the particular square of the grid the vessel is occupying.

D. See Questions 7.207 through 7.210 and 7.212.

Q. 7.212. With reference to ocean station vessels, what is meant by the grid system? Explain its operation.

A. The grid system is a system for indicating the location of an ocean station vessel within a certain area. The operation of the grid system may be understood with the aid of the following chart and explanation reproduced from "Radio Navigational Aids." The characteristic signal of station *A* referred to is "CB."

D. The center of the grid is the geographic position assigned to the station. If the ship is on station, i.e., within the 10-mile square at the center, the last two letters of the signal are "OS," the latitude and longitude designators, respectively. If the ship is off the station but on the grid, the latitude and longitude designators of whatever square the ship is in are transmitted as the last 2 letters of the signal. *The latitude designator is always given first.* The center of each grid square should be considered the location of the station vessel for all computations, thus giving a maximum error of 7½ miles and an average probable error of 2½ miles.



Center of grid is the established geographic location of the station.

The grid lines are 10 nautical miles apart.

Courtesy U.S. Hydrographic Office

Fig. 7.212. Position indication grid system for ocean station vessels.

Example.—Assuming we are dealing with Station *A*, and the ship's actual location is at the point marked *X* on the grid above, the Station's signal would be "CBIN." It is also evident that the station vessel bears 64° true 45 miles from its assigned position. See Questions 7.207 through 7.211.

Q. 7.213. Name frequencies used by station WWV, NSS, and NPG for transmitting time signals.

A. The following table shows the various frequencies and time of transmissions.

Station	*Time Signals*	*Operating Frequencies*
WWV	Continuously (24 hours per day)	2.5, 5, 10, 15, 20, 25, 30, 35
NSS	For 5 minutes immediately preceding each even hour	122, 4,390, 9,425, 12,630, 17,000 kc
NPG	0255-0300	115, 9,255, 12,540 kc
	0755-0800	115, 9,255, 12,540 kc
	1455-1500	115, 9,255, 12,540 kc
	1655-1700	115, 9,255, 12,540 kc
	1955-2000	115, 9,255, 12,540 kc
	2355-2400	115, 9,255, 12,540 kc

Q. 7.214. List one typical day CW frequency and one night CW frequency used in a CAA Overseas Foreign Aeronautical Communications Station.

A. A typical day CW frequency is 11,319 kc. A typical night CW frequency is 3,285 kc.

D. An example of CW frequencies used on the Europe-North America Route is as follows:

1. 12,776 kc
2. 11,319 kc
3. 8,554 kc
4. 8,538 kc
5. 6,577 kc
6. 6,563 kc
7. 3,285 kc
8. 3,248 kc

In general, the higher frequencies are used for daytime transmission, and the lower frequencies for nighttime transmission. The intermediate frequencies (around 6 to 8 mc) may be used in both day and night.

Q. 7.215. Which one of the following frequencies would work satisfactorily for CW air-to-ground communication and homing with the aircraft ADF?

1. 1,638 kc
2. 2,970 kc
3. 8,465 kc
4. 11,319 kc

A. The frequency of 1,638 kc.

D. This frequency would be most satisfactory from the point of view of homing. The next highest frequency is 2,970 kc which is beyond the tuning range of the ADF. The ADF tuning range usually ends at 1,750 kc.

Q. 7.216. Under normal conditions in a daylight flight between two points of approximately 1,100 nautical miles apart, what would be a good pair of CW air-to-ground frequencies to select?

A. Frequencies of 8,554 and 8,538 kc would be satisfactory.

D. A *pair* of frequencies may be used for communication. In this event, the aircraft transmits (and ground receives) on one frequency, while the ground station transmits (and aircraft receives) on the other frequency.

Q. 7.217. Why do scheduled aircraft change from "day" to "night" frequencies in radio communications? Which frequency, 5,692 kc or 3,162 kc, is better suited for day operation?

A. Aircraft change from day to night frequencies in order to insure satisfactory communication throughout the 24-hour period. The frequency of 5,692 kc is better suited for day operation.

D. See Questions 7.214 and 7.216.

Q. 7.218. An over-ocean aircraft is circling at the scene of distress where another aircraft has ditched. What would be an appropriate frequency for the circling aircraft to transmit homing signals on to permit surface vessels and other aircraft to effect a rendezvous at the scene?

A. An appropriate frequency would be 500 kc.

D. This frequency would be appropriate, since it is the international distress frequency for aircraft and surface vessels, and would permit the operation of all D/F and ADF equipment for homing.

Q. 7.219. What is meant by simplex operation in air-to-ground communication?

A. Simplex operation is communication in which both receiving and sending is accomplished on a single frequency.

D. The opposite of simplex operation is known as duplex or cross-band operation. In this case a *pair* of frequencies is used. (See Question 7.216.)

Q. 7.220. What is meant by "night effect" in reference to aircraft direction finding? What can be done to counteract night effect when taking aircraft radio bearings?

A. "Night effect" is a reflection of radio waves from the ionized layers which causes errors and fluctuations in bearings. To counteract night effect:

1. Increase the altitude of the aircraft, thereby increasing the strength of the direct wave.
2. Take an average of the fluctuations.
3. Select a lower-frequency station.

D. Night effect is most serious at sunrise and sunset. It may be present on stations at 1,750 kc at distances greater than about 20 miles. As the frequency decreases, the distance of the usuable direct wave will increase until at 100 kc the distance is about 200 miles. However, these are not hard and fast rules and great variations may occur.

Q. 7.221. How is wind drift compensated for when using a radio compass for homing?

A. The following procedure is applied when using a manually rotatable loop. Let us assume the airplane desires to fly a true course of 90° (east). With a true *heading* of 90°, the pilot finds that his airplane is drifting to the left, by observing the indicator of the radio compass, the aircraft is turned slightly into the wind (right) and the loop rotated the same number of degrees in the *opposite* direction. The radio-compass indicator will show the same amount of deviation from the intended route as before. This deviation, however, will gradually decrease to zero if sufficient correction has been made. When the indicator reads zero again, the aircraft is over the intended track. The allowance made for wind drift should now be decreased until the indicator remains centered.

D. With an ADF, the procedure is somewhat simpler. If, as before, the aircraft drifts to the left, the pilot turns to the right until the original bearing is again indicated. It is then, only necessary by trial and error to find the heading which will maintain the original bearing.

Q. 7.222. Is it possible for one aircraft to use a second aircraft as a homing facility with the presently installed ADF equipment? Explain.

A. It is possible to do this. It is, of course, necessary that the second aircraft transmit signals which are at a frequency within the tuning range of the ADF (100 kc to about 1,750 kc).

D. If the transmitting aircraft is rendezvousing over a specific point, the homing procedure is the same as homing on a fixed station. However, if the transmitting aircraft is flying a crossing course, the homing procedure is more difficult since the bearing is continually changing and the homing aircraft must fly a complicated changing course.

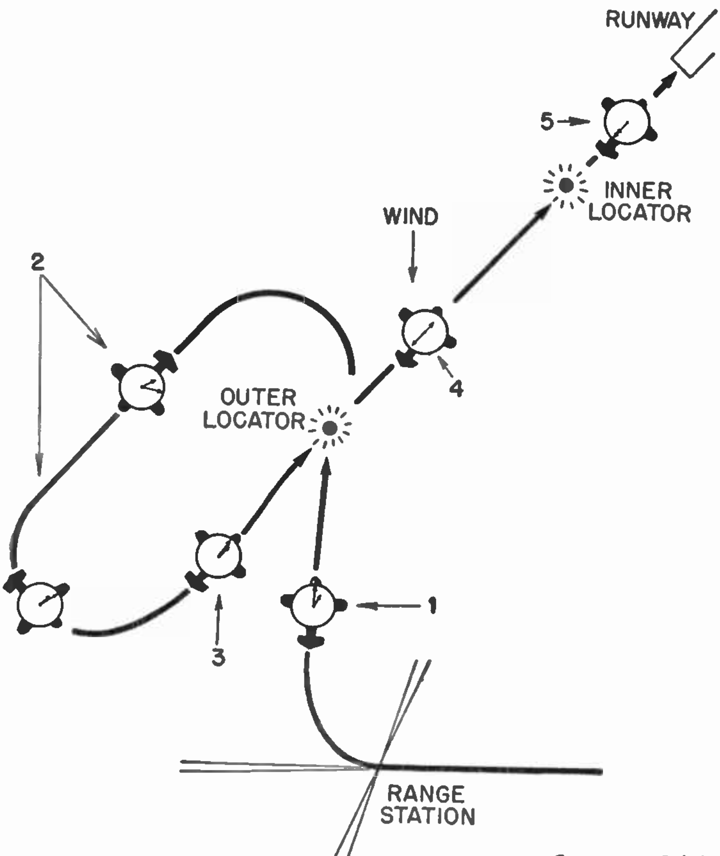
Q. 7.223. How is aircraft ADF equipment used to make an instrument approach?

A. Dual compass-locator stations may be used in connection with a dual ADF system in order to assist in tracking the ILS localizer course when making an ILS approach.

D. The following step-by-step diagrams clearly explain the function of the dual ADF. See the figure.

1. Pilot tunes dual ADF receivers to inner and outer locators, flies homing course from range station to outer locator.

2. While in holding pattern, pointers keep pilot advised of his position relative to both compass locators.



Courtesy CAA

Fig. 7.223. Use of dual compass locators in connection with ILS approach.

3. Pointers indicate aircraft has drifted off course; pilot applies correction.

4. Pointer tuned to outer locator reverses, indicating the outer locator has been passed. Pointers are on reciprocal bearings, indicating aircraft is on course.

5. Pointer turned to inner locator reverses, indicating the inner locator has been passed. Pointers are on same bearing, indicating that aircraft is still aligned on approach course.

This is reproduced from Airways Operations Training Bulletin No. 1.

Q. 7.224. What is the minimum number of ground stations required to provide an instantaneous radio fix with the aircraft D/F?

A. The minimum number of ground stations required is *two.*

D. An instantaneous fix may be made easily by means of a dual ADF. An example of this is shown in the figure. This type of fix could also be taken with a single-unit D/F by taking bearings on each station as rapidly as possible to minimize the plotting error.

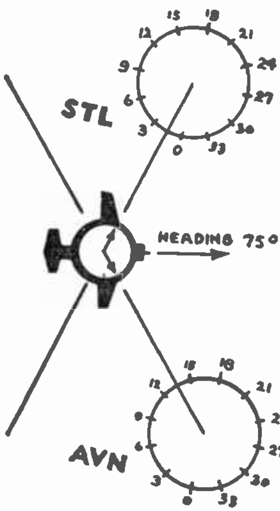


Fig. 7.224. Example of instantaneous fix with dual ADF.

Courtesy CAA

Q. 7.225. In aircraft radio direction finding, what is an instantaneous fix? A running fix?

A. An instantaneous fix results from the intersection of two or more bearing lines which are determined simultaneously (practically). A running fix is one in which bearings are taken at stated time intervals when the ground speed of the aircraft is known.

D. The following example (simplified) shows how a running fix is taken. See the figure. Let us assume that an aircraft wishes to take a running fix and is flying due east (true). A bearing X is taken and

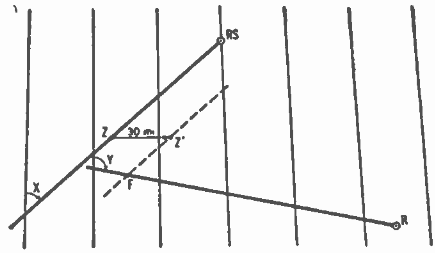


Fig. 7.225. A "running fix" from radio bearing.

Courtesy CAA

the time noted. After taking bearing X and drawing on the chart, the aircraft flies due east for 10 minutes at a ground speed of 180 mph. At the end of 10 minutes the ship will have covered 30 miles. At this time a bearing Y is taken on a second radio station. From any convenient point Z on the line of bearing X draw a line ZZ′ due east, a distance of 30 miles. Through point Z′ draw a line parallel to bearing line X. The intersection of this new bearing line Y with the new parallel line is the fix F.

Q. 7.226. Discuss briefly the D/F procedure known as "boxing."

A. "Boxing" the compass is an exercise which pilots use to familiarize themselves with the correlation between the 360° compass system and the corresponding directions.

D. An example of the practice of boxing is shown by the following examples:

Degrees	*Direction*
000°	True north
022°30′	North-northeast
045°	Northeast
090°	East
180°	South
270°	West

Q. 7.227. Radio-bearing errors due to terrain effect decrease as the altitude of the aircraft decreases. TRUE or FALSE?

A. This statement is FALSE.

D. Bearing errors due to terrain effect are most serious in the vicinity of the terrain causing the reflection and refraction of the radio waves. Therefore, the errors would tend to *increase* as the altitude decreases.

Q. 7.228. Will flying in or near the vicinity of a severe electrical storm cause erratic functioning of an aircraft ADF unit?

A. Yes.

D. When flying in the vicinity of a severe electrical storm, the loop may have a tendency to swing back and forth between the desired station and the storm. This is true because the electrical discharges cover a wide band of frequencies, some of which are within the band to which the ADF receiver is tuned. These discharges will have appreciable signal strength when the storm is close to the aircraft and thus will cause erratic functioning of the ADF.

Q. 7.229. Does the aircraft's heading affect the error in radio bearings caused by coast-line refraction?

A. The heading does not affect this error.

D. The coast-line refraction error is caused by bending of the radio waves passing over the coast line from a land station. Thus they cannot be affected by the heading of the aircraft.

Coast-line refraction errors are generally least when the line of bearing crosses a straight coast line at right angles, and greater when the angles are other than about 90°.

Q. 7.230. An aircraft is flying parallel to a coast line and observes a relative bearing of 10° on a radio beacon located ahead of the aircraft's position. Will the correct relative bearing be greater or less than the observed 10° relative? Explain.

A. The correct relative bearing will be greater than the observed relative bearing. This is due to the refraction of the radio wave when going from over land to over water.

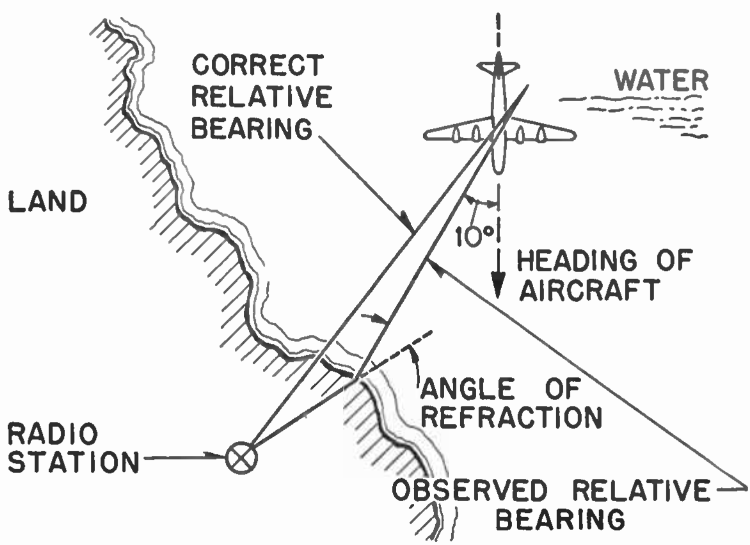


Fig. 7.230. Effect of refraction on relative bearings.

D. The correct relative bearing may be identified with the aid of the figure. You can see that the observed relative bearing of 10° has actually been refracted several degrees due to the greater conductivity of the sea water. A correction must be made for the error thus incurred, and this is often to be found on charts.

Q. 7.231. Explain fully the procedure in obtaining a radio fix on two stations using the aircraft D/F loop.

A. The following procedure applies when a Lambert chart is used.

In taking a radio bearing to obtain a line of position in determining a fix, it is necessary to note the following three items at the instant of taking the bearing.

1. The *compass* heading of the aircraft
2. The *relative* bearing of the radio station
3. The exact time.

Step 1. Convert the *compass* heading to a true heading (Question 7.243) by applying the correct variation and deviation applicable at the instant of taking the bearing.

Step 2. (See part (A) of the figure.) It is assumed that the true heading is 30°. Find the relative bearing of station *A* from the nose of the aircraft (clockwise) we find this *relative* bearing to be 15°.

Step 3. Add the true heading to the relative bearing *A* as 30° + 15 = 45°. This is the true bearing of the radio station *A* from the aircraft's position.

Step 4. Find the relative bearing of station *B* from the nose of the aircraft (clockwise). We find this *relative* bearing to be 300°.

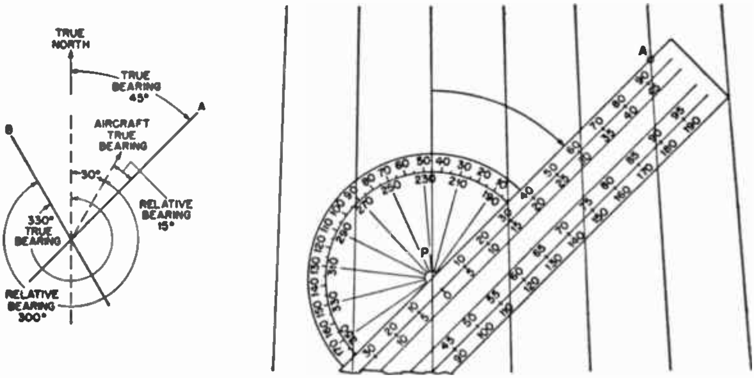
Step 5. Add the true heading of the aircraft (30°) to the relative bearing of station *B* (300°) to station *B* from the aircraft's position. Thus, 30° + 300° = 330° true bearing.

Step 6. Thus far we have the following:

(a) True heading of aircraft = 30°
(b) True bearing of station *A* = 45°
(c) True bearing of station *B* = 330°.

Step 7. The bearings must now be plotted on the chart and one method is as follows:

In part (B) of the figure, the pilot estimates his probable position to be in the vicinity of point *P*. The true bearing of station *A* (45°) is measured by means of the protractor at the meridian nearest the probable position. The protractor is moved vertically along the meridian (with the same angle) until its plotting edge passes through the radio station *A*. A line from station *A* is drawn along the edge of the protractor. This is the desired bearing from station *A*.



(A) (B) *(B) Courtesy CAA*

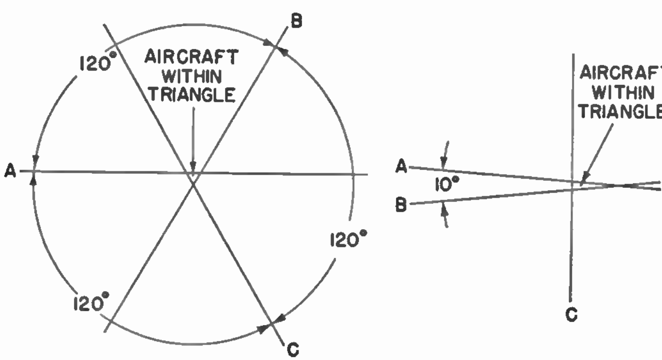
Fig. 7.231. (A) Radio fix on two stations, (B) plotting a radio bearing on a Lambert chart.

Step 8. In a similar manner the bearing is plotted for station *B*. The intersection of the two lines indicates the position of the aircraft at the time the bearings were taken. If the computations were made rapidly, it may be assumed that the aircraft is very close to the intersection.

D. When plotting bearings of Mercator charts, a correction must be applied. The angles of correction may be found from tables.

Q. 7.232. What angular separation of transmitting stations will give best results when taking radio bearings to get a three-station fix?

A. Best results will be obtained when the three stations are 120° apart.



(A) (B)

Fig. 7.232. (A) Best angular separation for three-station fix, (B) minimum angular separation for three-station fix.

D. When the stations are 120° apart, the triangle which represents the area of probable position will be such that the least possible error of position will occur. (See part (A) of the figure.) However, it should be noted that satisfactory bearings can be obtained when two of the stations are separated by as little as 10° as shown in part (B) of the figure. Note that, in the latter case, the triangle of position may be greatly elongated.

Q. 7.233. Explain the "45-90" degree distance-off procedure of determining distance from an aircraft to a radio-beacon station.

A. This is a method of determining position by means of only *one* radio-beacon station and is also referred to as "doubling the angle." (See the figure.)

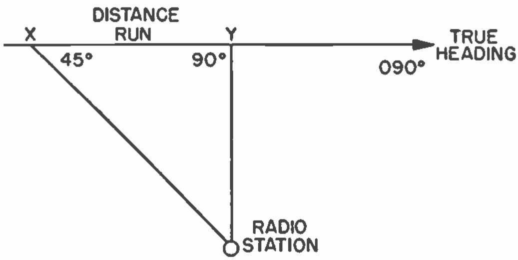


Fig. 7.233. The 45-90 degree method of obtaining fix.

Assume the ground speed is known to be 180 mph, on a true course of 90°. The aircraft reaches point *X* at which point the *relative* bearing of the radio station is found to be 45°. The time is noted and the same heading maintained until the relative bearing becomes 90° at point *Y*. The distance *XY* is computed and will be the same as the distance from the radio station to point *Y*, thus establishing the location of the aircraft. Assuming 10 minutes elapsed between *X* and *Y*, the aircraft is then 30 miles from the radio station.

D. This method does not have to be confined to 45° and 90° angles. The procedure is always true as long as the second angle is *doubled* with respect to the first. For accuracy, the first bearing (relative) should not be less than 30°.

Q. 7.234. On which side of an aircraft is a radio beacon located if the relative bearings taken aboard the aircraft are progressively increasing?

A. The radio beacon is located on the right side of the aircraft.

D. Relative bearings are always measured from the nose of the aircraft in a clockwise direction. Therefore, if the bearings are *increasing*, the radio beacon must be to the *right* of the aircraft.

Q. 7.235. Describe the procedure for determining sense (orientation) using an aircraft manual D/F loop and an aerophare.

A. There are several methods used to resolve the 180° ambiguity inherent with a loop. The following is known as the 90° method.

Step 1. Set the loop to the homing position (0 in the azimuth scale).

Step 2. Turn the aircraft to obtain a null, and adjust the volume control for a satisfactory null width.

Step 3. Check for the center of null with the azimuth.

Step 4. Set the gyrocompass to 0°, or note compass heading.

Step 5. Turn left 90° to a gyro heading of 270° and fly this heading 3 to 5 minutes.

Step 6. Turn aircraft *right* to 0° on gyro.

Step 7. Hold aircraft heading and rotate loop azimuth to null position.

Step 8. If null bearing has shifted *clockwise*, the station is *ahead*. If null bearing has shifted *counterclockwise*, the station is *behind*.

D. Radio compasses which employ visual indicating instruments usually do not require any orientation procedure. In this case, a right-rudder movement will cause the needle to move from left to right when *approaching* a station, and from right to left when flying *away* from a station.

Q. 7.236. Upon what factors does the usable range of an aircraft D/F loop depend?

A. The following factors will influence the range:

1. Receiver sensitivity
2. Altitude of aircraft
3. Frequency of transmissions
4. Dimensions and design of loop
5. Effectiveness of indicating equipment
6. Amount of interference present
7. Time of day or night.

D. See Questions 7.67, 7.68, 7.69, and 7.70.

Q. 7.237. With reference to loop orientation, what is meant by the "pointer-progression" method?

A. The "pointer-progression" method is an alternate method of loop orientation which may be used instead of the 90° method described in Question 7.235.

D. The procedure used in the pointer-progression system is as follows.

Step 1. Set the loop in *range* position. This is 90° off *null* position.

Step 2. Turn the ship right or left until a null is obtained, and adjust volume control for satisfactory null width.

Step 3. Observe the gyro or magnetic compass heading and fly a steady course.

Step 4. Note the *direction* of rotation of the loop which is necessary to maintain a *null* signal.

Step 5. If the rotation is *clockwise*, the station is off the *right* wing. If the rotation is *counterclockwise*, the station is off the *left* wing.

Step 5. Thus, having determined the direction of the station, a turn in that direction is made, and the loop may then be turned to the homing position.

Q. 7.238. An aircraft is establishing a fix with radio bearings. One station is dead ahead, the second station approximately abeam to the right. Which bearing is it advisable to secure first, the speed line or the course line?

A. It is advisable to secure the course line first.

D. The course line is the line from the aircraft to the station dead ahead. The *direction* of this does *not* vary. The direction of the speed line (abeam) *does* vary with time. It is, therefore, advisable to secure the *course* line *first*, since no errors of position will then be incurred regardless of the time which elapses until the speed line is secured.

Q. 7.239. Explain the method of determining the aircraft's position by "doubling the angle."

A. This procedure is fully discussed in Question 7.233.

Q. 7.240. Why is it necessary to maintain constant heading and level flight when taking radio bearings with the aircraft D/F?

A. A constant heading and level flight must be maintained to insure the accuracy of the bearing.

D. Radio bearings are *relative* bearings which must be added to the true heading of the aircraft to obtain a true bearing (Question 7.231). Thus it is necessary that an accurate reading of the true heading of the aircraft be made to insure the accuracy of the true bearing. This is accomplished by flying a straight, level course for the period of the readings. Deviations from the course may cause the compass to be erratic and thus make it difficult to obtain accurate readings.

Q. 7.241. To increase the relative bearing on an aircraft D/F loop, should the aircraft be turned RIGHT or LEFT?

A. The aircraft should be turned to the LEFT.

D. See Questions 7.230 and 7.234.

Q. 7.242. Describe briefly the operational procedure for calibrating an ADF installation in flight.

A. The following procedure applies specifically for the RCA AVR-21 ADF, but is similar for other types.

After the initial adjustments have been completed, a flight test and quadrantal error calibration are required. Select a day when the air is fairly smooth; greatest accuracy is obtained when flying at an altitude of approximately 1,000 feet.

When in the air, check all operational functions to insure high pointer sensitivity, correct loop drive phasing, and freedom from noise generated within the aircraft. There should be no bearing error or crawl as the receiver is tuned through the flat portion of the selectivity curve. The pointer drive to clear channel stations should be at a rate greater than 20° per second.

Quadrantal error calibration: Loop correction data should be obtained over flat country well away from shore lines or large rivers. Select a station in the 200- to 400-kc range, at a distance of 75 to 150 miles and so located as to have a wave travel path entirely over level country. Hills, lakes, shore lines, or extremely large cities will create detectable distortion in the wave front under certain conditions.

The calibration run should be planned with two operators: one operator to call out the directional gyro readings every 10°, the other operator to note and record the relative station bearing. While in flight, only the data obtained should be recorded; the actual calibration curve must be plotted later.

Two methods are described. The first method requires a minimum of air work and provides acceptable accuracy. Proceed as follows.

1. Select a well-defined land mark and fly the aircraft directly over the land mark toward the station. Observe that the indicator pointer reads with the indicator scale set a 0.
2. As the aircraft passes the land mark, set the directional gyro to 0.
3. Immediately start a one-half standard rate *flat* turn by forcing the aircraft to turn with the engine and rudder control.
4. During this turn, record the relative station bearing at every 10° of travel of the directional gyro. Also record the directional gyro heading, to avoid confusion when plotting.
5. Complete the turn back to the starting point, recheck the directional gyro 0, and start a turn in the opposite direction, recording the readings as before.

Proceed as follows to plot the error calibration.

1. On a large-scale map, locate the land mark and the station. Plot

the circles flown to approximate scale on the map, and with a protractor mark off 20° divisions to indicate the position error as related to the station.

2. Convert both directional gyro columns to the same sign to obtain the difference of travel between the directional gyro and the loop pointer.

3. From the map, add or substract the circle or position error to the ADF reading.

4. In the next column, record the difference in relative bearings between the directional gyro readings and the corrected ADF readings from Step 3.

5. Plot this last set of figures on graph paper against the corresponding directional gyro headings.

Note—If the directional gyro readings are laid out horizontally and the plus and minus error readings are laid out vertically from a center line, the resultant plot for 360° will be an approximate double sine wave. Between 0 and 90°, and between 180° and 270°, the error is positive; that is, the loop has lagged the actual relative station position, so the indicator pointer must be advanced for correct relative bearings. Between 90° and 180°, and between 270° and 360°, the error is negative.

The curve as plotted provides the advance or retard data to be applied to the corrector cam in the loop assembly. Odd readings may be disregarded as on most aircraft with a belly-loop installation there is no error at 0°, 90°, 180°, and 270° and the correction between these points is at a uniform rate in each quadrant.

An alternate calibration method is to "fly a sunflower" over a given land mark. Use a main highway or other well-defined land mark for aligning the directional gyro to 0, instead of a 0 heading on the station. Do not use a railroad track or a power line at low altitude, as some wave-front distortion may exist under conditions of poor ground conductivity. Proceed as follows.

1. Fly over the land mark at every 10° to 15° heading on the directional gyro, and record the station bearings.

2. Reset the directional gyro to the land mark at 15- to 20 minute intervals to correct gyro drift.

3. Continue to fly over the land mark until the initial starting point is reached, thus completing 360°.

When plotting the data thus obtained, determine the angle between the set directional gyro heading and the station position each time the land mark is crossed; then proceed as already described to obtain the correction curves.

The second calibration method may be more accurate than that first outlined; however, it requires extensive air work with its attendant operator and pilot fatigue, which may actually destroy the basic accuracy of the system.

Loop cam correction: After the correction data has been obtained by either of the two preceding methods, the loop cam correction may be applied as follows.

1. Remove the loop from the aircraft, take off the bottom plate and housing and remove the three screws holding the corrector mechanism and selsyn transmitter in place. No leads need be disconnected.
2. With a screwdriver, start applying corrections to the studs at the points where greatest correction is required. Take only one-half to one turn at a time on each screw, to avoid badly distorting the cam ribbon. In each case, use the stud directly beneath the calibration point under consideration. By rotating the selsyn drive plate, the applied correction at all points may be read from 0, positive or advance, and negative or retard.
3. Work the desired correction carefully around the complete azimuth marking until, when the "0" of the correction scale is opposite each azimuth mark, the cam pointer is exactly on the degrees-correction desired at that point.
4. Reassemble the transmitter in the loop assembly, taking care to exactly match the transmitter gear slot to the transmitter plate stud.

Fleet calibration: The preceding operations complete all quadrantal error corrections. On similar aircraft with a similar loop location, the quadrantal error will be within the reading error; hence for fleet operation one correction may be applied to all loop assemblies with the data taken from one aircraft.

Q. 7.243. Define the following: relative bearing, magnetic bearing, true bearing, Mercator bearing, true course, track, magnetic heading, compass heading, true heading, compass error, advanced bearing, retarded bearing, and radio line of position.

A. *Relative bearing*: The bearing of a radio station measured clockwise from the nose of the aircraft (See Questions 7.230, 7.234, and 7.241.)

Magnetic bearing: The true bearing corrected for the appropriate magnetic *variation*.

True bearing: The direction of one object from another, expressed as an angle measured clockwise from *true* north.

Mercator bearing: A radio bearing which is converted from a great-circle direction to a rhumb-line (straight-line) direction for plotting on a Mercator chart. (See Question 7.244.)

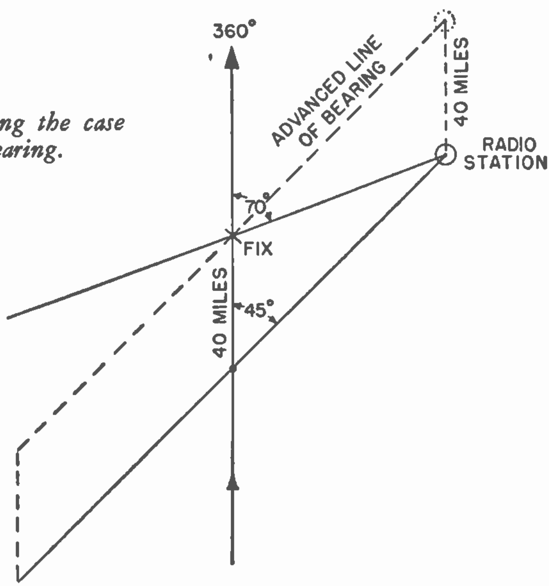
True course: The direction over the surface of the earth, expressed as an angle measured clockwise from true north, that an aircraft is intended to be flown. It is the course laid out on the chart or map.

Track: The *actual* path of an aircraft over the surface of the earth. Track is the path that *has been flown.*

Magnetic heading: The heading of the aircraft as indicated on a magnetic compass and corrected for magnetic variation. (But not compass deviation.)

Compass heading: The magnetic heading to which compass deviation has been applied.

Fig. 7.243. Illustrating the case of advanced bearing.



True heading: The direction in which the aircraft is pointed, measured in degrees from true north.

Compass error: The algebraic sum of the magnetic variation and compass deviation. Compass deviation is an error of compass reading mostly caused by the presence of nearby metallic objects.

Advanced bearing: An advanced bearing is a bearing in which a running fix is plotted by the use of two bearings on *one* station. It is best explained by an example. (See the figure.) An aircraft is flying a true course of 360° at a ground speed of 240 mph. At 1400 hours (2pm) a bearing is taken on a radio station and is found to be 45°

(relative). Ten minutes and 40 miles later another bearing is taken on the same station. This bearing is found to be 70° (relative). To obtain a fix, move the first bearing up in the direction of the true course the distance of 40 miles as shown by the dotted lines. The intersection of these two lines is the fix.

Retarded bearing: A retarded bearing is similar to an advanced bearing, except that instead of moving the first bearing up to intersect the second, the second bearing is moved *back* to intersect the first. In practice, the advanced bearing is preferred.

Radio line of position: A plotted line which is the result of a radio bearing. Usually the time is indicated showing when the bearing was made.

RADIO NAVIGATION OF AIRCRAFT

Q. 7.244. Explain why Mercator charts are used in long-range air navigation. What is a rhumb line? What is a great circle?

A. Mercator charts are used because they provide a projection on which all rhumb lines are represented as straight lines. A rhumb line is a line which crosses all meridians of the earth at a constant angle. A great circle is any circle drawn upon the earth which divides it into two *equal* parts.

D. A Mercator chart is so made, that all meridians of longitude are represented by parallel vertical lines, and all parallels of latitude are shown as parallel horizontal lines. The straight lines representing meridians and parallels all cross each other at right angles. This type of chart is used extensively in marine navigation and in air navigation when the aircraft carries a navigator.

A rhumb line on a Mercator projection is a *straight* line. This is a distinct advantage in the navigation of surface vessels, but the advantage is lost in the case of aircraft because of their far greater speed.

Q. 7.245. Give the rules for applying Mercator correction to a radio bearing taken by the aircraft; by the ground D/F station.

A. For bearings taken by the aircraft, the following rules apply.

1. In *north* latitudes, if the aircraft is *east* of the station the correction is *subtracted.*

2. In *north* latitudes, if the aircraft is *west* of the station, the correction is *added.*

3. In *south* latitudes, if the aircraft is *east* of the station, the correction is *added.*

4. In *south* latitudes, if the aircraft is *west* of the station, the correction is *subtracted.*

When bearings are taken from a ground station, the foregoing rules are reversed.

D. The path of a radio bearing is always a *great* circle. Therefore, it can only be represented on a Mercator chart by a *curved* line. To plot the bearing as a *straight* line (rhumb), a correction must be applied. This correction is equal to the angular distance between the rhumb line and the tangent to the curve, which represents on the Mercator projection, the great circle between the aircraft and the radio stations. For distances less than 100 miles, this correction is usually negligible.

Q. 7.246. On a Mercator chart, are the rhumb-line and great-circle tracks always represented by a straight line?

A. The rhumb line is, but the great-circle track is represented by a *curved* line.

D. See Question 7.245.

Q. 7.247. Explain why it is necessary to apply Mercator correction to radio bearings.

A. It is necessary to apply correction to plot a radio bearing as a *straight* line since the radio path is normally a great circle.

D. See Question 7.245 for explanation.

Q. 7.248. Under what conditions is it unnecessary to apply Mercator correction to an observed true bearing?

A. When the distance to the station is less than 100 miles.

D. If the distance is less than 100 miles, the maximum error will not exceed 1° except in high latitudes. (See also Question 7.245.)

Q. 7.249. What is meant by compass deviation? Magnetic variation?

A. Compass deviation is an error of compass reading, which is caused by the presence of magnetic metals and other magnetic disturbances in the aircraft.

Magnetic variation is the angle between *true* north as indicated on a chart, and *magnetic* north shown on a compass.

D. The conventional magnetic compass is actuated by the force of the earth's magnetic field and, therefore, indicates *magnetic* and not true directions. The magnetic north pole, for example, is not located at the geographical pole, but approximately at latitude 71° north and longitude 96° west. Variation may be east or west depending upon the place at which it is measured. For example, the variation at New York, N.Y., is approximately 11° west.

Q. 7.250. What is the relative bearing of a radio station, as observed on an aircraft, if the true bearing from a radio station to the aircraft is

060°, and the aircraft has a compass heading of 020° with a compass error of 2° west and a variation of 10° west?

A. The relative bearing of the radio station is 232°.

D. (See the figure.)

Step 1. Find the true heading (TH).

TH = Compass heading (CH) — deviation (D) — variation (V)

TH = 20 — 10 — 2

TH = 8°.

Step 2. Find the relative bearing (RB). Since the original bearing of 060° was taken from the ground, the bearing of the station from the aircraft would be 60 + 180 = 240° (true)

RB = true bearing (TB, taken from aircraft)—TH

RB = 240—8

RB = 232°.

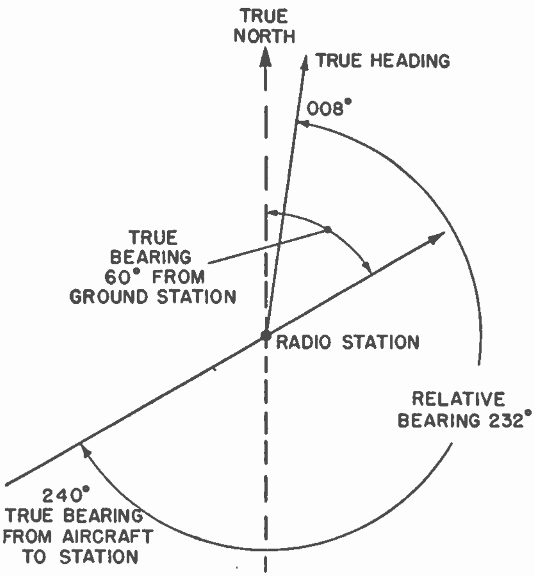


Fig. 7.250. Finding the relative bearing of a radio station.

NOTE—After consultation with the FCC, it was determined that there was a typographical omission in the wording of the question as it appeared in the mimeographed supplement No. 5 to the Study Guide. The wording of the question as given here is the corrected version, as the original wording made it practically impossible to answer the question. This explains any discrepancy in the wording of this question as it may appear in other sources.

Q. 7.251. An aircraft is flying from station A to station B using the dual ADF with the RED pointer on station A and the GREEN pointer on station B. What ADF readings would indicate that the aircraft is on course with a 15° drift angle?

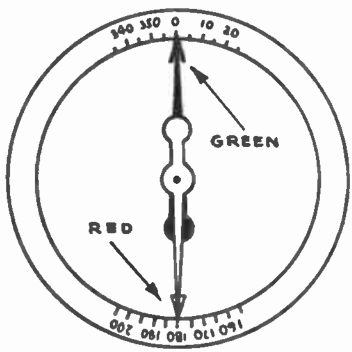
A. There are two possible solutions.

1. With the wind from the *left*, the GREEN pointer reads 15°, the RED pointer reads 195°.

2. With the wind from the *right*, the GREEN pointer reads 345°, the RED pointer reads 165°.

D. A dual ADF is actually two separate ADF units connected to a dual azimuth indicator. (See part (A) of the figure.) The control knobs of one ADF are colored RED and the indicator pointer for this one is similarly colored. The control knobs and indicator pointer of the second ADF are colored GREEN. When an aircraft is flying on a direct line between two stations, the two pointers are always 180° apart. If there is no wind drift the pointers appear as in part (B) of the figure. When there is a 15° drift angle and the wind is from the left, the pointers appear as in part (C) of the figure.

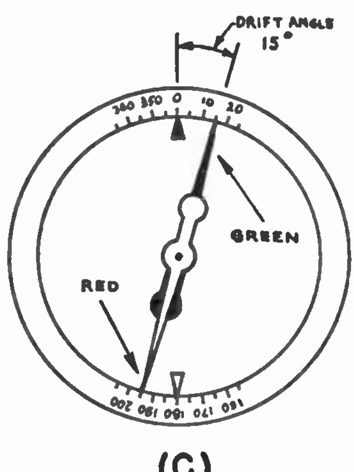
(A)



(B)

Courtesy Bendix

Fig. 7.251. (A) Type MN-42C dual azimuth indicator. (B) Plane on course-no drift. (C) Plane on course —15°.



(C)

Q. 7.252. An aircraft is on a true heading of 225°. Variation is 2° west and deviation is 3° east. What relative bearings would be necessary to obtain true bearings of 275° and 45°?

A. A relative bearing of 50° will give a true bearing of 275°. A relative bearing of 180° will be a true bearing of 45°.

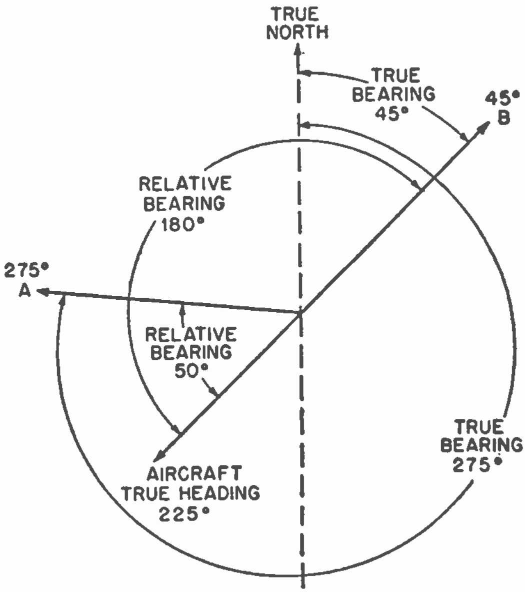


Fig. 7.252. Relating drift angle relative to true bearing.

D. See the figure. The aircraft has a *true* heading of 225°. Station *A* has a true bearing of 275°, and station *B* has a true bearing of 45°. The lines representing these are shown on the drawing. The relative bearing of station *A* is equal to the angle included from the true heading, clockwise to the true bearing *A* or $RB_A = 275 - 225 = 50°$. The relative bearing of station *B* is equal to the angle included from the true heading clockwise to the true bearing *B* or $RB_B = (360 - 225) + 45° = 180°$. The figures for variation and deviation are not needed for the solution to this problem. (See Question 7.243 for definitions.)

Q. 7.253. An aircraft is on a magnetic heading of 50° and relative bearings are being taken on a station off to the RIGHT. If it is desired to turn directly toward the station when a QDM of 90° is reached, what relative bearing will give the desired QDM?

A. A relative bearing of 40°.

D. The question is a little confusing since a *relative* bearing is measured from the nose of the aircraft, and all we are given is the *magnetic* and not the *true* heading. However, if we call this a *magnetic* relative bearing, the solution is as follows:

$$MRB = QDM - MH \text{ or}$$
$$MRB = 90 - 50 = 40°.$$

Q. 7.254. An aircraft is on a true bearing of 100° from a radio beacon. What is the relative bearing if the magnetic heading is 015°, and the variation is 10° west?

A. The relative bearing is equal to 95°.

D. Step 1. Find the true heading (TH).
TH = Magnetic heading (MH or CH) ± variation, ± deviation (No deviation given here) TH = CH — V

$$TH = 15 - 10 = 5°.$$

Step 2. Find the relative bearing (RB).

$$RB = \text{True bearing (TB)} - TH$$
$$RB = 100 - 5 = 95°$$

A simple rhyme used by the author and many other pilots, has been found to be of considerable help in remembering when to add or subtract variation and deviation.

Converting from true course to compass course:

If true to compass is the test, then east is least (—), and west is best (+).

From compass course to true course:

If compass must be true, then east will gain (+) and west will lose (—).

Q. 7.255. An aircraft observes a relative bearing of 254° on an aerophare. If the compass heading is 41°, deviation 2° east, variation 8° west, what is the true bearing of the aerophare?

A. The true bearing is 289°.

D. Step 1. Find the true heading.

$$TH = CH + D - V$$
$$TH = 41 + 2 - 8$$
$$TH = 35°.$$

Step 2. Find the true bearing.

$$TB = TH + RB$$
$$TB = 35 + 254$$
$$TB = 289°.$$

Q. 7.256. What is the true bearing of an aerophare with respect to an aircraft flying a magnetic heading of 127° if the loop reading is 10° left, deviation 3° west, variation 4° east, and the quadrantal error is plus 2°?

A. The true bearing of the aerophare is 116°.

D. Step 1. Find the true heading.

TH = CH—D+V

TH = 127—3+4

TH = 128°

Step 2. Find the relative bearing.

RB = Loop reading plus quadrantal error

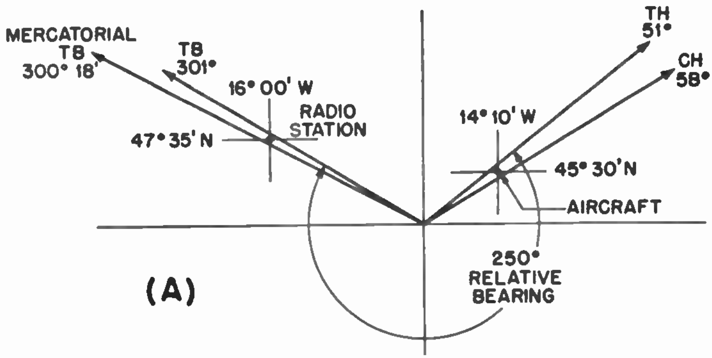
RB = 10+2=12°.

Step 3. Find the true bearing.

TB = TH—RB

TB = 128—12=116°.

Q. 7.257. An aircraft is flying on a CH of 058° in position 45° 30′ north and 14° 10′ west. A relative bearing of 250° is taken on a radio station located at 47° 35′ north and 16° 00′ west. Compass deviation is 3° east and magnetic variation is 10° west. What bearing should be plotted on a Mercator chart?



Mid-Lat.	Difference of longitude in degrees									
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
0°	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5°	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.5	0.5
10°	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0
15°	0.0	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.5
20°	0.0	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
25°	0.0	0.5	0.5	1.0	1.0	1.5	1.5	1.5	2.0	2.0
30°	0.5	0.5	1.0	1.0	1.5	1.5	2.0	2.0	2.5	2.5
35°	0.5	0.5	1.0	1.0	1.5	1.5	2.0	2.5	2.5	3.0
40°	0.5	0.5	1.0	1.5	1.5	2.0	2.0	2.5	3.0	3.0
45°	0.5	0.5	1.0	1.5	2.0	2.0	2.5	3.0	3.0	3.5
50°	0.5	1.0	1.0	1.5	2.0	2.5	2.5	3.0	3.5	4.0
55°	0.5	1.0	1.0	1.5	2.0	2.5	3.0	3.5	3.5	4.0
60°	0.5	1.0	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.5
65°	0.5	1.0	1.5	2.0	2.5	2.5	3.0	3.5	4.0	4.5
70°	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.0	4.5
75°	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0

(B)

Courtesy CAA

Fig. 7.257. (A) Plotting mercatorial bearing. (B) Correction required to convert a radio great circle bearing to mercatorial bearing.

A. The Mercator true bearing of the radio station is 300° 30′.

D. See the figure.

Step 1. Find the true heading.
TH = CH + D — V
TH = 58 + 3 — 10
TH = 51°.

Step 2. Find the true bearing *without* Mercator correction.
TB = TH + RB
TB = 51 + 250
TB = 301° (uncorrected).

Step 3. Determine the relative position of the aircraft with respect to the station. From part (A) of the figure, we see that the aircraft is east of the station.

Step 4. Determine the Mercator correction.

First. Find the *middle* latitude between the aircraft and station. Difference in latitudes = 47° 35′—45° 30′ = 2° 05′. Middle latitude = ½ of 2° 05′ plus 45° 30′ = 1° 0.025′ + 45° 30′ = 46° 32.5′.
For practical purposes = 45°.

Second. Find the *difference* in longitude between the aircraft and the station. Difference = 16° 00′ — 14° 10′ = 2° (practically)

Third. Consult the Table in part (B) of the figure and find that the correction is 0.5°. Since the aircraft is east of the station, the correction is *subtracted.*

Step 5. Find the Mercatorial bearing.
MB = TB—Correction
MB = 301°—0.5° (or 30′)
MB = 300° 30′.

Q. 7.258. An aircraft is tracking 315° at a ground speed of 240 mph. At 1800 GMT a radio station bears 315° relative and at 1805 GMT the same station bears 270° relative. What is the distance from the aircraft to the ground station at 1805 GMT?

A. The distance to the ground station is 20 miles.

D. This is a problem of "doubling the angle," since the reciprocal bearings are 45° and 90°. In this type of "fix" problem, the running distance is always equal to the distance to the ground station at the time of taking the second bearing. At 240 mph, the aircraft will cover 20 miles in 5 minutes and this is also the distance to the station.

Q. 7.259. An observed relative bearing is 75°. Which direction and how many degrees must the aircraft be turned to move the relative bearing to 125°?

A. The aircraft must be turned to the LEFT 50°.

D. See Questions 7.241 and 7.243.

Q. 7.260. An aircraft is flying in extreme turbulence. The first relative bearing is 90° and the second relative bearing is 95°. Is it safe to assume that the station is on the RIGHT?

A. It is reasonably safe to make this assumption.

D. The question is a trifle vague. It is assumed (in the answer) that the pilot is able to determine the attitude of the aircraft by visual or instrument means. If he knows he is not upside down, it is reasonably safe to assume the station to be on the RIGHT, since the two bearings are very close to each other and are at right angles to the aircraft heading.

Q. 7.261. An aircraft is homing on a radio station. The correct relative bearing is 0. If the null moves slowly from 0 to 355, 350, 345, and the compass heading remains constant, is the drift RIGHT or LEFT?

A. The aircraft is drifting to the RIGHT.

D. With a steady compass heading, the loop is being turned to the LEFT (counterclockwise). This indicates that the aircraft is drifting RIGHT of the homing station.

Q. 7.262. The compass heading is 125°. The aircraft is south of the radio beacon and both deviation and variation are 0°. What relative bearing will be indicated when the aircraft intercepts the 175° azimuth from the station?

A. The relative bearing will be 230°.

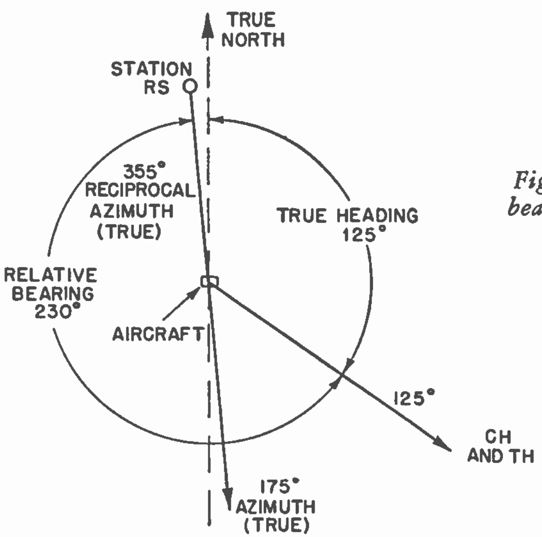


Fig. 7.262. Relative bearings from azimuth.

D. Since there is no deviation or variation, the compass heading is also the *true* heading. At the time the aircraft intercepts 175° azimuth (true), the true bearing will be 355°. This is the reciprocal of 175°. (See the figure.)

The relative bearing is found as follows:

RB = TB—TH
RB = 355—125
RB = 230°.

Q. 7.263. Given: Compass heading 195°
Deviation 9° west
Variation 6° east
Find true heading.

A. True heading is 192°.

D. TH = CH+V—D
TH = 195+9—6
TH = 192°.

NOTE—This is actually the *True Course* (TC) but since no wind drift is given, the true course is the same as the true heading. This also applies to some of the preceding questions.

Q. 7.264. If the compass heading is 289°, deviation 5° west, variation 7° east, and the relative bearing on the station 172°, what is the true bearing?

A. The true bearing is 103°.

D. Step 1. Find the true heading.
TH = CH—D+V
TH = 289—5+7
TH = 291°.
Step 2. Find the true bearing.
TB = TH+RB
TB = 291+172
TB = 463°.
Step 3. Since this is greater than 360°, subtract 360°.
TB = 463—360 = 103°.

Q. 7.265. An aircraft is on a compass heading of 236°. The relative bearing on a radio station is 326°. Variation is 23° east, deviation 2° west and the loop correction is minus (—) 4°. What is the true bearing?

A. The true bearing is 219°.

D. Step 1. Find the true heading (no wind).
TH = CH+V—D
TH = 236+23—2
TH = 257°.

Step 2. Find the true bearing.
TB = TH + RB—loop correction
TB = 257 + 326—4
TB = 579°.
Step 3. Subtract 360°.
TB = 579—360
TB = 219°.

Q. 7.266. The true bearing from a radio station to an aircraft is 068°. The aircraft is flying a compass heading of 016°, deviation 2° west, variation 11° west. What is the relative bearing on the aircraft loop?

A. The relative bearing is 65°.

D. Step 1. Find the true heading (no wind).
TH = CH—D—V
TH = 16—2—11
TH = 3°.
Step 2. Find the relative bearing.
RB = TB—TH
RB = 68—3
RB = 65°.

BIBLIOGRAPHY

It is recommended that the student obtain the following material to assist him in preparing for the Aircraft Radio Telegraph license.

KEY TO REFERENCE ABBREVIATIONS

CAR............Refers to Civil Air Regulations.
FCC............Refers to Rules and Regulations of the Federal Communications Commission.
IACO..........Refers to International Civil Aviation Organization publications.

* * * * * *

REFERENCE MATERIAL

The material listed below may be obtained by writing to the Superintendent of Documents, United States Government Printing Office, Washington 25, D.C.

CIVIL AIR REGULATIONS: Part 4B, Part 16, Part 29, Part 33, Part 40, Part 41, Part 42, Part 43, Part 44, Part 60, Part 61

Rules and Regulations of the Federal Communications Commission:
Part 9, Aeronautical Services
Part 13, Commercial Radio Operators

CAA Airways Operations Training Bulletin Series:

Bulletin No.	*Title*
1.	Instrument Landing System
2.	Location Markers and Homing Facilities
3.	Visual-Aural Ranges and Omniranges
4.	Distance Measuring Equipment and Offset Course Computer
5.	(Not Applicable)
6.	Radar Fundamentals and Surveillance, Precision and Route Radar
7.	LORAN

Miscellaneous Government Printing Office Publications:

Advanced Work in Aircraft Radio (NAVPERS 10314)
Aircraft Radio Equipment (NAVPERS 10312)
Aircraft Electrical Systems (NAVPERS 10315)
Advanced Work in Aircraft Electricity (NAVPERS 10316)
CAA Flight Information Manual
CAA Bulletin No. 24—Practical Air Navigation
CAA Bulletin No. 29—Pilots' Radio Manual

The material listed below may be obtained without charge by writing to the office of Aviation Information, Civil Aeronautics Administration, Washington 25, D. C.

CAA Safety Regulation Release No. 191, dated September 28, 1945
CAA Safety Regulation Release No. 272, dated December 19, 1947
CAA Safety Regulation Release No. 279, dated April 16, 1948
CAA Aviation Safety Release No. 288, dated June 3, 1948
CAA Aviation Safety Release No. 290, dated June 21, 1948

The material listed below may be obtained from the U. S. Navy Department, Hydrographic Office, Washington 25, D. C.

H. O. Publication No. 1-L (Loran Catalog)
H. O. Publication No. 205, Radio Navigational Aids

The material listed below may be obtained by writing to the Radio Technical Commission for Aeronautics, Room 109, 1724 F Street, N.W., Washington 25, D. C.

	Paper No.
Equipment Standards Airdrome Control Stations	66-47/DO-4
Air/Sea Distress Communications	139-47/DO-8
Testing Program Long Range Navigation Facilities	44-48/DO-14
Power Output-Airborne VHF Transmitters	41-48/DO-13
Nomenclature-Air Navigation-Air Navigation Systems	22-48/DO-11
Long Distance Air Navigation Aids in the North Atlantic Area	50-48/DO-16
Reduction of Precipitation Static Interference in Aircraft	68-47/DO-5

The ICAO material listed below may be obtained by writing to:

The Secretary General, ICAO Dominion Square Building, Montreal, Canada.

Procedure for Air Navigation Services:

Communication Procedures, Doc 4478 COM/501
ICAO Q Code, Doc 6100 COM/504
The Notam Code, Doc 6086 COM/505
Air Traffic Control (ATC), Doc 4444 RAC/501
Search and Rescue, Doc 2018 SAR/81

ELEMENT VIII

SHIP RADAR TECHNIQUES

Question 8.01. What are the FCC license requirements for the operator who is responsible for the installation, servicing, and maintenance of ship radar equipment?

Answer. Such an operator must have a first- or second-class radiotelephone or radiotelegraph license plus a ship radar endorsement. (Element 8)

Q. 8.02. Who may operate radar equipment in the Ship Service?

A. The Master, or any person designated by the Master may operate a ship radar station during the course of normal rendition of service.

Discussion: Only properly licensed personnel may supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing, or maintenance of ship radar equipment while it is radiating energy.

Q. 8.03. Under what conditions may a person who does not hold a radio operator license operate a radar station in the Ship Service?

A. The following conditions apply:

1. The radar equipment shall employ as its frequency-determining element a nontunable, pulse-type magnetron.

2. The radar equipment shall be capable of being operated during the course of normal rendition of service in accordance with the radio law and the rules and regulations of the Commission by means of exclusively external controls. See also preceding question.

Q. 8.04. Who may make entries in the installation and maintenance record of a ship radar station?

A. Entries shall be made by or under the personal supervision of the responsible installation, service, or maintenance operator concerned in each case. The station licensee is also jointly responsible for the faithful and accurate making of such entries.

Q. 8.05. What entries are required in the installation and maintenance record of a ship radar station?

A. The following entries are required:

1. The date and place of initial installation.
2. Any necessary steps taken to remedy any interference found to exist at the time of such installation.
3. The nature of any complaint (including interference to radio communication) arising subsequent to initial installation and the date thereof.
4. The reason for the trouble leading to the complaint, including the name of any component or component part which failed or was misadjusted.
5. Remedial measures taken, and the date thereof.
6. The name, license number, and date of the ship radar operator endorsement on the first- or second-class radio operator license of the responsible operator performing or immediately supervising the installation, servicing, or maintenance.

Q. 8.06. Who has the responsibility for making entries in the installation and maintenance record of a ship radar station?

A. See Question 8.04.

Q. 8.07. Within what frequency bands do ship radar transmitters operate?

A. The following bands are used: 3,000 to 3,246 mc, 5,460 to 5,650 mc, and 9,320 to 9,500 mc.

Q. 8.08. May fuses and receiving type tubes be replaced in ship radar equipment by a person whose operator license does not contain a ship radar endorsement?

A. Yes. No license is required for such replacement.

Q. 8.09. Explain briefly why radar interference to a radiotelephone receiver is frequently characterized by a steady tone in the radio loudspeaker.

A. A steady tone is often heard. This is the pulse repetition rate of keying the radar transmitter (or a harmonic) which is detected in the receiver and heard as an audio tone.

D. Radar transmitters are *pulse* modulated; that is, the carrier is turned on and off (or pulsed) at regular intervals. The pulse repetition rate is determined by the timing unit and is usually within audio range. It is possible for the timing signal to reach receivers directly through power lines, etc. or by being radiated and then detected in the receiver, where it is heard as a steady tone signal. This interference can *not* generally be "tuned out" of the receiver because of the harmonics present in each pulse which cause many heterodyning frequencies to be generated. Also, some of the interference is due to detection of the radar carrier signal by the communications receiver and it is not possible to tune out such interference.

Q. 8.10 Describe how various types of interference from a radar installation may be apparent to a person when listening to a communications receiver.

A. Radar interference in a communications receiver will generally take either or both of the two following forms:

1. A steady tone due to the pulsed rate. This will have a musical sound.

2. Noise or "hash." This is usually caused by such items as:

(a) Radar motor generator, or

(b) Improper grounding, bonding, and shielding.

D. See previous question and Question 3.212.

Q. 8.11. How are the various types of radar interference recognized in (a) auto-alarm equipment, (b) direction-finding equipment?

A. (a) Radar interference in auto-alarm equipment may be detected by plugging the earphones into the jack provided on the auto alarm for listening purposes and listening for hash or a steady tone. The radar may be shut down temporarily to determine if it is causing the interference detected.

(b) The same procedure as in (a) above may be used to detect radar interference in direction-finding equipment. It may also be advantageous to rotate the D/F loop in trying to find the source of interference, although radar interference from the same ship the D/F is on, may not have directional properties.

D. See Questions 8.09, 8.10, and 8.13.

Q. 8.12. On what frequencies should the radar serviceman look for radar interference to communication receivers on ships equipped with radar?

A. It is possible to find radar interference on practically any communication frequency because of the many harmonics produced by pulsing.

D. See Question 8.09.

Q. 8.13. In checking a direction finder for interference caused by

radar equipment, would it be a good policy to check for interference while the D/F loop is being rotated?

A. It would be a good policy, although not necessarily effective as the interference may not show directional properties especially if it is coming from the power line or timer.

D. See Questions 8.11 (b) and 8.15.

Q. 8.14. List at least two types of indications on a loran scope that signifies that a radar installation is causing interference to the loran.

A. Two types of indications on a loran scope signifying radar interference are:

1. Narrow vertical pulses or "spikes" moving across the scope screen.
2. Hash or "grass" in the vicinity of the scanning lines.

D. The "spikes" on a loran scope are caused by the radar *pulses* originating in the timing unit. Since there is no synchronization between the loran sweep and the radar pulsing, the spikes cannot remain stationary but will move across the screen. "Grass" interference would correspond to hash or noise if heard on a headset. It may originate in the motor generator set or be caused by poor grounding and bonding.

Q. 8.15. Is there any likelihood of a radar installation causing interference to radio receivers if long connecting lines are used between the radar transmitter and the radar modulator?

A. There is, if such lines are not shielded and terminated properly.

D. The pulses produced by the timing unit to trigger the radar transmitter (magnetron) are of extremely short duration and so contain many harmonic frequencies. Thus a pulse with a *repetition* rate of 1,000 cps and a pulse width of 1 microsecond could easily contain harmonic frequencies of appreciable amplitude up to and beyond 30 mc. If long connecting lines which are shielded improperly are used, the radiation of these harmonic frequencies may cause interference in any and all communications and other receivers which may tune to such harmonics.

Q. 8.16. What steps might be taken by a radar serviceman to eliminate a steady-tone of interference to radio communication receivers, or interference to loran receivers evidenced by "spikes?"

A. First check the grounding, bonding, and shielding of all units. If there are built-in filters in the radar set, check these. If not present, such filters may have to be installed.

D. The surest way to eliminate this type of interference is to prevent its *radiation*. Low-pass filters should be installed in all power lines to prevent interference from spreading through this path to other equipment. All grounding, bonding, and shielding should be thorough and well done.

It would be extremely difficult to try and filter out the radar pulses from receiving equipment. The reason for this is that the pulses are very steep and of short duration (1 microsecond or less). This means that such pulses contain *many* harmonics of the fundamental repetition rate. A radar with a pulse repetition rate of say 1,000 cps, could have harmonics of this rate, every 1,000 cps up to many megacycles. Thus, effective filtering is extremely difficult for either the radar transmitter or outside receiving equipment.

If, in this case, you tried to filter out (at the radar) all modulation frequencies above 1,000 cps, you would completely destroy the shape of the radar pulse by removing its harmonics. Under this condition, the radar could not function usefully.

Q. 8.17. What steps might be taken by a radar serviceman to reduce "grass" on a loran scope or motor-generator noise in communication receivers?

A. Make sure that the commutators, slip rings, and brushes are all in good condition. If filters are present at the motor-generator set, check these and also bonding and grounding as well as power connections for tightness and good contact. See also Questions 8.10 and 8.14.

D. See Question 3.212 for discussion and method of reducing this type of interference.

Q. 8.18. Name at least four pieces of radio or electronic equipment aboard ship that might suffer interference from the radar installation.

A. Some pieces of equipment which may suffer from radar interference are:

1. Communications receivers
2. Loran
3. Auto-alarm
4. Direction finder
5. Public-address system.

D. See Questions 8.09 through 8.17 and 8.19.

Q. 8.19. Why is it important that all units of a radar installation be thoroughly bonded to the ship's electrical ground?

A. There are two important reasons for this.

1. To place all external metal components at ship's ground and thus prevent the possibility of shock to operators and others.

2. To reduce interference caused by the radar to other pieces of electronic equipment on shipboard.

D. See Questions 8.14 and 8.17.

Q. 8.20. What may cause bright flashing pie sections to appear on a radar PPI scope?

A. This may be caused by a defective crystal in the afc section of the radar receiver.

D. This might also be caused by other defects in the afc system.

Q. 8.21. What symptoms on a radar scope would indicate that the radar receiver mixer crystal is defective?

A. Any or all of the following symptoms may be present:

1. "Targets" (or echos) will be unusually weak or will not be seen at all.

2. An excessive noise level ("grass") may be present on the scope.

3. The crystal current meter on the radar receiver will read abnormally low, or zero.

D. Great care should be taken in testing or replacing crystals as static charges may ruin them (See Question 8.49). The front-to-back resistance ratio is a measure of the condition of the crystal and may be checked as indicated in Question 8.22.

Q. 8.22 What tests may a radar serviceman make to determine whether or not the radar receiver mixer crystal is defective?

A. The serviceman may make a quick check by observing the reading on the crystal current meter of the radar receiver. Also, the front-to-back ratio of the crystal may be checked roughly by reading the forward and backward resistance on an ohmmeter.

D. One method of determining the condition of a crystal is to determine its front-to-back resistance ratio. This should be done with a high-impedance or electronic-type voltmeter. First measure the resistance across the crystal with the meter leads in either position. Then reverse the meter leads and measure it again. The larger reading, divided by the smaller reading, gives you the front-to-back ratio. In a normal crystal, this should be in the order of 20 to 1 or so. This may vary with different types, and you should find out the normal front-to-back ratios for the particular crystals in your radar. As a guide in measuring, the 1N23B crystals should read about 250 to 500 ohms for one polarity and about 10,000 ohms for the reverse polarity.

Q. 8.23. In a radar set, what are indications of (a) a defective magnetron, (b) a weak magnet in the magnetron, (c) defective crystal in the receiver converter stage?

A. (a) Defective Magnetron:

1. Sweep, noise, and range marks appear, but no targets.
2. Arcing in modulator tube.
3. Low magnetron current indication.
4. Arcing in magnetron.
5. Weak signals on PPI.
6. Targets appear "fuzzy" with "spokes" present.
7. Magnetron undercurrent relay drops out.
8. Poor afc action.

(b) Weak Magnet of Magnetron:

1. Magnetron current meter will show an increase.
2. Oscillation may stop under extreme cases of weakening.
3. Oscillation frequency will probably change.
4. Afc action may be poor.

(c) Defective Crystal:

See Question 8.21.

D. The magnetron should never be operated without the magnet in position. To do so, may destroy the tube in a short time. To prevent this from happening, an overload relay is generally provided to protect the magnetron from damage.

Q. 8.24. What precautions should a radar serviceman take when working with or handling a magnetron to prevent weakening or damage to the magnetron?

A. The following precautions should be taken to protect the *magnet* unit of the magnetron.

1. Do not subject the magnet to extreme heat.
2. Do not subject the magnet to shocks or blows.
3. Keep all magnetic materials, such as tools, away from the immediate vicinity of the magnet.

The magnetron tube proper should be treated as any other delicate electron tube.

Q. 8.25. What precaution should a radar serviceman observe when making repairs or adjustments to a radar set to prevent personal injury to himself or other persons?

A. First shut off all power. Then be sure to *discharge* all high-voltage capacitors *fully* by means of a suitable grounding stick or cable. Always handle cathode-ray tubes with great care. (If possible, wear gloves and goggles.)

Q. 8.26. Is there any danger in testing or operating radar equipment aboard ship when explosive or inflammable cargo is being handled?

A. There would be some danger due to the possibility of arcing occurring in various parts of the radar equipment. It would be best to take no chances and shut off the radar when inflammable or explosive cargo is being handled.

Q. 8.27. What considerations should be taken into account when selecting the location of the radar antenna assembly aboard ship?

A. There are two prime considerations:

1. The antenna proper should be located so that it will encounter a

minimum number of obstructions while scanning the area around the ship. This is particularly important in the directions forward and off the bows.

2. The length of waveguide run from the antenna to the radar transmitter should be kept to the minimum practical run.

D. 1. Because of the very high frequencies and the parabolic reflector used in radar transmission, the beam is concentrated into very narrow angles. Thus, any obstruction which is in the path of the beam blocks it almost as effectively as if it were a searchlight beam. This may produce areas in which no target pickup is possible and make the radar "blind" in certain directions. This is particularly undesirable in areas directly ahead or behind the ship because of possible collision conditions.

2. The waveguide from the antenna to the radar transmitter is a form of transmission line. There are some rather difficult mechanical considerations to be met in installing waveguides and these, in general, increase as the length of run becomes greater. In addition to the installation problem, the losses of the waveguide increase with greater lengths and there is also a greater possible accumulation of moisture due to condensation, in longer lengths of waveguide.

Q. 8.28. Describe briefly the construction of a waveguide. Why should the interior of the waveguide be clean. smooth, and dry?

A. A waveguide is a form of transmission line and consists of a hollow rectangular or circular pipe. The waves are carried *inside* of the pipe. Waveguides are frequently made of copper or brass and are often plated on the interior with silver to assure a smooth and highly conducting interior surface. The interior should be kept clean, smooth, and dry in order to assure minimum losses and prevent interior arcing.

D. See Question 3.502 for advantages and disadvantages of hollow wave guides.

Q. 8.29. When installing waveguides, why should long, perfectly level sections of waveguides be avoided? Why is a small hole about 1/8 inch in diameter sometimes drilled on the underside of an elbow in a waveguide near the point where it enters the radar transmitter?

A. Long, level runs are undesirable because of the possibility of accumulating condensed moisture inside of the waveguide. A small hole at the lowest point of the waveguide may be drilled to drain out condensed moisture in the waveguide.

D. See Questions 8.28 and 3.502.

Q. 8.30. Why are waveguides used in preference to coaxial lines for the transmission of microwave energy in most shipboard radar installations?

A. Waveguides are preferred over coaxial lines for transmitting microwave energy because their losses are considerable less and also because for a given size they can transmit higher power than a coaxial line.

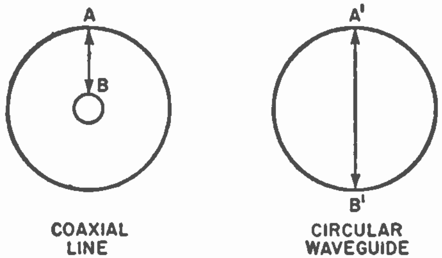


Fig. 8.30. Comparison between coaxial line and circular waveguide.

D. A simple comparison between a circular waveguide and a coaxial line of similar dimensions is made here to help illustrate the two advantages mentioned above. Refer to the figure. A coaxial line has an inner conductor which must be insulated from the outer conductor. Frequently, this is done by means of insulating beads. At microwave frequencies, the dielectric loss in the beads is considerable. A waveguide, as generally used, has only air as a dielectric. However, air has a negligible dielectric loss at practically any frequency which makes the dielectric losses in a hollow waveguide less than that of a coaxial line. The high-frequency current losses in a waveguide are also less than for a coaxial line. This is due to the elimination of the thin inner conductor in which most of the "copper losses" occur.

A waveguide can carry more power than a coaxial line of the same diameter. Referring again to the figure we can see that the distance *A'-B'* is greater than *A-B* in the coaxial line. Since the maximum voltage appears between points *A'-B'* in a round waveguide, it is evident that a greater airspace appears in the waveguide than in the coaxial line between maximum voltage points. This means a greater breakdown voltage rating for the waveguide, which, in turn, indicates a greater power handling capacity for a given outside diameter of line.

Q. 8.31. Why are rectangular cross-sectional waveguides generally used in preference to circular cross-sectional waveguides?

A. Circular waveguides are generally not used in radar because their electric field has a tendency to change direction at bends and thus change the polarization of the wave. Rectangular waveguides, on the other hand, can be made to maintain the desired polarization.

D. An exception to the above is to be found in a *rotating* joint which permits the antenna to move with respect to the fixed waveguide. This rotating joint must be circular for mechanical reasons, while the waveguide leading up to the rotating joint is usually rectangular. By means of special devices, the desired polarization is passed on to the antenna regardless of the rotation of the circular joint.

Q. 8.32. Describe how waveguides are terminated at the radar antenna reflectors.

A. There are a number of ways in which a waveguide may be terminated at the radar antenna reflector. Two methods are shown in the figure. In part (A) are shown three variations of "horn" radiators. These horns point into the parabolic reflector which forms the energy into a narrow beam. In part (B) of the figure, the wavelength is terminated in a polystyrene window placed at the focal point of the parabolic reflector.

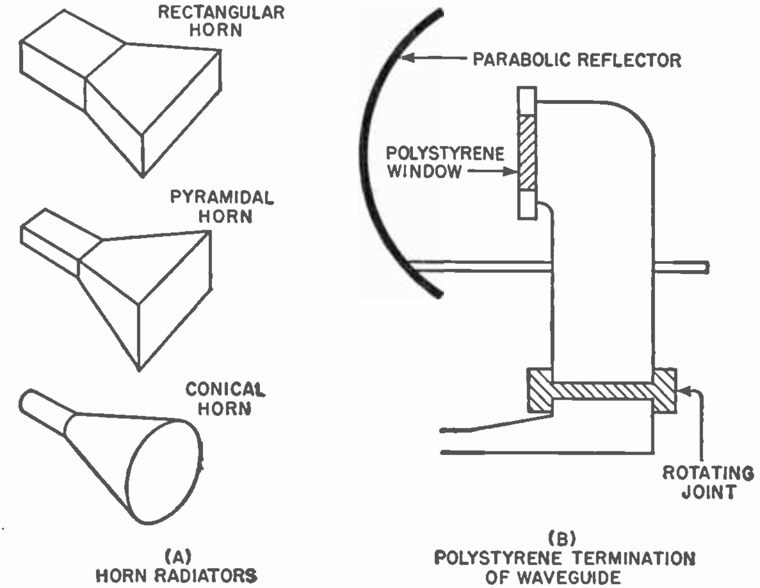


Fig. 8.32. Two methods of terminating waveguides.

D. A brief discussion of each of the two above-mentioned systems follows:

(a) Horn radiators are frequently used to obtain directive radiation in the microwave region. Their physical dimensions must be large when compared with the operating wavelength, but this becomes entirely practical at microwave frequencies. The operation of an electromagnetic horn radiator is similar to that of acoustic horns used with certain loudspeaker systems, that is, the horn serves to match the impedance of the waveguide to the impedance of external space. Horns are frequently directed toward a parabolic reflector, which then serves to concentrate the energy into a narrow beam suitable for accurate tracking purposes.

(b) Another method of terminating a waveguide at the antenna reflector is by means of a polystyrene window as shown in part (B) of the figure. The polystyrene window is placed at the focal point of the parabolic reflector. The "window" acts as an impedance-matching device between the waveguide and the parabolic reflector and free space. The correct impedance watch is obtained by selecting the correct physical dimensions of the window.

Q. 8.33. What precautions should be taken when installing vertical sections of waveguides with choke-coupling flanges to prevent moisture from entering the waveguide?

A. Moisture may be prevented from entering by inserting a suitable gasket at each choke-coupling flange and making certain that the flanges are joined tightly.

D. See also Question 8.29.

Q. 8.34. Why are choke joints often used in preference to flange joints to join sections of waveguides together?

A. Choke joints are often used in preference to simple flange joints because they prevent loss of energy when used as expansion or rotating joints and also because they will tolerate a moderate degree of misalignment of the waveguide sections without excessive losses.

D. See next question for sketches and discussion of choke joints.

Q. 8.35. Draw a longitudinal section of a waveguide choke joint and explain briefly its principle of operation.

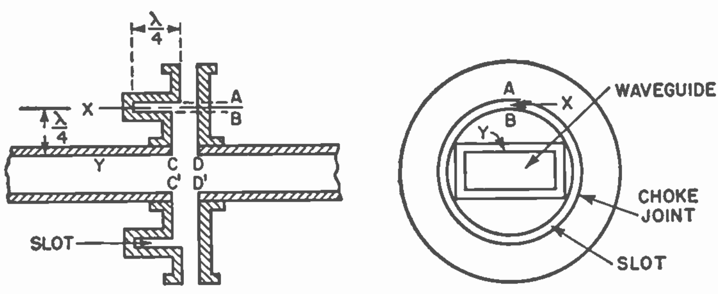


Fig. 8.35. Cross section of choke joint.

A. See the figure. The choke joint includes a circular groove (or "slot") which has a depth of one-quarter wavelength. This means that the input impedance of the slot (across *A-B*) will be infinite. The distance from the center of the slot to the waveguide (*X-Y*) is also a quarter wave. The infinite impedance of *A-B* is effectively transformed through the quarter-wave section *X-Y*, into a short circuit across *C-D*. Thus, *C* and *D* are effectively connected *electrically* even though they may not be mechanically.

D. Choke joints are commonly used to connect portions of a waveguide together. Such joints are used to fulfill one or more of these functions:

(a) To provide low loss electrical connection between two parts of the system, such as the waveguide and the magnetron itself.

(b) To provide mechanical isolation between two parts of the system so that vibration from one part will not damage another, for example, the antenna vibrations should not be transmitted to the magnetron.

(c) To permit the removal of certain sections of the waveguides to facilitate repairs and replacements.

The choke joint usually consists of two flanges. These are fixed to the waveguide at their center and face each other. The right-hand flange (in the figure) is machined flat while the left-hand flange contains the slot (described above).

In practice, the two flanges may be separated mechanically by as much as several millimeters. (One millimeter equals about 1/25 of an inch.) The separation must not, in general, exceed this distance to prevent excessive losses and reflections.

Q. 8.36. Describe how a radar beam is formed by a paraboloidal reflector.

A. A narrow beam of r-f energy is formed by a parabolic reflector in a manner which is analogous to the reflection of light from a parabolic *light* reflector as used in a searchlight.

D. The r-f energy is fed into the reflector at its focal point as shown in the figures of Question 8.32. Because of the paraboloidal shape of the reflector, practically all of the r-f energy which reaches the reflector will be effectively focused into a narrow beam and reflected. The parabolic reflector (or "dish") must be large in comparison with the wavelength. In general, the larger the reflector (diameter), the narrower will be the beam.

Q. 8.37. What effect, if any, does the accumulation of soot or dirt on the antenna reflector have on the operation of a ship radar?

A. A thin layer of soot or dirt has little or no effect upon the operation of a ship radar since the microwave energy is apparently able to penetrate a normal accumulation with only small losses.

D. An excessive amount of "crust" on the surface of the reflector may decrease the performance of the set, especially for weak targets and, in such cases, the reflecting surface should be wiped clean. It is more important to keep the plastic window at the end of the waveguide clean. An accumulation of soot or dirt here can introduce considerable loss.

Q. 8.38. What is the purpose of an echo box in a radar system? Explain the principle of operation of the echo box. What indications may be expected on a radar scope when using an echo box and the radar set is operating properly? When the radar set is not operating properly?

A. (a) The purpose of an echo box is to provide an artificial target which may be used to tune the receiver and also give an indication of the over-all radar system performance.

(b) An echo box is a very high *Q* resonant cavity which is shock-

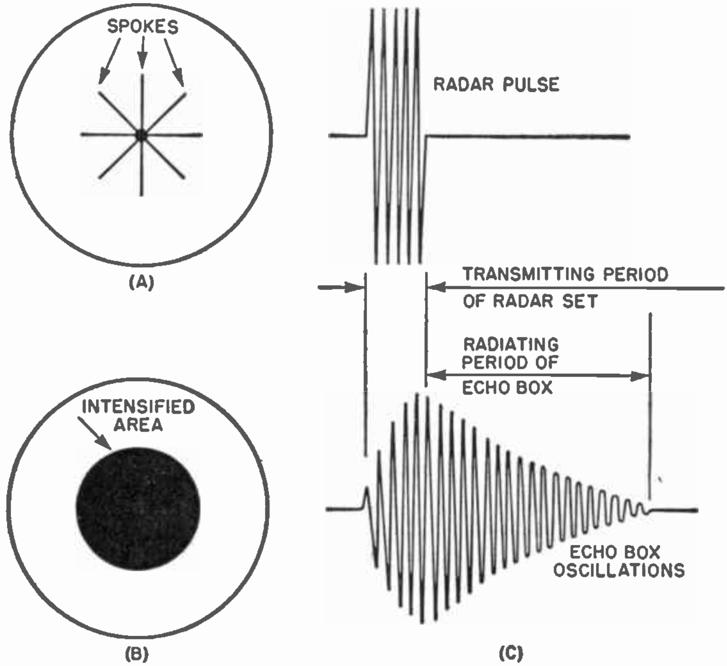


Fig. 8.38. (A) Indication on PPI due to motor-driven echo box, (B) indication on PPI due to echo box set at resonance, (C) relation between transmitted-pulse and echo-box oscillations.

excited by the transmitted pulse. In turn, its oscillations are returned to the receiver and appear as an artificial target on the radar scope.

(c) Ship radars generally use a PPI scope. When the echo box is motor-tuned (see discussion), the indication consists of a series of spokes extending radially outward from the center of the PPI scope as shown in part (A) of the figure. The spoke length is maximum when the radar is operating normally. When the echo box is simply left at resonance, the central portion of the PPI scope will be intensified as shown in part (B) of the figure.

(d) When the radar is not operating properly, the length of the spokes (or radius of intensified area) will be less than under normal operation.

D. Normal radar target signals do not, in general, furnish a satisfactory means of checking radar system performance. Variations in atmospheric conditions, the difference in the character of various signals, and also the lack of proper reference signals make it difficult for the operator to check the performance of the radar. This is particularly true of a ship radar where the geographical location of the radar may be constantly changing. To overcome these difficulties, a so-called "echo box" has been designed to furnish a standard reference signal so that the operation of the radar can be checked periodically against the reference in any geographical location. This echo box consists of a high *Q* resonant cavity with means provided for coupling some transmitter energy into and out of the box. In addition, a plunger arrangement is provided to change the length of the cavity and thus vary its resonant frequency. In some cases, this plunger is driven by a motor through a reciprocating device so that the cavity is periodically tuned through resonance for a short period of time. As previously described, this action results in a series of spokes being produced due to the sweep rotation of the PPI scope.

The action of the echo box in providing a reference signal is briefly as follows: During the short transmitting pulse, some of the transmitted energy is fed into the echo box and shock excites it into oscillations which increase in amplitude during the pulse time. This is shown in part (C) of the figure. At the end of the transmitting pulse, the echo box continues to oscillate at a decaying amplitude and reradiates energy back to the radar receiver. A short time after the end of the transmitted pulse, the amplitude of oscillations in the echo box will decrease below the sensitivity level of the receiver. The time from the end of the transmitter pulse to the time when the oscillations no longer produce an indication on the scope through the receiver is known as the "ringing time." This ringing time is a function of the power output of the transmitter and the sensitivity of the receiver and manifests itself on the PPI in the form of spokes or as an intensified area with a certain radius. The length of these spokes (or the radius) is measured when the radar system is known to be operating at good efficiency. Using this as a standard reference, periodic measurements are made with the echo box and any radical decrease in the ringing time means that either the transmitting or receiving components of the radar may be defective and repairs are in order.

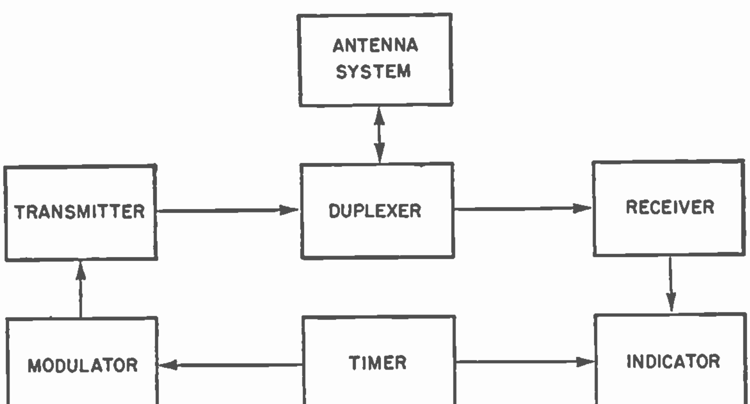


Fig. 8.39. Block diagram of radar set.

Q. 8.39. Draw a block diagram of a radar system, labeling the antenna, duplexer, transmitter, receiver, modulator, timer; and the indicator.

A. See the figure.

D. For a discussion of radar see Question 6.665. For a discussion of the duplexer, see Question 8.41.

Q. 8.40. Explan briefly the principle of operation of a radar system.

A. Very briefly, radar operates to detect an object at a distance by directing a narrow beam of r-f energy at the object and then detecting a portion of the reflected beam when it arrives back at the radar.

D. For a more complete discussion of radar, see Question 6.665.

Q. 8.41. Draw a simple block diagram of a radar duplexer system, labeling the waveguide, the TR box, the anti-TR box, the receiver, and the transmitter.

A. See the figure.

D. Ship radars use a common antenna system for transmitting and receiving. In such a system, it is necessary to protect the receiver from damage due to the high-power transmitter pulse and also to prevent the transmitter from absorbing too much power from the reflected echo between transmitting pulses. It is, therefore, necessary to provide some form of "switch" to disconnect the receiver effectively from the waveguide during the transmitter pulse and to disconnect the transmitter from the waveguide the rest of the time. Such a switch is often called a *duplexer*. This is not a simple switch, but is made up of certain measured lengths of waveguide and two special spark-gap tubes. How this switch operates may be seen with the aid of the simplified drawing shown in part (B) of the figure.

When the transmitter pulses, both of the spark gaps are fired and represent practically a short circuit across the gap terminals. The anti-TR connects into the waveguide a quarter-wavelength from its gap and thus reflects an open circuit across points *A* and *B*. The transmitter sees a very high impedance at *A-B* and does not "pour" any appreciable power into the anti-TR. The TR gap also fires at this time producing a short across *E-F*. This prevents all but a small amount of power from entering the receiver. A high impedance appears at *C-D*, one quarter-wavelength away, and permits the transmitter power to proceed to the antenna almost without loss. Thus while the transmitter is pulsing, the receiver is protected and the full power is delivered to the antenna. After the transmitter pulse, both gaps become open circuits. The shorting bar of the anti-TR line is a half-wavelength from *A-B* and reflects a *short* across these points (*A-B*). This short is, in turn, reflected to points *C-D* one quarter-wavelength away as an *open* circuit and effectively blocks received signals from passing this point toward the transmitter. Instead, the received power is effectively all shunted into the receiver. In part (C) of the figure is shown a complete drawing of a typical duplexer.

Q. 8.42. Draw a simple block diagram of a radar receiver, labeling the signal crystal, the local oscillator, the afc crystal stage, the i-f amplifier, and the discriminator.

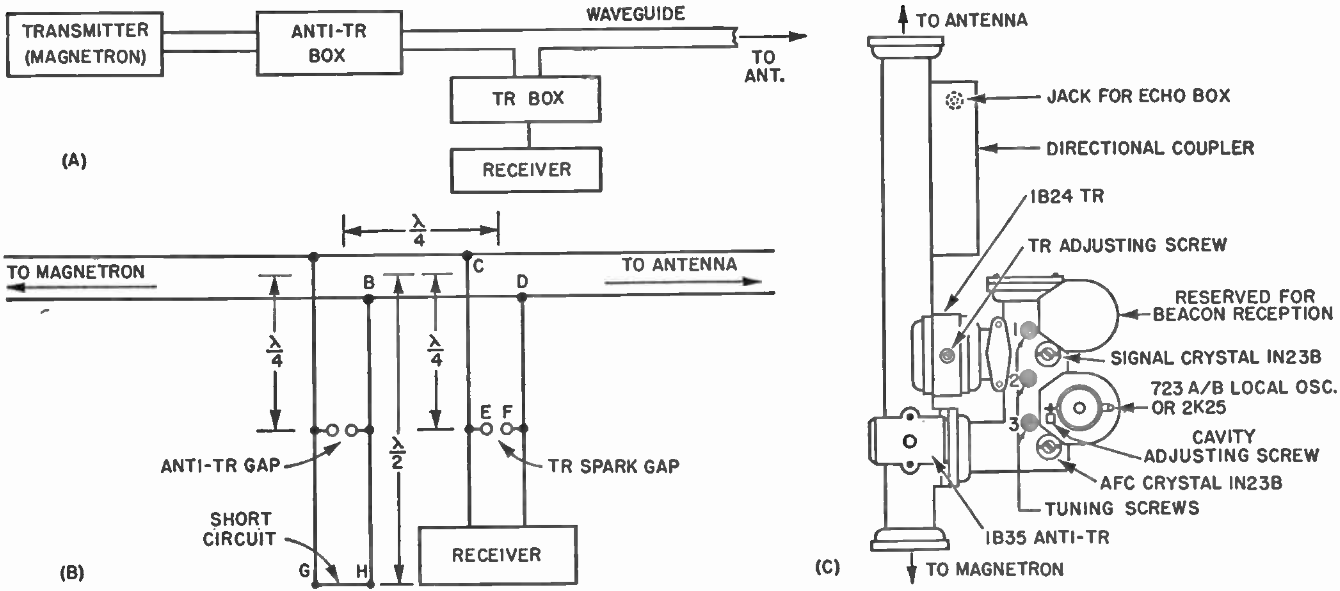


Fig. 8.41. (A) Block diagram of duplexer, (B) Simplified diagram of duplexer, (C) Duplexer assembly.

A. See the figure.

D. For general discussion of a radar receiver, see Question 6.665. A brief discussion of the afc system follows. Two signals are fed into the afc crystal detector. One is from the magnetron (greatly attenuated), the other from the local oscillaor (reflex klystron). The difference frequency between these two is detected, amplified, and fed into the discriminator. The discriminator is reasonated at 30 mc, the normal i-f frequency of the signal circuits. If the magnetron and local oscillator are operating at their correct frequencies 30 mc apart (to produce 30 mc i.f.) there will be no output from the discriminator. If, however, either the magnetron or klystron (or both) should drift in frequency, the output of the afc crystal will be greater or less than 30 mc. This will cause an output voltage from the discriminator whose sign and magnitude is proportional to the drift. This control voltage is amplified and fed back to the reflector plate of the klystron in such a way as to cause the frequency of the klystron to change to a value needed to produce again a 30 mc i.f.

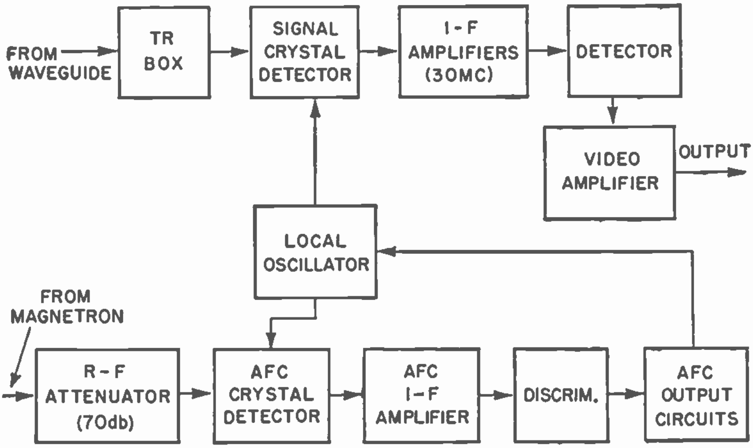


Fig. 8.42. Simplified diagram of radar receiver.

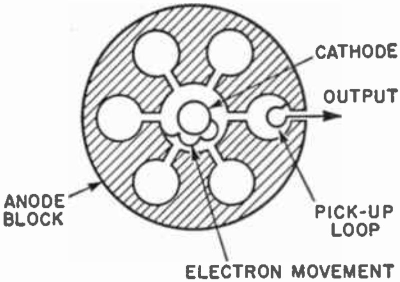


Fig. 8.43. Cross section of magnetron showing electron movement.

Q. 8.43. Draw a simple cross-sectional diagram of a magnetron showing the anode, cathode, and the direction of electronic movement under the influence of a strong magnetic field.

A. See the figure.

Q. 8.44. Explain briefly the principle of operation of the magnetron.

A. (See Question 8.43 for figure.) For a description of operation, see Question 3.351.

Q. 8.45. Why is the anode in a magnetron in a radar transmitter normally maintained at ground potential?

A. This is done to protect personnel from high-voltage shocks and to reduce the problem of insulating the magnetron from the chassis.

D. The anode (containing the resonant cavities) comprises the metal shell of the magnetron. This is mechanically coupled to the waveguide. If the high-voltage pulse were to be applied to the anode, it would be as a highly positive pulse. This would necessitate the insulation of the anode from the chassis as well as the insulaton of the waveguide from the anode. This is difficult to do and expensive. In addition, even if the insulation were present, there would be great danger to personnel encountering the magnetron or even the waveguide. To overcome this, the metal shell of the magnetron (and waveguide) is *grounded* and a *negative* high-voltage pulse fed into the *cathode* of the magnetron. This makes construction much simpler and also is much safer for handling by personnel.

Q. 8.46. Draw a simple frequency-converter circuit (mixer) as frequently used in radar superheterodyne receivers and indicate which is the crystal stage.

A. See the figure. (See also figure 8.41.)

D. See Question 6.665.

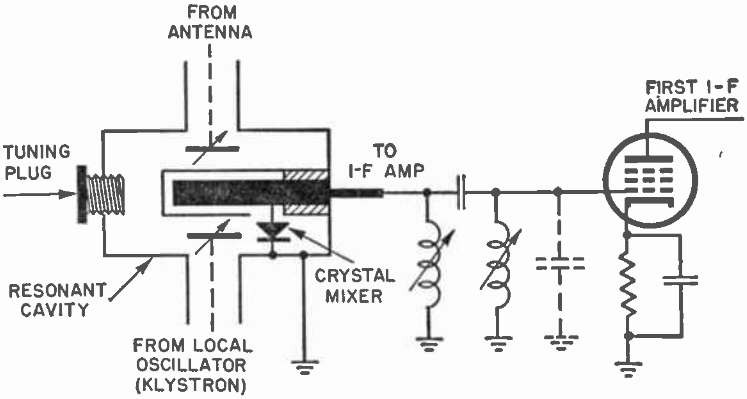


Fig. 8.46. Mixer circuit of radar receiver.

Q. 8.47. What is the purpose of the klystron tube in a radar set?

A. The klystron tube is the local oscillator of the radar receiver.

It is coupled to the mixer crystal to produce the i.f. as shown in Question 8.46.

Q. 8.48. Explain briefly the principle of operation of the reflex klystron.

A. A schematic of a reflex klystron is shown in the figure. The klystron is a resonant-cavity device which is energized by the action of "bunches" of electrons. Briefly, it operates as follows: Electrons are emitted by the cathode in a steady stream and accelerated toward the cavity grids by the potential on the accelerating grid. When the stream of electrons first enters the cavity grids, the resonant cavity is shock-excited into oscillation thus producing alternating voltages across the cavity grids. The fields produced by these alternating potentials act upon the electron stream to produce "bunches" of electrons separated by spaces in which there are very few electrons. After passing the cavity grids, the *bunches* are repelled by the negative potential of the repeller plate and return again to these grids. The bunches have the proper *spacing* and *timing* when returning so that oscillations are maintained in the resonant cavity. The volume of the cavity is varied to make large changes of frequency. Small changes of frequency are made by varying the repeller voltage over a narrow range.

D. See also Question 3.531.

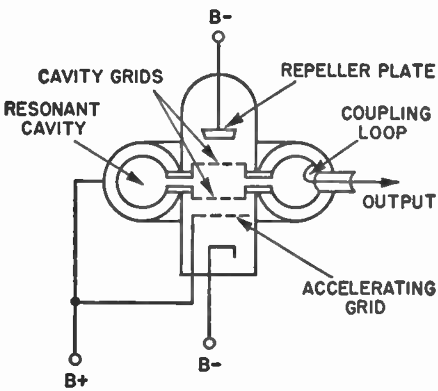


Fig. 8.48. Reflex klystron.

Q. 8.49. What care should be taken when handling silicon crystal rectifier cartridges for replacement in radar superheterodyne receivers?

A. The technician should discharge any static charge in his body by touching a convenient ground with his hands. The crystal should be handled very carefully as it may be damaged mechanically by applying excessive pressures.

D. The silicon crystals which are used as mixers (and afc crystals) have a *low*, safe current rating. They may be damaged by static charges accumulated on the body of the person handling them. Such persons should first "discharge" themselves by touching a suitable grounding point. The crystals are wrapped in lead foil when stored, to protect them against stray charges. This foil should not be removed, until the crystal is placed in use. The unit into which the crystal is inserted should also be grounded before installation.

Q. 8.50. What nominal intermediate frequencies are commonly found in radar receivers?

A. Radar receivers commonly use i.f.'s of 30 or 60 mc.

D. See Question 3.531.

Q. 8.51. Describe briefly the construction and operation of radar TR and anti-TR boxes. What is the purpose of a "keep alive" voltage?

A. The operation of TR and anti-TR boxes is fully described in Question 8.41. The construction of a TR box is shown in the figure. This consists of a TR tube mounted in a resonant cavity. The high Q of the cavity reduces the power needed to maintain the spark gap. The TR tube contains two metal electrodes which act as a spark gap. The tube itself is partially evacuated and has a small amount of water vapor inside to reduce the time of deionzation.

A third electrode is placed inside of one of the main electrodes. This is known as a "keep-alive" electrode. It has a "keep-alive" voltage applied to it. This is a constant negative potential (about 1,000 volts) which keeps the gas and vapor in the tube slightly ionized at all times and accelerates the breakdown of the main gap. A TR box is similar to an anti-TR box, but may not have a "keep-alive" electrode in the TR tube.

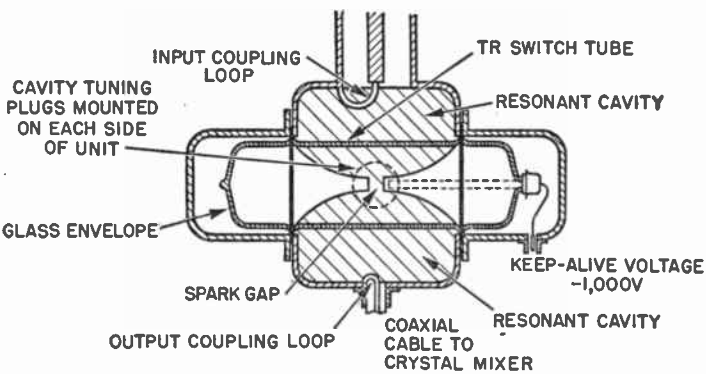


Fig. 8.51. Cross section of TR switch.

D. See Question 8.41.

Q. 8.52. What is the purpose of the discriminator stage in a radar superheterodyne?

A. The discriminator is part of the afc system. Its function is to generate a corrective voltage which is sent to the local oscillator (klystron) to maintain the correct intermediate-frequency difference output from the mixer.

D. See Question 8.42 for a discussion of the afc system.

Q. 8.53. What type of detector is used frequently in radar receivers?

A. A silicon crystal detector (mixer) is commonly used.

D. See Questions 8.40, 8.42, 8.46, and 8.49.

Q. 8.54. What is "sea return" on a radar scope?

A. "Sea return" is the reflection or "echo" of radar signals bouncing off the waves of the sea and returning to the radar set.

D. See Question 6.667.

Q. 8.55. Explain briefly the purpose of the sensitivity time control circuit in a radar set.

A. The sensitivity time control automatically reduces the gain of the radar receiver for nearby targets, to reduce interference from such effects as sea return.

D. For a discussion of this effect, see Question 6.667.

Q. 8.56. What is the distance in nautical miles to a target if it takes 123 microseconds for a radar pulse to travel from the radar antenna to the target, back to the antenna and be displayed on the PPI scope?

A. The distance to the target is 10 nautical miles.

D. A radar pulse will go out 1 nautical mile *and return* in about 123 microseconds. Therefore, in 123 microseconds, the distance to the target is,

$$\frac{123}{12.3} = 10 \text{ nautical miles.}$$

Q. 8.57. What is the purpose of an "artificial transmission line" in a radar set?

A. An "artificial transmission line" determines the shape and duration of the transmitted pulse.

D. (See also Question 8.58.) Ship radar transmitters generally have output r-f pulses varying in length from ¼ to 1 microsecond. This output r-f pulse is obtained by triggering the magnetron with a high-voltage d-c pulse. The pulse must have a fixed duration and a square top for good magnetron frequency stability. In order to obtain a suitable driving pulse a "line-controlled" blocking oscillator is frequently employed. This consists of a high-voltage blocking oscillator whose pulse output duration is controlled by an artificial transmission line in its grid circuit. Briefly, the operation is as follows: A driving pulse from the synchronizer is applied to the blocking oscillator (one-shot) and forces it into conduction, thus starting the output pulse. This pulse also travels down the artificial line and is reflected when it reaches its open end. This reflected pulse comes back to the grid of the blocking oscillator with negative polarity cutting it off and terminating the output pulse. By suitable selection of the constants of the line, the time of travel up and back can be determined to a very close degree, thus controlling the length of the output pulse. The pulse from the blocking oscillator triggers a modulator tube which actually pulses the magnetron at high voltage (10 to 15 kv). The construction of an artificial transmission line is described in Question 8.58.

Q. 8.58. Draw a simple diagram of an artificial transmission line showing inductance and capacitance, source of power, the load, and the electronic switch.

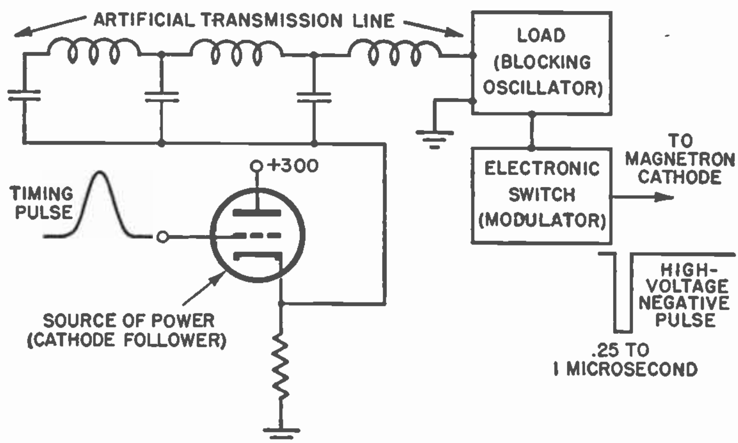


Fig. 8.58. Artificial transmission line and associate circuits.

A. See the figure, and also Question 8.57.

D. A convenient means of producing a very short duration rectangular pulse is to use an artificial transmission line. This is a device, which by lumped constants of capacitance and inductance, simulates an actual line with a certain characteristic impedance and wavelength. An actual line is not used because its physical length would be prohibitive. The required pulse duration is controlled by designing the line to have a certain equivalent "length." Thus it takes an impulse a definite time to travel to the end of the line (open) and be reflected back to the load, in this case, the grid circuit of a blocking oscillator. The operation of this circuit is described in Question 8.57. See also Question 8.61.

Q. 8.59. What component in a radar set determines the pulse repetition rate?

A. The pulse repetition rate is determined by the timer (or synchronizer) unit.

D. See Question 6.665. One typical marine radar has repetition rates of 750 and 3,000 cycles per second.

Q. 8.60. What circuit element determines the operating frequency of the self-blocking oscillator?

A. (See the figure for a typical blocking oscillator of the free-running type.) In the diagram shown, the main determining circuit elements of frequency are the bias capacitor *C1* and resistor *R1*.

D. The question is a little indefinite since there is no *single* circuit element which determines the repetition frequency. All of the circuit elements, including the tube and transformer as well as the operating potentials, affect the frequency. However, it is true that *R1* and *C1* have the greatest effect on frequency.

In marine radar sets, a synchronized blocking oscillator is used to produce the trigger pulse for the transmitter. This may oscillate for only one cycle for each synchronizing pulse applied to the grid. In this case, the repetition frequency is determined solely by the synchronizing pulses.

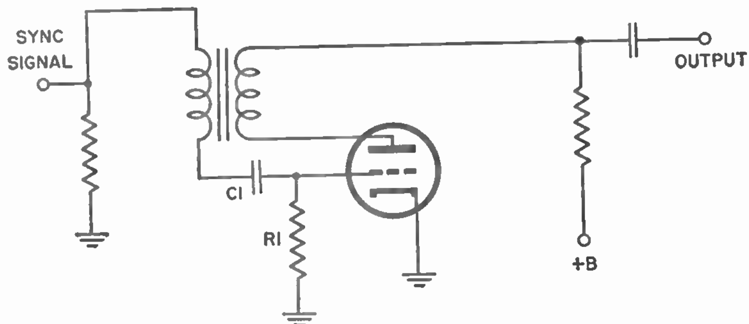


Fig. 8.60. Circuit of synchronized blocking oscillator.

Q. 8.61. What is the purpose of the rotary spark gap used in some radar sets?

A. The rotary spark gap is a mechanical system for modulating a magnetron directly at high level.

D. When an *electromatic* modulator tube is used, it is frequently connected in a manner shown in the simplified drawing which is part (A) of the figure. This operates briefly as follows: Between triggering pulses, the modulator tube *V1* is held below cut-off by a fixed bias. During this interval, the high-voltage capacitor *C1* charges through the charging diode *V2*, as shown by the dotted arrows, to about 12,000 volts (for example). When the triggering pulse appears, it overcomes

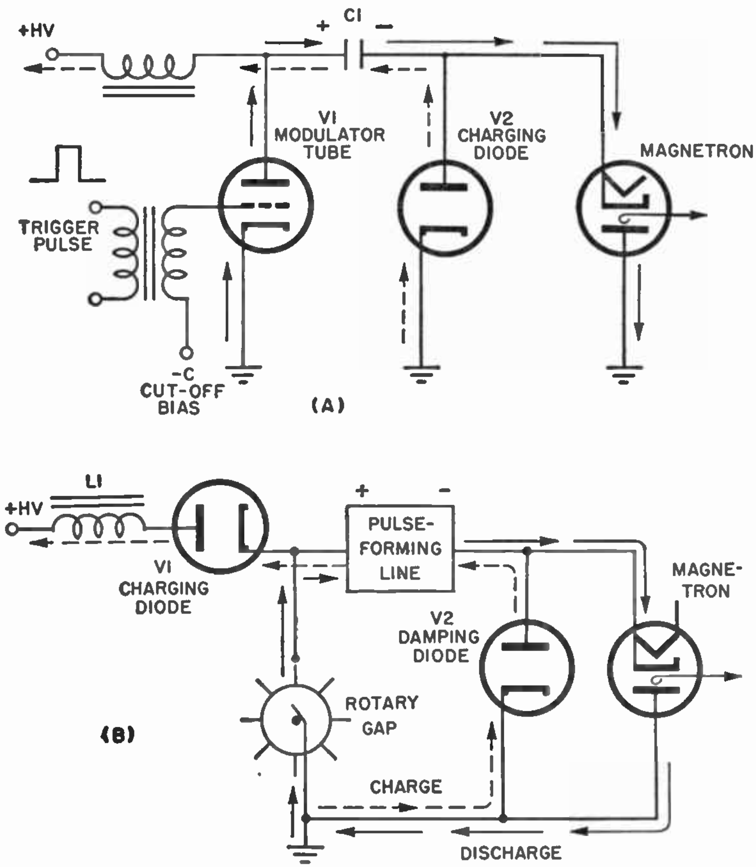


Fig. 8.61. (A) Electronic modulator for magnetron, (B) rotary spark-gap modulator.

the modulator bias, the modulator tube conducts heavily, and the high voltage of *C1* is applied to the magnetron with negative polarity. This is shown by the solid arrows. *C1* only discharges a relatively small amount, thus maintaining almost a constant voltage.

Some radar units use a spark gap and pulse-forming line instead of the blocking-oscillator modulator system. This has the advantage of generating the magnetron high-voltage d-c pulse directly at high level instead of having to amplify it in several tubes. No modulator tubes are required and the efficiency is very high (80 to 90 per cent). It has, however, the disadvantages of being a *mechanical* rather than an electronic device, of generating radio-frequency interference which must be filtered, and offering no opportunities for accurate pulse shaping. A simplified drawing of such a system is shown in part (B) of the figure. The true operation of this circuit is quite complicated, but a simplified explanation follows. The rotary gap makes contacts at a very high rate, commonly at 400, 800, or 1,600 times per second. When the gap is open, the pulse-forming line charges through V1, L1 and V2. This produces shock excitation of a resonant circuit consisting of L1 and the capacitance of the pulse-forming line. Because of the diodes, the oscillation causes the line to charge to a voltage about 1.8 times the applied voltage and remain at the value. When the gap fires, the voltage at point *A* becomes zero and the now negative pulse-forming line voltage is applied to the magnetron for the duration of the arc. The cycle then repeats.

Q. 8.62. What is the peak power of a radar pulse if the pulse width is 1.0 microsecond, pulse repetition rate is 900 and the average power is 18 watts? What is the duty cycle?

A. The peak power is 20,000 watts. The duty cycle is 0.0009.

D. Step 1: The duty cycle must *first* be found.

$$\text{Duty cycle} = \frac{\text{Pulse width}}{\text{Pulse repetition time}}$$

$$\text{Pulse repetition time} = \frac{1}{F} = \frac{1}{900}$$

$$\text{Duty cycle} = \frac{0.000001}{1/900} = 0.0009.$$

Step 2: Find the peak power.

$$\text{Peak power} = \frac{\text{Average power}}{\text{Duty cycle}} = \frac{18}{0.0009} = 20{,}000 \text{ watts.}$$

Q. 8.63. What is meant by "bearing resolution" of a radar set?

A. Bearing resolution may be defined as the ability of a radar set to distinguish between targets at the same range but different azimuth directions.

D. Bearing resolution is mainly determined by the *width* of the radar beam. A narrow beam is better able to separate targets at the same radial distance than a wide beam. The resolution is also influenced by the receiving circuits and the PPI scope.

Q. 8.64. Explain how heading flash and range-marker circles are produced on a radar PPI scope.

A. (a) Heading flash is produced whenever the radar beam points dead ahead. This is accomplished by closing a switch in the antenna which causes an intensifier pulse of short duration to intensify a radial line of the PPI scope representing the heading.

(b) Range-marker circles are produced on a radar PPI scope as follows: A range-marker oscillator, in conjunction with suitable squaring and peaking circuits produces "pips" (or short positive pulses). There is a definite spacing between these pips corresponding to range in miles (or yards), which is a function of the range-marker oscillator frequency. These pips are produced in synchronism with sweep and are

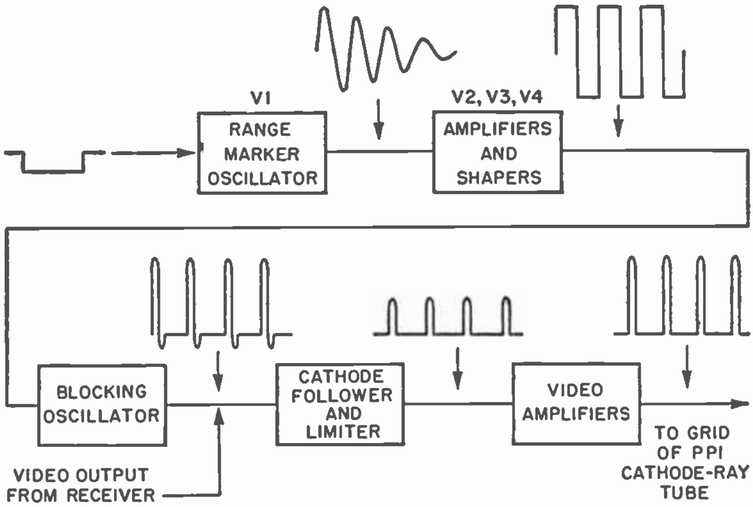


Fig. 8.64. Block diagram of a range-marker system.

applied at intensified pulses to the grid of the PPI. Each time the sweep causes the beam to go out from the center to the edge, a series of accurately spaced intensified pips appears. Since the sweep rotates, these pips then form range-marker circles. (See Figure 7.189.)

D. (a) The radar operator must know exactly when the radar beam is dead ahead so that he can accurately indicate the relative bearing of all targets. The PPI sweep line is normally blanked out as it rotates with only the targets intensifying the screen. To provide heading flash (or dead-ahead indication) it is necessary to intensify the sweep line momentarily each time the antenna points dead ahead. Briefly, this is accomplished by the momentary closing of a cam-actuated microswitch located in the antenna assembly. This microswitch is closed only when the antenna points dead ahead. When the switch is closed it acuates a circuit which produces an intensifier pulse of the desired duration. This pulse (positive) is fed to the grid of the PPI scope where it causes a bright sweep line to appear on the PPI in an azimuth indication corresponding to the dead-ahead position of the antenna.

(b) A block diagram of a range-marker generating system from a typical marine radar[2] is shown in the figure. This operates as follows:

1. The negative input pulse to *V1* shock excites an *L-C* tank circuit in the cathode into sine-wave oscillation. The frequency depends on the range in use and the *number* of range rings desired on that particular range. On the 1½ mile range, three rings will be seen on one model.

[2]Radiomarine Corp. of America.

2. The sine waves from the *L-C* tank are then shaped by the three following stages to form *square* pulses with extremely sharp leading edges.

3. The positive output of these amplifiers is used to trigger a "one-shot" (or single-swing) blocking oscillator which generates a short duration (⅓ microsecond) pulse in synchronization with the leading edge of each squared-up pulse. These are the range-marker pulses.

4. The range-marker pulses are then fed through a cathode follower and limiter into a two-stage video amplifier. The output of the video amplifier then feeds directly into the grid of the PPI where each pip produces an intensification of the sweep.

Q. 8.65. Draw a diagram of a cathode-ray tube as used in radar showing the principal electrodes in the tube and the path of the electron beam.

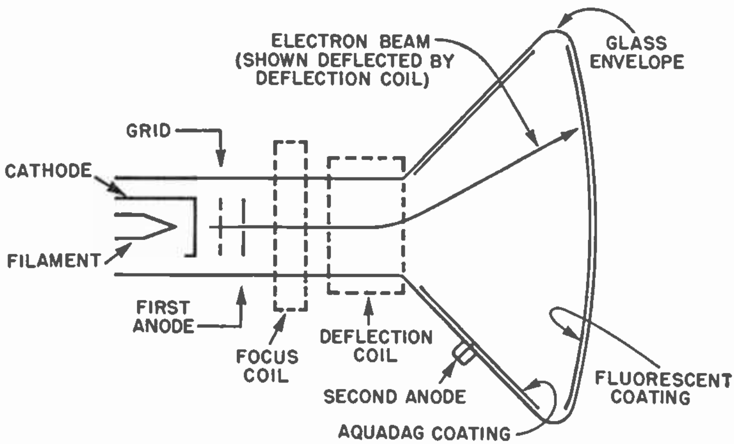


Fig. 8.65. Cross section of a cathode-ray tube.

A. See the figure.

D. See Questions 8.66, 8.67, and 8.68.

Q. 8.66. What is the purpose of aquadag coatings on radar cathode-ray tubes?

A. (See figure 8.65.) The purpose of the aquadag coating is to act as an anode of a cathode-ray tube.

D. Aquadag is a graphite solution in water which is applied as a coating to the inside of cathode-ray tubes (as in figure 8.65). It is a good conductor and is employed in radar cathode-ray tubes as a second anode. It also acts as an electrostatic shield to protect the electron beam from stray electric fields.

Q. 8.67. Explain the principle of operation of the cathode-ray PPI tube and explain the function of each electrode.

A. 1. PRINCIPLE OF OPERATION. A PPI tube is one on which a "map" of the area being scanned is presented insofar as targets and fixed land echoes are concerned. (See figure 7.189.) The center of the

PPI screen represents the position of the radar antenna. The electron beam moves out radially from the center to the outer edge and is *rotated* in synchronism with the radar antenna. In practice, the scanning beam proper is blanked out and only the target indications and range rings are *intensified* on the screen. The distance from the center of the screen to the target is a measure of the *range*, while the radial *direction* indicates the target's azimuth bearing (relative).

2. FUNCTION OF ELECTRODES. (See figure 8.65.) The PPI tube has a filament similar to that used in receiving tubes. This filament heats up and, in turn, heats a coated cathode, causing electrons to be emitted from the cathode. These electrons first encounter a grid which functions in a manner similar to the grid in a conventional triode. That is, it controls the amount of electrons passing it and, thus, the *intensity* of the spot produced on the PPI screen. After passing the grid, the electrons (now restricted to a fairly narrow stream), are acted upon by the first anode, which produces some acceleration of the electron stream toward the screen. Further and final acceleration is provided by the second anode (aquadag coating).

D. PPI tubes frequently employ *magnetic* focusing accomplished by a focus coil which is located as indicated in figure 8.65. Deflection is usually accomplished by a magnetic deflection coil which moves the beam radially out from the center to the outer edge of the screen. The rotating effect of the sweep may be accomplished by *rotating* the deflection coil mechanically in synchronism with the antenna. (See Question 8.69.)

Another method of rotating the sweep, employs fixed deflection coils. This system employs a *rotating magnetic field*, which is synchronized with the movement of the radar antenna.

Q. 8.68. What precautions should the service and maintenance operator observe when replacing the cathode-ray tube in a radar set?

A. The radar power-supply system should be turned off and *all* high-voltage capacitors *completely discharged* by a well-insulated screwdriver or other device. Care must be taken to avoid breakage of a cathode-ray tube which may result in serious injury to the serviceman.

D. It has been demonstrated recently that cuts resulting from broken cathode-ray tubes (or other fluorescent devices) may result in serious poisoning of the bloodstream. This is due to the action of the fluorescent material. Therefore, be especially careful in disposing of such broken devices to avoid cutting the hands, arms, or face. The use of gloves is to be recommended in such cases.

Q. 8.69. Draw a simple diagram showing how a synchro generator located in the radar antenna assembly is connected to a synchro motor located in the indicator to drive the deflection coils. Show proper designation of all leads, designating where a-c voltages (if needed) are applied.

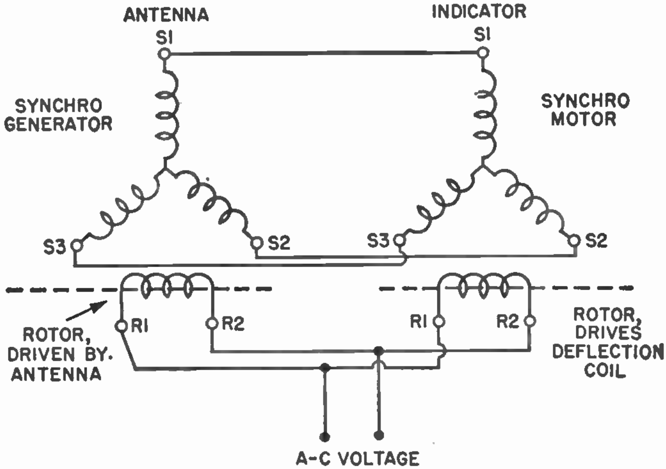


Fig. 8.69. Synchro circuit of radar set.

A. See the figure.

D. The operation of this system is exactly the same as the autosyn as explained in Question 7.85. The power frequency does not have to be 400 cps, but could be any other frequency such as 60 or 800 cps.

APPENDIX

APPENDIX I

PART 13—RULES GOVERNING COMMERCIAL RADIO OPERATORS

(Selected extracts)

§ 13.6 *Operator license, posting of.* The original license of each station operator shall be posted at the place where he is on duty, except as otherwise provided in this part or in the rules governing the class of station concerned.

§ 13.61 *Operating authority.* The various classes of commercial radio operator licenses issued by the Commission authorizes the holder thereof to operate radio stations, except amateur, as follows:

(a) Radiotelegraph first-class operator license. Any station except—

(1) Stations transmitting television, or

(2) Any of the various classes of broadcast stations other than remote pickup and ST broadcast stations, or

(3) On a cargo vessel (other than a vessel operated exclusively on the Great Lakes) required by treaty or statute to be equipped with a radiotelegraph installation, the holder of this class of license may not act as chief of sole operator until he has had at least 6 months' satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States.

(4) On an aircraft employing radiotelegraphy, the holder of this class of license may not operate the radiotelegraph station during the course of normal rendition of service unless he has satisfactorily completed a supplementary examination qualifying him for that duty, or unless he has served satisfactorily as chief or sole radio operator on an aircraft employing radiotelegraphy prior to February 15, 1950. The supplementary examination shall consist of:

(i) Written examination element: 7.

(5) At a ship radar station licensed in the Ship Service, the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy unless he has satisfactorily completed a supplementary examination qualifying him for that duty and received a ship radar endorsement on his license certifying to that fact: *Provided*, That nothing in this subparagraph shall be construed to prevent persons holding licenses not so endorsed from making replacements of fuses or of receiving-type tubes. The supplementary examination shall consist of:

(i) Written examination element: 8.

(b) Radiotelegraph second-class operator license. Any station except—

(1) Stations transmitting television, or

(2) Any of the various classes of broadcast stations other than remote pickup and ST broadcast stations, or

(3) On a passenger vessel required by treaty or statute to maintain a continuous radio watch by operators or on a vessel having continuous hours of service for public correspondence, the holder of this class of license may not act as chief operator, or

(4) On a vessel (other than a vessel operated exclusively on the Great Lakes) required by treaty or statute to be equipped with a radiotelegraph installation, the holder of this class of license may not act as chief or sole operator until he has had at least 6 months' satisfactory service in the aggregate as a qualified radiotelegraph operator in a station on board a ship or ships of the United States.

(5) On an aircraft employing radiotelegraphy, the holder of this class of license may not operate the radiotelegraph station during the course of normal rendition of services unless he is at least 18 years of age and has satisfactorily completed a supplementary examination qualifying him for that duty, or unless he has served satisfactorily as chief or sole radio operator on an aircraft employing radiotelegraphy prior to February 15, 1950. The supplementary examination shall consist of:

(i) Transmitting and receiving code test of 25 words per minute plain language and 20 code groups per minute.

(ii) Written examination element: 7.

(6) At a ship radar station license in the Ship Service, the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy unless he has satisfactorily completed a supplementary examination qualifying him for that duty and received a ship radar endorsement on this license certifying to that fact: *Provided*, That nothing in this subparagraph shall be construed to prevent persons holding licenses not so endorsed from making replacements of fuses or of receiving-type tubes. The supplementary examination shall consist of:

(i) Written examination element: 8

(c) Radiotelegraph third class operator permit. Any station except:

(1) Stations transmitting television, or

(2) Any of the various classes of broadcast stations other than noncommercial educational FM broadcast stations using transmitters with power ratings of 10 watts or less, remote pickup broadcast stations and ST broadcast stations, or

(3) Coastal telephone stations (other than when transmitting manual radiotelegraphy for identification or for testing) at which the power in the antenna of the unmodulated carrier wave is authorized to exceed 250 watts, or

(4) Coastal harbor telephone stations (other than in the Territory of Alaska and other than when transmitting manual radiotelegraphy for identification or for testing) at which the power in the antenna of the unmodulated carrier wave is authorized to exceed 250 watts, or

(5) Ship stations or aircraft stations other than those at which the installation is used solely for telephony and at which the power in the antenna of the unmodulated carrier wave is not authorized to exceed 250 watts, or

(6) Ship telegraph, coastal telegraph or marine-relay stations open to public correspondence, or

(7) Radiotelegraph stations on board a vessel required by treaty or

statute to be equipped with a radio installation, or

(8) Aircraft stations while employing radiotelegraphy:

Provided, That (1) such operator is prohibited from making any adjustments that may result in improper transmitter operation, and (2) the equipment is so designed that the stability of the frequencies of the transmitter is maintained by the transmitter itself within the limits of tolerance specified by the station license, and none of the operations necessary to be performed during the course of normal rendition of the service of the station may cause off-frequency operation or result in any unauthorized radiation, and (3) any needed adjustments of the transmitter that may affect the proper operation of the station are regularly made by or under the immediate supervision and responsibility of a person holding a first- or second-class commercial radio operator license, either radiotelephone or radiotelegraph as may be appropriate for the class of station involved, who shall be responsible for the proper functioning of the station equipment and (4) in the case of ship radiotelephone or aircraft radiotelephone stations when the power in the antenna of the unmodulated carrier wave is authorized to exceed 100 watts, any needed adjustments of the transmitter that may affect the proper operation of the station are made only by or under the immediate supervision and responsibility of an operator holding a first- or second-class radiotelegraph license, who shall be responsible for the proper functioning of the station equipment.

(d) Radiotelephone first-class operator license. Any station except—

(1) Stations transmitting telegraphy by any type of the Morse Code, or

(2) Ship stations licensed to use telephony and power in excess of 100 watts for communication with coastal telephone stations.

(3) At a ship radar station licensed in the Ship Service, the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy unless he has satisfactorily completed a supplementary examination qualifying him for that duty and received a ship radar endorsement on his license certifying to that fact: *Provided*, That nothing in this subparagraph shall be construed to prevent persons holding licenses not so endorsed from making replacements of fuses or of receiving-type tubes. The supplementary examination shall consist of:

(i) Written examination element: 8.

(e) Radiotelephone second-class operator license. Any station except—

(1) Stations transmitting telegraphy by any type of the Morse Code, or

(2) Standard broadcast stations, or

(3) International broadcast stations, or

(4) FM broadcast stations, or

(5) Noncommercial educational FM broadcast stations with transmitter power rating in excess of 1 kilowatt, or

(6) Television broadcast stations licensed for commercial operation, or

(7) Ship stations licensed to use telephony and power in excess of

100 watts for communication with coastal stations.

(8) At a ship radar station licensed in the Ship Service, the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy unless he has satisfactorily completed a supplementary examination qualifying him for that duty and received a ship radar endorsement on his license certifying to that fact: *Provided*, That nothing in this subparagraph shall be construed to prevent persons holding licenses not so endorsed from making replacements of fuses or of receiving-type tubes. The supplementary examination shall consist of:

(i) Written examination element: 8.

(f) Radiotelephone third-class operator permit. Any station except—

(1) Stations transmitting television, or

(2) Stations transmitting telegraphy by any type of the Morse code, or

(3) Any of the various classes of broadcast stations other than non-commercial educational FM broadcast stations using transmitters with power ratings of 10 watts or less, remote pickup broadcast stations and ST broadcast stations, or

(4) Coastal stations at which the power in the antenna of the unmodulated carrier wave is authorized to exceed 250 watts, or

(5) Coastal harbor telephone stations, other than in the Territory of Alaska, at which the power in the antenna of the unmodulated carrier wave is authorized to exceed 250 watts, or

(6) Ship stations or aircraft stations other than those at which the installation is used solely for telephony and at which the power in the antenna of the unmodulated carrier wave is not authorized to exceed 250 watts: *Provided*, That (1) Such operator is prohibited from making any adjustments that may result in improper transmitter operation, and (2) the equipment is so designed that the stability of the frequencies of the transmitter is maintained by the transmitter itself within the limits of tolerance specified by the station license, and none of the operations necessary to be performed during the course of normal rendition of the service of the station may cause off-frequency operation or result in any unauthorized radiation, and (3) any needed adjustments of the transmitter that may affect the proper operation of the station are regularly made by or under the immediate supervision and responsibility of a person holding a first- or second-class commercial radio operator license, either radiotelephone or radiotelegraph as may be appropriate for the class of station involved, who shall be responsible for the proper functioning of the station equipment, and (4) in the case of ship radiotelephone or aircraft radiotelephone stations when the power in the antenna of the unmodulated carrier wave is authorized to exceed 100 watts, any needed adjustments of the transmitter that may affect the proper operation of the station are made only by or under the immediate supervision and responsibility of an operator holding a first- or second-class radiotelegraph license, who

shall be responsible for the proper functioning of the station equipment.

(g) Restricted radiotelephone operator permit. Any station except—

(1) Stations transmitting television, or

(2) Stations transmitting telegraphy by any type of the Morse Code, or

(3) Any of the various classes of broadcast stations other than remote pickup and ST broadcast stations, or

(4) Coastal telephone stations or coastal harbor stations other than in the Territory or Alaska, or

(5) Ship stations licensed to use telephony for communication with coastal telephone stations;

(6) At a ship radar station licensed in the Ship Service, the holder of this class of license may not supervise or be responsible for the performance of any adjustments or tests during or coincident with the installation, servicing or maintenance of the radar equipment while it is radiating energy: *Provided*,That nothing in this subparagraph shall be construed to prevent any person holding such a license from making replacements of fuses or of receiving-type tubes: *Provided*, That (1) Such operator is prohibited from making any adjustments that may result in improper transmitter operation, and (2) the equipment is so designed that none of the operations necessary to be performed during the course of normal rendition of service may cause off-frequency operation or result in any unauthorized radiation, and (3) any needed adjustments of the transmitter that may affect the proper operation of the station are regularly made by or in the presence of an operator holding a first- or second-class license, either radiotelephone or radiotelegraph, who shall be responsible for the proper operation of the equipment.

§ 13.63 *Operator's responsibility.* The licensed operator responsible for the maintenance of a transmitter may permit other persons to adjust a transmitter in his presence for the purpose of carrying out tests or making adjustments requiring specialized knowledge or skill, provided that he shall not be relieved thereby from responsibility for the proper operation of the equipment.

§ 13.71 *Issue of duplicate or replacement licenses.* (a) An operator whose license, permit or authorization has been lost, mutilated or destroyed shall immediately notify the Commission. A properly executed application for duplicate should be submitted to the office of issue, embodying a statement of the circumstances involved in the loss, mutilation or destruction of the license or permit for which a duplicate is desired. If the license or permit has been lost, the applicant must state that reasonable search has been made for it, and further, that in the event it be found either the original or the duplicate will be returned for cancellation. The applicant should also submit documentary evidence of the service that has been obtained under the original license or permit, or a statement under oath or affirmation embodying that information.

(b) The holder of any license, permit or authorization whose name is legally changed may make application for replacement document to indicate the new legal name, by submitting a properly executed application to the office of issue, accompanied by the license, permit or authorization affected and by documentary evidence of the legality of the name change.

§ 13.72 *Exhibiting signed copy of application.* When a duplicate or replacement operator license or permit has been requested, or request has been made for renewal upon service or for an endorsement or a verification card, the operator shall exhibit in lieu of the original document a signed copy of the application which has been submitted by him.

§ 13.74 *Posting requirements for operator.* (a) Performing duties other than, or in addition to, service or maintenance at two or more stations. The holder of any class of radio operator license or permit of the diploma form (as distinguished from the card form) who performs any radio operating duties, as contrasted with but not necessarily exclusive of service or maintenance duties, at two or more stations at which posting of his license or permit is required shall post at one such station his operator license or permit and shall post at all other such stations a duly issued verified statement.

(b) Performing service or maintenance duties at one or more stations. The holder of a radiotelephone or radiotelegraph first- or second-class radio operator license who performs, or supervises, and is responsible for service or maintenance work on any transmitter of any station for which a station license is required, shall post his license at the transmitter involved whenever the transmitter is in actual operation while service or maintenance work is being performed: *Provided*, That in lieu of posting his license, he may have on his person either his license or a verification card: *And provided further*. That if he performs operating duties in addition to service or maintenance duties he shall, in lieu of complying with the foregoing provisions of this paragraph, comply with the posting requirements applicable to persons performing such oerating duties, as set forth in paragraph (a) of this section and in the rules and regulations applicable to each service.

§ 13.75 *Record of service and maintenance duties performed.* In every case where a station log or service and maintenance records are required to be kept and where service or maintenance duties are performed which may affect the proper operation of a station, the responsible operator shall sign and date an entry in the log of the station concerned, or in the station maintenance records if no log is required, giving:

(a) Pertinent details of all service and maintenance work performed by him under his supervision;

(b) His name and address; and

(c) The class, serial number and expiration date of his license: *Provided*, That the responsible operator shall not be subject to requirements in paragraphs (b) and (c) of this section in relation to a station, or stations of one licensee at a single location, at which he is regularly employed as an operator on a full time basis and at which his license is properly posted.

APPENDIX II

EXTRACTS FROM RADIO LAWS

(A) *EXTRACTS OF THE COMMUNICATIONS ACT OF 1934, AS AMENDED*

PURPOSES OF ACTS

§ 1 For the purpose of regulating interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of the national defense, for the purpose of promoting safety of life and property through the use of wire and radio communication, and for the purpose of securing a more effective execution of this policy by centralizing authority heretofore granted by law to several agencies and by granting additional authority with respect to interstate and foreign commerce in wire and radio communication, there is hereby created a commission to be known as the "Federal Communications Commission," which shall be constituted as hereinafter provided, and which shall execute and enforce the provisions of this Act.

* * * * * *

LICENSE FOR RADIO COMMUNICATION OR TRANSMISSION OF ENERGY

§ 301 It is the purpose of this Act, among other things, to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by persons for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license. No person shall use or operate any apparatus for the transmission of energy or communications or signals by radio (a) from one place in any Territory or possession of the United States or in the District of Columbia to another place in the same Territory, possession, or district; or (b) from any State, Territory, or possession of the United States, or from the District of Columbia to any other State, Territory, or possession of the United States; or (c) from any place in any State, Territory, or possession of the United States, or in the District of Columbia, to any place in any foreign country or to any vessel; or (d) within any State when the effects of such use extend beyond the borders of said State, or when interference is caused by such use or operation with the transmission of such energy, communications, or signals from within said State to any place beyond its borders, or from any place beyond its borders to any place within said State, or with the transmission or reception of such energy, communications, or signals from and/or to places beyond the borders of said State; or (e) upon any vessel or aircraft of the United States; or (f) upon any other mobile stations within the jurisdiction of the United States, except under and in accordance with this Act and with a license in that behalf granted under the provisions of this Act.

GENERAL POWERS OF THE COMMISSION

§ 303 Except as otherwise provided in this Act, the Commission from time to time, as public convenience, interest, or necessity requires, shall—

* * * * * *

(1) Have authority to prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such citizens of the United States as the Commission finds qualified;

(m) (1) Have authority to suspend the license of any operator upon proof sufficient to satisfy the Commission that the licensee—

(A) Has violated any provision of any Act, treaty, convention binding on the United States, which the Commission is authorized to administer, or any regulation made by the Commission under any such Act, treaty, or convention; or

(B) Has failed to carry out a lawful order of the master or person lawfully in charge of the ship on which he is employed; or

(C) Has willfully damaged or permitted radio apparatus or installations to be damaged; or

(D) Has transmitted superfluous radio communications or signals or communications containing profane or obscene words, language, or meaning, or has knowingly transmitted—

(1) False or deceptive signals or communications, or

(2) A call signal or letter which has not been assigned by proper authority to the station he is operating; or

(E) Has willfully or maliciously interfered with any other radio communications or signals; or

(F) Has obtained or attempted to obtain, or has assisted another to obtain or attempt to obtain, an operator's license by fraudulent means.

(2) No order of suspension of any operator's license shall take effect until fifteen days' notice in writing thereof, stating the cause for the proposed suspension, has been given to the operator licensee who may make written application to the Commission at any time within said fifteen days for a hearing upon such order. The notice to the operator licensee shall not be effective until actually received by him, and from that time he shall have fifteen days in which to mail the said application. In the event that physical conditions prevent mailing of the application at the expiration of the fifteen-day period, the

application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay. Upon receipt by the Commission of such application for hearing, said order of suspension shall be held in abeyance until the conclusion of the hearing which shall be conducted under such rules as the Commission may prescribe. Upon the conclusion of said hearing the Commission may affirm, modify, or revoke said order of suspension.

(n) Have authority to inspect all radio installations associated with stations required to be licensed by any Act or which are subject to the provisions of any Act, treaty, or convention binding on the United States, to ascertain whether in construction, installation, and operation they conform to the requirements of the rules and regulations of the Commission, the provisions of any Act, the terms of any treaty or convention binding on the United States, and the conditions of the license or other instrument of authorization under which they are constructed, installed, or operated.

* * * * * *

(r) Make such rules and regulations and prescribe such restrictions and conditions, not inconsistent with law, as may be necessary to carry out the provisions of the Act, or any international radio or wire communications treaty or convention, or regulations annexed thereto, including any treaty or convention insofar as it relates to the use of radio, to which the United States is or may hereafter become a party.

* * * * * *

OPERATION OF TRANSMITTING APPARATUS

§ 318 The actual operation of all transmitting apparatus in any radio station for which a station license is required by this Act shall be carried on only by a person holding an operator's license issued hereunder, and no person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Commission: *Provided*, *however*, That the Commission if it shall find that the public interest, convenience, or necessity will be served thereby may waive or modify the foregoing provisions of this section for the operation of any station except (1) stations for which licensed operators are required by international agreement, (2) stations for which licensed operators are required for safety purposes, (3) stations engaged in broadcasting, and (4) stations operated as common carriers on frequencies below thirty thousand kilocycles: *Provided, further*, That the Commission shall have power to make special regulations governing the granting of licenses for the use of automatic radio devices and for the operation of such devices.

* * * * * *

DISTRESS SIGNALS AND COMMUNICATIONS

§ 321 (a) The transmitting set in a radio station on shipboard may be adjusted in such a manner as to produce a maximum of radiation, irrespective of the amount of interference which may thus be caused, when such station is sending radio communications or signals of distress and radio communications relating thereto.

(b) All radio stations, including Government stations and stations on board foreign vessels when within the territorial waters of the United States shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies which will interfere with hearing a radio communication or signal of distress, and, except when engaged in answering or aiding the ship in distress, shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress, so far as possible, by complying with its instructions.

INTERCOMMUNICATION IN MOBILE SERVICE

§ 322 Every land station open to general public service between the coast and vessels or aircraft at sea shall, within the scope of its normal operations, be bound to exchange radio communications or signals with any ship or aircraft station at sea; and each station on shipboard or aircraft at sea shall, within the scope of its normal operations, be bound to exchange radio communications or signals with any other station on shipboard or aircraft at sea or with any land station open to general public service between the coast and vessels or aircraft at sea: *Provided*, That such exchange of radio communication shall be without distinction as to radio systems or instruments adopted by each station.

INTERFERENCE BETWEEN GOVERNMENT AND COMMERCIAL STATIONS

§ 323 (a) At all places where Government and private or commercial radio stations on land operate in such close proximity that interference with the work of Government stations cannot be avoided when they are operating simultaneously, such private or commercial stations as do interfere with the transmission or reception of radio communications or signals by the Government stations concerned shall not use their transmitters during the first fifteen minutes of each hour, local standard time.

* * * * * *

USE OF MINIMUM POWER

§ 324 In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

FALSE DISTRESS SIGNALS; REBROADCASTING; STUDIOS OF FOREIGN STATIONS

§ 325 (a) No person within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

CENSORSHIP; INDECENT LANGUAGE

§ 326 Nothing in this Act shall be understood or construed to give the Commission the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the Commission which shall interfere with the right of free speech by means of radio communication.

NOTE TO § 326:

The last sentence of § 326 was repealed and recodified as § 1464 of the Criminal Code 18 U. S. C. 1464, effective September 1, 1948. The last sentence of § 326 was as follows: "*No person within the jurisdiction of the United States shall utter any obscent, indecent, or profane language, by means of radio communication.*"

§ 1464 reads as follows; "§ *1464. Broadcasting Obscene Language. Whoever utters any obscene, indecent, or profane language by means of radio communication shall be fined not more than $10,000 or imprisoned not more than two years, or both.*"

* * * * * *

SHIP RADIO INSTALLATIONS AND OPERATIONS

§ 351 (a) Except as provided in § 352 hereof, it shall be unlawful— (1) For any ship of the United States, other than a cargo ship of less than sixteen hundred gross tons, to be navigated in the open sea outside of a harbor or port, or for any ship of the United States or any foreign country, other than a cargo ship of less than sixteen hundred gross tons, to leave or attempt to leave any harbor or port of the United States for a voyage in the open sea, unless such ship is equipped with an efficient radio installation in operating condition, in charge of and operated by a qualified operator or operators, adequately installed and protected so as to insure proper operation, and so as not to endanger the ship and radio installation, as hereinafter provided, and in the case of a ship of the United States, unless there is on board a valid station license issued in accordance with this Act;

(2) For any passenger ship of the United States of five thousand gross tons, or over, to be navigated outside of a harbor or port, in the open sea, or for any such ship of the United States or any foreign country to leave or attempt to leave any harbor or port of the United States for a voyage in the open sea, unless such ship is equipped with an efficient radio direction finder apparatus (radio compass) properly adjusted in operating condition as hereinafter provided, which apparatus is approved by the Commission;—

* * * * * *

OPERATORS, WATCHES, AUTO-ALARM

§ 353(a) Each cargo ship required by this part to be fitted with a radio installation and which is not fitted with an auto-alarm, and each passenger ship required by this part to be fitted with a radio installation, shall, for safety purposes, carry at least two qualified operators.

(e) On all ships of the United States fitted with an auto-alarm, said apparatus shall be in operation at all times while the ship is being navigated outside of a harbor or port when the operator is not on watch.

* * * * * *

AUTHORITY OF MASTER

§ 358 The radio installation, the operators, the regulation of their watches, the transmission and receipt of messages, and the radio service of the ship except as they may be regulated by law or international agreement, or by rules and regulations made in pursuance thereof, shall in the case of a ship of the United States be under the supreme control of the master.

* * * * * *

GENERAL PENALTY

§ 501 Any person who willfully and knowingly does or causes or suffers to be done any act, matter, or thing, in this Act prohibited or declared to be unlawful, or who willfully and knowingly omits or fails to do any act, matter, or thing in this Act required to be done, or willfully and knowingly causes or suffers such omission or failure, shall upon conviction thereof, be punished for such offense, for which no penalty (other than a forfeiture) is provided herein, by a fine of not more than $10,000 or by imprisonment for a term of not more than two years, or both.

VIOLATION OF RULES, REGULATIONS, AND SO FORTH

§ 502 Any person who willfully and knowingly violates any rule, regulation, restriction, or condition made or imposed by the Commission under authority of this Act, or any rule, regulation, restriction, or condition made or imposed by any international radio or wire communications treaty or convention, or regulations annexed thereto, to which the United States is or may hereafter become a party, shall, in addition to any other penalties provided by law, be punished, upon conviction thereof, by a fine of not more that $500 for each and every day during which such offense occurs.

* * * * * *

UNAUTHORIZED PUBLICATION OF COMMUNICATIONS

§ 605 No person receiving or assisting in receiving, or transmitting, or assisting in transmitting, any interstate or foreign communication by wire or radio shall divulge or publish the existence, contents, substance, purport, effect, or meaning thereof, except through authorized channels of transmission or reception, to any person other than the addressee, his agent, or attorney, or to a person employed or authorized to forward such communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any communication and divulge or publish the existence, contents, substance, purport, effect, or meaning of such intercepted communication to any person; and no person not being entitled thereto shall receive or assist in receiving any interstate or foreign communication by wire or radio and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the existence, contents, substance, purport, effect, or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: *Provided*, That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcast, or transmitted by amateurs or others for the use of the general public, or relating to ships in distress.

(B) *EXTRACTS FROM THE INTERNATIONAL TELECOMMUNICATION CONVENTION, ATLANTIC CITY, 1947*

ARTICLE 32

§ 1 Members and Associate Members agree to take all possible measures, compatible with the system of telecommunication used, with a view to insuring the secrecy of international correspondence.

* * * * * *

ARTICLE 43

§ 1 Stations performing radio communication in the mobile service shall be bound, within the limits of their normal employment, to exchange radio communications reciprocally without distinction as to the radio system adopted by them.

* * * * * *

ARTICLE 44

§ 1 All stations, whatever their purpose, must be established and operated in such a manner as not to result in harmful interference to the radio services or communications of other Members or Associate Members or of recognized private operating agencies, or of other duly authorized operating agencies which carry on radio service, and which operate in accordance with the provisions of the Radio Regulations.

* * * * * *

ARTICLE 45

§ 1 Radio stations shall be obligated to accept, with absolute priority, distress calls and messages regardless of their origin, to reply in the same manner to such messages, and immediately to take such action in regard thereto as may be required.

ARTICLE 46

Members and Associate Members agree to take the steps required to prevent the transmission or circulation of false or deceptive distress or safety signals and the use, by a station, of call signs which have not been regularly assigned to it.

(C) *EXTRACTS FROM THE INTERNATIONAL RADIO REGULATIONS ANNEXED TO THE INTERNATIONAL TELECOMMUNICATIONS CONVENTION, ATLANTIC CITY, 1947*

ARTICLE 13

372 § 1 Unnecessary transmissions and transmission of superflous signals and correspondence are forbidden to all stations.

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382 § 9 The transmission of signals without identification is forbidden to all stations.

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ARTICLE 21

485 The administrations bind themselves to take the necessary measures to prohibit and prevent:

486 (a) the unauthorized interception of radiocommunications not intended for the general use of the public;

487 (b) the divulgence of the contents, simple disclosure of the existence, publication or any use whatever without authorization, of information of any nature whatever obtained by the interception of the radiocommunications mentioned in 486.

* * * * * *

ARTICLE 22

488 § 1 (1) No transmitting station may be established or operated by a private person or by any enterprise without a license issued by the government of the country to which the station in question is subject.

* * * * * *

ARTICLE 23

493 § 1 (1) The governments or appropriate administrations of countries where a mobile station calls may require the production of the license. The operator of the mobile station, or the person responsible for the station, must facilitate this examination. The license must be kept in such a way that it can be produced without delay. As far as possible, the license, or a copy certified by the authority which has issued it, should be permanently exhibited in the station.

ARTICLE 26

565 § 1 The service of a mobile station is placed under the supreme authority of the master or of the person responsible for the ship, aircraft, or other vehicle carrying the mobile station.

566 § 2 The person holding this authority must require the operators to comply with these Regulations.

567 § 3 The master or the person responsible, as well as all persons who may have knowledge of the text or even of the existence of the radiotelegrams, or of any information whatever obtained by means of the radiocommunication service, are placed under the obligation of observing and ensuring the secrecy of correspondence.

* * * * * *

ARTICLE 29

610 § 6 (1) Before emitting, every station must listen for a period long enough to satisfy itself that it will not cause harmful interference to transmissions in progress within its range; if such interference is likely, the station awaits the first break in the transmission with which it might interfere.

* * * * * *

679 § 26 Where it is necessary for a mobile station to send signals for testing or adjustment which are liable to interfere with the working of a neighbouring coast or aeronautical station, the consent of the station must be obtained before such signals are sent.

680 § 27 When it is necessary for a station in the mobile service to make test signals, either for the adjustment of a transmitter before making a call or for the adjustment of a receiver, they must not continue for more than 10 seconds and must be composed of a series of VVV followed by the call sign of the station emittting the test signals.

* * * * * *

ARTICLE 37

871 § 5 Aircraft.

Any aircraft in distress must transmit the distress call on the frequency on which the land or mobile stations capable of helping it, keep watch. When the call is addressed to stations of the maritime service, the frequencies to be used shall be the international distress frequency 500 kc/s or other watchkeeping frequencies of these stations.

872 § 6 (1) In radiotelegraphy, the distress signal consists of the group ...———... transmitted as a single signal in which the dashes must be emphasized so as to be distinguished clearly from the dots.

873 (2) In radiotelephony, the distress signal consists of the word MAY-DAY pronounced as the French expression "m'aider".

874 § 7 These distress signals indicate that the ship, aircraft, or other vehicle sending the distress signal is threatened by grave and imminent danger and requests immediate assistance.

875 § 8 The distress call and message are sent only on the authority of the master or person responsible for the ship, aircraft or other vehicle carrying the mobile station.

879 § 11 The distress call, when sent by radiotelephony, is generally preceded by the signal ...———... produced by a whistle or any other suitable means.

* * * * * *

882 § 14 (1) The distress call must be followed as soon as possible by the distress message. This message comprises:

—the distress call;

—the name of the ship, aircraft, or vehicle in distress;

—particulars of its position, the nature of the distress and the kind of assistance desired;

—any other information which might facilitate the rescue.

883 (2) As a general rule, a ship signals its position in latitude and longitude (Greenwich), using figures for the degrees and minutes, together with one of the words NORTH or SOUTH and one of the words EAST or WEST. The signal .—.—.— is used to separate the degrees from the minutes. When practicable, the true bearing and distance in nautical miles from a known geographical point may be given.

884 (3) As a general rule, and if time permits, an aircraft shall transmit in its distress message the following information:

—estimated position and time of the estimate;

—true heading and indicated air speed;

—altitude;

—type of aircraft;

—nature of distress;

—intention of person in command (such as forced alighting on the sea or crash landing).

885 (4) As a general rule, an aircraft in flight signals its position:

—if possible by latitude and longitude (Greenwich), using figures for the degrees and minutes, together with one of the words NORTH and SOUTH and one of the words EAST or WEST; or

—by the name of the nearest place, and its approximate distance in relation thereto, together with one of the words NORTH, SOUTH, EAST, or WEST, as the case may be, or, when practicable, by words indicating intermediate directions.

886 § 15 After the transmission of its distress message, the mobile station transmits two dashes of approximately 10 seconds' duration each, followed by its call sign, to permit direction-finding stations to determine its position. This transmission will be repeated at frequent intervals in case of necessity.

* * * * * *

895 § 19 (1) Stations of the mobile service which receive a distress message from a mobile station which is, beyond any possible doubt, in their vicinity, must immediately acknowledge receipt (see 913, 914 and 915). If the distress call has not been preceded by the alarm signal,

these stations may transmit this alarm signal with the permission of the authority responsible for the station (for mobile stations see 565), taking care not to interfere with the transmission of acknowledgements of receipt sent by other stations.

896 (2) Stations of the mobile service which receive a distress message from a mobile station which, beyond any possible doubt, is not in their vicinity, must allow a short interval of time before acknowledging receipt of the message, in order to permit stations nearer to the mobile station in distress to answer and acknowledge receipt without interference.

* * * * * *

900 § 22 The control of distress traffic is the responsibility of the mobile station in distress or of the mobile station which, by the application of the provisions of 892 and 893, has sent the distress call. These stations may, however, delegate the control of the distress traffic to another station.

* * * * * *

932 § 34 (1) The urgency signal may be transmitted only on the authority of the master or the person responsible for the ship, aircraft or other vehicle carrying the mobile station.

933 (2) The urgency signal may be transmitted by a land station only with the approval of the responsible authority.

934 § 35 (1) In radiotelegraphy, the urgency signal consists of three repetitions of the group XXX, sent with the letters of each group and the successive groups clearly separated from each other. It is sent before the call.

935 (2) In radiotelephony, the urgency signal consists of three repetitions of the word PAN pronounced as the French word "panne". It is sent before the call.

936 § 36 (1) The urgency signal indicates that the calling station has a very urgent message to transmit concerning the safety of a ship, aircraft or other vehicle or of some person on board or within sight.

937 (2) The urgency signal has priority over all other communications, except distress. All mobile and land stations which hear it must take care not to interfere with the transmission of the message which follows the urgency signal.

938 (3) Where the urgency signal is used by a mobile station, it must, as a general rule, be addressed to a specific station.

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940 § 38 (1) Mobile stations which hear the urgency signal must continue to listen for at least three minutes. At the end of this period, if no urgency message has been heard, they may resume their normal service.

941 (2) However, land and mobile stations which are in communication on frequencies other than those used for the transmission of the urgency signal and of the call which follows it may continue their normal work without interruption provided the urgency message is not addressed "to all stations" (CQ).

943 § 40 (1) In radiotelegraphy, the safety signal consists of three repetitions of the group TTT, sent with the letters of each group and the successive groups clearly separated from each other. It is sent before the call.

944 (2)In radiotelephone, the word SÉCURITÉ, pronounced as the French "sécurité, repeated three times, is used for the safety signal.

945 § 41 (1) The safety signal indicates that the station is about to transmit a message concerning the safety of navigation or giving important meterological warnings.

946 (2) The safety signal and the message which follows it are sent on the distress frequency or on one of the frequencies which may be used in case of distress . . .

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949 § 43 All stations hearing the safety signal must continue to listen on the frequency on which the safety signal has been transmitted until they are satisfied that the message is of no interest to them. They must, moreover, not make any transmissions likely to interfere with the message.

RADIOTELEGRAMS

ARTICLE 38

Order of Priority of Communications in the Mobile Service

950 The order of priority of communications in the mobile service is as follows:

1. Distress calls, distress messages and distress traffic.
2. Communications preceded by the urgency signal.
3. Communications preceded by the safety signal.
4. Communications relative to radio direction-finding bearings.
5. Radiotelegrams relative to the navigation and safe movement of aircraft.
6. Radiotelegrams relative to the navigation, movements, and needs of ships; weather observation messages destined for an official meteorological service.
7. Government radiotelegrams for which priority right has been claimed.
8. Service radiotelegrams relating to the working of the radiocommunication service or to radiotelegrams previously transmitted.
9. All other communications.

(D) *EXTRACTS FROM THE RULES AND REGULATIONS OF THE FEDERAL COMMUNICATIONS COMMISSION*

§ 1.401 *Notice of violation.* Any licensee who appears to have violated any provision of the Communications Act of 1934 or of the Rules and Regulations of the Federal Communications Commission shall be served with a notice calling the facts to his attention and requesting a statement concerning the matter. Within 3 days from receipt of such notice, or such other period as may be specified, the licensee shall send a written answer direct to the office of the Commission originating the official notice. If an answer cannot be sent, nor an acknowledgment made within such 3-day period by reason of illness or other unavoidable circumstances, acknowledgment and answer shall be made at the earliest practicable date with a satisfactory explanation of the delay. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answers to other notices. If the notice relates to violations that may be due to the physical or electrical characteristics of transmitting apparatus, the answer shall state fully what steps, if any, have been taken to prevent future violations, and if any new apparatus is to be installed, the date such apparatus was ordered, the name of the manufacturer, and promised date of delivery. If the installation of such apparatus requires a construction permit, the file number of the application shall be given, or if a file number has not been assigned by the Commission such identification shall be given as will permit ready identification thereof. If the notice of violation relates to lack of attention to or improper operation of the transmitter, the name and license number of the operator in charge shall be given.

* * * * * *

§ 1.404 *Suspension of operator licenses.* Whenever it appears that grounds exist for suspension of an operator license, as provided in Section 303 (m) of the Act, the Bureau of Law after conferring with the other Bureaus of the Commission prepares a report and other necessary papers which are presented to the Commission for action. If the Commission concludes that suspension proceedings should be instituted, a suspension order will be issued. No order of suspension of any operator's license shall take effect until 15 days' notice in writing thereof, stating the cause for the proposed suspension, has been given to the operator licensee who may make written application to the Commission at any time within said 15 days for a hearing upon such order. The notice to the operator licensee shall not be effective until actually received by him, and from that time he shall have 15 days in which to mail the said application. In the event that physical conditions prevent mailing of the application before the expiration of the 15-day period, the application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay. Upon receipt by the Commission of such application for hearing, said order of suspension shall be held in abeyance until the conclusion of the hearing which shall be conducted under such rules as the Commission shall deem appropriate. Upon the conclusion of said hearing, the Commission may affirm, modify, or revoke said order of suspension. If the license is ordered suspended, the operator shall send his operator license to the office of the Commission in Washington, D. C., on or before the effective date of the order, or, if the effective date has passed at the time notice is received, the license shall be sent to the Commission forthwith.

PART 2—FREQUENCY ALLOCATIONS AND TREATY MATTERS; GENERAL RULES AND REGULATIONS

§ 2.1 *Definitions.* The following definitions are issued:

Base station (*FB*). A land station in the land mobile service carrying on a service with land mobile stations.

Citizens radio service. A radiocommunication service of fixed, land, or mobile stations, or combinations thereof, intended for use by citizens of the United States for private or personal radiocommunication (including radio signaling, control of objects by radio, and other purposes.)

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Domestic fixed service. A fixed service intended for the transmission of information between points, all of which lie within the 48 states and the District of Columbia, except for the domestic haul of international traffic.

* * * * * *

Experimental station (*EX*). A station utilizing Hertzian waves in experiments with a view to the development of science or technique. This definition does not include amateur stations.

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Facsimile. A system of telecommunication for the transmission of fixed images with a view to their reception in a permanent form.

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Fixed service. A service of radiocommunication between specified fixed points.

* * * * * *

Industrial radio service. Any service of radiocommunication essential to, operated by, and for the sole use of those enterprises which for purposes of safety or other necessity require radiocommunication in order to function efficiently, the radio transmitting facilities of which are defined as fixed, land, or mobile stations.

Industrial, scientific, and medical equipment. Devices which use Hertzian waves for industrial, scientific, medical, or any other purposes including the transfer of energy by radio and which are neither used nor intended to be used for radiocommunication.

Land station (*FL*). A station in the mobile service not intended for operation while in motion.

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Land transportation radio services. Any service of radio communication operated by, and for the sole use of certain inland transportation carriers, the radio transmitting facilities of which are defined as fixed, land, or mobile stations.

* * * * * *

Mobile station (*MO*). A station in a mobile service intended to be used while in motion or during halts at unspecified points.

Public correspondence. Any telecommunication which the offices and stations, by reason of their being at the disposal of the public, must accept for transmission.

* * * * * *

Public safety radio service. Any service of radiocommunication essential to either the discharge of non-federal governmental functions relating to public safety responsibilities or the alleviation of an emergency endangering life or property, the radio transmitting facilities of which are defined as fixed, land, or mobile stations.

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§ 2.102 *Nomenclature of frequences.* Frequencies shall be expressed in kilocycles per second (kc) at and below 30,000 kilocycles and in megacycles per second (Mc) above this frequency.

* * * * * *

§ 2.201. *Emission, modulation and transmission characteristics.* The following system of designating emission, modulations and transmission characteristics shall be employed.

(a) The emission characters used in connection with frequency assignments express:

(1) Necessary bandwidth.
(2) Type of modulation or emission.
(3) Type of transmission.
(4) Supplementary characteristics authorized.

(b) Types of modulation and emission are symbolized according to the following letters:

(1) Amplitude modulation	A
(2) Frequency (or phase) modulation	F
(3) Pulsed emission	P

(c) Types of transmission are symbolized according to the following numbers:

(1) Absence of any modulation intended to carry information..	0
(2) Telegraphy without the use of modulating audio frequency	1
(3) Telegraphy by the keying of a modulating audio frequency or audio frequencies or by the keying of the modulated emission (special case: an unkeyed modulated emission)	2
(4) Telephony	3
(5) Facsimile	4
(7) Television	5
(7) Composite transmissions and cases not covered by the above	9

* * * * * *

§ 2.402 *Control of distress traffic.* The control of distress traffic is the responsibility of the mobile station in distress or of the mobile station which, by the application of the provisions of § 2.403, has sent the distress call. These stations may, however, delegate the control of the distress traffic to another station.

§ 2.403 *Retransmission of distress message.* Any station which becomes aware that a mobile station is in distress may transmit the distress message in the following cases:

(a) When the station in distress is not itself in a position to transmit the message.

(b) In the case of mobile stations, when the master or the person in charge of the ship, aircraft or other vehicles carrying the station which intervenes believes that further help is necessary.

(c) In the case of other stations, when directed to do so by the station in control of distress traffic or when it has reason to believe that a distress call which it has intercepted has not been received by any station in a position to render aid.

§ 2.404 *Resumption of operation after distress.* No station having been notified to cease operation shall resume operation on frequency or frequencies which may cause interference until notified by the station issuing the original notice that the station involved will not interfere with distress traffic as it is then being routed or until the receipt of a general notice that the need for handling distress traffic no longer exists.

§2.405 *Operation during emergency.* The licensee of any station, except amateur, may, during a period of emergency in which the normal communication facilities are disrupted as a result of hurricane, flood, earthquake, or similar disaster, utilize such station for emergency communication service in communicating in a manner other than that specified in the instrument of authorization: *Provided,*

(a) That as soon as possible after the beginning of such emergency use, notice be sent to the Commission at Washington, D. C., and to the Engineer in Charge of the district in which the station is located, stating the nature of the emergency and the use to which the station is being put, and

(b) That the emergency use of the station shall be discontinued as soon as substantially normal communication facilities are again available, and

(c) That the Commission at Washington, D. C., and the Engineer in Charge shall be notified immediately when such special use of the station is terminated: *Provided, further,*

(d) That in no exent shall any station engage in emergency transmission on frequencies other than, or with power in excess of, that specified in the instrument of authorization or as otherwise expressly provided by the Commission, or by law: *And provided further,*

(e) That the Commission may, at any time, order the discontinuance of any such emergency communication undertaken under this section.

PART 3—RULES GOVERNING RADIO BROADCAST SERVICES

§ 3.57 *Operating power; maintenance of.* The licensee of a broadcast station shall maintain the operating power of the station within the prescribed limits of the licensed power at all times except that in an emergency when, due to causes beyond the control of the licensee it becomes impossible to operate with the full licensed power, the station may be operated at reduced power for a period of not to exceed 10 days, provided that the Commission and the Engineer in Charge shall be notified in writing immediately after the emergency develops. (See Operating Power Tolerance.)

§ 3.183 *Logs, by whom kept.* Each log shall be kept by the person or persons competent to do so, having actual knowledge of the facts required, who shall sign the log when starting duty and again when going off duty. The logs shall be made available upon request by an authorized representative of the Commission.

* * * * * *

§ 3.185 *Correction of logs.* No log or portion thereof shall be erased, obliterated, or willfully destroyed within the period of retention provided by the rules. Any necessary correction may be made only by the person originating the entry who shall strike out the erroneous portion, initial the correction made, and indicate the date of correction.

§ 3.186 *Rough logs.* Rough logs may be transcribed into condensed form, but in such case the original log or memoranda and all portions thereof shall be preserved and made a part of the complete log.

* * * * * *

§ 3.565 *Operator requirements.* (a) If the transmitter power rating is in excess of 1 kilowatt, one or more operators holding first-class radiotelephone licenses shall be on duty at the place where the transmitting apparatus of the station is located and in actual charge thereof.

(b) If the transmitter power rating is in excess of 10 watts but not greater than 1 kilowatt, one or more operators holding first- or second-class radiotelephone licenses shall be on duty at the place where the transmitting apparatus of the station is located and in actual charge thereof.

PART 7—RULES GOVERNING COASTAL AND MARINE RELAY SERVICES

§ 7.34 *Identification of radiotelephone station.* The name (geographical location as approved by the Commission) of a coastal harbor station shall be announced upon the completion of each communication with any other station and at the conclusion of each transmission made for any other purpose.

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§ 7.84. *Retention of radio station logs.* Logs of a radio station shall be retained by the licensee for a period of one year: *Provided, however,* That logs involving communications incident to a disaster or which include communications incident to or involved in an investigation by the Commission and concerning which the licensee has been notified, shall be retained by the licensee until he is specifically authorized in writing by the Commission to destroy them: *Provided, further,* That logs incident to or involved in any claim or complaint of which the licensee has notice shall be retained by the licensee until such claim or complaint has been fully satisfied or until the same has been barred by statute limiting the time for the filing of suits upon such claims.

§ 8.195 *Requirement for ship radar installation.* In addition to other applicable rules and regulations ship radar installations shall be governed by the following:

(a) *Definition.* The term "ship radar installation" or "ship radar station" as used herein means a radio station located on board ship licensed for the transmission of energy by radio for the purpose of automatically detecting land and other objects through the reception of the effects of such transmission, with a determination of their direction and distance.

(b) *Application for license and condition of issuing license.* (1) Applications for ship radar station licenses shall be made in accordance with the provisions of part 1 of the Commission's rules and regulations. (2) Any license issued shall be subject to the condition that the station licensee, in relation to the proper operation of the station in accordance with the radio law and rules and regulations of the Commission, will be represented on board the radar-equipped vessel by the person who at any given time occupies the position of master.

* * * * * *

(D) *Posting of ship radar station license.* The ship radar station license shall be posted in a conspicuous place at the principal radar operating position.

* * * * * *

(f) *Authorized emission for radar transmitters.* Any transmitter of a ship radar station which operates within a frequency band allocated in section 8.195 (g) shall use special (pulsed) type of emission only.[1]

(g) *Allocation of frequencies for ship radar stations.* The following frequency bands are allocated for use by ship radar stations:[2]

3000 to 3246 Mc
5460 to 5650 Mc
9320 to 9500 Mc

(h) *Frequency tolerance.* The frequency at which maximum emission occurs shall be within the assigned frequency band and shall not be closer than 1.5/T megacycles per second to the upper and lower limits of the assigned frequency band, where T is the pulse duration in microseconds.

(i) *Frequency measurements.* The licensee of a ship radar station shall take the necessary measures to insure that the transmitter operates within the tolerance limits specified in section 8.195 (h).

(j) *Name plate on radar installation.* Each ship radar station installation the manufacture of which was completed on or after December 10, 1947, shall be furnished with a durable name plate with the manufacturer's name, transmitter model number, and month and year of completion of manufacture permanently inscribed thereon. Such name plate shall be affixed to the indicator housing at the principal

[1] For the purpose of this part of the rules, the term "special (pulsed) type of emission" means radio frequency energy which is emitted in the form of short bursts of energy repeated at regular intervals, the duration of each burst being much shorter than the interval between bursts.

[2] The associated transmitting frequencies of radar beacons (racons) are, respectively as follows: 3256, 5450, and 9310 megacycles.

radar operating position or to some other component of the radar installation which is readily accessible for inspection.

(k) *External adjustments.* Radar transmitters which have means available for external adjustments, the manipulation of which may cause operation not in accordance with section 8.195 (h), will not be licensed in the ship service.

(l) *Design and construction.* The design and construction of radar equipment intended for licensing in ship service shall be such that when properly installed, its use will produce no interference to the radio communication service of any ship.

(m) *Type approval of radar equipment.* (1) To determine the acceptability of radar equipment for licensing in the ship service, such equipment will be examined by duly authorized representatives of the Commission for compliance with the provisions of sections 8.195 (f), (g), (h), (j), (k), and (l) of these rules, and if found in compliance therewith, appropriate type approval will be issued.

(o) *Radio operator requirements.* (1) No radio operator license is required for the operation on board ship, during the course of normal rendition of service, of ship radar stations licensed in the ship service: *Provided,* That the following conditions are met or provided for by the licensee of the station:

(i) The radar equipment shall employ as its frequency determining element a nontunable, pulse-type magnetron.

(ii) The radar equipment shall be capable of being operated during the course of normal rendition of service in accordance with the radio law and the rules and regulations of the Commission by means of exclusively external controls, and

(iii) Operation during the course of normal rendition of service pursuant to this subparagraph, must be performed exclusively by the master of the radar-equipped ship or by one or more other persons responsible to him and authorized by him to do so.

(2) All adjustments or tests during or coincident with the installation, servicing, or maintenance of the equipment while it is radiating energy must be performed by or under the immediate supervision and responsibility of a person holding a first or second class commercial radio operator license, radiotelephone or radiotelegraph, containing a ship radar endorsement, who shall be responsible for the proper functioning of the equipment in accordance with the radio law and the Commission's rules and regulations and for the avoidance and prevention of harmful interference from improper transmitter external effects: *Provided, however,* That nothing in this subparagraph shall be construed to prevent persons not holding such licenses or not holding such licenses so endorsed from making replacements of fuses or of receiving-type tubes.

(3) Nothing in this paragraph shall be construed to change or diminish in any respect the responsibility of any ship radar station licensee for having and maintaining control over the station licensed to him, or for the proper punctioning and operation of such station in accordance with the terms of the station license.

(p) *Installation and maintenance record.* (1) The station licensee of each ship radar station shall provide and require to be kept at the station a permanent installation and maintenance record. Entries in this record shall be made by or under the personal direction of the responsible installation, service, or maintenance operator concerned in each particular instance, but the station licensee shall have joint responsibility with the responsible operator concerned for the faithful and accurate making of such entries as are required by this paragraph.

(2) Each entry in this record shall be personally signed by the responsible operator concerned.

(3) The following entries shall be made in this record:

(i) The date and place of initial installation.

(ii) Any necessary steps taken to remedy any interference found to exist at the time of such installation.

(iii) The nature of any complaint (including interference to radio communication) arising subsequent to initial installation, and the date thereof.

(iv) The reason for the trouble leading to the complaint, including the name of any component or component part which failed or was misadjusted.

(v) Remedial measures taken, and the date thereof.

(vi) The name, license number, and date of the ship radar operator endorsement on the first or second class radio operator license of the responsible operator performing or immediately supervising the installation, servicing, or maintenance.

§ 8.223 *Disposition of logs.* Ship station logs shall be fully completed at the end of each voyage and before the operator(s) responsible leaves(s) the ship. The radio log currently in use shall be kept by the licensed operator(s) of the station and during use shall be located in the radio operating room of the vessel. At the conclusion of each voyage terminating at a port of the United States, the original radio log (or a duplicate thereof) dating from the last departure of the vessel from a United States port shall be retained under proper custody on board the vessel for a sufficient period of time (not required to be retained for more than 24 hours) to be available for inspection by duly authorized representatives of the Commission. Thereafter, the original log (and duplicate log, if provided) may be filed at an established shore office of the ship station licensee, and shall be retained as stipulated by section 2.54 of part 2.

§ 8.224 *Retention of radio station logs.* Logs of a radio station shall be retained by the licensee for a period of 1 year: *Provided, however,* That logs involving communications incident to a disaster or which include communications incident to or involved in an investigation by the Commission and concerning which the licensee has been notified, shall be retained by the licensee until he is specifically authorized in writing by the Commission to destroy them: *Provided further,* That logs incident to or involved in any claim or complaint of which the licensee has notice shall be retained by the licensee until such claim or complaint has been fully satisfied or until the same has been barred by statute limiting the time for the filing of suits upon such claims.

PART 9—RULES AND REGULATIONS GOVERNING AERONAUTICAL SERVICES

§ 9.3 *Aircraft radio station.* A radio station on board any aircraft including all radio transmitting devices operated in the aeronautical radiocommunication service.

(a) *Air carrier aircraft station.* A radio station aboard an aircraft engaged in, or essential to, transportation of passengers or cargo for hire. For the purpose of these rules, and at the option of the applicant, an aircraft weighing less than 10,000 pounds may be considered as a private aircraft even though actually engaged in air carrier operation. The election by the applicant will determine the application form to be used, the equipment and frequencies to be employed, and the regulations applicable to the aircraft radio station.

(b) *Private aircraft station.* A radio station on board an aircraft not operated as an air carrier.

§ 9.4 *Ground radio station.* Any radio station on the ground equipped or engaged in radio communications or radio transmission of energy.

(a) *Airdrome control radio station.* A radio station providing communications between an airdrome control tower and aircraft or aeronautical mobile utility stations.

(b) *Aeronautical land station.* A land station in the aeronautical mobile service carrying on a service with aircraft stations, but which may also carry on a limited communication service with other aeronautical land stations.

(c) *Aeronautical fixed station.* A radio station used in the fixed service for the handling of communications between fixed points relating solely to actual aviation needs.

(d) *Aeronautical mobile utility station.* A mobile radio station used for communications at airdromes with the control tower, ground vehicles, and aircraft on the ground.

(e) *Operational fixed station.* A fixed station not open to public correspondence operated by and for the sole use of those agencies operating, their own radiocommunication facilities in the Public Safety, Industrial, Land Transportation, Marine, or Aviation Services.

§ 9.5 *Aeronautical navigational radio station.* A radio station for aeronautical purposes involving the transmission of special radio signals intended solely to assist in the determination of aircraft position, including that relative to collision hazards.

(a) *Radio beacon station.* A special radio station, the emissions of which are intended to enable an aircraft to determine: (1) Its radio bearing or direction with reference to the radio beacon station, or (2) the distance which separates it from the latter, or (3) both of these.

(b) *Radio direction finding station.* A radio station equipped with special apparatus for obtaining radio bearing.

(c) *Radio range station.* A form of radio beacon, the emissions of which provide definite track guidance.

(d) *Localizer station.* A directional radio beacon normally associated with an instrument landing system which provides guidance in the horizontal plane to an aircraft for purposes of approach in landing.

(e) *Glide path station.* A directional radio beacon associated with an instrument landing system which provides guidance in the vertical plane to an aircraft for purposes of approach in landing.

(f) *Marker station.* A radio station marking a definite location on the ground as an aid to navigation.

(g) *Ground control approach station.* A station used for the purpose of controlling from the ground the approach and landing of aircraft.

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§ 9.8 *Aeronautical public service station.* A radio station, ground or aircraft, operated in the aeronautical public communication service.

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§ 9.192 *Availability for inspections.* All classes of stations in the aeronautical service and the maintenance records of said stations shall be made available for inspection upon request of an authorized representative of the Commission made to the licensee or to his representative.

§ 9.193. *Permissible communications.* All ground stations in the aeronautical radiocommunication service shall transmit only communications for the safe, expeditious and economical operation of aircraft and the protection of life and property in the air: *Provided, however,* That aeronautical public service stations, and Aeronautical Advisory and Civil Air Patrol land and mobile stations may communicate in accordance with the particular sections of these rules which govern the operation of those classes of stations.

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§ 9.312 *Frequencies available.* The following frequencies are available to aircraft stations in the aeronautical radiocommunication service.

(a) *375 kilocycles.* International direction finding frequency for use outside the continental United States.

(b) *457 kilocycles.* Working frequency exclusively for aircraft on sea flights desiring an intermediate frequency.

(c) *500 kilocycles.* International calling and distress frequency for ships and aircraft over the seas.

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(e) *8280 kilocycles.* Interim calling and distress frequency for use by ships and aircraft in addition to 500 kilocycles or in lieu thereof where 500 kilocycles is not available.

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(g) *121.5 megacycles.* This frequency is a universal simplex channel for emergency and distress communications. It will provide a means of calling and working between the various services in connection with search and rescue operations, an emergency means for direction finding purposes and a means for establishing air to ground contact with lost aircraft. This frequency will not be assigned to aircraft unless there are also assigned and available for use other frequencies to accommodate the normal communications needs of the aircraft.

PART 10—RULES GOVERNING PUBLIC SAFETY RADIO SERVICES

§10.105 *Modulation requirements.* (a) When amplitude modulation is used for telephony, the modulation percentage shall be sufficient to provide efficient communication and shall be normally maintained above 70 per cent on peaks, but shall not exceed 100 per cent on negative peaks.

(b) When phase or frequency modulation is used for telephony, the deviation arising from modulation shall not exceed plus or minus 15 kc. from the unmodulated carrier.

(c) Each transmitter first authorized or installed after July 1, 1950, shall be provided with a device which will automatically prevent modulation in excess of that specified in paragraphs (a) and (b) of this section which may be caused by greater than normal audio level: *Provided, however,* That this requirement shall not be applicable to transmitters authorized to operate as mobile stations with a maximum plate power input to the final radio frequency stage of 3 watts or less.

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§ 10.108 *Transmitter measurements.* (a) The licensee of each station shall employ a suitable procedure to determine that the carrier frequency of each transmitter, authorized to operate with a plate input power to the final radio frequency stage in excess of 3 watts, is maintained within the tolerance prescribed in this part. This determination shall be made, and the results thereof entered in the station records, in accordance with the following:

(1) When the transmitter is initially installed;

(2) When any change is made in the transmitter which may affect the carrier frequency or the stability thereof;

(3) At intervals not to exceed 6 months, for transmitters employing crystal-controlled oscillators.

(4) At intervals not to exceed 1 month, for transmitters not employing crystal-controlled oscillators.

(b) The licensee of each station shall employ a suitable procedure to determine that that plate power input to the final radio frequency stage of each base station or fixed station transmitter, authorized to operate with a plate input power to the final radio frequency stage in excess of 3 watts, does not exceed the maximum figure specified on the current station authorization. Where the transmitter is so constructed that a direct measurement of plate current in the final radio frequency stage is not practicable, the plate input power may be determined from a measurement of the cathode current in the final radio frequency stage. When the plate input to the final radio frequency stage is determined from a measurement of the cathode current, the required entry shall indicate clearly the quantities that were measured, the measured values thereof, and the method of determining the plate power input from the measured values. This determination shall be made, and the results thereof entered in the station records, in accordance with the following:

(1) When the transmitter is initially installed;

(2) When any change is made in the transmitter which may increase the transmitter power input;

(3) At intervals not to exceed 6 months.

(c) The licensee of each station shall employ a suitable procedure to determine that the modulation of each transmitter, authorized to operate with a plate input power to the final radio frequency stage in excess of 3 watts, does not exceed the limits specified in this part. This determination shall be made and the results thereof entered in the station records, in accordance with the following:

(1) When the transmitter is initially installed;

(2) When any change is made in the transmitter which may affect the modulation characteristics;

(3) At intervals not to exceed 6 months.

(d) The determinations required by paragraphs (a), (b), and (c) of this section may, at the option of the licensee be made by any qualified engineering measurement service, in which case, the required record entries shall show the name and address of the engineering measurements service as well as the name of the person making the measurements.

(e) In the case of mobile transmitters, the determinations required by paragraphs (a) and (c) of this section may be made at a test or service bench: *Provided,* The measurements are made under local conditions equivalent to actual operating conditions; *And provided further,* That after installation the transmitter is given a routine check to determine that it is capable of being satisfactorily received by an appropriate receiver.

§ 10.152 *Station identification.* (a) The required identification for stations in these services shall be the assigned call signal.

(b) Nothing in this section shall be construed as prohibiting the transmission of additional station or unit identifiers which may be necessary for systems operation; *Provided, however,* Such additional identifiers shall not be composed of letters or letters or digits arranged in a manner which could be confused with an assigned radio station call signal.

(c) Except as indicated in paragraphs (d), (e) and (f) of this section, each station in these services shall transmit the required identification at the end of each transmission or exchange of transmissions, or once each 30 minutes of the operating period, as the licensee may prefer.

(d) A mobile station authorized to the licensee of the associated base station and which transmits only on the transmitting frequency of the associated base station is not required to transmit any identification.

(e) A mobile station which is either separately licensed to a different licensee, transmits on any frequency other than the transmitting frequency of the associated base station, or which has no associated base station shall transmit the required identification at the end of each transmission or exchange of transmissions, or once each 30 minutes of the operating period, as the licensee may prefer. Where election is made to transmit the required identification at 30-minute intervals, a single mobile unit in each general geographic area may be assigned the responsibility for such transmission and thereby eliminate any necessity for every unit of the mobile station to transmit the required identification. For the purpose of this paragraph, the term "each general geographic area" means an area not smaller than a single city or county and not larger than a single district of a State where the district is administratively established for the service in which the radio system operates.

(f) Stations which are entirely automatic in their operation will be considered for exemption from the requirements of paragraph (c) of this section.

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§ 10.159 *Inspection of tower lights and associated control equipment.* The licensee of any station in these services which has an antenna or antenna supporting structure required to be illuminated by the terms of the station authorization:

(a) Shall make a daily check of the tower lights either by visual observation of the tower lights or by observation of an automatic indicator which shows whether the tower lights are operating properly.

(b) Shall report immediately by telephone or telegraph to the nearest Airways Communication station or office of Civil Aeronautics Administration any observed failure of a code or rotating beacon light not corrected within 30 minutes, regardless of the cause of such failure. Further notification by telephone or telegraph shall be given immediatly upon resumption of the required illumination.

(c) Shall inspect at intervals not to exceed three months all code or rotating beacons and automatic lighting control devices to insure that such apparatus is functioning properly.

(d) Shall measure at intervals not to exceed three months, the voltage under load at the socket of each light required to be installed. When it is not practicable to measure the socket voltage directly, such voltage may be computed from measurements under load at some other point in the circuit. When the socket voltages are not measured directly, the entry in the station records shall clearly indicate the method used in the calculation thereof.

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§ 10.161 *Content of station records.* Each licensee of a station in these services shall maintain records in accordance with the following:

(a) For all stations, the results and dates of the transmitter measurements required by these rules and the name of the person or persons making the measurements.

(b) For all stations, when service or maintenance duties are performed, the responsible operator shall sign and date an entry in the station record giving:

(1) Pertinent details of all duties performed by him or under his supervision;

(2) His name and address, and

(3) The class, serial number, and expiration date of his license, *Provided,* That the information called for by subparagraphs (2) and (3) of this paragraph, so long as it remains the same, need be entered

only once in the station record at any station where the responsible operator is regularly employed on a full-time basis and at which his license is properly posted.

(c) For all base and fixed stations, the name or names of persons responsible for the operation of the transmitting equipment each day, together with the period of their duty. Each such person shall sign, not initial, the record both when coming on and when going off duty.

(d) For stations in the special emergency service a record showing the nature and time of each communication: *Provided, however*, That such stations, when operated by communications common carriers for line break bridging purposes, need merely record the hours of operation and the purpose for which used.

(e) For stations whose antenna or antenna supporting structure is required to be illuminated, a record in accordance with the following:

(1) The time the tower lights are turned on and off each day if manually controlled.

(2) The time the daily check of proper operation of the tower lights was made.

(3) In the event of any observed failure of a tower light:

(i) Nature of such failure.

(ii) Date and time the failure was observed.

(iii) Date, time, and nature of the adjustments, repairs, or replacements made.

(iv) Identification of Airways Communication station (Civil Aeronautics Administration) notified of the failure of any code or rotating beacon light not corrected within 30 minutes, and the date and time such notice was given.

(v) Date and time notice was given to the Airways Communication station (Civil Aeronautics Administration) that the required illumination was resumed.

(4) Upon completion of the periodic inspection required at least once each 3 months;

(i) The date of the inspection and the condition of all tower lights and associated tower lighting control devices, together with the socket voltages measured under load at the sockets or computed from measurements under load at other points.

(ii) Any adjustments, replacements, or repairs made to insure compliance with the lighting requirements and the date such adjustments, replacements, or repairs were made.

§ 10.162 *Form of station records.* (a) The records shall be kept in an orderly manner and in such detail that the data required are readily available. Key letters or abbreviations may be used if proper meaning or explanation is set forth in the record.

(b) Each entry in the records shall be signed by a person qualified to do so having actual knowledge of the facts to be recorded.

(c) No record or portion thereof shall be erased, obliterated, or willfully destroyed within the required retention period. Any necessary correction may be made only by the persons originating the entry who shall strike out the erroneous portion, initial the correction made and indicate the date of the correction.

APPENDIX III

TABLE 1.—*Abbreviations available for all services*

Abbreviations	Question	Answer or advice
QRA	What is the name of your station?	The name of my station is . . .
QRB	How far approximately are you from my station?	The approximate distance between our stations is . . . nautical miles (*or* . . . kilometres).
QRC	By what private enterprise (*or* State administration) are the accounts for charges for your station settled?	The accounts for charges of my station are settled by the private enterprise . . . (*or* State administration).
QRD	Where are you bound and where are you from?	I am bound for . . . from . . .
QRE	What is your estimated time of arrival at . . . (place)?	My estimated time of arrival at . . . (place) is . . . hrs.
QRF	Are you returning to . . . (place)?	I am returning to . . . place *or* Return to . . . (place).
QRG	Will you tell me my exact frequency (*or* that of . . .)?	Your exact frequency (*or* that of . . .) is . . . kc/s (*or* Mc/s).
QRH	Does my frequency vary?	Your frequency varies.
QRI	How is the tone of my transmission?	The tone of your transmission is . . . (1 Good; 2 Variable; 3 Bad).
QRK	What is the readability of my signals (*or* those of . . .)?	The readability of your signals (*or* those of . . .) is . . . (1 Unreadable; 2 Readable now and then; 3 Readable, but with difficulty; 4 Readable; 5 Perfectly readable).
QRL	Are you busy?	I am busy (*or* I am busy with . . .). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by static?...	I am troubled by static.
QRO	Shall I increase power?..........	Increase power.
QRP	Shall I decrease power?..........	Decrease power.

TABLE 1.—*Abbreviations available for all services*—Continued

Abbreviations	Question	Answer or advice
QRQ	Shall I send faster?	Send faster (. . . words per minute).
QRR	Are you ready for automatic operation?	I am ready for automatic operation. Send at . . . words per minute.
QRS	Shall I send more slowly?	Send more slowly (. . . words per minute).
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready.
QRW	Shall I inform . . . that you are calling him on . . . kc/s (*or* Mc/s)?	Please inform . . . that I am calling him on . . . kc/s (*or* Mc/s).
QRX	When will you call me again?	I will call you again at . . . hours [on . . . kc/s (*or* Mc/s)].
QRY	What is my turn? (Relates to communication.)	Your turn is No. . . . (*or* according to any other indication). (Relates to communication).
QRZ	Who is calling me?	You are being called by . . . [on kc/s (*or* Mc/s)].
QSA	What is the strength of my signals (*or* those of . . .)?	The strength of your signals (*or* those of . . .) is . . . (1 Scarcely perceptible; 2 Weak; 3 Fairly good; 4 Good; 5 Very good).
QSB	Are my signals fading?	Your signals are fading.
QSC	Are you a cargo vessel? (See art. 33, sec. V.)	I am a cargo vessel.
QSD	Is my keying defective?	Your keying is defective.
QSG	Shall I send . . . telegrams at a time?	Send . . . telegrams at a time.
QSI	....	I have been unable to break in on your transmission *or* Will you inform . . . (call sign) that I have been unable to break in on his transmission [on . . . kc/s (*or* Mc/s)].
QSJ	What is the charge to be collected per word to . . . including your internal telegraph charge?	The charge to be collected per word to . . . including my internal telegraph charge is . . . francs.

TABLE 1.—*Abbreviations available for all services*—Continued

Abbre-viations	Question	Answer or advice
QSK	Can you hear me between your signals?	I can hear you between my signals.
QSL	Can you acknowledge receipt?	I am acknowledging receipt.
QSM	Shall I repeat the last telegram which I sent you, or some previous telegram?	Repeat the last telegram which you sent me (*or* telegram(s) number(s) . . .).
QSN	Did you hear me [*or* . . . (call sign)] on . . . kc/s (*or*	I did hear you [*or* . . . (call sign)] on . . . kc/s (*or* Mc/s).
QSO	Can you communicate with . . . direct or by relay? Mc/s)?	I can communicate with . . . diect (*or* by relay through . . .).
QSP	Will you relay to . . . free of charge?	I will relay to . . . free of charge.
QSQ	Have you a doctor on board [*or* is . . . (name of person) on board]?	I have a doctor on board [*or* . . . (name of person) is on board].
QSU	Shall I send or reply on this frequency [*or* on . . . kc/s (*or* Mc/s)] (with emissions of class . . .)?	Send or reply on this frequency [*or* on . . . kc/s (*or* Mc/s)] (with emissions of class . . .).
QSV	Shall I send a series of V's on this frequency [*or* . . . kc/s (*or* Mc/s)]?	Send a series of V's on this frequency [*or* . . . kc/s (*or* Mc/s)].
QSW	Will you send on this frequency [*or* . . . kc/s (*or* Mc/s)] (with emissions of class . . .)?	I am going to send on this frequency [*or* on . . . kc/s (*or* Mc/s)] (with emissions of class . . .)
QSX	Will you listen to . . . [call sign(s)] on . . . kc/s (*or* Mc/s)?	I am listening to . . . [call sign(s)] on . . . kc/s (*or* Mc/s).
QSY	Shall I change to transmission on another frequency?	Change to transmission on another frequency [*or* on . . . kc/s (*or* Mc/s)].
QSZ	Shall I send each word or group more than once?	Send each word or group twice (*or* . . . times).
QTA	Shall I cancel telegram number . . . as if it had not been sent?	Cancel telegram No. . . . as if it had not been sent.
QTB	Do you agree with my counting of words?	I do not agree with your counting of words; I will repeat the first letter or digit of each word or group.
QTC	How many telegrams have you to send?	I have . . . telegrams for you (*or* for . . .).
QTE	What is my TRUE bearing from you? *or*	Your TRUE bearing from me is . . . degrees (at . . . hours)

TABLE 1.—*Abbreviations available for all services*—Continued

Abbreviations	Question	Answer or advice
	What is my TRUE bearing from ... (call sign?) *or*	Your TRUE bearing from ... (call sign) was ... degrees (at ... hours) *or*
	What is the TRUE bearing of .... (call sign) from ... (call sign?) *or*	The TRUE bearing of ... (call sign) from ... (call sign) was ... degrees at ... hours
QTF	Will you give me the position of my station according to the bearings taken by the direction finding stations which you control? (See appendix 15.)	The position of your station according to the bearings taken by the direction finding stations which I control was ... latitude ... longitude, class ... at ... hours. (See appendix 15.)
QTG	Will you send two dashes of 10 seconds each followed by your call sign (repeated ... times) [on ... kc/s (*or* Mc/s)]? *or*	I am going to send two dashes of 10 seconds each followed by my call sign (repeated ... times) [on ... kc/s (*or* Mc/s)] *or*
	Will you request ... to send two dashes of 10 seconds followed by his call sign (re-repeated ... times) on ... kc/s (*or* Mc/s)?	I have requested ... to send two dashes of 10 seconds followed by his call sign (repeated ... times) on ... kc/s (*or* Mc/s).
QTH	What is your position in latitude and longitude (*or* according to any other indication)?	My position is ... latitude ... longitude (*or* according to any other indication).
QTI	What is your TRUE track? ...	My TRUE track is ... degrees.
QTJ	What is your speed? Requests the speed of a ship or aircraft through the water or air respectively.)	My speed is ... knots (or kilometres per hour). (Indicates the speed of a ship or aircraft through the water or air respectively.)
QTK	What is the speed of your aircraft in relation to the surface of the earth?	The speed of my aircraft in relation to the surface of the earth is ... knots (*or* kilometres per hour).
QTL	What is your TRUE heading (TRUE course with no wind)?	My TRUE heading is ... degrees.
QTN	At what time did you depart from ... (place)?	I departed from ... (place) at ... hours.
QTO	Have you left dock (*or* port)? *or* Are you airborne?	I have left dock (*or* port) *or* I am airborne.

TABLE 1.—*Abbreviations available for all services*—Continued

Abbreviations	Question	Answer or advice
QTP	Are you going to enter dock (*or* port)? *or* Are you going to alight (*or* land)?	I am going to enter dock (*or* port) *or* I am going to alight (*or* land).
QTQ	Can you communicate with my station by means of the International Code of Signals?	I am going to communicate with your station by means of the International Code cf Signals.
QTR	What is the correct time?	The correct time is ... hours.
QTS	Will you send your call sign for ... minutes(s) now (*or* at ... hours) [on ... kc/s (or Mc/s)] so that your frequency may be measured?	I will send my call sign for ... minute(s) now (*or* at ... hours) [on ... kc/s (*or* Mc/s)] so that my frequency may be measured.
QTU	What are the hours during which your station is open?	My station is open from ... to ...hours.
QTV	Shall I stand guard for you on the frequency of ... kc/s (*or* Mc/s) (from ... to ... hours)?	Stand guard for me on the frequency of ... kc/s (*or* Mc/s) (from . . . to . . . hours).
QTX	Will you keep your station open for further communication with me until further notice (*or* until ... hours)?	I will keep my station open for further communication with you until further notice (*or* until . . . hours).
QUA	Have you news of . . . (call sign)?	Here is news of . . . (call sign).
QUB	Can you give me, in the following order, information concerning: visibility, height of clouds, direction and velocity of ground wind at ... (place of observation)?	Here is the information requested . . .
QUC	What is the number (*or* other indication) of the last message you received from me [*or* from ... (call sign)]?	The number (*or* other indication) of the last message I received from you [or from . . . (call sign)] is . . .
QUD	Have you received the urgency signal sent by ... (call sign of mobile station)?	I have received the urgency signal sent by . . . (call sign of mobile station) at . . . hours.
QUF	Have you received the distress signal sent by . . . (call sign of mobile station)?	I have received the distress signal sent by . . . (call sign of mobile station) at . . . hours.
QUG	Will you be forced to alight (*or* land)?	I am forced to alight (*or* land) immediately. *or*

TABLE 1.—*Abbreviations available for all services*—Continued

Abbreviations	Question	Answer or advice
QUG	(Continued)	I shall be forced to alight (or land) at . . . (position or place).
QUH	Will you give me the present barometric pressue at sea level?	The present barometric pressure at sea level is...(units).
QUI	Are your navigation lights working?	My navigation lights are working.
QUJ	Will you indicate the TRUE course for me to steer toward you (*or* ...) with no wind?	The TRUE course for you to steer toward me (*or* ...) with no wind is ... degrees at . . . hours.
QUK	Can you tell me the condition of the sea observed at ... (place or coordinates)?	The sea at ... (place or coordinates) is ...
QUL	Can you tell me the swell observed at ... (place or coordinates)?	The swell at ... (place or coordinates) is ...
QUM	Is the distress traffic ended?	The distress traffic is ended.
QUN	Will vessels in my immediate vicinity [(*or* in the vicinity of . . . latitude . . . longitude) (*or* of . . .)] please indicate their position, TRUE course and speed?	My position, TRUE course and speed are ...
QUO	Shall I search for . . . (1 Aircraft; 2 Ship; 3 Survival craft;) in the vicinity of . . . latitude . . . longitude (or according to any other indication)?	Please search for . . . (1 Aircraft; 2 Ship; 3 Survival craft;) in the vicinity of . . . latitude . . . longitude (*or* according to any other inindication).
QUP	Will you indicate your position by . . . (1 Searchlight; 2 Black smoke trail; 3 Pyrotechnic lights)?	My position is indicated by . . . (1 Searchlight; 2 Black smoke trail; 3 Pyrotechnic lights).
QUQ	Shall I train my searchlight nearly vertical on a cloud, occulting if possible and, if your aircraft is seen, deflect the beam up wind and on the water (*or* land) to facilitate your landing?	Please train your searchlight on a cloud, occulting if possible and, if my aircraft is seen or heard, deflect the beam up wind and on the water (*or* land) to facilitate my landing.

TABLE 1.—*Abbreviations available for all services*—Continued

Abbreviations	Question	Answer or advice
QUR	Have survivors . . . (1 Received survival equipment; 2 Been picked up by rescue vessel; 3 Been reached by ground rescue party)?	Survivors . . . (1 Are in possession of survival equipment dropped by . . . 2 Have been picked up by rescue vessel; 3 Have been reached by ground rescue party).
QUS	Have you sighted survivors or wreckage? If so, in what position?	Have sighted . . . (1 Survivors in water; 2 Survivors on rafts; 3 Wreckage) in position . . . latitude . . . longitude (*or* according to any other indication).
·QUT	Is position of incident marked?	Position of incident is marked (by . . .).
·QUU	Shall I home ship or aircraft to my position?	Home ship or aircraft [1 . . . (call sign) to your position by transmitting your call sign and long dashes on . . . kc/s (*or* Mc/s); 2 . . . (call sign) by transmitting on ... kc/s (*or* Mc/s) courses to steer to reach you].
·QUV	What is my MAGNETIC bearing from you (*or* from . . .)? (This signal, in general, will not be used in the Maritime Mobile Service.)	Your MAGNETIC bearing from me (*or* from . . .) was . . . degrees at . . . hours. (This signal, in general, will not be used in the Maritime Mobile Service.)
·QUX	Will you indicate the MAGNETIC course for me to steer toward you (*or* ...) with no wind? (This signal, in general, will not be used in the Maritime Mobile Service.)	The MAGNETIC course for you to steer to reach me (*or* ...) with no wind was . . . degrees at . . . hours. (This signal, in general, will not be used in the Maritime Mobile Service.)

TABLE 2.—*Miscellaneous abbreviations and signals*

Abbreviation or signal	Definition
AA	All after . . . (used after a question mark to request a repetition).
AB	All before . . . (used after a question mark to request a repetition).
ABV	Repeat (*or* I repeat) the figures in abbreviated form.
ADS	Address (used after a question mark to request a repetition).
$\overline{\text{AR}}$	End of transmission (.—.—. to be sent as one signal).
$\overline{\text{AS}}$	Waiting period (.—... to be sent as one signal).
BF	Signal used to interrupt a transmission in progress.
BN	All between ... and ... (used after a question mark to request a repetition).
BQ	A reply to an RQ.
C	Yes.
CFM	Confirm (*or* I confirm).
CL	I am closing my station.
COL	Collate (*or* I collate).
CP	General call to two or more specified stations. (See art. 32.)
CQ	General call to all stations. (See art. 31.)
CS	Call sign (used to request a call sign).
DB	I cannot give you a bearing, you are not in the calibrated sector of this station.
DC	The minimum of your signal is suitable for the bearing.
DF	Your bearing at . . . (time) was . . . degrees, in the doubtful sector of this station, with a possible error of . . . degrees.
DG	Please advise me if you note an error in the bearing given.
DI	Bearing doubtful in consequence of the bad quality of your signal.
DJ	Bearing doubtful because of interference.
DO	Bearing doubtful. Ask for another bearing later [*or* at . . . (time)].
DP	Possible error of bearing may amount to . . . degrees.
DS	Adjust your transmitter, the minimum of your signal is too broad.
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.
DY	This station is not able to determine the sense of the bearing. What is your approximate direction relative to this station?
DZ	Your bearing is reciprocal. (To be used only by the control station of a group of direction-finding stations when it is addressing stations of the same group.)
DE	Used to separate the call sign of the station called from the call sign of the calling station.
ER	Here . . .
ETA	Estimated time of arrival.
ITP	The punctuation counts.

TABLE 2.—*Miscellaneous abbreviations and signals.—Continued*

Abbreviation or signal	Definition
JM	Make a series of dashes if I may transmit. Make a series of dots to stop my transmission (not to be used on 500 kc/s except in cases of distress).
K	Invitation to transmit.
MN	Minute (*or* Minutes).
MSG	Prefix indicating a message to or from the master of a ship concerning its operation or navigation.
N	No.
NIL	I have nothing to send to you.
NW	Now.
OK	We agree (*or* It is correct).
P	Prefix indicating a private radiotelegram.
PBL	Preamble (used after a question mark to request a repetition).
PTR	Used by a coast station to request the position and next port of call of a mobile station. (See 700.)
R	Received
REF	Reference to . . . (*or* Refer to . . .).
RPT	Repeat (*or* I repeat) (*or* Repeat . . .).
RQ	Indication of a request.
SIG	Signature (used after a question mark to request a repetition).
$\overline{\text{SOS}}$	Distress Signal (...— — —... to be sent as one signal).
SS	Indicator preceding the name of a ship station.
SVC	Prefix indicating a service telegram.
SYS	Refer to your service telegram.
TFC	Traffic.
TR	Used as a prefix to indicate reply to PTR.
TTT	This group when sent three times constitutes the safety signal. (See 943.)
TU	Thank you.
TXT	Text (used after a question mark to request a repetition).
$\overline{\text{VA}}$	End of work (...—.— to be sent as one signal).
W	Word(s) *or* [Group(s)].
WA	Word after . . . (used after a question mark to request a repetition).
WB	Word before . . . (used after a question mark to request a repetition).
XXX	This group when sent three times constitutes the urgency signal. (See 934.)

TABLE 3.—*Extracts from the Telegraph Regulations (Paris Revision, 1949) annexed to the International Telecommunication Convention (Atlantic City, 1947)*

219 § 4. Morse Code Signals.

Spacing and length of signals:

250 (a) A dash is equal to three dots;

251 (b) The space between the signals forming the same letter is equal to one dot;

252 (c) The space between two letters is equal to three dots;

253 (d) The space between two words is equal to seven dots.

* * * * * *

255 LETTERS

a .—	i ..	r .—.
b —...	j .———	s ...
c —.—.	k —.—	t —
d —..	l .—..	u ..—
e .	m ——	v ...—
..—..	n —.	w .——
f ..—.	o ———	x —..—
g ——.	p .——.	z —.——
h	q ——.—	y ——..

256 FIGURES

1 .————	6 —....
2 ..———	7 ——...
3 ...——	8 ———..
4 ....—	9 ————.
5	0 —————

* * * * * *

259 SIGNS

Full stop (period	[.]	.—.—.—
Comma	[,]	——..——
Colon	[:]	———...
Question mark (note of interrogation) or request for repetition of a transmission not understood	[?]	..——..
Apostrophe	[']	.————.
Hyphen or dash	[-]	—....—
Fraction bar	[/]	—..—.
Brackets (parentheses) (before and after the words)	[()]	—.——.—
Inverted commas (quotation marks) (before and after the words)	[""]	.—..—.

TABLE 3.—*Extracts from the Telegraph Regulations (Paris Revision, 1949) annexed to the International Telecommunication Convention (Atlantic City, 1947)*—Continued

259 SIGNS—continued

Administrations and recognized private operating agencies using code converters may use the apostrophe twice, before and after the words, to signal inverted commas (quotation marks).

Double hyphen	[=]	— · · · —
Understood		· · · — ·
Error		· · · · · · · ·
Cross or signal for the end of a telegram or of transmission		· — · — ·
Invitation to transmit		— · —
Wait		· — · · ·
End of work		· · · — · —
Starting signal (to precede every transmission)		— · — · —

260 The provisions regarding the transmission of fractional numbers which are applicable to instruments using International Telegraph Alphabet No. 1 (§ 2) shall also be applicable to instruments using the Morse code.

261 A group consisting of figures and letters shall be transmitted without space between figures and letters.

262 The following letters and signals may be used in relations between countries which accept them:

ã · — · —	ñ — — · — —
á or å · — — · —	ö — — — ·
ch — — — —	ü · · — —

* * * * * *

221 A number which includes a fraction shall be transmitted with the fraction linked to the whole number by a single hyphen.

Examples: 1-3/4 and not 13/4; 3/4-8 and not 3/48; 363-1/2 4 5642 and not 3631/2 4 5642.

APPENDIX IV

SMALL VESSEL DIRECTION FINDERS*

The use of the radio direction finder or radio compass for navigation purposes is not new. For a period of several years hundreds of coastal, lake and ocean-going ships have realized excellent results from such equipment.

Equipment has recently been made available which permits the small boat owner also to take advantage of this radio aid to navigation. The apparatus, while no different electrically from that used aboard large vessels, is, however, specialized in certain features. The principal differences are the space required and ease of installation.

Figure 1 shows the normal manner of mounting the loop handwheel above the receiver so as to require the least table space. Since the small vessels for which this equipment was designed are invariably of wooden construction, the loop may be inside the cabin, thus avoiding the more elaborate loop-rotating mechanisms employed on larger craft which, of necessity, use an outside loop.

Present-day rotating loop antenna usually consist of several turns of wire enclosed in some form of electrostatic shield. The shield is necessary to reduce the effect of local induction fields and to preserve electrical symmetry.[1] The loop may be considered as an inductance coil, having a relatively short length along its axis, but a large diameter. For purposes of explanation a single-turn loop having vertical and horizontal legs will be used. This is shown in Figure 2(a).

As the electromagnetic wave radiated by the transmitting station passes across the vertical legs of the loop as shown in Figure 2(b) voltages are induced in the vertical members of the loop which are slightly out of phase with each other, but of equal amplitude. This pre-supposes that the transmission path is along the surface of the earth, which is practically true at medium and low frequencies except during certain times of the year and day when occasional sky-wave reception occurs. Since the sky-wave comes down at an angle with the earth's surface, voltages would be induced in the horizontal members of the loop, which are detrimental to sharp and finite "bearings" on the signal path. This effect, because it is worse at night, is called "night effect."

Figure 2(c) represents a cross-sectional view of the vertical members of the loop, the arrows representing the arrival path of signals from various directions. The signal, if it arrives from direction *A* (in the

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[1]For Bibliography, see end of this article.

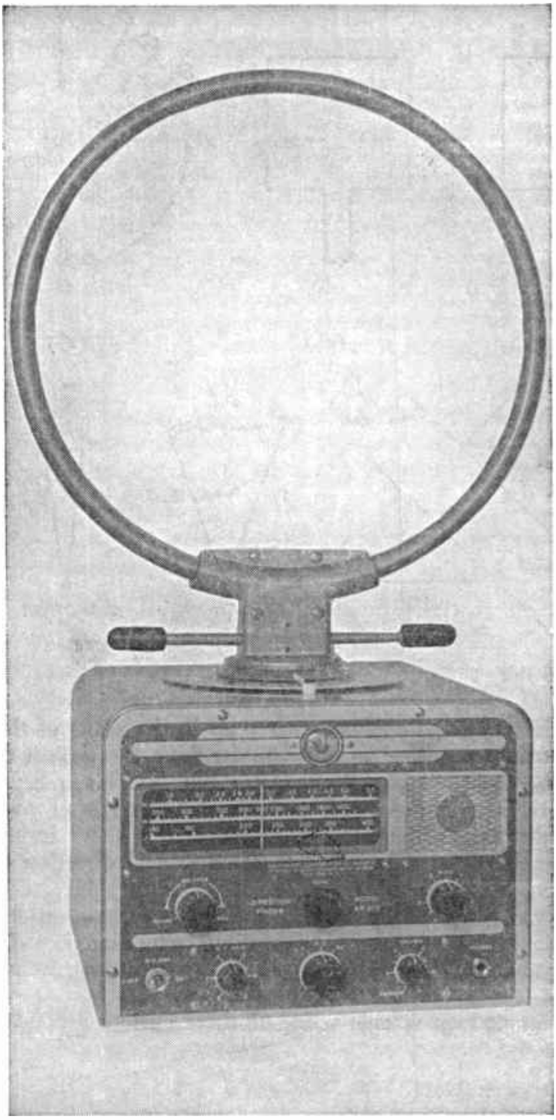


Fig. 1.

plane of the loop), would first produce a voltage in conductor No. 1 after which the wave front passes across conductor No. 2 and induces a like voltage. The distance between the conductors and the wavelength of transmission determines the actual phase relationship. If the signal

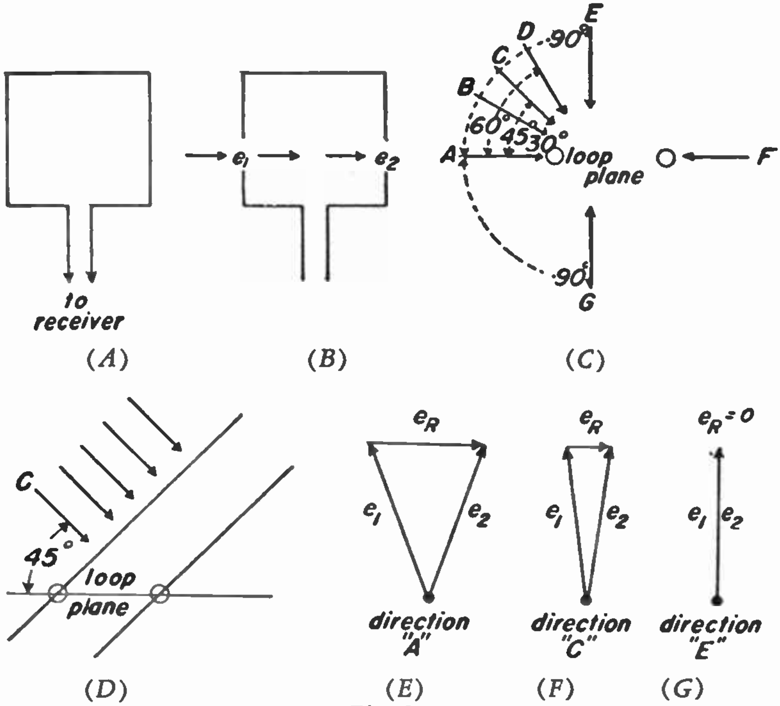


Fig. 2.

is arriving from any direction other than in the plane of the loop, the wave-front does not have to travel so far from the time it crosses conductor No. 1 until it passes conductor No. 2. This is represented in Figure 2(d) as a signal wave arriving at an angle of 45° with the plane of the loop. Figures 2(e), (f), and (g) show respectively the resultant loop voltages (e_R) due to signal-arrival direction of *A* (loop plane), *C* (45°), and *E* (perpendicular to loop plane). Obviously, if a signal path is in the loop plane, the response or loop resultant voltage will be maximum whether it be coming from direction *A* or *F* Figure 5(c), and will be minimum or zero if arriving from directions *E* or *G*.

The resultant loop voltage acting to drive current around the loop is approximately[2]

$$e_R = 2\pi \epsilon N \frac{(\text{loop area})}{\lambda} \cos\theta \qquad (1)$$

where e = field strength of radio wave in volts per meter.
N = number tof turns in loop.
λ = wavelength in meters.
θ = angle of arrival with respect to plane of loop.

Obviously for any given loop and transmitting frequency (wavelength) the resultant voltage is dependent on the angle of the loop plane and the signal path or

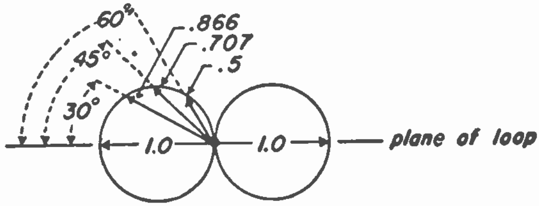


Fig. 3.

$$e_R = k \cos \theta \qquad (2)$$

If equation (2) be plotted on rectilinear coordinates for all values of θ between 0 and 360 degrees, the resulting curve of response voltage is the familiar figure-of-eight or "loop characteristic" shown in Figure 3.

From a consideration of Figure 3 it will be seen that if the loop be rotated ± 30 degrees from that position giving maximum signal, the strength of signal in the indicator (head phones, meter, or whatever is used) will vary only from 100 per cent to 86.6 per cent, a change which is hardly perceptible in the head phones, and certainly the indication is too broad to give a good "bearing" regardless of the type of signal reproducer or indicator used. It is for this reason that the null point or point of zero reception is used for taking bearings since turning the loop a degree or so either side of the null produces a *large* percentage change in the received signal. Thus when the signal is at a null point the loop lane is broadside or perpendicular to the wave front of the incoming signal. A pointer attached to the loop-rotating shaft will refer the bearing to a reference line such as the "keel line" or "lubber line" of a ship or to true north in cases where a gyro-compass repeater card is the direction-finder scale.

Figure 4(a) shows schematically a loop tuned and connected across the input elements of a vacuum tube. It would be possible to take only "rough" bearings with this arrangement since the two legs of the loop are unsymmetrical with respect to ground. Figure 4(b) considers one leg

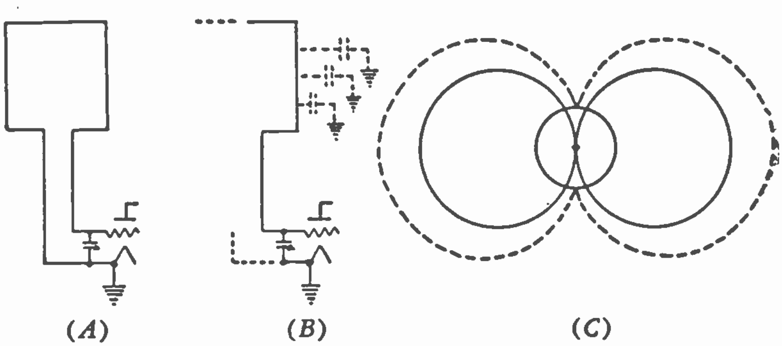
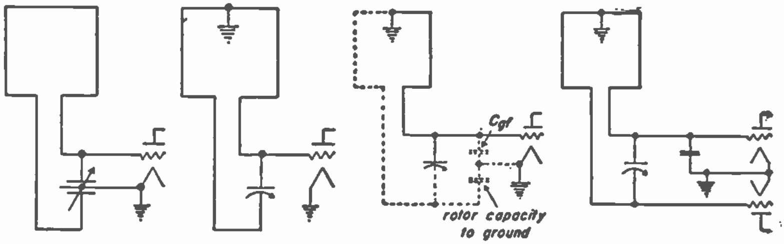


Fig. 4.



(A) (B) (C) (D)

Fig. 5.

of the loop and shows the distributed capacity to ground. Obviously any voltage developed by the signal wave across the capacity to ground will be amplified equally well regardless of the direction of the incoming wave. This effect is known as "vertical" and obscures the minimum of the loop figure-of-eight characteristic.[3] This is shown by Figure 4(c), the dotted line being the complete characteristic obtained by adding vectorially the voltage responses of the vertical effect and the loop. The elimination of "vertical" may be partially accomplished by arranging the loop circuit in a symmetrical manner as in Figure 5(a) or 5 (b) and grounding the electrical center of the loop circuit. These circuits utilize only one-half of the total loop resultant voltage as excitation for the grid-cathode circuit of the tube. The additional capacity of the rotor of the loop-tuning capacitor maintains the symmetry at the tube input terminals. This is shown in Figure 5(c). The use of push-pull tubes would have the same effect except that the stator would be padded with capacity to ground to preserve the balance as in Figure 5(d). The use of a split-stator loop-tuning capacitor as in Figure 5(a) would be ideal except for the mechanical disadvantage that it requires four times the number of plates. The vertical antenna effect is still present to a certain degree, however, since the voltages induced in both legs of the loop are additive when their effect is considered across the grid-cathode elements of the tubes. This is shown more clearly by Figure 6.

The solid ± signs and arrows are those indicating instantaneous polarities due to the circulating current in the loop while those shown dotted indicate the polarities produced due to "antenna" effect. It is obvious that if the voltages represented by the dotted arrows in the secondary of the r-f transformer T_1 were equal and 180° out of phase the vertical effect of the loop is nil and a perfect zero or null would be obtained when the loop is turned broadside to the incoming signal.

A method of balancing the voltages induced in each loop leg due to reflections and spurious radiations from external metallic objects and not necessitating the use of push-pull tubes is shown in Figure 14.

L_1C_1 resonate at the loop frequency, but when the switch is on "balance" the additional inductance of L_2 loads the balancer circuit to a frequency approximately 90 per cent of the signal frequency. Thus *at* the signal frequency the circuit composed of L_1, L_2, S_1 and S_2, and C_1 is predominantly inductive reactance, hence the currents flowing

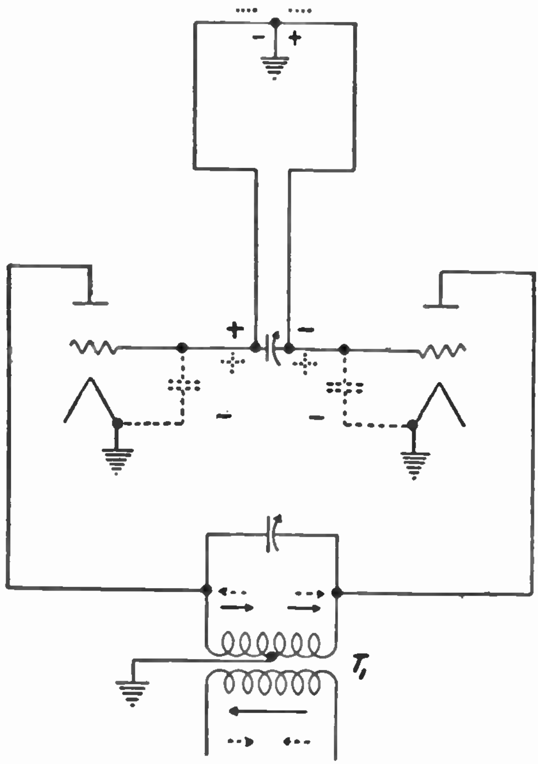


Fig. 6.

through the small rotors of the balancer unit (S_1 and S_2) are lagging the voltage induced in L_1 by the vertical antenna almost 90 degrees. The small voltages induced in the stators P_1 and P_2 are then either approximately in phase with the loop leg voltages or out of phase 180°, depending on how the balancer rotor is adjusted when taking a bearing. Figure 8 shows vectorially how the balancer functions. The resultant loop voltage is exaggerated for clearness.

e_a = voltage induced in vertical antenna by transmitter.

i_a = antenna current (leads e_a by about 90 degrees since vertical antenna reactance at the signal frequency is highly capacitive).

e_{L1} = voltage induced in L_1 due to current in coupling coil L.

e_1 and e_2 = loop-leg voltages induced by signal (in phase when loop broadside to signal, but of slightly different amplitude due to nearby objects).

i_{L1} = current in balancer rotors (almost 90° behind e_{L1}).

e_{P1} and e_{P2} = voltages induced in P_1 and P_2 to compensate for inequalities in the voltages induced in individual loop legs.

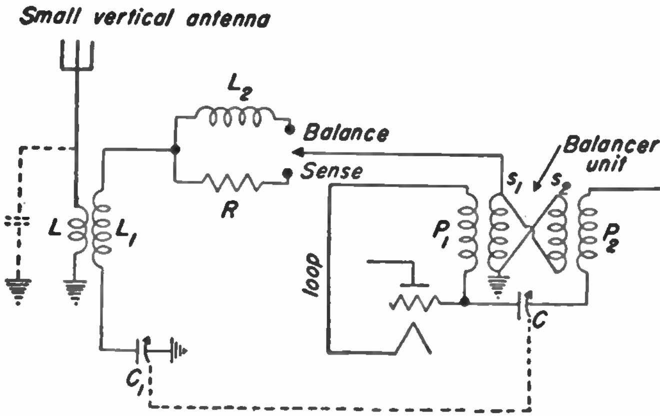


Fig. 7.

Therefore $e_1 + e_{P1} = e_2 - e_{P2}$ (approximately) and an almost perfect balance or "null" occurs.

That a loop antenna receives or rejects equally well from either one or two directions is a well known fact. Referring to Figure 2(c) signals arriving from either direction *E* or *G* would produce no resultant loop voltage and from directions *A* or *F* would produce maximum indications.

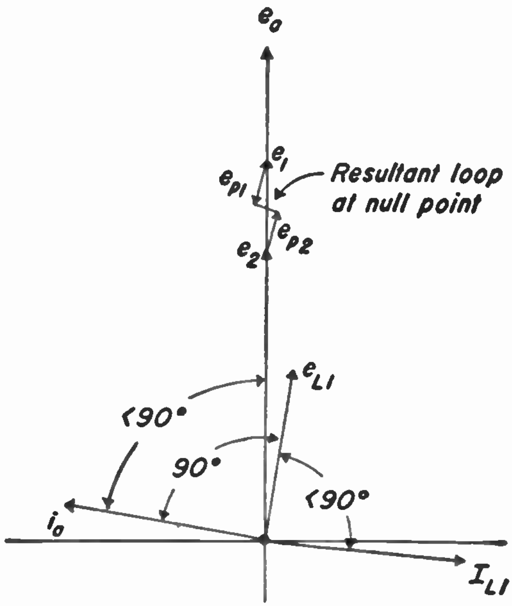
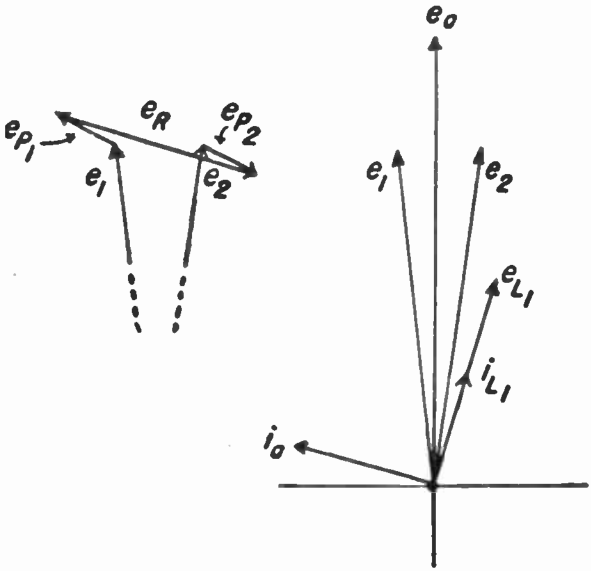


Fig. 8.



(A) (B) (C)

Fig. 9.

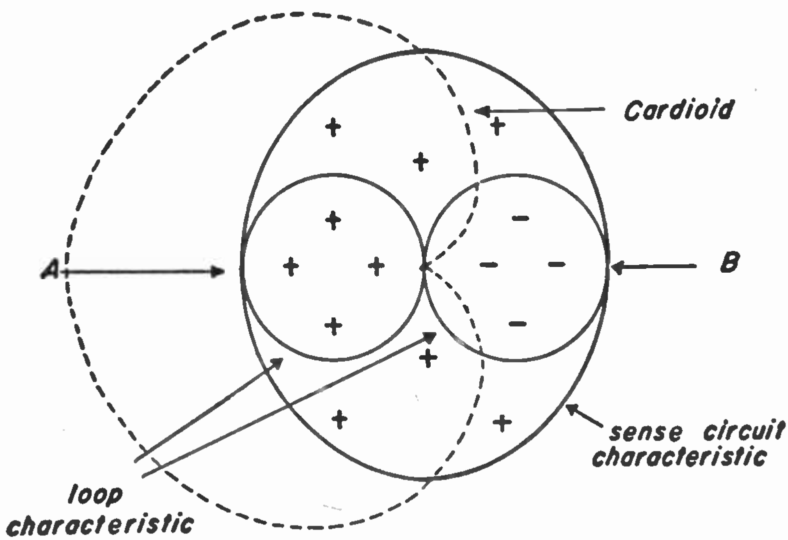


Fig. 10.

This is known as the bi-lateral characteristic. If a loop can be made to indicate which of the two possible directions is correct, then it is said to have a unilateral characteristic or "sense." Referring to Figure 7 this is accomplished by turning the small rotors S_1 and S_2 so that voltages induced in stators P_1 and P_2 add and subtract to the loop leg voltages respectively. Resistor R is then placed in series with circuit L_1 C_1 S_1 S_2 by the balance-sense switch. Since the load coil L_2 is not in series with L_1 C_1 etc., during sense determination, the circuit is tuned to the signal frequency and rotor currents (in S_1 and S_2) produced voltages in P_1 and P_2 which are approximately 90 degrees out of phase with the loop resultant voltage. This is shown by Figure 9. The vector subscripts are identical to those in Figure 8.

Figures 9(b) and (c) show how the vectors add to produce a louder signal, Figure 9(b) or a weaker signal, Figure 9(c), depending on which leg of the loop is the closer to the transmitting station. The response as explained above has the characteristic of a cardioid or heart-shaped diagram as shown in Figure 10.

Figure 10 illustrates how the cardioid is formed by assigning + and —values to each leg of the loop and an arbitrary + value to the voltage is added by the sense circuit. Thus when the plane of the loop is in the path of the signal (or the loop is rotated so that direction "A" occurs) the total response is maximum; and conversely, when rotated so that the signal appears to come from direction "B," the total response is zero. The choice of sense-antenna length, and particularly of the tuned circuit constants will materially affect the shape of the cardioid as shown in Figure 11 for different values of sense resistor R (Figure 7).

The sense resistor R not only serves as a method for adjusting the shape of the heart-shaped characteristic, but assures that circuit L_1C_1 is "tuned" to the signal frequency or that the current i_{L1} is in phase with voltage e_{L1}, a condition necessary for the sense determination as in Figure 9.

Direction finders, when used on shipboard in particular, are subject to an error known as "deviation" or "displacement." This error is the difference between the observed radio bearing or apparent signal direction and the true direction and is caused by the fact that the loop is located close to stays, railings, funnels, eac. It is also due in no small degree to the effect of the hull, if of steel, on the electromagnetic field

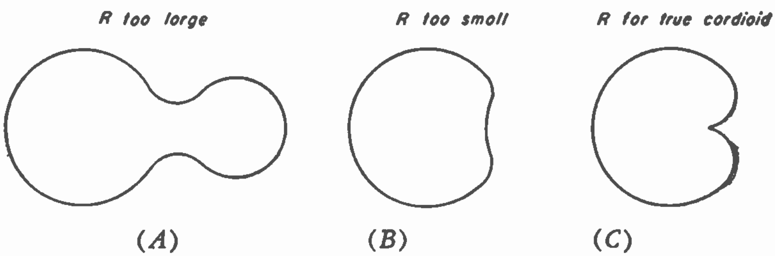


Fig. 11.

NANTUCKET VINEYARD AND LONG ISLAND SOUNDS

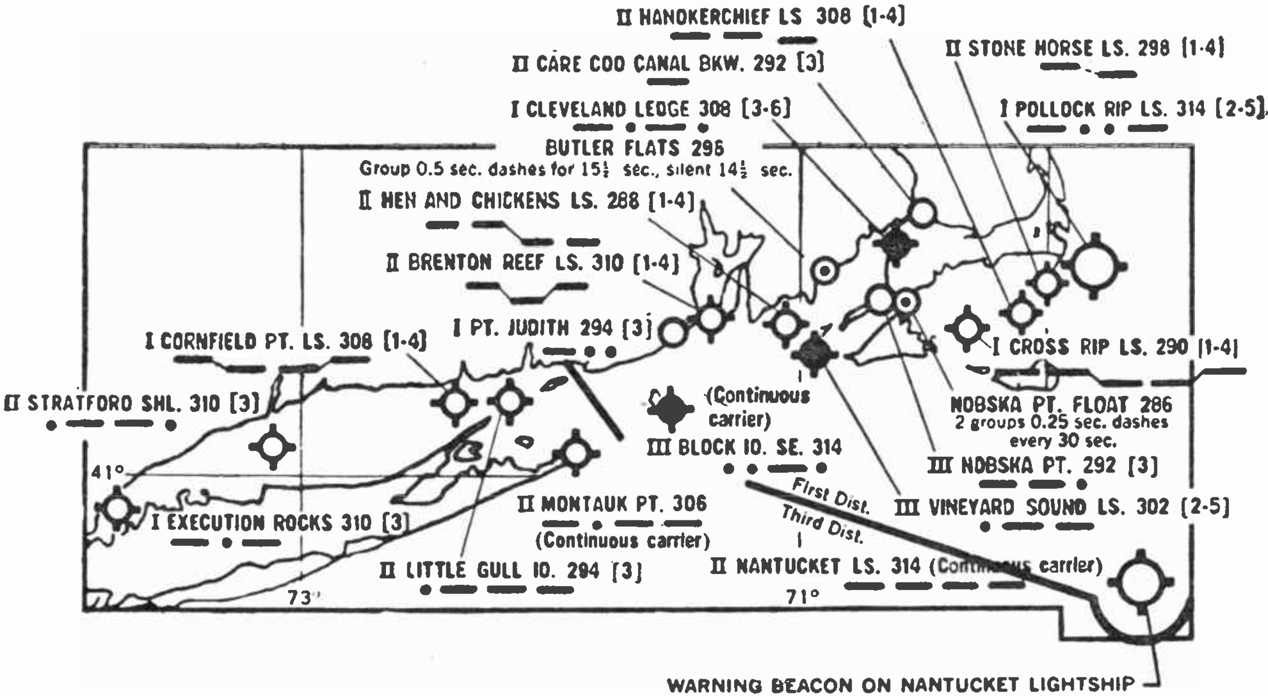


Fig. 12.

of the signal.[4] Displacement errors are usually quadrantal since bearings taken on signals arriving at angles of approximately 45 degrees with the ship's keel line are found to deviate most from the true bearing. The tendency is for observed radio bearings to be bunched or crowded toward the keel line of the ship with minimum or no deviation fore and aft and abeam.[1] It is for these reasons that marine direction finders require calibration. For example: if the plane of the plane of the loop was making an angle of 40 degrees with the keel line of the ship, but by process of calibration the signal was known to be arriving from a direction of 45 degrees referred to the keel line, the corrected scale would actually indicate the correct bearing, or 45 degrees. The method used on the equipment shown in Figure 1 is to provide a chart directly on the scale so that the correction at various angles is mentally added or subtracted at the instant of taking the bearing.

A brief mention of receiver requirements over and above those already discussed in connection with the antenna and input circuits would not be amiss. Around the coast-line of North America and on the Great Lakes the United States and Canadian governments operate approximately 140 marine beacon stations which send a characteristic identification signal as specified periods during each hour. Beacon transmitters are arranged geographically in order that cross bearings may be taken to "fix" the ship's position. The frequencies used are in the special band allocated for this service only, i.e., 285 to 315 kc. Usually three stations situated at strategic points (on lightships or at lighthouses) use the same frequency in order that, when navigating in their vicinity, the direction-finder receiver will not require retuning when shifting from one beacon to another. Clear weather transmissions from each group are ordinarily twice each hour for ten-minute periods. The transmission time for any one station in the group is one minute, after which the two other stations in the group follow in succession, etc. During foggy weather each station is "on" every third minute. The frequency separation of adjacent groups is always 8 or more kc. and since low power is used, the same group frequency may be used again if employed several hundred miles away. This reduces the chances of sky-wave interference. Frequency assignments are from 286 to 314 in 2-kc. steps. This allows for up to 1000-cycle modulation without side-band interference with other services at the edges of the beacon band.

Figure 12 represents a section of Nantucket, Vineyard, and Long Island Sounds and shows 15 beacons, their frequency, time of transmission and identifying signal. Thus, Nantucket Lightship transmits the character — — — — for one minute as the second (2) station of the group on 314 kc. The other members of this group are Pollock Rip Lightship and Block Island SE. Clear weather transmission periods of this group are (2-5) or the second and fifth 10-minute periods after the hour, for example 10:10 to 10:20 and 10:40 to 10:50.

As additional protection during foggy weather, many of the beacon stations send a 1-second and 5-second blast on their fog horn and synchronized with a similar radio signal at the conclusion of each "one-minute" period (actually a 52-second period so as to finish the 5-second

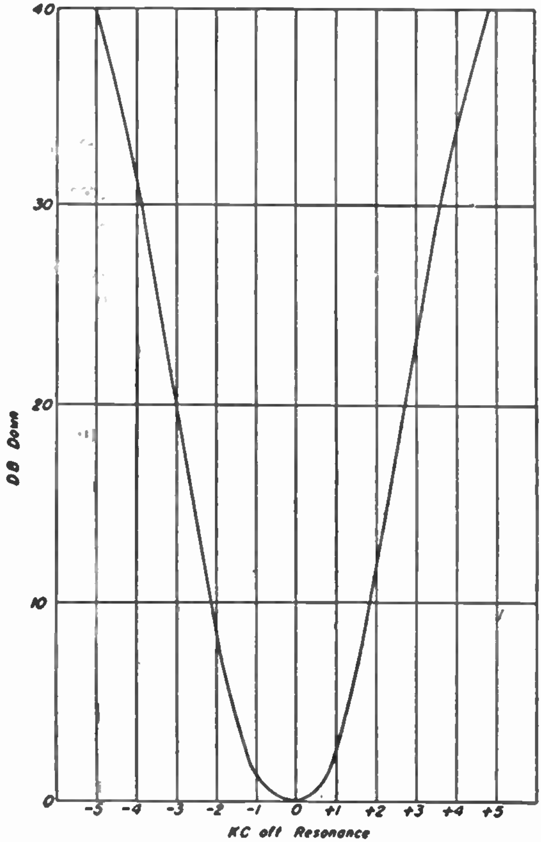


Fig. 13.

dash at the end of the one-minute period). Thus by timing the space between a certain part of the radio signal and the corresponding part of the fog horn signal and dividing seconds elapsed by 5.5, the distance in nautical miles is ascertained to an accuracy of 10 per cent.

Modern direction-finder receivers attain a high degree of selectivity and sensitivity. These properties are necessary for the following reasons. Since the bearing is necessarily taken at the "null point" of the desired signal for reasons already explained, as much sensitivity as is practical for the prevailing noise level is desirable so that a greater contrast between the null point and a few degrees off null is obtained. Thus an interfering signal, if coming from a point other than broadside to the loop plane, although considerably weaker in field strength, might produce a loop resultant voltage comparable to the desired signal, were the selectivity insufficient. Satisfactory selectivity, bearing this feature in mind, has been found to be approximately as in Figure 13.

The receiver shown in Figure 1 utilizes 7 tubes in a superheterodyne circuit. A stage of r-f amplification is used for the reduction of image response and contributes to over-all selectivity and sensitivity. In many cases a c-w (A_1) signal is more readible through severe noise and static, therefore a separate c-w oscillator is provided to beat with the signal at the intermediate frequency. The receiver covers a frequency band of 270 to 520 kc.

The lighting supply voltage on small boats may be 6, 12, 32 or 110 volts d.c. In order to charge the 6-volt storage battery used for tube-heater supply, the battery is automatically connected to the boat's lighting supply through an appropriate size lamp bulb when the "on-off" switch on the receiver panel is "off." Two 45-volt dry-cell "B" batteries are used for plate supply to the vacuum tubes.

When the same nomenclature as for equation (1) is used, the effective height[2] of a loop antenna is:

$$h = 2\pi N \frac{(\text{loop-area})}{\lambda} \cos\theta. \tag{3}$$

Obviously for a loop of only a few turns, and having a small diameter compared to wavelength, the effective height is small. The need for a sensitive receiver is at once apparent since the field strength of a beacon transmitter may be only a few microvolts per meter.

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[1]Solt, *Proc. I.R.E.*, Vol. 20, No. 2.
[2]Terman, "Radio Engineering."
[3]Blair and Lewis, *Proc. I.R.E.*, Vol. 19, No. 9.
[4]Keen, "Wireless Direction Finding and Directional Reception."

INFORMATION ON RADIOMARINE AR-8711 RADIO DIRECTION FINDER

The following information* with regard to operating instructions, installation instructions and technical data, and routine maintenance of the Radiomarine AR-8711 Radio Direction Finder are presented in order to assist the student in understanding the operation of a modern direction finder.

SECTION 1—CONDENSED OPERATING INSTRUCTIONS

1.1—The following summary describes the general use of the equipment. For further details refer to Section 3.

1.2—Conventional broadcast (BC) reception, or reception on the low frequency (LF) or medium frequency (MF) bands:

(a) Turn on power with VOLUME control. Place BALANCE control in REC. position. B.F. OSC. in OFF position. Select frequency band desired. Tune in signal and adjust VOLUME D.F. GAIN and NULL controls are not used for ordinary reception.

1.3—Radio Direction Finding (taking bearings with the loop);

(a) Power ON with VOLUME control. BALANCE in OFF posi-

*Courtesy I.F. Byrnes and H.B. Martin, Engineering Dept., Radiomarine Corp. of America.

tion at first. NULL in OFF POSITION. Select band and tune in signal.
Use D.F. GAIN to regulate signal (normal VOLUME control is not used for D.F. work).

(b) Now rotate loop. Signal from speaker will get weaker and tuning eye will "open" *when* the loop reaches the "null" position. Increase D.F. GAIN so that signal gets noticeably stronger when loop is shifted a few degrees either side of the null. Then the null position gives an approximate bearing by reading the *red* pointer over azimuth scale. This assumes you know "sense" or general direction of incoming signal. To sharpen bearing and and to check sense, see below.

(c) Sharper bearing: BALANCE from OFF to "balance" position. Now adjust balance, D.F. GAIN, and move loop a little until null is as sharp as possible. Apply bearing correction from calibration chart (see 5.5).

(d) Sense determination: BALANCE in "sense" position. Lower D.F. GAIN. Now move loop from null to several degrees higher (clockwise.) If signal *decreases*, the bearing previously shown by *red* pointer has correct sense. If signal *increases*, turn loop 180 degrees, get new null, and recheck sense. See 3.4(h).

SECTION 2—GENERAL DESCRIPTION

2.1—General: Radiomarine Model AR-8711 is a modern, compact combination Radio Direction Finder and Entertainment Broadcast Receiver especially designed for shipboard service on small craft where space is at a premium. The unit covers three frequency bands including radiobeacon, broadcast and marine radiotelephone frequencies. Power is derived from the boat's battery or line supply.

2.2—Applications: The AR-8711 may be used to take bearings on signals from other vessels or regular marine beacons, or broadcast stations Two or more bearings will give a "fix" for determining your position. Other uses are reception of boadcast stations, weather reports, and as a standby receiver for the marine telephone band.

2.3—Equipment Description: The equipment is made of corrosion-resistant, lightweight aluminum, and consists of a sensitive eight-tube receiver, a built-in loudspeaker, and a rotatable loop which is mounted on top of the cabinet. Provision is also made for the use of earphones. Compact power units, separate from the equipment, are designed to operate from a boat's 6, 12, 32 or 115 volt D.C. supply or a 115 volt A.C. line. The loop unit has two handles for rotating the loop, a movable compass rose and azimuth scale, and two fixed pointers (fiducial marks) for reference points. On special order an outside loop may be used instead of the inside loop normally furnished with the equipment. Both loops have a locking knob. An external antenna from 12 to 24 feet in length is used for broadcast and communications reception, sense determination, and for sharpening the null in the balance position.

2.4—Panel Controls: A minimum number of controls provide efficient operation. They are marked as follows. See Figure 14 for their panel locations.

Fig. 14.

B. F. OSC.
OFF ON—For switching the beat frequency oscillator on under unfavorable conditions of static or interference, and for code reception (CW).
D.F. GAIN—For controlling gain when using equipment as a direction finder.
L.F. B.C. M.F.—For selecting frequency band.
L.F.—Low Frequency .... 130— 400 kc.
B.C.—Broadcast .... 540—1750 kc.
M.F.—Medium Frequency.. 1740—5500 kc.
VOLUME
PWR-OFF—For turning set off and on and controlling volume when using equipment as a receiver.
PHONES —For plugging in earphones in place of the speaker.
BALANCE
CONTROL—BALANCE—For getting sharp nulls.
SENSE—For determining general direction of beacon or other transmitter.
REC.—Connects sense antenna for broadcast and radio communications reception.
OFF—For taking approximate bearings.
TUNE —For station selection.

NULL

OFF —For obtaining sharp nulls on weak and noisy signals.

2.5—*List of Major Components and Accessories*:

(a) Inside Loop Installation
Receiver, loop and azimuth scale.
Power unit with attached 10 foot cable and Jones connector.
Complete set of operating tubes.

(b) Outside Loop Installation
Receiver.
Outside loop with azimuth scale.
Power unit with attached 10 foot cable and Jones connector.
Complete set of operating tubes.

2.6—*Electrical Specifications*:

Selectivity—The over-all selectivity at 300 kc. is as follows:
20 db down—13 kc. bandwidth
40 db down—16 kc. bandwidth
60 db down—22 kc. bandwidth

(b) Sensitivity—Less than 100 microvolts per meter will produce 50 milliwats of output with a signal-to-noise ratio of 6 db.

(c) Frequency Ranges—L.F., 130-400 kc.—B.C., 540-1750 kc.—and M.F., 1740-5500 kc. Regular marine beacons are in the L.F. band between 285 and 325 kc. Broadcast stations are in the B.C. band. Ship telephone stations are in the M.F. band between 2000 and 3000 kc.

(d) Power Consumption—About 30 watts. (Does not include power lost in series resistor, when operating from 115 v. D.C.)

(e) Tube Complement:

RCA Type 6BJ6	V-101	R. F. Amplifier
RCA Type 6BE6	V-102	Converter
RCA Type 6BJ6	V-103	1st I. F. Amplifier
RCA Type 6BJ6	V-104	2nd I. F. Amplifier
RCA Type 6AQ6	V-105	Detector, AVC and Null Amplifier
RCA Type 12AX7	V-106	(1/2) BFO (1/2) 1st Audio Amplifier
RCA Type 6E5	V-107	Null Indicator and Tuning Eye
RCA Type 6AK6	V-108	Power Output
Type OZ4A	V-401	Rectifier (used only with 32/115 volt D. C. power unit).
RCA Type 6X4	V-601	Rectifier (used only with 115 volt A. C. power unit).

Section 3—OPERATION

3.1—General: This section will assist the navigator in obtaining maximum performance when operating the AR-8711 equipment as a radio direction finder. With proper use, this instrument can be invaluable as a practical aid to navigation.

3.2—Theory of Operation: The incoming radio signal from a radiobeacon or other transmitter is picked up by the rotatable electrostatically shielded loop. The directive receiving properties of the loop enable a radio bearing to be taken. When the plane or broad side of the loop is at right angles to the line of direction of the incoming radio wave, the signal is zero or nearly so. That is, looking through the "hole" of the loop provides a direct line of sight to the beacon. When the loop is turned 90° from the position of minimum signal, the pickup is at a maximum. With the loop in a position for maximum signal strength, it will be observed that a change of several degrees in rotation will cause the signal to vary by only a small amount. However, with the loop in the minimum signal position, a small change in the loop angle provides a relatively large change in signal. For these reasons radio bearings are always taken at a minimum signal position (null) for the greatest accuracy.

3.3—Compass Rose and Azimuth Scale: The movable compass rose and is also marked with cardinal and intercardinal points. When an inside loop is used, the azimuth scale is on top of the receiver cabinet. Since the scale can be rotated independently of the loop, it may be set, as desired, either to zero along the lubber line or to the magnetic compass bearing. A red index marker is located on the top of the cabinet toward the rear. With the zero set opposite the red index, radio bearings are indicated relative to the ship's bow. With the scale set the same as the magnetic compass, with proper correction for variation and deviation, radio bearings are then relative to the north. All bearing readings are made with the red pointer as the indicator. The white pointer serves only to indicate the reciprocal or opposite direction. The red and white pointers are attached to the base of the assembly which rotates around the azimuth scale.

3.4—Procedure for Taking Bearings:

(a) Rotate the VOLUME control clockwise to turn the power ON.

(b) The D.F. GAIN control is the one to be used for adjusting receiver sensitivity and loudspeaker output when taking bearings. In this case the VOLUME control is used only for turning power ON and OFF (the VOLUME control is used for broadcast, or other normal reception only when the BALANCE control is in the REC. position).

(c) After selecting the frequency band desired (LF, BC or MF), tune in the signal for maximum volume and adjust D.F. GAIN to a suitable value.

(d) Unlock the loop so that it turns freely. The loop lock is a knob at the rear of the receiver cabinet on inside loop installations, and at the bottom of the loop shaft on outside installations. The loop should be kept locked when not in use to avoid unnecessary movement when the vessel rolls or pitches.

(e) The NULL and B.F. OSC. controls should be placed in the OFF position. The BALANCE control should be placed, temporarily, also in the OFF position.

(f) Now rotate the loop. When the loop reaches the "null" or bearing position, the signal from the loudspeaker will get weaker and the tuning eye will "open." At this null point it is generally desirable to increase D. F. GAIN so that, when the loop is rotated a few degrees either side of the null, there will be a noticeable increase in the signal. You now have an approximate bearing at the null point and, if the general direction of the incoming signal is known, the *red* pointer will give the bearing with respect to the azimuth scale. Additional operations are necessary to obtain a more accurate bearing and to check "sense" (direction) as outlined below.

(g) To obtain a more accurate bearing and a sharper null, shift the BALANCE control from the OFF to the BALANCE position. Now vary the loop while adjusting the BALANCE control until the null is sharply defined. When doing this, it is desirable to adjust D.F. GAIN to get the sharpest bearings. Then, for maximum accuracy, the bearing may be corrected by referring to the calibration charts (see 5.5) and also corrected for Mercator effect (beyond the scope of this book). When taking bearings with respect to true north, refer to 3.5.

(h) To determine the "sense" or general direction of the incoming signal, an understanding of the following procedure is essential. The loop can give two nulls, on any signal, each about 180 degrees apart. To eliminate this 180 degree ambiguity, when the general direction of the signal is not known, it is necessary to take a "sense" reading. First get a good null as outlined above. Then change BALANCE control to the SENSE position. Signal will get stronger with loop still in same position. Lower D.F. GAIN so signal is not too loud. Now rotate loop several degrees toward higher azimuth scale readings. If signal gets *weaker* the sense is correct and the *red* pointer showed the correct bearing when it was previously adjusted to a good null. If signal gets *stronger* when loop is moved to higher scale readings, then the bearing is shown (approx.) by *white* pointer. Since the white pointer should not be used for accurate bearings, the loop should now be turned 180 degrees, a new null and bearing determined in the "balance" position, and finally the direction checked again in the "sense" position. All this may seem complicated at first, but by taking bearings and checking sense on signals whose direction is known (such as a station dead ahead or a few degrees off the bow), it is possible to acquire valuable practice and skill.

3.5—True North Bearings and Fix Determination:

(a) While the direction finder may be used frequently for taking bearings with respect to the ship's bow (relative bearings), it is necessary to take bearings with respect to true north for a "fix" (determining your own vessel's position). In this case the ship's magnetic compass, properly corrected for variation and deviation, is to be used as a basic reference.

(b) For example, assume that a radio bearing has been taken relative to the ship's bow and the red pointer reads 30 degrees off the starboard bow. Assume that the corrected magnetic course is 10 degrees east of north. The movable azimuth scale would then be shifted so that the 10 degree mark on this scale lines up with the *red index* .The red pointer will then, of course, read 40 degrees against the azimuth scale and this is the bearing with respect to true north. As another example, assume a bearing is taken which is 60 degrees off the port bow. If corrected magnetic course is 10 degrees and with the azimuth scale set accordingly, then the red pointer will read a true bearing of 310 degrees.

(c) For a "fix" determination, see Question 6.288 in this book. The directional lines are plotted on the chart, and the intersection indicates the "fix."

3.6—Use of Other Panel Controls:

(a) The B.F. OSC, when turned on, produces a "beat note" in the loudspeaker or phones. This condition will be found of value with weak or noisy signals, or when continuous wave signals are to be received. The tuning eye and the NULL control are not to be used with the B.F. OSC. turned ON.

(b) The control marked NULL, when switched from the OFF position, acts as a "squelch." In other words, signals below a certain strength, depending upon the adjustment of the NULL control, will produce no output from the loudspeaker. This feature can be used when "homing" on a dead ahead signal as follows. First obtain a null in the usual manner with the NULL control OFF. Now adjust the NULL control and increase D.F. GAIN. If the loop is moved a few degrees either side of the null position, the signal should come in strong. At the null position the signal should be very weak or zero. The loop may now be locked. If the vessel changes its course, the signal will be heard. By alternating the course to the correct heading the signal will be silenced and the course maintained in this manner. Best results are obtained by using the lowest possible setting of the NULL control.

3.7—The Accuracy of Bearings: Maximum accuracy of bearings requires the use of a "Calibration Chart" as explained further in section

5, paragraph 5.5. In addition the careful navigator should note the following points:

(a) Bearings taken near sunrise or sunset may be variable and good nulls may be difficult to obtain. This is called "night effect" and is caused by radio waves which are reflected from the upper atmosphere. Night effect is worse at longer ranges and at higher frequencies such as the 2000-3000 kc. telephone band.

(b) Broadcast stations, which are usually quite powerful, give good nulls. However, such signals frequently pass over considerable land and become "bent," giving bearing errors. Bearings taken in clear weather, when your position is known, will permit you to determine which broadcast stations give the least error.

(c) The best stations for bearings are the radiobeacon stations operated by the U. S. Coast Guard and by other government agencies. There are shown on the charts on pages 32, 33 and 34. Study these charts to determine the "characteristic signal" (for identifying the station), the "frequency" (kilocycles), and the "operating schedule." Also see section 7 in this book.

(d) Do not expect great accuracy when taking bearings over considerable distances from vessels which are transmitting in the 2000-3000 kc. band. Errors will be least on vessels dead ahead and will become more accurate as the distance becomes less.

APPENDIX V

AUTOMATIC ALARM*

More than ten years ago it was recognized that safety at sea would be improved if some means could be developed to enable a ship in distress to summon aid at any time by radio from a nearby vessel, especially during those periods when the radio operator on the nearby vessel might not be "on watch." Early developement and tests indicated that a special distress signal, international in scope and known to all radio equipped ships, would be desirable. Such a signal would then actuate an automatic receiving device on vessels in the vicinity of the ship in distress and by means of bells or other means call attention to the fact that a distress call was being transmitted. This special signal (which supplements and does not supersede the conventional SOS . . . — — — . . . signal) is known as the automatic alarm signal and the special receiving apparatus is called the auto alarm. The auto-alarm signal is transmitted by the ship in distress just prior to sending the normal S O S signal.

The form of the alarm signal was specified at the International Radio Telegraph Convention held in Washington in 1927 and later at the International Telecommunication Convention of Madrid, 1932. It consists of a series of dashes and spaces, each dash having a duration of four seconds and each space between dashes a duration of one second. Twelve such dashes and spaces can be transmitted in a period of one minute. The auto-alarm apparatus is then designed to actuate the bells when a certain number of consecutive dashes and spaces are correctly received. European practice provides for auto-alarm operation after three correct dashes and spaces are received, while present United States practice is based on four dashes and spaces. Reasons for this difference are discussed later.

An "International Convention for the Safety of Life at Sea" was held in London in 1929 and attended by representatives of the principal maritime nations of the world. At this convention certain regulations were adopted pertaining to radio aboard ship and particularly with reference to "watches" in the radio room of cargo vessels. It was ruled that cargo vessels of over 5500 gross tonnage, not fitted with an auto alarm, shall, while under way, keep a continuous watch by means of an operator or operators. On ships which are fitted with an auto alarm, this apparatus must be in operation at all times when the operator is not on watch.

Before auto alarms may be installed aboard ships to meet the requirements of the various international conventions, the type of apparatus used must be approved by the Government having jurisdiction over the vessel. The Government of the United States deposited its ratification of the 1929 Safety at Sea Convention on Aug. 7, 1936.

In October, 1935, the Federal Communications Commission prepared

* Reprinted through the courtesy of *RCA* Review and the authors, I. F. Byrnes and H. B. Martin, Engineering Dept., Radiomarine Corp. of America.

specifications and test procedures for the guidance of American manufacturers in the development of a satisfactory auto alarm. Some of the outstanding technical conditions that must be satisfied and the manner in which the various requirements are met in the Radiomarine auto alarm, are discussed in the following paragraphs. Part I covers the principal design requirements. Part II describes the technical design of the AR-8600 Auto Alarm.

PART I

There are two basic elements in an auto alarm, namely the radio receiver and the selector. Each element requires a design quite unlike that satisfactory for other services. The radio receiver must be arranged to possess uniform sensitivity over a frequency range from 487.5 to 512.5 kc., or a total band width of 25 kc. The normal distress frequency is 500 kc., but provision must be made for the auto-alarm receiver to accept signals outside the exact frequency, thereby permitting some variation in the adjustment of the radio transmitter on the vessel in distress. The bandwidth of the alarm receiver must also be fixed as an integral part of the design and not be adjustable by the operator. To meet F.C.C. requirements as to sensitivity the receiver must function with an input of 500 microvolts applied through 500 micromicrofarads, 10 microhenrys and 5 ohms over the specified 25 kc. band. Then, on the basis of the ship's antenna having an effective height of 5 meters, a field strength of 100 microvolts per meter will be sufficient. In actual practice with average shipboard main antennas it is easy to obtain effective heights greater than 5 meters so that the maximum sensitivity of the auto alarm is more apt to be limited by the prevailing noise level.

Selectivity requirements for the auto-alarm receiver may be analyzed as follows: Above 512.5 kc. interference may first be expected from broadcast stations operating in the channels around 550 kc. Broadcast stations whether located along coastlines or considerably inland may be expected to lay down either a strong ground wave which might interfere with coastwise vessels, or a sky wave at night which may be a source of difficulty. F.C.C. specifications state that the auto alarm, when adjusted for 500 microvolts input, must not be made inoperative with an interfering modulated signal of 25,000 microvolts at 550 kc. When the interfering signal is 650 kc. it may have an amplitude of 100,000 microvolts without affecting the auto alarm. Below 487.5 kc. interference may be expected from marine traffic in the band from 375 to 500 kc. Selectivity requirements in this band call for no interference from a 25,000 microvolt signal at 450 kc. and a 100,000 microvolt signal at 375 kc.

Overload characteristics of the auto-alarm receivers are of importance. When the operator goes off watch he places the auto alarm in circuit and adjusts the sensitivity control to an optimum value for the prevailing noise level as explained later. The apparatus must then be capable of accepting a very strong signal from a nearby vessel without blocking or overloading. Automatic volume control used in the conventional manner is of no assistance for this problem because the desired incoming signals are completely keyed, that is, the carrier wave is either on or off. AVC would simply raise the gain of the receiver each time the incoming signal was cut off, and during this interval the noise and static picked up the antenna would tend to block the receiver. Time delay in an AVC circuit is also inadmissible since the receiver and selector circuits must recognize extremely short "breaks" in incoming signals in order to permit the alarm signal to function through interference on 500 kc. This action is explained further in the selector design. Satisfactory design to meet F.C.C. rules must provide operation with a 90,000 microvolt signal at 500 kc., when the receiver is adjusted to also respond to a 500 microvolt input.

Since the auto alarm when connected in circuit operates as an unattended device for several hours, means must be provided to indicate when operation is not normal. There is a possibility that prolonged static of high level will "hold over" some of the relays in the selector unit. It is therefore necessary to arrange for a warning light or its equivalent to show on the bridge so that the radio operator may be instructed to readjust the sensitivity control. Vacuum tubes in the apparatus may burn out. If his occurs a "no current" relay is used to energize the warning bells which are located on the bridge, in the radio operator's cabin and in the radio room. Failure of the source of energy which rings the bells is shown by continuous burning of the warning lights, located alongside the bells.

After the radio signal passes through the receiver it controls the selector mechanism. To allow for reasonable variations in the timing of the alarm signal the selector must be designed to accept dashes having a duration of 3.5 to 4.5 seconds and spaces from 0.1 to 1.5 seconds. The question of operation through interfering signals in the 487.5 to 512.5 kc. band as well as the possibility of false alarms must also be considered when determining the selector timing tolerances. The alarm must function through a reasonable amount of interference on the same frequency as the distress signal. This interference may produce two effects on the selector. One effect is to prolong the normal four-second alarm signal in case the interference appears at just the correct time to add to the desired signal. The second effect of interference is to "fill in" the normal one-second spaces. If the spaces are completely filled in at the correct time the selector functions to reject the signals and it will do the same if interference unduly prolongs the desired dashes.

Ordinary telegraphic traffic does not interfere, even though on the same frequency, with normal operation of the auto alarm, especially if the selector unit is responsive to extremely short spaces. The minimum U. S. requirement is one-tenth second and if the design provides performance equal to or better than this value, then the alarm signal will pass through the selector as long as some "break" takes place in the interfering signal when the "space" occurs in the alarm signal.

The possibility of false alarms is determined by a combination of three main factors, namely fortuitous or accidental combinations of signals or noise equivalent to the alarm signal, timing tolerances of the selector and finally the number of dashes and spaces which are selected to ring the bells. As mentioned in the first part of this paper, European practice is to arrange for the bells to ring when three consecutive dashes and spaces pass through the receiver and selector. F.C.C. requirements are based on ringing the bells after four consecutive dashes and spaces are correctly received. The four-dash cycle considerably minimizes the possibly of false alarms since the chances are quite remote for accidental combination of signals to repeat themselves four times to imitate the alarm signal. On the other hand it is somewhat more difficult under conditions of severe interference for the auto alarm to accept the four-instead of the three-dash cycle. It may be mentioned that current designs of American auto alarms may be easily arranged to accept either the three- or four-dash cycle and in any case no international operating difficulties arise since the vessel in distress always sends twelve or more dashes.

A rugged design of auto alarm is necessary to withstand successfully the operating conditions which obtain aboard ships. In typical cases the auto alarm will be "on the air" for an average of approximately 5000 hours yearly. All the time the alarm is in circuit the receiver and certain parts of the selector are continually responding to ordinary telegraphic signals, static, inductions, etc. This entails considerable wear and tear of any moving parts and for this reason moving parts should be kept to a minimum, while relays and the like must withstand hundreds of thousands of cycles of operation. The design must also include provision for testing by sending a local alarm signal through the circuits, together with suitable meters and controls to enable the operator to check the over-all performance. F.C.C. specifications also call for ability to endure shipboard vibration, humidity and temperature. A single master switch to place the auto alarm in service is required which must be so arranged that power cannot be applied to the alarm circuits unless the main antenna is connected to the alarm receiver and having an interlocking feature to prevent the ship transmitter from being keyed unless the auto-alarm receiver is turned off.

PART II

The design of equipment necessary for performance as indicated in Part I can best be considered by using a natural division of receiver and selector requirements; that is, the receiver must have sufficient sensitivity and uniform reception over a band of 487.5 to 512.5 kc. and a selector system to differentiate between static and ordinary communication and the auto-alarm signal. In order to start selector operation some form of d-c amplifier is indicated. The plate circuit of this d-c amplifier must have sufficient power and correct characteristics to work a fast operating signal relay, the contacts of which initiate selector action. Certain characteristics of tuned circuits may be used to evolve the receiver design. Bandpass intercoupling circuits are indicated from a consideration of the selectivity and bandwidth requirements, as well as considerable amplification, in order to control the grid circuit of the d-c amplifier or signal relay tube. The coefficient of coupling

(k) of individual r-f transformers would be of the order of 0.06 to provide the necessary bandwidth.

Bandwidth = k × resonant frequency (approximately).

A circuit over-coupled to this extent would have a severe valley at the resonant frequency if modern high Q coils were used. High Q circuits are desirable in order to secure high attenuation outside of the pass

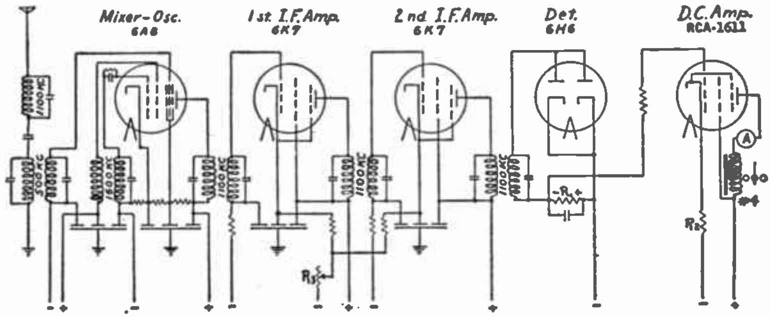

Fig. 1.

band. The effect of double humps with a severe trough between them is even more pronounced when it is realized that several r-f stages must be used in cascade in order to provide sufficient sensitivity. By using a frequency greater than 500 kc. the coefficient of coupling in the band-pass circuits may be reduced and still give the required bandwidth, and in addition, the response within the band may be made uniform since the coupling need not be much greater than the critical value. Figure 1 illustrates schematically the tube and circuit layout of a superheterodyne receiver used to produce the required results.

A total of eight tuned circuits is utilized for necessary amplification and selectivity. A signal between 487.5 and 512.5 kc., with attenuation of signals outside of these limits, is applied to the mixer-oscillator tube type 6A8 where it is mixed with the local oscillator operating at a frequency of 1600 kc. The difference beat between signal and oscillator frequency, or 1087.5 to 1112.5 kc., is amplified by two stages utilizing super control pentodes type 6K7 and then applied to diode detector type 6H6. The d-c voltage developed across diode resistor R_1 is used to control the grid circuit of d-c amplifier RCA-1611, whose plate relay initiates or stops selector action. The selectivity obtainable from such a layout is considerably in excess of requirements. For example, with the sensitivity control set for 500 microvolts, the signal necessary at 450 kc., to produce selector action is well in excess of 100,000 microvolts which is four times the required amount. Likewise, the same values hold for a frequency of 550 kc. An interfering signal of 25,000 microvolts at the antenna-ground terminals of the receiver, could be as close to 512.5 kc. as 533 kc. and on the other side of the auto-alarm band, the same strength signal could be as close as 467 kc., before interference would result. A wave trap directly in the antenna lead is provided for the attenuation of strong broadcast signals utilizing fre-

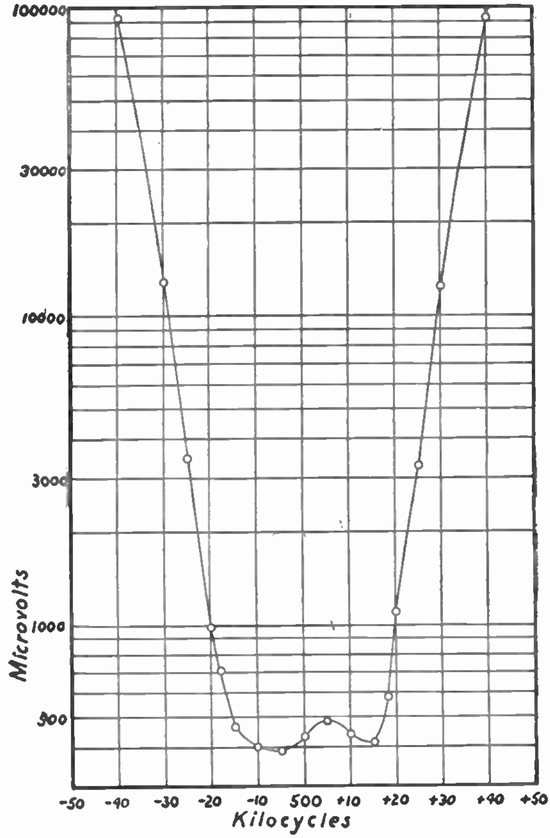

Fig. 2.

quency assignments in the passband accepted by the intermediate-frequency amplifiers. The response curve is shown in Figure 2.

It is desirable to use the ship's 110-volt line in order to avoid frequent B battery replacements or a dynamotor. This factor is quite important in selecting the tubes and circuits used. All metal tubes are used throughout. A 500-microvolt signal between the limits of 487.5 and 512.5 kc., irrespective of modulation or modulation frequency and including spark signals, must produce sufficient voltage of the polarity shown on the diode load resistor R_1 (Figure 1) to control the grid of the d-c amplifier tube. This tube has a "no-signal" plate current value of approximately 7 milliamperes; thus signal relay No. 4 is normally energized. The 500-microvolt signal then reduces this relay current to below its drop-out value of 3 to 4 milliamperes. If the signal remains long enough, selector action obtains as explained later. A signal stronger than 500-microvolts merely produces plate currents cut-off in the signal relay tube. "Downwards" operation of the signal relay is desirable inasmuch as a strong signal does not excessively deflect the milliammeter shown as A in Figure 1, and some sort of saturation circuit provision is, therefore, not necessary. A saturation circuit might be subject to a time lag when being restored to normal and thus limit the high speed operation of the signal relay. This is quite important, since this relay must recognize breaks of one-tenth second or less. Sensitivity control R_3 is provided for adjustment to optimum sensitivity, consistent with the prevailing noise level caused by atmospherics and man-made static. Thus to adjust for proper operation, the sensitivity control would beturned to its maximum counter-clockwise position, which gives minimum sensitivity for the receiver, and then turned clockwise until the plate current reading of the signal relay tube is approximately one milliampere less than the former reading. For example, if the plate current which flows through the signal relay reads 7 milliamperes with the sensitivity control set to the extreme counter-clock wise point, the control would be turned clockwise so that the average reading would be approximately 6 milliamperes. Bursts of static would then drive the signal relay current below the drop-out value and the contacts which initiate selector action would be occasionally or continually chattering, depending on existing noise conditions. Quite obviously, a sensitivity control is necessary; since if the auto alarm was permanently adjusted to respond to a 500-microvolt signal, during the heavy static season, and especially in the tropics, the signal relay would be de-energized most of the time and the receiver would be "blocked," insofar as ability to receive the auto-alarm signal is concerned. In the event that this condition occurs, that is, where an increase in static level sufficient to drive the signal relay current below the drop-out value occurs, and continues for more than 3.5 seconds, warning lights installed beside each alarm bell will be turned on and will remain lighted until the static reduces in value, or the sensitivity control is set to the proper point for the new level.

The characteristics of an acceptable selector unit will next be considered. Since 16 hours per day or approximately 5000 hours per day of operation are necessary, the selector unit, to be most reliable, should have a minimum of moving parts. As previously mentioned, the standard automatic alarm signal is composed of 12 dashes and spaces, but the alarm bells are to be actuated after the receipt of four dashes with tolerances of 3.5 to 4.5 seconds and spaces with tolerances of 0.1 to 1.5 seconds. Thus if the space between the first and second dashes is completely filled by interference, the alarm would be actuated at the end of the sixth dash. If interference prolongs the length of any dash beyond 4.5 seconds, or completely fills in the space between dashes, the mechanism used for selection would be restored to normal. Thus, of the 12 dashes composing the signal, 4 consecutive dashes having a space at the beginning and ending of the group, as well as between dashes, must be received before the alarm bells will ring. The obvious advantage of a 12-dash signal is that it permits more chances of the alarms being actuated under severe conditions of interference both from

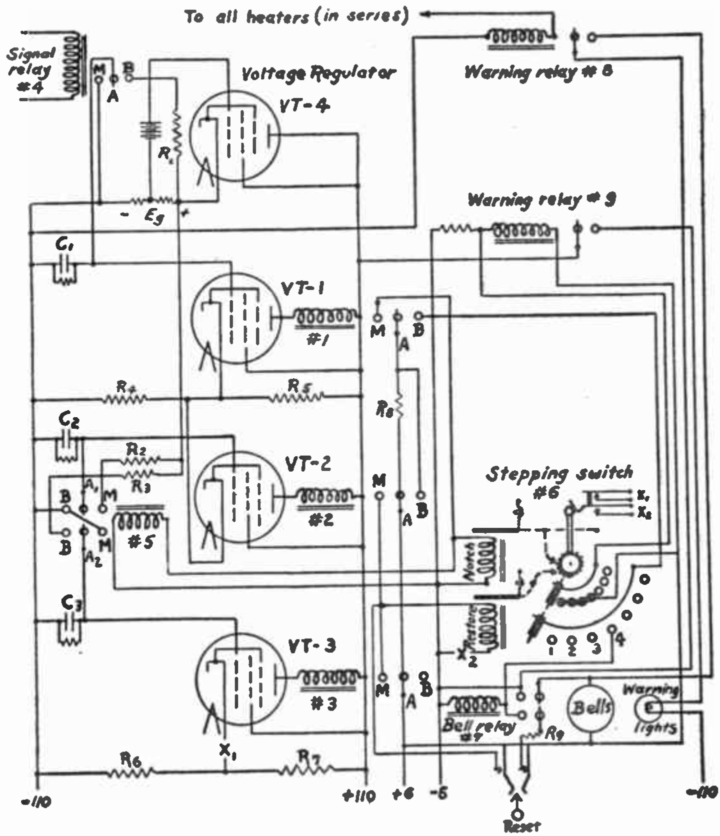

Fig. 3.

a standpoint of prolonging the dashes and filling in the spaces. The aforementioned dash and space tolerances seemingly impose difficult terms for the selector response. For example four dashes and the intervening three spaces might vary in a total elapsed time between 14.3 and 22.5 seconds. Obviously the selector must check individual dashes and spaces since any attempt to use the sum would result in the false alarm probability being greatly increased.

The schematic circuits of the receiver and selector units are shown separately for explanation purposes, but are combined on one panel in practice. Figure 3 shows a simplified circuit of the selector unit. Elapsed time of signal duration is measured by *RC* circuits connected in the grid circuits of individual selector tubes. The principle utilized is the familiar one of current decay in a series *RC* circuit.

If $E_g =$ steady source of charging voltage
$C =$ capacity in farads
$R =$ series resistance
$t =$ time
$i =$ instantaneous current at time t
$\epsilon =$ base of naperian logarithms

then $$i = \frac{E_g}{R} \epsilon^{-\frac{t}{RC}}.$$

If $e_c =$ Capacitor voltage at time t
$$e_c = Eg - iR$$

therefore $$e_c = Eg \left(1 - \epsilon^{-\frac{t}{RC}}\right).$$

At time $t = RC$, $e_c = 63\%$ of its maximum value Eg.

Referring to Figures 1 and 3, the selector action is as follows. An incoming signal of 500 microvolts or greater, of either A-1, A-2 or B emission, between 487.5 and 512.5 kc. produces a d-c voltage across the diode resistor R_1 of the correct polarity, as indicated in Figure 1, to reduce I_b of the d-c amplifier or signal relay tube below its drop-out value. Contacts *AM* (*A* refers to "armature" or moving contact, *B* to "break" and *M* to "make" contacts when relay is energized) are normally closed since relay No. 4 (Figure 3) is energized when no signals are being received. The reduction of I_b of the relay tube therefore causes contacts *AB* to be closed, which applies charging voltage E_g, developed by the voltage regulator tube, to C_1 through R_1. Since the grid-cathode circuit of VT-1 is connecetd across C_1, as C_1 charges, the grid of VT-1 becomes less negative and eventually I_{b1} begins to flow, gradually increasing to several milliamperes. Thus if a signal persists for 3.5 seconds I_{b1} becomes 5 milliamperes and relay No. 1 closes contacts *AM*. These contacts apply six volts obtained from the storage battery to the "notch" coil of the stepping switch No. 6, which moves up one step and the warning lights go "on." The coil of auxiliary relay relay No. 5 is in parallel with the notch coil of the stepping switch and, therefore, contacts A_1M are made. This starts C_2 charging through R_2 and if the signal persists up to or greater than 4.5 seconds I_{b2} of VT-2 becomes 5 milliamperes, which closes selector relay No. 2, and its contacts *AM*, in turn, apply six volts to the "restore" coil of the stepping relay. As soon as *A* leaves *B* of selector relay No. 2, R_8 is inserted in series with the notch coil and auxiliary relay coil to prevent damage to the low resistance notch coil, due to an overlong signal or continuous "blocking" by static. The warning lights continue to glow until the signal stops or has a slight break in it. A break in the received signal allows signal relay No. 4 contacts *AM* to return the grid of VT-1 to a value greater than that required for plate current cut-off, which allows No. 1 relay contacts *AM* to open, thus removing the voltage from the "notching" coil and auxiliary relay No. 5, in turn allowing the "restore" coil of the stepping switch to return the lever wiper to normal. Contacts A_1B of auxiliary relay No. 5 then bias the grid of VT-2 beyond cut-off and allow selector relay No. 2 to open contacts *AM*, which removes the six-volt supply from the restore coil of the stepping switch. VT-1 thus serves to check the minimum length of a dash (dashes less than 3.5 seconds do not actuate the stepping switch), and VT-2 serves to check the maximum acceptable length of dash (dashes greater than 4.5 seconds energize the restore coil of the stepping switch which "restores" when the signal stops). Four dashes, if greater than 3.5 seconds and less than 4.5 seconds would then actuate No. 1 relay four times and the stepping switch wiper would rest on Contact 4. Then if a break occurs at the end of the fourth dash, Contacts *AB* of No. 1 selector relay are closed which applies six volts to the bell ringing relay No. 7. Once closed, this relay applies six volts to the bells and is held closed by its auxiliary or hold-in contacts. In order to stop the bells the reset button on the auto alarm panel must be pressed. The bells are not allowed to ring until the fourth dash is broken (and within prescribed limits), since if this was not done three correct dashes and the fourth one of *any* length greater than 3.5 seconds would cause an alarm.

VT-3 serves two purposes. If one, two, or three currently timed dashes are received, the stepping switch wiper comes to rest on Contact 1, 2 or 3 respectively and would remain in one of these positions indefinitely until another dash was received, which would then ring the bells. This is, of course, improper operation. In order to prevent such a condition the grid of VT-3 is normally connected to the charging voltage E_g through charging resistor R_3. The cathode circuit of VT-3 connects through interlock contacts X_1 in the stepping switch, which are open when the stepping switch is on the zero or "normal" contact only. Thus after a "notch" has occurred auxiliary relay No. 5 contacts A_2M are closed which biases the grid of VT-3 to its below cut-off value as determined by voltage divider resistors R_6 and R_7. At the conclusion of the dash auxiliary relay No. 5 contacts A_2B are made and after an interval of five seconds I_{b3} in selector relay No. 3 reaches a value of 5 milliamperes, thus closing No. 3 relay contacts *AM*. These contacts in turn apply six volts to the restore coil of the stepping switch which will then be returned to normal. In the event that the second or following dash is completed within five seconds from the end of the previous dash, selector relay No. 3 does not close contracts *AM*. This then allows the maximum spaces between dashes to be the difference between five seconds and the initial closing time of relay No. 1, or 1.5 seconds. Such a method is necessary for the proper checking of spaces, since if an attempt were made to check spaces directly, any form of interference occurring during the space would "fill in" and cause an error in timing.

In order to indicate line voltage failure as well as tube heater burn-out, warning relay No. 8 is connected in series with all tube heaters which in turn are heated from the ship's 110-volt line. A failure of either tube heater or line voltage will cause the alarm bells to ring. The bells will, or course, stop ringing if the line voltage is restored. A test button is provided on the auto alarm panel which, when held in, prevents the bridge and operator's room bells from ringing during routine testing of the auto alarm receiver and selector.

Warning relay No. 9 is connected across the storage battery through a series resistor. Failure of the battery supply will allow relay No. 9 to deenergize and turn on the warning lights at each bell location point. Warning of power failure is therefore obtained except for simultaneous failure of both the 110-volt ship's line supply and the storage battery. The chances of simultaneous failure are very remote.

Following is a summary of warnings:

(1) *Bells ringing* may be caused by
- (a) Receipt of auto alarm signal.
- (b) Receipt of a false auto alarm signal caused by a fortuitous combination of static and keyed interference.
- (c) Loss of ship's line voltage.
- (d) Tube heater burn-out.

(2) *Warning lights burning continuously* are caused by
- (a) Receipt of a continuous signal from a transmitter whose key is being held down for a period considerably greater than 4.5 seconds.
- (b) Sensitivity control set too high for the prevailing noise level.
- (c) Loss of 6-volt battery supply.

(3) *Warning lights burning intermittently* are caused by
- (a) Occasional long bursts of static.
- (b) Transmitter testing using dashes slightly longer than 3.5 seconds.
- (c) Heavy 500 kc. interference caused by several telegraph transmitters transmitting at the same time.

Warnings as under (3) are to be expected and indicate that the auto alarm is functioning correctly. Warnings as under (1) and (2) should be investigated as to their cause.

The complete auto alarm installation consists of:

(A) The auto alarm receiver and selector chassis.

(B) A cable junction box which also provides mountings for
- (1) The radio room bell.
- (2) The radio room warning light.
- (3) Fuses for both 110-volt and 6-volt supplies.
- (4) Charging lamps for the 6-volt battery.

(C) An "antenna-on-off" switch which
- (1) When in the "receive" position (operator "off watch")
  - (a) Connects the main ship antenna to the auto alarm.
  - (b) Opens transmitter key relay power supply circuit.
  - (c) Connects the 110-volt supply to the auto alarm.
  - (d) Connects the 6-volt supply to the auto alarm.
- (2) When in the "off" position (operator "on watch")
  - (a) Connects the ship antenna to the lighting switch.
  - (b) Closes key relay power supply circuit.
  - (c) Removes the 110-volt and 6-volt tube and relay supply voltages.
  - (d) Places 6-volt battery on charge.

(D) Two bells and warning light boxes, one each to be located on the bridge and in the operator's room.

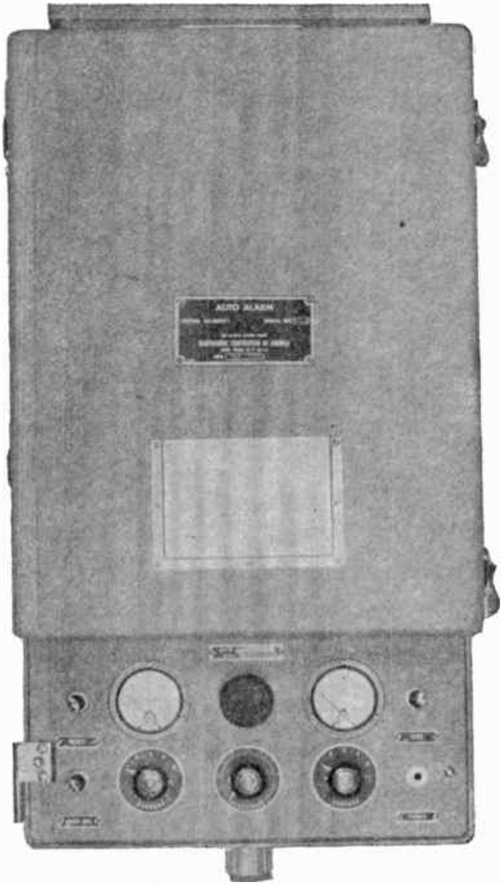

Fig. 4.

(E) One 6-volt storage battery.

A small oven, thermostatically controlled and containing the three selector relays for special protection against the humid conditions encountered at sea, keeps the auto alarm chassis perfectly dry inside. All adjustments which affect timing or bandwidth are made relatively inaccessible by cover plates.

Figure 4 shows the auto alarm receiver in its cast cabinet. The cabinet is made in two sections; the back section, which mounts on bulkhead by means of rubber shock mounts, is fitted with hinges on which the panel is hung. When the panel is swung into its cabinet, the inside is firmly sealed by means of a hollow rubber tube pressing against the back of the panel. The front section of the cabinet is also hinged to the back section. The hinge is of special construction so that the panel may be lifted off the hinge. The front section of the cabinet covers the

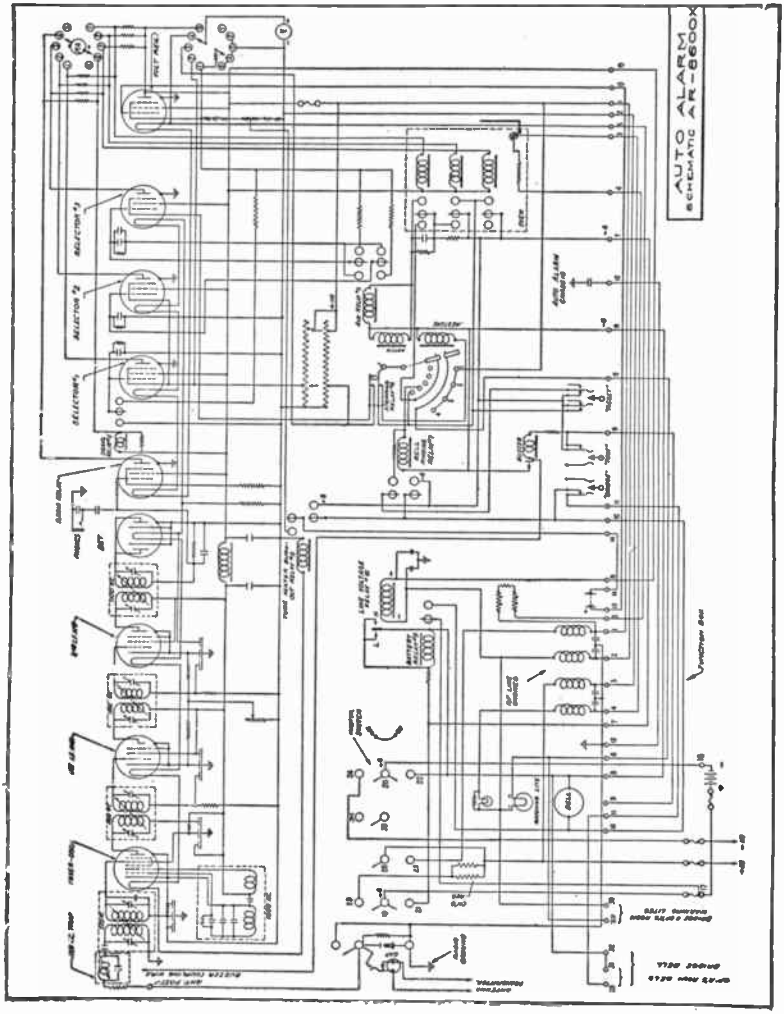

Fig. 5.

upper section of the panel, but leaves the meters, meter switch, phone jack, test buttons and sensitivity control accessible for observation and adjustment. Figure 5 shows a complete schematic diagram of the auto alarm unit.

Acknowledgment and appreciation is expressed to Mr. Chas. J. Pannill for his cooperation and encouragement during this work.

INDEX OF SUBJECTS

INSTRUCTIONS FOR USING THIS INDEX

All topics listed in the index are tabulated by *question numbers* rather than page numbers. It is believed that this will make for more convenient usage.

The question number immediately following each topic is *directly* associated with it. All other numbers are associated with the topic.

Topics are generally listed under *general* headings, such as, "Receivers," "Rules and Regulations," and so on.

Every question in the book is referred to in this index. This makes it possible to use the book as a general radio reference book, covering a multitude of points in receivers, transmitters, meters, electrical machinery, and many other topics of interest.

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