VOLUME 15 MARCH, 1927 NUMBER 3

PROCEEDINGS
of
The Institute of Radio Engineers

PUBLISHED MONTHLY BY

THE INSTITUTE OF RADIO ENGINEERS
Publication Office 21 Center St., Middletown, N. Y.

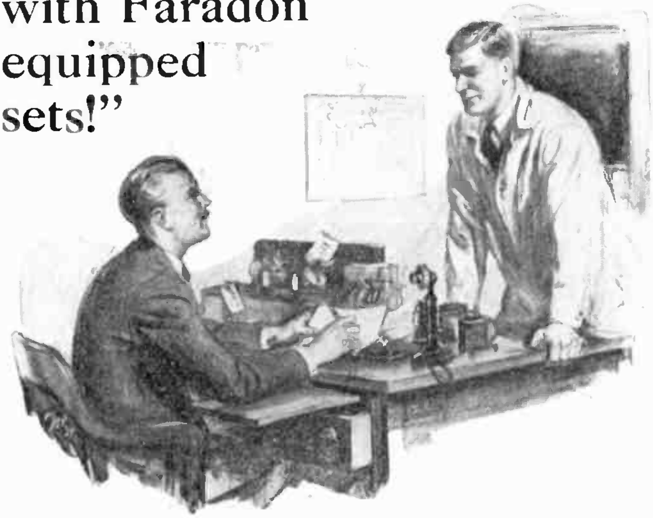
Editorial and Advertising Departments
37 West 39th Street, New York, N. Y.

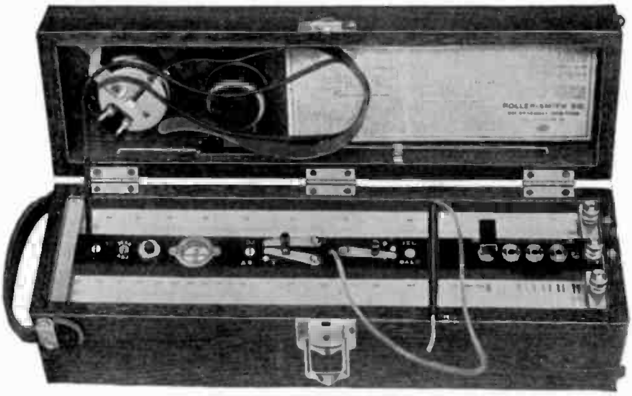
Subscription $10.00 per Annum in the United States
$11.00 in all other Countries

General Information and Subscription Rates on Page 165

Entered as second-class matter, at the Post-Office, at Middletown, N. Y., under the Act of March 3, 1879.

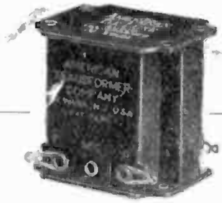
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized October 7, 1918.





AmerTran | AmerTran | AmerTran | AmerTran | AmerTran | AmerTran | AmerTran | AmerTran

Quality Performance



The AmerTran De Luxe

Made in 2 Types for 1st and 2nd Stages. $10.00 Each

For one and one-half years the AmerTran De Luxe has been used with great success by engineers and experimenters seeking improved audio amplification.

The secret of its excellence centers chiefly in the special alloy core material which provides the high inductance needed for the normal amplification of the fundamental base tones. This makes possible an improved coil structure for maintaining the higher frequencies with no appreciable "peak" or "drop" until beyond the useful range.

There is a remarkable absence of the muffling of sibilant sounds and "background"—often noticeable with transformers having "drooping" characteristics.

The AmerTran De Luxe is well made and designed to give long, dependable service. Metal cased, and embedded in a solid compound, it is not affected by climatic changes.

Quality performance is an AmerTran creed. AmerTran is the accepted unit for genuinely fine receiving apparatus.

Correspondence with our Engineering Department is cordially invited.

The American Transformer Co.

178 EMMET STREET NEWARK, N. J.

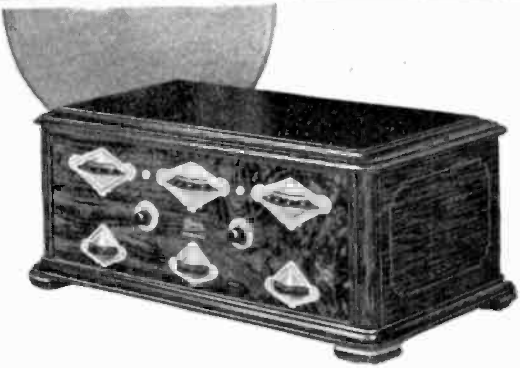
Other AmerTran Products

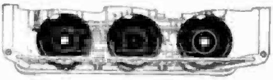
AmerTran Power Transformer
Type PF 52—$18.00 Each

AmerTran Audio Transformer
Type AF6 and AF7—$5.00 Each

AmerChoke Type 854—$6.00 Each

AmerTran | AmerTran | AmerTran | AmerTran | AmerTran | AmerTran | AmerTran | AmerTran





A New WESTON Model to meet a New Radio Need

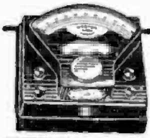
WESTON now offers you an every-day practical means of measuring Battery Eliminator Voltages. The familiar Weston Model 489 Radio Table Voltmeter is now made with a very high internal resistance (1,000 ohms per volt) for measuring Battery Eliminator Voltages. ¶This instrument is extremely sensitive and requires only one milliampere for full scale deflection.

WESTON MODEL 489 BATTERY ELIMINATOR VOLTMETER

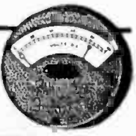
made in double range combinations of 250/50 volts, the latter range can be supplied with an external multiplier to increase it to 500 volts. Handsomely enclosed in Bakelite, supplied with a pair of 30 inch flexible cables.

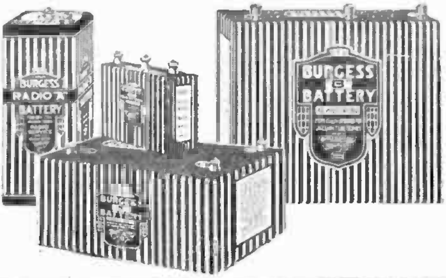
Only $28

WESTON ELECTRICAL INSTRUMENT CORPORATION
73 Weston Avenue, Newark, N. J.



STANDARD THE WORLD OVER
WESTON
Pioneers since 1888




BURGESS
RADIO A
BATTERY
BURGESS
B
BATTERY


RADIOTRON
UX 201-A

PROCEEDINGS OF

The Institute of Radio Engineers

Volume 15 MARCH, 1927 Number 3

CONTENTS

GENERAL INFORMATION

The Proceedings of the Institute are published monthly and contain the papers and the discussions thereon as presented at meetings.

Payment of the annual dues by a member entitles him to one copy of each number of the Proceedings issued during the period of his membership.

Subscriptions to the Proceedings are received from non-members at the rate of $1.00 per copy or $10.00 per year. To foreign countries the rates are $1.60 per copy or $11.00 per year. A discount of 25 per cent is allowed to libraries and booksellers.

The right to reprint limited portions or abstracts of the articles, discussions, or editorial notes in the Proceedings is granted on the express conditions that specific reference shall be made to the source of such material. Diagrams and photographs in the Proceedings may not be reproduced without securing permission to do so from the Institute through the Secretary.

It is understood that the statements and opinions given in the Proceedings are the views of the individual members to whom they are credited, and are not binding on the membership of the Institute as a whole.

Publication Office 21 Center Street, Middletown. N. Y.
Editorial and Advertising Departments. 37 West 39th St., New York, N. Y.

OFFICERS AND BOARD OF DIRECTION, 1927

(Terms expire January 1, 1928, except as otherwise noted)

PRESIDENT
RALPH BOWN

VICE-PRESIDENT
FRANK CONRAD

MANAGERS

MELVILLE EASTHAM
J. V. L. HOGAN
L. A. HAZELTINE
A. E. REOCH
R. H. MANSON

R. H. MARRIOTT
L. E. WHITTEMORE
(Serving until January 1, 1929)

J. F. DILLON
R. A. HEISING
(Serving until January 1, 1930)

TREASURER
WARREN F. HUBLEY

SECRETARY
ALFRED N. GOLDSMITH

ASSISTANT SECRETARY
JOHN M. CLAYTON

PUBLICATION OF "PROCEEDINGS"
ALFRED N. GOLDSMITH, editor
GEORGE R. METCALFE, assoc. editor

INSTITUTE SECTIONS

BOSTON SECTION

CHAIRMAN	SECRETARY-TREASURER
George W. Pierce	Melville Eastham, 11 Windsor St., Cambridge, Mass.

CANADIAN SECTION

CHAIRMAN	SECRETARY
D. Hepburn	C. C. Meredith, 110 Church St., Toronto, Ontario

CHICAGO SECTION

CHAIRMAN	SECRETARY
G. M. Wilcox	H. E. Kranz, 703 N. 5th Ave., Maywood, Illinois

CONNECTICUT VALLEY SECTION

CHAIRMAN	SECRETARY-TREASURER
W. G. Cady	K. S. Van Dyke, Scott Laboratory, Middletown, Conn.

LOS ANGELES SECTION

CHAIRMAN	SECRETARY
L. Taufenbach	L. Elden Smith, 340 N. Painter Ave., Whittier, Cal.

PHILADELPHIA SECTION

CHAIRMAN	SECRETARY
J. C. Van Horn	David P. Gullette, 1533 Pine Street, Philadelphia, Pa.

ROCHESTER, N. Y. SECTION

CHAIRMAN	SECRETARY
V. M. Graham	Harvey Klumb, 34 Clinton Ave., Rochester, N. Y.

SAN FRANCISCO SECTION

CHAIRMAN	SECRETARY-TREASURER
J. F. Dillon	D. B. McGowan, Custom House, San Francisco, Cal.

SEATTLE SECTION

CHAIRMAN	SECRETARY-TREASURER
John Greig	R. B. Wilson, 1132 Highland Ave., Bremerton, Washington

WASHINGTON SECTION

CHAIRMAN	SECRETARY-TREASURER
A. Hoyt Taylor	F. P. Guthrie, 122 Conn. Ave., Washington, D. C.

COMMITTEES OF THE INSTITUTE OF RADIO ENGINEERS, 1927

Committee on Meetings and Papers

R. H. MARRIOTT, Chairman
STUART BALLATINE
R. R. BATCHER
CARL DREHER
W. G. H. FINCH
ERICH HAUSMANN
L. A. HAZELTINE
G. W. PICKARD
PAUL WEEKS
W. WILSON

Committee on Admissions

F. CONRAD, Chairman
ARTHUR BATCHELER
HARRY F. DART
C. P. EDWARDS
A. H. GREBE
L. A. HAZELTINE
R. A. HEISING
L. M. HULL
F. H. KROGER
A. G. LEE
F. K. VREELAND

Committee on Revision of the Constitution

J. H. DELLINGER, Chairman
J. V. L. HOGAN
DONALD MCNICOL

Committee on Publicity

W. G. H. FINCH, Chairman
DAVID CASEM
ORRIN E. DUNLAP
F. EHRET
E. H. HANSEN
LLOYD JACQUET
J. F. J. MAHER
J. G. UZMANN
WILLIS K. WING
R. F. YATES

Committee on Membership

HARRY F. DART, Chairman
M. C. BATSEL
M. BERGER
GEORGE BURGHARD
F. A. CANAVACIOL
E. M. DELORAINE
COL. J. F. DILLON
DR. L. J. DUNN
C. P. EDWARDS
W. G. H. FINCH
C. M. JANSKY, JR.
ROBERT S. KRUSE
WILLIAM J. LEE
PENDLETON E. LEHDE
C. L. RICHARDSON
F. H. SCHNELL
E. R. SHUTE
G. S. TURNER
E. H. ULRICH

All Section Secretaries, ex-officio

Committee on Institute Sections

DAVID H. GAGE, Chairman
M. BERGER
L. F. FULLER
D. HEPBURN

COMMITTEES OF THE INSTITUTE—(Continued)

L. G. PACENT
M. C. RYPINSKI
E. R. SHUTE

Committee on Standardization

L. E. WHITTEMORE, CHAIRMAN.
M. C. BATSEL
EDWARD BENNETT
A. J. CARTER
E. L. CHAFFEE
J. H. DELLINGER
MELVILLE EASTHAM
C. P. EDWARDS
GENERAL FERRIE
A. N. GOLDSMITH
L. A. HAZELTINE
J. V. L. HOGAN
L. M. HULL
F. A. KOLSTER
R. H. LANGLEY
MAJOR J. O. MAUBORGNE
R. H. MANSON
DONALD MCNICOL
E. L. NELSON
H. S. OSBORNE
LT. COMDR. W. J. RUBLE
E. H. SHAUGHNESSY
H. M. TURNER
C. A. WRIGHT
HIDETSUGU YAGI
J. ZENNECK

INSTITUTE ACTIVITIES

NEW YORK MEETING, FEBRUARY 2.

At the February meeting of the Institute, held in the Engineering Societies Building, a paper entitled "Vacuum-Tube Nomenclature" by Dr. E. L. Chaffee was presented. The paper was discussed at length by Dr. Chaffee, J. E. Smith, George R. Metcalfe, J. C. Warner, A. V. Loughren and others. About two hundred members attended the meeting.

FEBRUARY MEETING OF BOARD OF DIRECTION

At the meeting of the Board of Direction, held at Institute Headquarters on February 2, the following were present: Dr. Ralph Bown, President; Dr. A. N. Goldsmith, Secretary; W. F. Hubley, Treasurer; Donald McNicol, Past-President; R. A. Heising, J. V. L. Hogan, R. H. Marriott, L. E. Whittemore and J. M. Clayton, Assistant Secretary.

For the position of Manager, with terms of one year each, the following were appointed by the Board of Direction: J. V. L. Hogan, L. A. Hazeltine and R. H. Manson.

The following Institute officers were appointed by the Board: W. F. Hubley, Treasurer; Dr. A. N. Goldsmith, Editor of Publications and Secretary.

Upon recommendation of the Admissions Committee the following transfers and elections were approved by the Board: Transfer to the grade of Fellow, Frank Conrad. Election to Fellow grade, Dr. K. W. Wagner. Transfer to Member grade: B. W. David, C. E. Drew, Glenn D. Gillett, Virgil M. Graham, Oscar B. Hanson, H. W. Lamson, P. K. McElroy. The following were elected to Member grade: W. E. Barber, C. D. Barbulesco, K. E. Edgeworth, E. H. Freeman, J. D. Graf, L. M. Heron, J. W. Millon, Jr., Miss Mary T. Loomis, E. J. T. Moore and I. P. Rodman.

One hundred and eighteen Associate and eight Junior members were elected.

A geographical distribution of membership, prepared in book form, was presented to the Board by the committee composed of E. R. Shute, D. H. Gage, and M. Berger. This list will be useful not only in ascertaining the present membership distribution but also in planning the work of future Sections of the Institute.

Standard forms of procedure to be followed in the establishment of a Section, and a standard Section Petition form, were submitted to the Board by the Sections Committee and were adopted.

Committee Activities

PROGRESS OF COMMITTEE ON STANDARDIZATION, 1926

Early in 1926 the Institute published a report of the Committee on Standardization which was the result of the work of the Committees of 1923, 1924, and 1925.

During the year 1926 the Committee has carried on its work through five subcommittees, of which the Chairmen are as follows:

1. Vacuum Tubes—L. A. Hazeltine.
2. Circuit Elements—Professor H. M. Turner.
3. Receiving Sets—Dr. J. H. Dellinger.
4. Electro-Acoustic Devices—R. H. Manson.
5. Power Supply—R. H. Langley.

These subcommittees have undertaken the formulation of methods of expressing and measuring the characteristics of radio receiving apparatus and associated circuit elements and devices falling within their respective fields. No general effort is being made to revise the definitions contained in the recently published report, but recommendations will be made as to any new definitions or symbols or any changes which the subcommittees find, during the course of their work, to be desirable.

Coordination of this work with that of other organizations interested in this general subject is facilitated by the presence on this committee of representatives from the Radio Division of the National Electrical Manufacturers' Association, the Radio Manufacturers' Association, and of the Standardization Committee of the American Institute of Electrical Engineers.

The progress made by the several subcommittees during the year 1926 may be summarized briefly as follows:

1. *Vacuum Tubes—L. A. Hazeltine, Chairman.*

Meetings of this subcommittee were held in New York on May 28 and July 1, 1926. A draft of a report was prepared based upon the discussions at these meetings. This draft has been submitted to the members of the subcommittee for further consideration and comments are to be submitted in writing to the Chairman. The subcommittee has also under consideration the subject of standard algebraic symbols for the more important vacuum tube quantities.

2. *Circuit Elements—Prof. H. M. Turner, Chairman.*

The Chairman of this subcommittee has been collecting, by correspondence, the suggestions of the members as to standard methods for measuring the more important characteristics of the elements comprising radio circuits, such as condensers, inductors and resistors. The material will be circulated to the members of the subcommittee for consideration and it is expected that a meeting will be held in the near future.

3. *Receiving Sets—Dr. J. H. Dellinger, Chairman.*

A meeting of this subcommittee was held in New York on December 1, 1926. A draft has been prepared covering "Tentative Standard Tests for Broadcast Receiving Sets". In addition to the overall tests of "sensitivity", "selectivity" and "fidelity" covered by this draft, the subcommittee has given definite consideration to characteristics of certain portions of receiving sets, and to tests of audio-transformers and of amplifiers. Drafts of proposals covering a number of these questions have been submitted by members of the subcommittee and circulated to others. Consideration of these matters will be continued at the next meeting.

4. *Electro-Acoustic Devices—R. H. Manson, Chairman*

At the request of the Chairman of the subcommittee, one of the members has prepared a draft of recommendations covering the following aspects of electro-acoustic devices used in radio communication.

a. General Terms and Definitions.

b. Telephone Receivers.
c. Telephone Transmitters.
d. Performance Indices.

Copies of this draft were sent to the members of the subcommittee for study and comment. A preliminary meeting of the subcommittee was held in New York on January 10, 1927. The Chairman is asking that comments and proposals be submitted to him in writing not later than February 15 so that another meeting of the subcommittee may be held soon after that date.

5. *Power Supply—R. H. Langley, Chairman*

The Chairman of this subcommittee has been in touch with the work of the corresponding committees of the National Electrical Manufacturers' Association and the Radio Manufacturers' Association and feels that the most satisfactory progress can be made by this subcommittee if it has for its consideration the reports of the mid-winter meetings of these two manufacturers' associations. It is expected that these reports will be available some time in February of 1927. At that time the subcommittee plans to undertake the study of such questions as life testing of batteries used in radio, method of rating batteries for radio purposes, and the specification and measurement of the characteristics of socket-power units.

All of the Standardization work is under the general supervision of L. E. Whittemore, Chairman of the Committee on Standardization, 1927.

SECTIONAL COMMITTEE ON RADIO, A. E. S. C.

The Sectional Committee on Radio, American Engineering Standards Committee, is sponsored by the American Institute of Electrical Engineers and the Institute of Radio Engineers. Its Executive Committee is composed of the following:

Prof. J. H. Morecroft, Chairman; Dr. C. H. Sharp, Vice-Chairman; Dr. A. N. Goldsmith, Secretary and the Chairmen of the Technical Committees.

There are five Technical Committees actively functioning at this time. The chairmen of these are:

Transmitting and Receiving Sets and Installation, A. F. Van Dyck.

Component Parts and Wiring, L. G. Pacent.

Vacuum Tubes, Dr. J. H. Dellinger.

Electro-Acoustic Devices, L. Espenschied.

Power Supply and Outside Plant, L. W. Chubb.

The report of activities of these Technical Committees since October, 1926 is as follows:

Committee on Transmitting and Receiving Sets and Installation. No formal meetings of the Committee have been held. The following material originating within the Committee is being considered:

1. Methods of classification of radio circuits.
2. Methods of tests of receivers.
3. Use of "preferred numbers".

No material for standardization has as yet been submitted to the Committee by cooperating bodies.

Committee on Component Parts and Wiring. The first general meeting of this Committee was held on December 1, 1926. Those present were: L. G. Pacent, Chairman; Melville Eastham, E. P. Powers, W. F. Hubley and E. L. Hall.

The field of activity of the Committee was outlined by the Chairman. Information was received concerning the various stages to be followed in the formation of a standard, both prior to action by the Committee and subsequently.

The subject of vacuum tubes and sockets being suggested as being proper material for standardization, a subcommittee composed of Messrs. Eastham, Hubley, and Hall was appointed to investigate the work of other Committees to avoid any possible duplication of effort and fields covered by the Committee on Component Parts and Wiring.

Committee on Electro-Acoustic Devices. The first formal meeting of this Committee was held in the office of the Institute of Radio Engineers on November 19, 1926. The following committee members and guests were present: Mr. Whittemore, Acting Chairman and Messrs. Hund, Weyl, Pressley Trainer, Harris, Ringel, Scanlon, Manson, Olney, Frederick, and McKown.

It was agreed that the following devices come within the scope of the Committee:

a. Telephone Receivers.

b. Loud Speakers.
c. Microphones and Condenser Transmitters.

It was further agreed that the standard symbols adopted by the Institute of Radio Engineers for telephone receiver, loud speaker, and telephone transmitter should be recommended for adoption by the Sectional Committee on Radio, A. E. S. C. The terminal markings adopted by the N. E. M. A. were suggested for adoption by the Sectional Committee on Radio.

The color code to be used in cords was discussed although no decision as to the actual colors was reached.

For the purpose of defining the characteristics of loud speakers the following list was considered for discussion at a future meeting:

1. Transmission frequency characteristics.
2. Efficiency.
3. Frequency range.
4. Volume capacity as limited by:
    a. non-linearity of response.
    b. clearance and mechanical strength of parts.
    c. overheating.
5. D-c. carrying capacity.
6. Insulation breakdown voltage
7. D-c. resistance.
8. Impedance.

It was decided that, in connection with the plotting of transmission frequency characteristics, a logarithmic frequency scale should be used for abscissae.

It is planned to circulate drafts of proposed standards for measuring or specifying the characteristics outlined above, for study and comment.

Committee on Vacuum Tubes. Dr. J. H. Dellinger has been appointed Chairman of the Committee on Vacuum Tubes, succeeding Dr. V. B. Jolliffe, resigned.

No formal meetings of the Committee have been held. It is planned to circulate prints of the exact dimensions and tolerances of the UX-tube base among Committee members as soon as these are available.

Committee on Power Supply and Outside Plant. While no meetings of the Committee on Power Supply and Outside Plant have been held, material for standardization from all available services has been collected and distributed to the Committee membership. No action has been taken, however, due to the rapidity of change in design of apparatus having made it difficult to tabulate and work up material for the Committee.

News of the Sections

LOS ANGELES SECTION

The Los Angeles Section held a meeting on January 17th in the Commercial Club of Los Angeles. The meeting was addressed by Lee Yount who read a paper entitled "Methods of Explaining Technical Radio to the Layman". The paper was discussed by various members present, including N. E. Brown, D. C. Wallace and W. W. Lindsay, Jr. Fifty members attended the meeting.

Following the discussion of the paper, the annual election of officers was held with the following resutls: Chairman, L. Taufenbach; Vice-Chairman, D. C. Wallace; Secretary-Treasurer, L. Elden Smith; Board of Managers: W. W. Lindsay, Jr., Dr. E. C. Waters and Lee Yount.

The next meeting of the Los Angeles Section will be held at the Commercial Club of Los Angeles on February 2nd. A paper will be read by Dr. MacKeown of the California Institute of Technology, entitled, "Vacuum Tubes".

CONNECTICUT VALLEY SECTION

On January 28th a meeting of the Connecticut Valley Section was held in the auditorium of the United Electric Light Company of Springfield, Conn. The speaker was Dr. G. W. Pickard who read a paper "The Correlation of Radio Reception with Solar Activity and Terrestrial Magnetism". The paper was discussed by E. A. Laport, Dr. W. G. Cady, Dr. K. S. Van Dyke, G. W. Pettengill and others.

A short talk was given by Alfred Crossley on "Recent Work at the U. S. Naval Research Laboratory".

The attendance at this meeting was thirty-five.

PHILADELPHIA SECTION

A meeting of the Philadelphia Section was held on January 28th at the Bartol Laboratories. A paper was read by A. G. Shafer being in the main a discussion of the paper "Vapor Alkali Detector Tubes". General discussion followed. Twenty-six members attended the meeting.

The annual election of officers was held with the following result: Chairman, J. C. Van Horn; Secretary-Treasurer, David P. Gullette. The Chairman appointed a Membership Committee composed of S. J. Hutchinson, A. G. Shafer and H. H. Brown.

ROCHESTER SECTION

The Rochester Section held a meeting on January 7th at the Sagamore Hotel, Rochester. Francis H. Engel presented a paper on "Vacuum Tubes". The paper was discussed by R. H. Manson and others. The attendance at this meeting was fifty-four.

During the month of February the Rochester Section provided speakers and conducted the noon luncheons of the Rochester Engineering Society. Meetings were held on the first, eighth, fifteenth and twenty-second.

The next meeting of the Rochester Section will be held on March 4, at the Sagamore Hotel. Dr. A. Hund will deliver a paper on "Piezo-Electric Quartz Crystals".

PROPOSED SECTION AT DETROIT

A second preliminary organization meeting looking to the formation of a Section of the Institute at Detroit, Michigan, was held on January 21st in the Federated Radio Trade School. Thomas E. Clark presided. Temporary officers were elected as follows: Chairman, Thomas E. Clark; Vice-Chairman E. D. Glatzel; Secretary, Walter R. Hoffman. The temporary Chairman appointed the following committee Chairmen: Meetings and Papers, A. B. Buchanan; Membership Committee, G. S. Rouston.

The next meeting will be held on February 18th.

WASHINGTON SECTION

A meeting of the Washington Section was held on February 9, 1927 in Harvey's Restaurant. The speaker of the evening was Alfred Crossley of the U. S. Naval Research Laboratory. The paper presented was, "Piezo-Electric Crystal Controlled Transmitters". The paper was discussed by Dr. A. Hund and others. The attendance at the meeting was forty.

The next meeting of the Washington Section will be on March 9, 1927 at Harvey's Restaurant. The program will be preceded by a dinner. The speaker will be C. Francis Jenkins who will present a paper on "Visual Radio".

CANADIAN SECTION

A meeting of the Canadian Section was held on the evening of February 2, 1927, in the Electrical Building of the University of Toronto, Toronto, Canada. The presiding officer was D. Hepburn. The meeting was addressed by R. H. Coombs, the subject of the paper being "Radio Broadcasting". A general discussion followed in which the effect of harmonic suppressors and the influence on reception of sun spots were brought out.

Twenty-three members of the Section and twenty-nine guests were present at the meeting.

The next meeting of the Canadian Section will be held on March 2, 1927 in the Electrical Building of the University of Toronto. J. M. Thompson will deliver a paper on "Audio Amplification".

Correction

In the paper by A. Crossley on Piezo-Electric Crystal-Controlled Transmitters, in the Proceedings for January, 1927, the development of the crystal oscillator circuit, shown in Fig. 19, was erroneously credited to R. B. Meyer. This circuit was developed by F. B. Monar and was applied by Meyer to the special transmitter system shown in Fig. 20.

Advertising

You have undoubtedly noticed the number of new advertisers who have appeared in each issue of the "Proceedings" since it became a monthly publication. In addition to these new people it has been especially gratifying that practically all of our old advertisers have decided to appear regularly in every issue of the new "Proceedings"—that is, twelve times a year instead of six as formerly.

We are presenting the "Proceedings" on its merits as an advertising medium to every established concern in, or allied with, the Industry. But we need the help of our members and readers to secure maximum results. There are still other manufacturers who could advertise profitably in the "Proceedings". Perhaps the manufacturer in whose product you are interested in is one of them.

If you believe, as we do, the "Proceedings" is a good place to advertise will you kindly bring it to the attention of the man in your organization who passes upon advertising expenditures and then write us his name so that we may communicate with him.

An increase in advertising revenue is one way in which it will be possible to give you a bigger and better "Proceedings". Any assistance you can render will be appreciated.

VACUUM-TUBE NOMENCLATURE

By

E. Leon Chaffee

(Cruft Laboratory, Harvard University, Cambridge, Mass.)

The ease of reading and comprehension of a mathematical discussion is largely dependent upon the simplicity and consistency of the nomenclature. Who has not experienced a certain irritation when reading a mathematical article which is framed in a system of symbols demanding such a useless expenditure of mental effort to remember the meanings of the symbols that little energy is left for the appreciation and understanding of the real truths imparted?

The ideal system of nomenclature is one which demands the least mental effort in distinguishing and remembering the meanings of the symbols. To this end the symbols should be, so far as practicable, suggestive of the quantities that they represent. Initial letters accomplish this aid to memory as, for instance, R is generally used to denote resistance, and C for capacity. Very often, however, the variety of quantities to be represented is so great that the system of using initial letters is inadequate and some other simple and consistent scheme must be used in addition. Some of the symbols of necessity may be arbitrary but whenever possible suggestive symbols should be used. Long usage finally overcomes the objection to an arbitrary symbol but it is surely better to dispense if possible with the period of becoming used to the symbol. I for current is an example of an arbitrary symbol which usage has made a part of the generally accepted nomenclature.

Many branches of science have a standardized system of nomenclature which in some cases is even internationally adopted. The language of expression is then the same in all books and articles. The science of vacuum tubes has unfortunately not yet arrived at this happy state and because of the variety of systems of nomenclature used by different authors it is often difficult to wade through a mathematical article in this subject. Probably the reasons that vacuum tube nomenclature has not become standardized are first, because of the comparative newness of the science, and second and most important, because of the peculiar complexity of the situation due to the great variety of quantities which must be distinguished. The Standardization Committee of the Institute of Radio Engineers has fixed upon certain symbols but the author finds the system of nomenclature given by the Committee inadequate and in some cases inconvenient. The author is fully aware of the caution that should be exercised in suggesting new symbols but since the question of nomenclature is still in a state of flux and because the system presented in this paper has received considerable thought and has been found to work well, he believes he is justified in presenting it for discussion at this time.

The general scheme in the system of nomenclature here presented is to represent different kinds of the same quantity as, for instance, steady, instantaneous, average or root-mean-square current by different forms of the same letter with perhaps super or sub symbols to furnish sufficient variety. *Subscripts* are reserved to signify *location,* as I_p means plate current, and also to denote *frequency,* as I_{p1} is a plate current of frequency 1. Following out this scheme the meanings of various forms and symbols may now be explained.

Capital letters are used only for quantities which are not directly functions of time, current, or potential but which may be functions of frequency then indicated by the proper subscript.

Small letters represent quantities which are functions of time, or of potential or current. Therefore, instantaneous quantities are always represented by lower-case letters. This has of course been general practice in electrical science.

Bold-faced letters represent vector or complex quantities.

CAPITAL LETTER SYMBOLS

Plain capital letters which signify electrical quantities such as current and potential denote the root-mean-square values of sinusoidally varying quantities.

Example: I_p is the r. m. s. value of the sinusoidal part of the plate current. If there are several components of the plate current having different frequencies then it is necessary to specify the frequency by a subscript thus, I_{p1} is the low-frequency component.

Plain capital letters which signify circuit elements such as resistance, inductance, etc. denote elements which are not functions of time, current or potential but which may be functions of frequency then denoted by the proper subscript.

Example: R, L, C and M represent respectively resistance, inductance, capacity and mutual inductance which are independent of time, current and potential. If a circuit element, say the resistance, depends upon frequency, then R_h is the resistance for the high frequency. The reactance X and impedance Z are of course always functions of frequency which need not be expressed by a subscript unless ambiguity arises.

One dash over a capital letter signifying an electrical quantity denotes an unvarying or steady quantity or component.

Example: $\overline{E}$ is the steady component of the electromotive force represented in Fig. 1.

One dash over a capital letter signifying a circuit element denotes the value of that quantity when a steady current is flowing.

Example: $\overline{R}$ is the value of the resistance offered to a steady current.

Two dashes over a capital letter denotes the time average of the quantity.

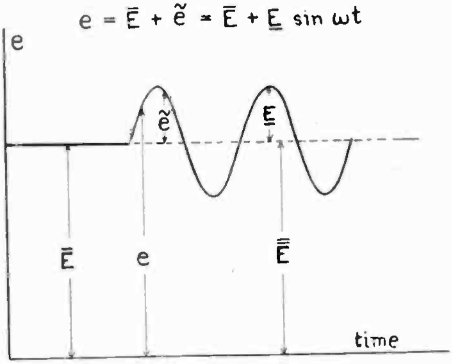


FIGURE 1

Example: $\overline{\overline{E}}$ represents the average value of the non-sinusoidal e.m.f. shown in Fig. 2. In certain cases $\overline{\overline{E}}$ is identical in value with E as in Fig. 1.

One dash below a capital letter signifying an electrical quantity denotes the maximum value of the sinusoidally varying component of the quantity.

Example: E represents the maximum value of the alternating portion of the e.m.f. shown in Fig. 1.

Two dashes below a capital letter signifying an electrical quantity denotes the peak value of the non-sinusoidally varying quantity.

Example: The significance of $\underline{\underline{E}}$ is shown in Fig 2.

A caret sign over a capital letter denotes the equivalent or effective value of the quantity.

Example: The resistance component of the equivalent impedance of a transformer as seen from the primary circuit is $\hat{R}_1 = R_1 + \dfrac{M^2\omega^2R_2}{Z_2^{\,2}}$ where subscripts 1 and 2 refer to quantities in the primary and secondary circuits, respectively.

Wavy line or tilde over a capital letter signifying a circuit element denotes the value of that quantity offered to an alternating current.

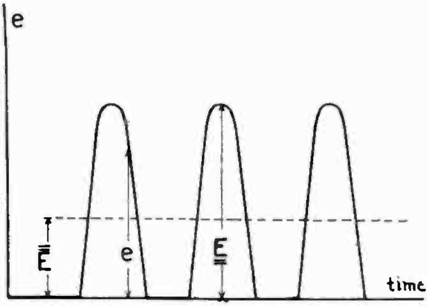


FIGURE 2

Example: $\widetilde{R}$ is the resistance of a circuit to alternating current when it is necessary to signify that it is different from the value offered to a steady current.

Small Letter Symbols

Plain small letters which signify electrical quantities such as current and electromotive force denote total instantaneous values.

Example: In Figs. 1 and 2, e indicates the total instantaneous e. m. f. at any time t.

Plain small letters signifying circuit elements such as resistance, conductance, amplification factor, etc. which are functions of potential or current are used to denote the values of these characteristics for infinitesimal variations of current or e. m. f. These values thus defined are called *variational* values and each of the quantities is usually the slope of a characteristic curve at some prescribed point.

Examples: If $i=f(e)$ expresses the characteristic curve of a conductor which may be a vacuum tube, then the value of $\frac{de}{di}$ is the variational resistance denoted by r. The reciprocal of r or $\frac{di}{de}$ is the variational conductance denoted by k. The characteristic curve and the value of r are shown in Fig. 3.

The amplification factor μ of a tube is a variational quantity.

The complex impedance of the plate circuit of a triode containing an inductive-resistance load is a function of the plate variational resistance and hence a function of the voltage impressed on the tube. It should, therefore, be de-

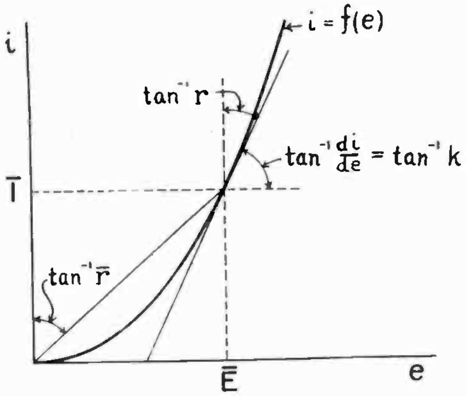


FIGURE 3

noted by a small letter, thus $z=(R+r_p)+jX$ whereas the impedance of the load alone is $Z=R+jX$. The admittance of the load is $Y=G-jB$ but the admittance of the whole circuit is $y=g-jb$, both g and b being functions of r_p.

One dash over a small letter signifying a circuit element, which is itself a function of the impressed e.m.f. or current, denotes the value of the element for steady current.

Example: If $i=f(e)$ as shown in Fig 3, then $\bar{r}=\frac{\bar{E}}{\bar{I}}$

$\bar{r}$ is obviously a function of $\bar{E}$ but is independent of time.

A wavy line or tilde over a small letter denotes the instantaneous value of a sinusoidal alternating quantity or of the sinusoidal component of a periodic quantity.

Example: Referring to Fig. 1, $\tilde{e}$ is the instantaneous value of the superposed sinusoidal e.m.f. Then $\tilde{e}=\underline{E}\sin \omega t$, and $e=\bar{E}+\tilde{e}$. In Fig. 2, $e-\bar{\bar{E}}$ is not a sinusoidal e.m.f. but can be developed in a Fourier series, so that

$$e-\bar{\bar{E}}=\underline{E}_1\cos\omega t+\underline{E}_2\cos 2\omega t+$$
$$=\tilde{e}_1+\tilde{e}_2+\tilde{e}_3+$$

USE OF SUBSCRIPTS

Subscripts are in general reserved to denote location and frequency, the frequency subscript always following the location subscript when both are necessary.

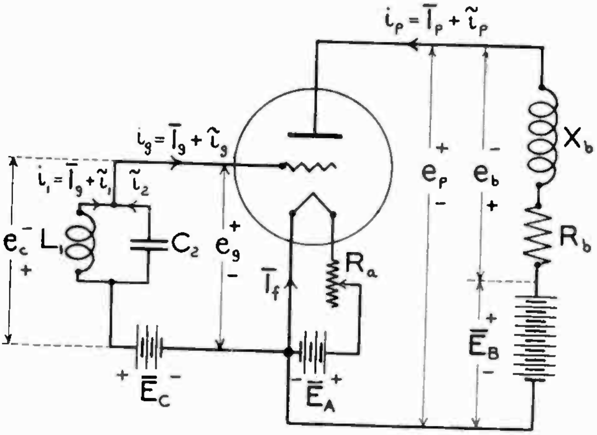


FIGURE 4

Location Subscripts. Particular meanings have been allocated to certain letters used as location subscripts.

Subscripts *f*, *p* and *g* indicate that the quantities to which they are attached are directly associated with the filament, plate and grid, respectively, of a triode.

Example: e_p is the instantaneous plate to filament potential. E_f is the steady voltage across the filament. $\tilde{i}_g$ is the instantaneous value of the sinusoidal component of grid current while I_g is the r.m.s. value of this component of grid current and not the r.m.s. value of the total grid current. r_p is the variational resistance of the plate-to-filament path of a triode.

Subscripts a, b, and c are used to denote quantities associated with the series impedances in the filament, plate and grid circuits, respectively, which are external to the triode.

Example: $Z_b = R_b + jX_b$. See Fig. 4. The total instantaneous voltage across Z_b is e_b which is equal to $E_b + \tilde{e}_b$.

Subscripts A, B, and C are used to denote quantities associated with batteries or generators in the filament, plate and grid circuits, respectively.

Example: In Fig. 4, E_B is the plate battery voltage and E_C the grid battery voltage.

Subscripts 1, 2, 3, etc., are used to denote different circuits.

Example: In Fig. 4, the parallel branch in the grid circuit is made up of two parts, one denoted by subscript 1 and the other by subscript 2. Other numbers or letters could equally well be used as subscripts to distinguish the two branches, or prime and second marks might be more convenient in some cases instead of subscripts. From the definition of subscript c the symbol Z_c is the equivalent series impedance of the parallel branch. Also

$$\hat{\mathbf{Y}}_c = G_c - jB_c = \frac{R_1}{R_1^2 + L_1^2\omega^2} - j\left(\frac{L_1\omega}{R_1^2 + L_1^2\omega^2} - C_2\omega\right),$$ when no ambiguity arises as here the use of the caret sign to denote equivalent value is unnecessary.

Frequency Subscripts. Various subscripts may be used to denote frequency. If, as in modulation and detection, there are two frequencies to distinguish, a high or modulated frequency, and a low or modulation frequency, the subscripts h and l are convenient. An intermediate frequency can be denoted by subscript i. If, on the other hand, harmonics are to be indicated, then the frequencies are all multiples of a fundamental and the numbers 1, 2, 3, etc. can be used to denote the multiple frequencies. In order to differentiate frequency subscripts from location subscripts, it is suggested that the former be represented by heavier type or by italic.

Example: The plate circuit impedance Z_b may have a different value for the high and low frequencies indicated by Z_{bh} *and* Z_{bl}, respectively. As an example of the use of numbers, the plate current of an oscillator might be expressed as follows:

$$i_p=\overline{\overline{I}}_p+\tilde{i}_{p1}+i_{p2}+\text{- - - - - - - -}$$

SPECIAL SYMBOLS

Special letters have become generally accepted as expressing certain quantities. For instance μ is generally accepted as meaning the amplification factor of a tube. Some of these the author includes in the system of nomenclature here presented but others he has rejected as being in his mind unsuited or inconsistent with the system. A list of some of these special symbols is given below with explanatory notes.

The plate and grid currents of a triode are functions of the plate and grid potentials as given by the following expressions

$$i_p=\Phi(\partial_p,\partial_g) \qquad (1)$$

and

$$i_g=\Psi(\partial_p,\partial_g) \qquad (2)$$

The total differentials of i_p, and i_g are

$$di_p=\frac{\partial i_p}{\partial e_p}de_p+\frac{\partial i_p}{\partial e_g}de_g \qquad (3)$$

and

$$di_g=\frac{\partial i_g}{\partial e_p}de_p+\frac{\partial i_g}{\partial e_g}de_g \qquad (4)$$

The partial derivatives of (3) and (4) have been given significant names and symbols.

$\frac{\partial i_p}{\partial e_p}$ is the *variational plate conductance* and is denoted by k_p. The author objects to the use of g_p for this quantity. In engineering g means the real part of a complex admittance whereas as defined above, k_p is simply the reciprocal of a resistance and k has long been used to denote conductance. It is true that when very short waves are used the time of flight of the electron is appreciable and the characteristics of the tube are then complex quantities. In this case however, equations (1) and (2) are inadequate for time must enter as a third independent variable and then a g_p may properly be defined but not as $\frac{\partial i_p}{\partial e_p}$.

The reciprocal of $\frac{\partial i_p}{\partial e_p}$ or $\frac{\partial e_p}{\partial i_p}$ is the *variational plate resistance* denoted by r_p.

$\frac{\partial i_p}{\partial e_g}$ *is the variational grid-to-plate conductance* or simply the variational mutual conductance, and is denoted by σ_p. The symbol g_m has been suggested and has to a certain extent been accepted for denoting the mutual conductance. The same objection to the use of g arises here as in the previous case. Furthermore, it has been customary to use g with various subscripts for all of the coefficients in (3) and (4). This is objectionable because the differentiation between mutual conductance and plate conductance, two different quantities although dimensionally the same, depends upon subscripts rather than upon main symbols. A formula containing four kinds of g's differentiated only by subscripts is more bewildering than one in which the differentiation is by main symbols. Furthermore, differentiation of different quantities by subscripts violates the scheme of nomenclature here presented.

Objection might well be raised to the use of the word mutual in a sense which is not in accordance with its strict definition implying equal reciprocal action. There is here no equal reciprocal action but because of long usage it is believed that the meaning of mutual may perhaps be extended to apply to this case.

If the plate current is constant, then $-\frac{\partial e_p}{\partial e_g}$ is denoted by μ_p and is known as the *variational amplification factor*. From relation (3)

$$\mu_p = \frac{\sigma_p}{k_p} = \sigma_p r_p \tag{5}$$

is the *variational plate-to-grid mutual conductance* denoted by σ_g. $\frac{\partial i_g}{\partial e_p}$ is usually a negative quantity so that with the second negative sign in the definition, σ_g is intrinsically positive. σ_g is called the *variational reflex mutual conductance.*

$\frac{\partial i_g}{\partial e_g}$ is the *variational grid conductance* denoted by k_g.

Its reciprocal or $\frac{\partial e_g}{\partial i_g}$ is the *variational grid resistance* or r_g.

If i_g is held constant then $\frac{\partial e_g}{\partial e_p}$ is the *variational reflex factor* and is denoted by μ_g. According to (4) we have

$$\mu_g = \frac{\sigma_g}{k_g} = \sigma_g r_g \tag{6}$$

We may now write (3) and (4) in the forms

$$di_p = k_p de_p + \sigma_p de_g \tag{7}$$

$$di_g = -\sigma_g de_p + k_g de_g \tag{8}$$

All of the coefficients of (7) and (8) are usually positive quantities.

The inter-electrode capacities of a triode are denoted by C_p, C_g *and* C_m, which are respectively the plate-to-filament capacity, the grid-to-filament capacity, and the mutual or plate-to-grid capacity.

In order to illustrate further the use of the notation, the expressions for the equivalent input admittance of a triode when k_g is negligible are given as developed by the author.

$$\hat{y}_g = \hat{g}_g - j\hat{b}_g$$ where

$$\hat{g}_g = C_m\omega \frac{C_m\omega G_b - \sigma_p[B_b - (C_m + C_p)\omega]}{[k_p + G_b]^2 + [B_b - (C_m + C_p)\omega]^2} \tag{9}$$

and

$$\hat{b}_g = -\omega \left\{ C_g + C_m \left[1 + \frac{C_m\omega[B_b - C_m + C_p)\omega] + \sigma_p[k_p + G_b]}{[k_p + G_b]^2 + [B_b - (C_m + C_p)\omega]^2} \right] \right\} \tag{10}$$

In (9) and (10) G_b and B_b are the components of the plate load $Y_b = G_b - jB_b$.

The detecting or demodulating quality of a triode has been defined in various ways. The author has developed the theory of detectors in a paper published in I. R. E. Vol. 15, No. 1 and has found the following definitions of detection coefficient convenient.

Just as in the case of amplification, the ability of a tube to amplify depends upon the ampilfication factor μ_p but the actual amplification obtained also depends upon the impedance load in the plate circuit, so in detection certain characteristics of the tube determine the rectifying ability of a tube but the actual rectification obtained depends as well upon the several impedance in the plate and grid circuits and upon a rather complex combination of them with the tube characteristics. There is however some need for an expression involving only the characteristics of the tube which can be used as a basis of comparison of different tubes used as detectors. Therefore, two detection coefficients are defined.

In order to make clearer the definitions, the following expressions giving two of the components of the rectified plate current the steady component and the component of modulation frequency, are copied from the article referred to above.

$$\overline{\Delta^2 I_p} = \frac{r_p}{4(r_p+R_b)}\left[-\frac{\sigma_p r_g R_c}{r_g+R_c}\cdot\frac{\partial k_g}{\partial e_g}+\frac{\partial \sigma_p}{\partial e_g}+\frac{\mu_p^2 R_{bh}^2+X_{bh}^2}{(r_p+R_{bh})^2+X_{bh}^2}\cdot\frac{\partial k_g}{\partial e_p}\right. \tag{11}$$

$$\left.-\frac{2\mu_p\sqrt{R_{bh}^2+X_{bh}^2}}{\sqrt{(r_p+R_{bh})^2+X_{bh}^2}}\cdot\frac{\partial \sigma_p}{\partial e_p}\right]\left[\frac{\hat{r}_{gh}^2+\hat{x}_{gh}^2}{(\hat{r}_{gh}+R_{ch})^2+(\hat{x}_{gh}+X_{ch})^2}\right]$$

$$\left(1+\frac{m^2}{2}\right)(\underline{\Delta E_{oh}})^2$$

$$=\overline{(Det.\ 1)}\left(1+\frac{m^2}{2}\right)(\underline{\Delta E_{oh}})^2 \tag{12}$$

$$\Delta^2 I_{pl} = \frac{r_p}{4(r_p+Z_{bl})}\left[-\frac{\sigma_p r_g \mathbf{Z}_{cl}}{r_g+\mathbf{Z}_{cl}}\cdot\frac{\partial k_g}{\partial e_g}+\frac{\partial \sigma_p}{\partial e_g}+\frac{\mu_p^2(R_{bh}^2+X_{bh}^2}{(r_p+R_{bh})^2+X_{bh}^2}\cdot\frac{\partial k_p}{\partial e_p}\right. \tag{13}$$

$$\left.-\frac{2\mu_p\sqrt{R_{bh}^2+X_{bh}^2}}{\sqrt{(r_p+R_{bh})^2+X_{bh}^2}}\cdot\frac{\partial \sigma_p}{\partial e_g}\right]\left[\frac{\hat{r}_{gh}^2+\hat{x}_{gh}^2}{(\hat{r}_{gh}+R_{ch})^2+(\hat{x}_{gh}+X_{ch})^2}\right]$$

$$\sqrt{2}m(\underline{\Delta E}_{oh})^2$$

$$=(\mathbf{Det.\ I})_l\sqrt{2}m(\Delta\underline{E}_{oh})^2 \tag{14}$$

Formulas (11) and (13) are derived for and hence apply *only* for a very small applied radio-frequency voltage in the grid circuit. This is indicated by the Δ sign. The impressed voltage is assumed to be

$$\widetilde{\Delta e}_{oh}=\underline{\Delta E}_{oh}(I+m\sin\omega_l t)\sin\omega_h t$$

where m is the degree of modulation, $\frac{\omega_l}{2\pi}$ is the modulation frequency and $\frac{\omega_h}{2\pi}$ is the high or modulated frequency. $(\underline{\Delta E}_{oh})$ is then the maximum value of the unmodulated high-frequency impressed voltage in the grid circuit. $\overline{\Delta^2 I_p}$ of (11) is the change in steady value of plate current represented as of second order magnitude for mathematical consistency.

$\Delta^2 I_{pl}$ is, according to the notation, the r. m. s. value of the sinusoidal component of plate current of modulation frequency $\frac{\omega_l}{2\pi}$; $\overline{R}_c$ is the resistance to steady current of the series load in the grid circuit such as a grid leak resistance, and Z_{cl} is the complex series impedance to modulation frequency of any load in the grid circuit. If a grid leak and condenser are used Z_{cl} is the equivalent series impedance of the parallel combination. R_{bh} and X_{bh} are, respectively, the series resistance and reactance to the radio frequency of any load in the plate circuit. $\hat{r}_{gh}$ and $\hat{x}_{gh}$ are, respectively, the equivalent input resistance and reactance to the high frequency of the triode. R_{ch} and X_{ch} are the series resistance and reactance to the high frequency of any series load in the grid circuit. The other factors have been defined.

In expressions (12) and (14) the current detection coefficients $\overline{(\mathit{Det.}\ \mathrm{I})}$ and $(\mathbf{Det.\ I})_l$ are used to denote portions of (11) and (13). These expressions constitute definitions of the new quantities, the *total current detection coefficients*. In words the definitions are given below although the verbal definitions are of questionable value.

The *total steady-current detection coefficient* is the change in plate current per unit squared radio amplitude. $(m=0)$.

The *total current detection coefficient for modulation frequency* is the r. m. s. value of the component of plate current modulation frequency per unit squared radio amplified when the modulation is $\frac{1}{\sqrt{2}}$.

It will be noted that $\overline{(\mathit{Det.}\ I)}$ *and* $(\mathbf{Det.\ I})_l$ are identical except for the value of the external grid and plate impedances. Therefore $(\mathbf{Det.\ I})_l$ *becomes* $\overline{(\mathit{Det.}\ I)}$ *if* Z_{cl} and Z_{bl} are given their values at zero frequency.

It is usually preferable to specify the effective fictitious voltage of rectification which if acting in the plate circuit would give rise to the rectified components of plate current given in (11) and (14). These effective voltages are obviously

$$\overline{\Delta^2 \hat{E}} = (r_p + R_{bl}) \overline{\Delta^2 I_p}$$

and (15)

$$\Delta^2 \hat{\mathbf{E}}_p = (r_p + \mathbf{Z}_{bl}) \; \Delta^2 \mathbf{I}_{pl} \tag{16}$$

Accordingly corresponding total voltage detection coefficients can be defined as

$$(\overline{Det.\ E}) = (r_p + R_b) \quad (\overline{Det.\ I}) \tag{17}$$

and

$$(\underline{\mathbf{Det.\ E}})_l = (r_p + \mathbf{Z}_{bl}) \, (\underline{\mathbf{Det.\ I}})_l \tag{18}$$

Objection might be raised to the cumbersome form of the symbols for detection coefficient. A plain *D* has been used but this symbol is rejected because of its mathematical use to denote derivative. The form chosen is both suggestive and explanatory, although a trifle awkward. The expression has precedence in the expressions *Div, Curl,* etc. and it is used so little in mathematical formulae that this objection of awkwardness is of slight importance.

Returning now to the general expressions (11) and (13), we may assume there is no radio impedance in the plate circuit and no audio or radio series impedance in the grid circuit. Then (11) and (13) reduce to

$$\overline{\Delta^2 I_p} = \frac{r_p}{4(r_p + R_b)} \cdot \frac{\partial \sigma_p}{\partial e_g} \cdot \left(1 + \frac{m^2}{2}\right) (\Delta E_{oh})^2 \tag{19}$$

and

$$\Delta^2 \mathbf{I}_p = \frac{r_p}{4(r_p + \mathbf{Z}_{bl})} \cdot \frac{\partial \sigma_p}{\partial e_g} \cdot \sqrt{2} m (\Delta \mathbf{E}_{oh})^2 \tag{20}$$

These expressions give the rectification due to curvature of the plate current curve. Obviously $\frac{\delta \sigma_p}{\delta e_g}$ is the characteristic of the tube which measures the rectification under these conditions so that we may define a *simple voltage detection coefficient for plate-circuit rectification* for the tube as

$$(det.\ e)_p = \frac{r_p}{4} \cdot \frac{\partial \sigma_p}{\partial e_g} \tag{21}$$

This quantity is independent of frequency and may be conveniently used as a basis of comparing tubes. Note that it is indicated by a small initial letter to distinguish it from the total detection coefficients.

Tubes are often used as detectors with a grid leak and condenser or the equivalent. If then we assume that there is no plate load for the radio frequency and no grid impedance for the radio frequency in series with the impressed voltage, and also that the rectification due to plate curvature is negligible, then the first term of (11) and (13) is important and they become

$$\overline{\Delta^2 I_p} = -\frac{r_p}{4(r_p+\overline{R}_b)} \cdot \frac{\sigma_p r_g \overline{R}_c}{r_g+\overline{R}_c} \cdot \frac{\partial k_g}{\partial e_g} \left(1+\frac{m^2}{2}\right) (\underline{\Delta E_{oh}})^2 \quad (22)$$

and

$$\Delta^2 \mathbf{I}_{lp} = -\frac{r_p}{4(r_p+\mathbf{Z}_{bl})} \cdot \frac{\sigma_p r_g \mathbf{Z}_{cl}}{r_g+\mathbf{Z}_{cl}} \cdot \frac{\partial k_g}{\partial e_g} \sqrt{2}m \, (\underline{\Delta \mathbf{E}_{oh}})^2 \quad (23)$$

Although we can get rid of the $\overline{R}_b$ and $\mathbf{Z}_{bl}$ by expressing the voltage detection coefficient, it is not so easy to make the definition independent of $\overline{R}_c$ and $\mathbf{Z}_{cl}$ except by assuming the series impedance for modulation frequency in the grid circuit infinite. Then we may define the *simple voltage detection coefficient for grid-circuit rectification* as

$$\begin{aligned} (det.\ e)_g &= -\frac{r_p r_g \sigma_p}{4} \cdot \frac{\partial k_g}{\partial e_g} \\ &= -\frac{\mu_p}{4k_g} \cdot \frac{\partial k_g}{\partial e_g} \end{aligned} \quad (24)$$

This expression, too, is independent of frequency and is about the simplest form for use in comparing tubes. Comparative curves of detection coefficient, however, furnish the best basis of comparison and measure of detection property of a triode.

No claim of completeness is made for the system of nomenclature given above. It is presented in the hope that it may serve as a further step toward the early standardization of a system of symbols.

INFLUENCE ON THE AMPLIFICATION OF A COMMON IMPEDANCE IN THE PLATE CIRCUITS OF AMPLIFIERS[*]

BY

J. E. ANDERSON

A common impedance in the plate circuits of two or more tubes in an amplifier produces either a decrease or an increase in the amplification. Whether it is the one or the other depends on the type of circuit, on the number of tubes sharing the common impedance, on the phase relations of the various impedances, and on the absolute value of the amplification when the common impedance is zero. For certain values of the common impedance the amplification will increase indefinitely, and the circuit will then oscillate. In general the circuit can only oscillate at one frequency at which the common impedance has the required value.

There are practically no circuits in which there is not a common impedance of appreciable magnitude. Noteworthy examples are: the resistance of a partially exhausted plate battery; the impedance of a plate battery eliminator; the resistance of the balancing potentiometer arms in a-c. heated filament receivers.

If an expression for the amplification in any circuit be obtained, taking into account the impedance in common with two or more plate circuits, it will generally be of the form

$$M=\frac{a+bZ}{A+BZ} \tag{1}$$

in which A, B, a and b are complex quantities involving the circuit parameters and Z is the common impedance. All of these quantities are functions of the frequency. Whether Z will produce an increase or a decrease in the amplification depends on the signs of the complex quantities associated with Z in (1), particularly on the signs of A and B. Since these two quantities may differ in sign, it is evident that for one value of Z the denominator in (1) will vanish. The

---

[*] Received by the Editor September 13, 1926.

amplification will then increase indefinitely, and the circuit will oscillate, provided that the numerator does not also vanish at the same time. This it does not do under any practical conditions. Hence the condition for oscillation in the amplifier is that

$$A+BZ=0. \tag{2}$$

Since this is a complex equation, both the real and the imaginary parts must vanish together. If the common impedance in the plate circuits should satisfy equation (2) at some frequency, the circuit will oscillate at that frequency. In this paper, that value of Z which satisfies this equation will be designated by Z_0 to distinguish it from the actual value of the common impedance. It is independent of the value of Z and is a function of the frequency and of the circuit constants.

If it is only required to determine whether the amplification will be increased or decreased by the common impedance, or whether the circuit might oscillate at some frequency, it is not necessary to obtain the complete expression for amplification, but only the denominator. The effect of the common impedance of any given type may be deduced from the characteristics of Z_0 as obtained from equation (2). Since Z must in all cases be an actual impedance, it must either lie in the first or the fourth quadrant. If it is composed of resistance and inductance it will lie in the first quadrant; if it is composed of resistance and capacity it will lie in the fourth. When Z_0 lies in the first quadrant, the amplification will be increased when the reactance of Z is positive, and the circuit might oscillate at some frequency in the band over which the reactance of Z_0 is positive. Similarly, when Z_0 lies in the fourth quadrant, the amplification will be increased when the reactance of Z is negative, and the circuit might oscillate at some frequency in the band which makes the reactance of Z_0 negative. When Z_0 lies in either the second or the third quadrant, the amplification will be decreased by all possible values of Z, and the circuit cannot oscillate, because then the real part of Z_0 is negative, which would require a resistance of the same sign in the common impedance in order to satisfy equation (2). In some circuits Z_0 will never enter either the first or the fourth quadrant; in others it will never enter the second or the third; and in still others it may move throughout the four quadrants as the frequency varies.

ANALYSIS OF TWO-TUBE, TRANSFORMER-COUPLED AMPLIFIER

The two-tube, transformer-coupled amplifier shown in Fig. 1 will be first considered. Let μ_1 be the amplification constant of the first tube, E_1 the input voltage to that tube, i_1 the a-c. component of the plate current in the tube, z_1 the total impedance in the plate circuit exclusive of the common impedance, Z_1 the load impedance, also exclusive of Z. Let the corresponding quantities in the second stage be subscripted by 2, but otherwise the same. Let the current in Z be denoted by i. The effective emf in the first plate circuit is $-\mu_1 E_1$ and that in the second, $-\mu_2 E_2$, the negative signs being employed to account for the fact that the tubes change the phase of the input voltage. The input voltage E_2 to the second tube is equal to $aZ_1 i_1$, where a is the transformer ratio, assumed to be constant and positive. The current in the common impedance is the sum of the two plate currents. Hence the following equations result:

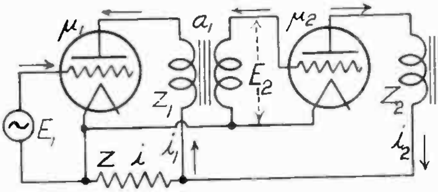


Figure 1

$$\left.\begin{aligned} -\mu_1 E_1 &= z_2 i_2 + Zi \\ -\mu_2 E_2 &= z_1 i_1 + Zi \\ E_2 &= aZ_1 i_1 \\ i &= i_1 + i_2 \end{aligned}\right\} \tag{3}$$

These reduce to

$$\left.\begin{aligned} -\mu_1 E_1 &= (z_1 + Z) i_1 + Z i_2 \\ 0 &= (a\mu_2 Z_1 + Z) i_1 + (z_2 + Z) i_2 \end{aligned}\right\} \tag{4}$$

The amplification in the circuit may be defined as the ratio of the voltage across the final load to the initial input voltage. In this case, then, $M = Z_2 i_2 / E_1$. Since only the final current is involved, it is only necessary to solve equations (4) for i_2 in order to get the amplification. The solution is

$$M = \frac{\mu_1 Z_2 (a\mu_2 Z_1 + Z)}{z_1 z_2 + Z(z_1 + z_2 - a\mu_2 Z_1)} \tag{5}$$

When the denominator in (5) is zero the amplification is infinite, and therefore the condition for oscillation is

$$Z_0 = \frac{z_1 z_2}{a\mu_2 Z_1 - (z_1 + z_2)} \tag{6}$$

From both equations (5) and (6) it is apparent that the common impedance causes an increase in the amplification and that oscillation at some frequency is possible, provided that the resistance in the common impedance is high enough.

In defining voltage E_2 it was assumed that the transformer ratio was positive, or such that the phase of the primary and secondary voltages remains the same. When a pair of leads to the transformer is reversed, that is when the sign of a in equation (6) is changed, all the terms in the denominator of (6) become negative. This also makes Z_0 negative. Then the circuit can no longer oscillate at any frequency, and there will be a decrease in the amplification. This is exactly the reverse from the case of intentional inductive feed-back, which requires a negative ratio for oscillation. The reason for the difference is not difficult to find. In Fig. 1 the in-phase components of the currents and voltages have been indicated by arrows in the case of positive ratio. It will be seen that part of i_2 is forced by Z to back up through the primary of the transformer and through the first tube, and that this part of i_2 is in phase with i_1. The primary current and voltage are thus increased, and consequently the amplification is also increased. When the ratio is negative all the arrows pertaining to the second tube are reversed. Currents i_1 and i_2 will be in phase in Z. This will increase the voltage drop in Z, and consequently the current circulating in the plate circuit of the first tube will be decreased. This in turn will decrease the primary voltage and the amplification. In the case of ordinary inductive feed-back i_2, or a part of it, comes through the primary of the transformer in the opposite direction, and thus the ratio must be negative if i_1 and i_2 are to be in phase.

Since all the impedances entering into Z_0 in equation (6) are inductive, one might assume that the reactance of Z_0 is positive, but that is not necessarily the case. For some frequencies it may be negative. The angle of Z_0, or Ψ_0, is equal to the sum of the angles of the two factors in the numerator diminished by the angle of the denominator. The negative term in the denominator has a negligible effect on the angle of the denominator, and therefore this angle is that of Z_1. If the angles of z_1 and z_2 be θ_1 and θ_2, respectively, and that Z_1 be Φ_1, then $\Psi_0=\theta_1+\theta_2-\Phi_1$. For low frequencies the negative term will exceed the two positive terms. Oscillation is then possible, and the amplification will be increased, when the common impedance consists, for example, of a resistance with a condenser across it. For frequencies above that which makes $\Psi_0=0$, oscillation is possible, and the amplification will be increased, when the common impedance consists of resistance and inductance. When $\Psi_0=0$, pure resistance only is required for oscillation, and at the frequency where that occurs oscillation is most probable because the absolute value of Z_0 is then a minimum.

In a circuit having no more than two reactive branches it is easy to calculate the frequencies at which Ψ_0 will be —90 deg., 0 deg. and 90 deg., that is, to predetermine the frequency bands in which the amplification will be increased when the common impedance has negative or positive reactance. It may thus be proved from equation (6) that Z_0 can never lie in either the second or the third quadrant. Also it may be proved that if the sign of the transformer be made negative there is no frequency which will bring Z_0 into the first or the fourth quadrant.

It is interesting to examine equation (6) graphically.

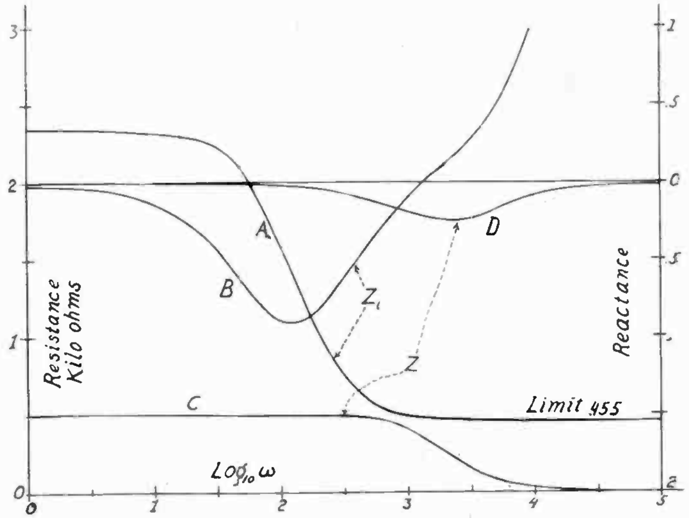


Figure 2

In Fig. 2, Curve *A* is the locus of the real part of Z_0 and Curve *B* is the locus of the imaginary component, plotted as functions of the common logarithm of the angular velocity of the current vector. In computing the data for these curves the following values of impedances and constants were used: $z_1=20,000+j25\omega$, $z_2=18,000+j5\omega$, $Z_1=4,000+j25\omega$, $a=6$, and $\mu_2=8$. The scale at the left refers to the real part and that at the right to the imaginary components.

The locus of the real part of Z_0 starts with a high value for low frequencies, drops rapidly between 31.6 and 1,000 radians, and finally approaches the limiting value 455 ohms as the frequency increases. The locus of the reactance starts at zero for zero frequency, decreases to a minimum just above 100 radians, and then rises as the frequency increases. It crosses the axis of zero reactance at about 1,300 radians. It is the region in which the reactance is negative that is of chief interest, because in most receivers the common impedance consists of the resistance of the "B" battery with some intentional or distributed capacity across it, the angle of which is always negative.

The loci of the real and imaginary parts of an impedance, Z, consisting of 500 ohms shunted with a one microfarad condenser are also plotted in Fig. 2. Curve C is that of the real and Curve D that of the imaginary. Below 316 radians the effective resistance is practically 500 ohms; above 10,000 radians it is very small. The reactance of the impedance is very small for both high and low frequencies, but it reaches a negative maximum at the frequency where the rate of change of the real part is greatest.

At a point, just below 1000 radians, Curves B and D intersect. At this frequency, then, the first condition for oscillation is satisfied, because the reactance of the common impedance is equal to the reactance of Z_0. The circuit will oscillate at this frequency provided the second condition is also satisfied. If it does not oscillate at the point, there will be a prominent peak in the amplification, the height of which depends on how nearly the second condition is satisfied.

Curves A and C do not intersect at any point, and therefore the second condition for oscillation is not satisfied. However, they approach each other very closely at one point, and the frequency where this occurs is very close to the frequency where the two reactances are equal. The amplification peak will therefore be high. There are three ways in which to make Curves A and C intersect, and hence to cause oscillation in the circuit. In the first place the resistance in the common impedance may be increased. This will raise Curve C for all frequencies. For one value of the resistance the two curves will be tangent at one point; for higher values of the resistance there will be two points of intersection. Intersection of the two curves may also be caused by reducing the capacity of the condenser across the resistance, provided, of course, that the resistance used is greater than the limiting value of the real part of Z_0. With the smaller capacity across the resistance Curve C will remain close to the 500 line for higher frequencies. Intersection may also be brought about by increasing the amplification, that is, by increasing μ_2 and a. This will lower the right hand portion of Curve A. If the amplification is high enough there will be an intersection no matter how close to the axis Curve C may be.

TWO-TUBE, DIRECT-COUPLED AMPLIFIER

All the equations used in the analysis of Fig. 1 apply in the case of a two-tube, direct-coupled circuit such as is shown in Fig. 3, with the exception of the definition of the input voltage to the second tube. In this case $E_2 = Z_1 i_1 + Zi$, which is the sum of the voltage drops in the coupling and common impedances. If this change be made in equations (3) they reduce to (7), in which $Y_2 = (\mu_2 + 1)$

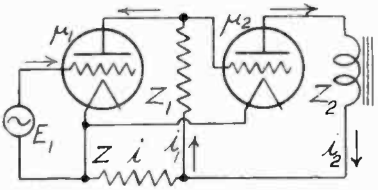


Figure 3

$$-\mu_1 E_1 = (z_1 + Z)i_1 + Zi_2$$
$$0 = (\mu_2 Z_1 + Y_2 Z)i_1 + (z_2 + Y_2 Z)i_2 \qquad (7)$$

Equations (7) yield the following expression for amplification and for the critical value of Z:

$$M = \frac{\mu_1 Z_2(\mu_2 Z_1 + Y_2 Z)}{z_1 z_2 + Z(R_1 \mu_2 + z_1 + z_2)} \qquad (8)$$

$$Z_0 = \frac{-z_1 z_2}{(R_1 \mu_2 + z_1 + z_2)} \qquad (9)$$

If the circuit in Fig. 3 is resistance-coupled there is only one reactance branch, that containing z_2. The angle of the denominator of (9) is very small no matter what the angle of z_2 or θ_2, may be. Hence $\Psi_0=180°+\theta_2$, that is, Z_0 lies in the third quadrant when the reactance of z_2 is positive and in the second quadrant when it is negative. Hence when the circuit in Fig. 3 is resistance coupled it cannot oscillate at any frequency, and the amplification will be decreased for all frequencies. Why this is so is obvious from Fig. 3. Current i_2 flows through Z in the opposite direction from i_1, and hence it reduces the input voltage to the second tube, since $Zi+Z_1i_1$ will be less than Z_1i_1 alone.

When the coupling in this circuit is a choke coil instead of a resistance, there may be a frequency band in which Z_0 will lie in the fourth quadrant. This occurs when $\theta_1+\theta_2$ is considerably greater than 90 deg., and before the angle of the denominator has become large. The larger $R_1\mu_2$ is the wider will be the band in which oscillation might occur. However, since both z_1 and z_2 will have considerable distributed capacity it is probable that in a practical case the angles will not become large enough to project Z_0 into the fourth quadrant, and then the circuit would be stable for all frequencies.

ANALYSIS OF MULTITUBE AMPLIFIERS

In the system of simultaneous equations applying to any given circuit there must be as many currents and as many voltage equations as there are tubes sharing the common impedance. All the voltage equations will be of the form $-\mu_nE_n=z_ni_n+Zi$, and the current summation will be of the form $i=\Sigma i_m$. The auxiliary voltage input equations will be in the form of either $E_{n+1}=a_nZ_ni_n$ or $E_{n+1}=Z_ni_n+Zi$, depending on whether the coupling between the nth and the $(n+1)$st tube is by transformer or by impedance. If the circuit has more than two tubes, both types of coupling may occur in the same amplifier.

To obtain the complete solution for the amplification in a circuit having more than two tubes entails a great deal of work. However, if only the condition for oscillation in the circuit is required, the work may be shortened, because this condition is simply that the determinant of the system of equations shall vanish. It is only necessary to arrange the coefficients in determinant form, write out its value, and equate it to zero. In applying the method it is quickest to regard the current in the common impedance as one of the unknown and make the determinant of one order higher than the number of tubes involved.

THREE-TUBE, TRANSFORMER-COUPLED CIRCUIT

The determinant for a three-tube, transformer-coupled circuit takes the following form:

$$\begin{array}{r|cccc|} & i_1 & i_2 & i_3 & i \\ -\mu_1 E_1 = & z_1 & 0 & 0 & Z \\ 0 = & a_1 Z_1 \mu_2 & z_2 & 0 & Z \\ 0 = & 0 & a_2 Z_2 \mu_3 & z_3 & Z \\ 0 = & -1 & -1 & -1 & 1 \end{array} \qquad (10)$$

Currents are written at the top of the columns and the voltages at the left of the rows simply to identify the coefficients. The last row is the current summation equation. This determinant may be reduced by making use of the property that any line, row or column, may be added to, or subtracted from, any other parallel line without changing the value of the determinant. The value of the above determinant will be found to be

$$D = z_1 z_2 z_3 + Z[z_1 z_2 + z_2 z_3 + (a_1 Z_1 \mu_2 - z_1)(a_2 Z_2 \mu_3 - z_3)] \qquad (10b)$$

whence

$$Z_0 = \frac{-z_1 z \; z_3}{z_1 z_2 + z_2 z_3 + (a_1 Z_1 \mu_2 - z_1)(a_2 Z_2 \mu_3 - z_3)} \qquad (11)$$

is obtained as the condition for oscillation by placing D equal to zero.

No definite conclusions as to the probability of oscillation in this three-tube, transformer-coupled circuit can be reached without substituting actual values of constants and impedances. However, the apparent sign of the denominator in (11) is always positive and the apparent sign of the numerator always negative. Hence it would seem that this circuit will not oscillate as readily as the two-tube circuit when the ratio in that circuit was positive. That this might be so is borne out by the directions of the currents in Fig. 4a. Currents i_1 and i_3 flow in the same direction while current i_2 flows in the opposite. Hence i_2 aids i_1, and i_3 aids i_2 but opposes i_1. Due to the relative values of the currents, the opposition just about neutralizes the conjunction. But on account of phase relations introduced by the impedances there may be a certain frequency band over which the amplification is increased by the common impedance, as actual substitution has shown. It is not safe to trust to the apparent sign of Z_0.

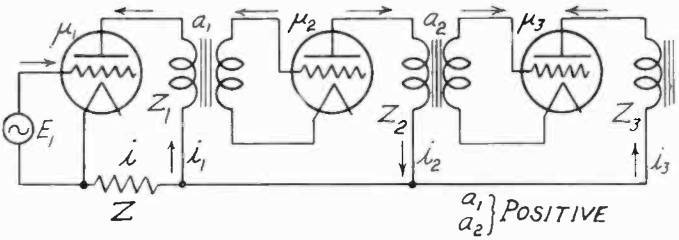


Figure 4a

When both of the transformer ratios are negative, the signs of all the terms in the denominator of (11) are positive, while the sign of the numerator remains negative. Then Z_0 apparently lies in either the second or the third quadrant, and one would expect a stable circuit. In Fig. 4b the in-phase components of the currents have been indicated. All flow in the same direction, and therefore both i_2 and i_3 tend to reduce the amplification. If there is any band in which the amplification will be increased it can only be because the phase relations of the impedances are such as to bring Z_0 out of the second or third quadrant into the quadrant in which Z lies.

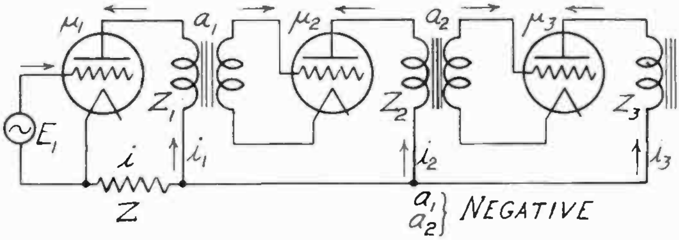


Figure 4b

If the two transformer ratios have different signs, the apparent sign of Z_0 becomes positive. The two cases show about the same propensity to oscillate, both as judged from the formula and from the circuit diagrams Figs. 4c and 4d, and both are apparently less stable than either of cases 4a or 4b.

FOUR-TUBE, TRANSFORMER-COUPLED CIRCUIT

The determinant for the solution of a four-tube, transformer-coupled amplifier may be obtained from (10) by adding another row and another column to that determineral q is defined $q_n = a_n Z_n \mu(n+1)$.

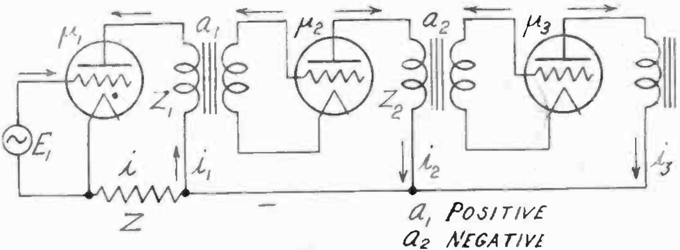


Figure 4c

and. The row to be added is $0 = a_3 Z_{3\ 4} i_3 + z_4 i_4 + Zi$ and the column is $0, 0, 0, z_4, -1$. This fifth order determinant yields the following expression as the condition for oscillation:

$$Z_0 = \frac{z_1 z_2 z_3 z_4}{(q_1 - z_1) q_2 (q_3 - z_4) + z_1 z_2 (q_3 - z_4) + z_3 z_4 (q_1 - z_1) - z_2 z_3 (z_1 + z_4)} \quad (12)$$

In this equation the q's are used to save space and the gen-
In (12) all the a's are positive and then the apparent

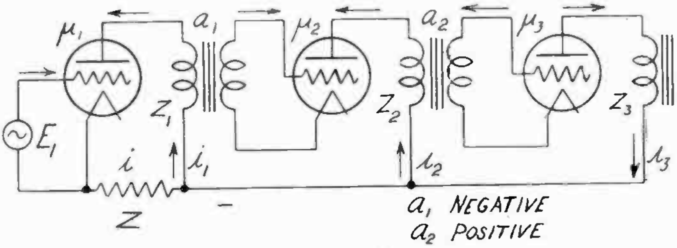


Figure 4d

sign of Z_0 is positive. It is quite possible, therefore, that this represents an unstable connection. If the sign of any one of the a's is changed the apparent sign of Z_0 becomes negative, because the terms containing the a's are dominant.

But changing the sign of one ratio does not necessarily put Z_0 in the second or the third quadrant for all frequencies. It does, however, shift the frequency band in which oscillation might, and in which regeneration will, occur. It will be noted that the middle transformer occupies a somewhat symmetrical position in the equation as well as in the circuit. It is not affected by end conditions like the other two. The other two transformers produce similar effects on the amplification, and differences are entirely due to differences in tube and load characteristics. Therefore there is very little difference produced by changing the signs of the ratios of either. It will also be observed that when all the *a's* are negative, all the terms in the denominator of (12) are negative, which also makes the apparent sign of Z_0 negative. Therefore, one might surmise that this represents the most stable connection. However, when all the signs are the same the absolute value of Z_0 is least, and this would threaten the stability of the circuit in case the phase relations of the impedances should project Z_0 into the first or the fourth quadrant.

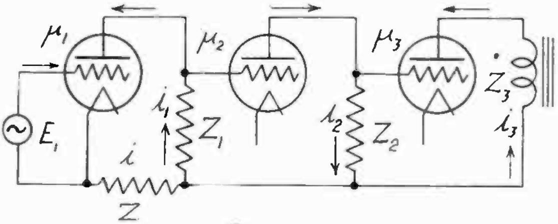


Figure 5

THREE-TUBE, DIRECT-COUPLED AMPLIFIER

The determinant for a three-tube direct-coupled amplifier such as that shown in Fig. 5 takes the form

$$\begin{vmatrix} z_1 & 0 & 0 & Z \\ \mu_2 Z_1 & z_2 & 0 & Y_2 Z \\ 0 & \mu_3 Z_2 & z_3 & Y_3 Z \\ -1 & -1 & -1 & 1 \end{vmatrix} \qquad (13)$$

in which $Y_2=(\mu_2+1)$ and $Y_3=(\mu_3+1)$. When written out this becomes

$$D=z_1 z_2 z_3-Z[(R_1\mu_2+z_1)\,(\mu_3 Z_2-z_3)-z_2(z_3+Y_3 z_1)] \qquad (13b)$$

The condition for oscillation in this circuit is, therefore,

$$Z_0 = \frac{z_1 z_2 z_3}{(R_1\mu_2 + z_1)(\mu_3 Z_2 - z_3) - z_2(z_3 + Y_3 Z_1)} \qquad (14)$$

It appears from this equation that a three-tube, direct-coupled amplifier is likely to oscillate. The apparent sign of Z_0 is always positive because the negative terms in the denominator are small compared with the positive terms. It is only in case the angles of the various impedances should be such as to project Z_0 into the second or the third quadrant that the amplification would be decreased by the common impedance.

Since resistance-coupled amplifiers of odd stages often oscillate, it will be interesting to substitute typical values in (14).

Let $z_1 = z_2 = 1.4 \times 10^5$ ohms, $z_3 = 8{,}000 + j5\omega$, $R_1 = 40{,}000$ ohms, $\mu_2 = 20$, $\mu_3 = 6$, and $Z_2 = 10^5$ ohms. With these values Z_0 becomes

$$Z_0 = \frac{8{,}000 + j5\omega}{21.36 - j2.755 \times 10^{-4}\omega}.$$

As long as the reactance of z_3 is positive Z_0 can never lie in the fourth quadrant. At zero frequency it lies along the axis of reals, and as the frequency increases it advances into the first quadrant. At about 1800 cycles it passes into the second quadrant. Hence the region in which there will be augmented amplification is from zero to 1800 cycles, and for this the reactance of the common impedance must be positive. Inductance is required in series with the common resistance. The amount of inductance needed for oscillation at any frequency may be calculated. For instance, at 1000 radians the critical value of Z is $370 + j238$, and the required inductance is 238 millihenrys. The resistance must also be 370 ohms, or there will be no oscillation. At 10,000 radians the impedance required is $71.6 + j2350$. Thus the required inductance has decreased slightly and the required resistance has been reduced to about a fifth of its former value. The required conditions at both of these frequencies are likely to be met in a battery eliminator that has been inadequately by-passed. And the required resistance may be encountered in an ordinary "B" battery which is still in a comparatively good condition.

If there is an appreciable capacity across the load impedance, Z_0 will turn around and pass into the fourth quadrant instead of passing into the second for the higher frequencies. The circuit might then oscillate when there is a condenser across the resistance of the "B" battery. The frequency at which the load impedance is in parallel resonance is not likely to be a critical one as far as oscillation is concerned, because the required resistance is very high at that point, although the required reactance is negative and very small.

FOUR-TUBE, DIRECT-COUPLED AMPLIFIER

The equation for Z_0 in a four-tube, direct-coupled amplifier contains many terms of different signs and of uncertain magnitude. It is difficult to interpret without the substitution of actual values. It may easily be obtained by adding another row and another column to the determinant (13), and it is not necessary to give it here. It indicates that the four-tube circuit is more stable than the three-tube circuit. If the added stage is resistance-coupled, and if the constants in this stage are the same as those used in equation (14), the complete expression for the four-tube circuit reduces to

$$Z_0 = \frac{-(8,000 + j5\omega)}{328 - j2.185 \times 10^{-3}} \cdot$$

From this equation it is obvious that the circuit represented cannot oscillate until the frequency is high enough to advance Z_0 into the fourth quadrant. This occurs at 15,500 radians, or at 2,470 cycles. For higher frequencies the amplification will be increased by the common impedance provided its reactance is negative. At 10,000 cycles the angle of Z_0 is $-$ 68 deg. 40 min. and the impedance for oscillation is $330 - j830$. At that frequency this impedance is given by a resistance of 2,420 ohms shunted by a condenser of 0.0165 microfarad. This combination is likely to occur in practice.

By tracing the currents in the plate circuits of the amplifier it is clear why the circuit cannot oscillate at low frequencies. Currents i_1 and i_3 are in phase with each other and currents i_2 and i_4 are opposed to them. The sum of the even currents is always greater than the sum of the odd. Consequently, there is more current trying to reduce the amplification than to increase it. But as the frequency increases, less and less of i_4 will be in phase with i_2. There will be one frequency above which the sum of i_2 and the in-phase component of i_4 will be less than i_3. Then the circuit will regenerate. Capacity across the load impedance will prevent i_4 from getting far out of phase with i_2, and consequently this would act as a stabilizer of the amplifier.

EXPERIMENTAL EVIDENCE IN SUPPORT OF THEORY

There is some evidence in support of the theory advanced in this paper. In the first place it is a well known fact that broadcast receivers become noisy during the last stages of life of the "B" battery when its resistance is high, and that the amplification becomes noticeably uneven. Many have also experienced oscillation in sets served by "B" battery eliminators, particularly in three-tube, resistance-coupled circuits. In one case such a set oscillated at a very low frequency when served by a certain eliminator, and it would not stop oscillating until a condenser of thirteen microfarads was put across the output of the filter. Another receiver which had two stages of resistance coupling and one stage of transformer proved to be a terrific oscillator on an ordinary "B" battery. The amplification constants of the tubes in this circuit were in order of occurrence 20, 8 and 6, and the transformer ratio was also six. The equation applicable to the case showed that reversing the ratio of the transformer should have little effect on the behavior of the circuit. Actually it caused only change in pitch. Change of tubes had similar effect.

In an effort to salvage the preceding amplifier it was changed to a transformer, resistance, transformer-coupled circuit. The tubes now used had amplification constants of eight, eight and six, while the transformer ratios were three and two. But this set oscillated, too, and it had three modes of oscillation, one of which was at a super-audible frequency. There was one combination of transformer ratios which gave a stable connection, and this was later used for testing the theory.

When a fresh "B" battery was used, the circuit worked satisfactorily on all combinations of ratios, but it began to oscillate when a resistance of six ohms was inserted in series with the battery. With ten ohms in series the circuit was in an uproar. When a semi-exhausted "B" batteries was used the circuit oscillated violently, and no shunt condenser up to four microfarads had any perceptible effect on the intensity.

With this circuit the following experiment was tried. An extra "B" battery was provided, and the circuit was so arranged that the detector tube could be put on either the common battery or on the separate. When the detector was on the separate battery the circuit did not oscillate even when there was a fairly high resistance in series with either of the batteries. But when the detector was put on the common battery the circuit oscillated when there was only a small amount of resistance in series with the battery. The resistance in the common battery was then adjusted until the circuit just stopped oscillating, and the detector was alternately put on the common and on the separate batteries. When on the common, the volume was fully 100 per cent. greater than it was when on the separate. The stable connection was then arranged and the same comparison made. This time the volume was down about 50 per cent. when the detector was on the common battery. Although the voltage on the amplifier was 135 volts, the common portion was only 45 volts, that is, common to all the tubes. When more cells were included in the common battery the tendency to oscillate increased, which was partly due to increased amplification and partly to increased common impedance.

The equation applicable to the above circuit is

$$Z_0 = \frac{z_1 z_2 z_3 z_4}{\mu_3 Z_2 (q_1 - z_1)(q_4 - z_4) + z_3 z_4 (q_1 - z_1) - z_1 z_2 (\mu_3 + 1)(q_4 - z_4) - z_2 z_3 (z_1 + z_4)} \qquad (15)$$

in which $q_1 = a_1 Z_1 \mu_2$ and $q_4 = a_2 Z_3 \mu_4$.

From equation (15) one would expect the circuit to be oscillatory when both transformer ratios have the same sign, either positive or negative, and also when a_2 is negative and a_1 is positive. The circuit appears to be most stable when a_1 is negative and a_2 is positive, because then most of the terms in the denominator of (15) are negative.

METHODS OF AVOIDING OSCILLATION

Several methods of avoiding oscillations may be suggested. The first step, of course, should be taken when the amplifier is designed. Not all types of circuit are equally subject to oscillation, and only those which are relatively stable should be employed. To avoid oscillations and distortion in a set that is already built, the only thing to do is to reduce the common impedance. This may be done by connecting a very large condenser across the plate voltage supply, or the common impedance; by always employing batteries of low resistance; by using a separate battery for one, or perhaps two, tubes in the circuit, one of which should be the first tube entering into the amplifier. Another way of reducing the trouble is to employ a choke coil and a series condenser so that the a-c. component of the current in the last tube may be shunted around the common impedance, as is done to protect the loud speaker coils from the d-c. component of the plate current.

While the theory of the vanishing denominator explains why a circuit will oscillate at a given frequency when the impedance in common with the plate circuits has the required value, it does not explain why a circuit will oscillate at any frequency with a given value of the common impedance. But this difficulty disappears when it is remembered that nearly all the circuit parameters which enter into the expression for the critical value of the common impedance, as determined by the vanishing denominator, change both with frequency and with current level. The circuit automatically finds the frequency and the current level where the denominator vanishes, and proclaims the discovery.

SUMMARY

It has been pointed out that the common impedance in the plate circuits of two or more tubes in an amplifier will affect the output, and that under certain conditions will cause distortion and oscillation. A theory has been developed to explain this phenomenon. Several typical amplifier circuits have been analyzed with the theory. Some experimental evidence has been adduced in support of the theory. Methods of avoiding oscillation and distortion have been suggested.

SYMBOLS AND NOTATION

a_n, the voltage ratio of the nth transformer in the circuit.

D, the value of the determinant of the system of simultaneous equations pertaining to an amplifier.

E_n, the input voltage to the nth tube in the circuit.

$E_{n+1}=a_m Z_n i_n$, is the input voltage of the $(n+1)$st tube when preceded by a transformer of ratio a.

$E_{n+1}=Z_n i_n+Zi$, the input voltage to the $(n+1)$st tube when this is coupled to the nth tube by means of an impedance coil or a resistance.

i, the current in the common impedance Z. It is equal to Σi_n.

i_n, the a-c. component of the current in the plate circuit of the nth tube.

$j=\sqrt{-1}$

M, the complex amplification of the circuit.

μ_n, the amplification constant of the nth tube.

ω, the angular velocity of the current, or $2\pi\times$ frequency.

q_n, abbreviation for $a_n Z_n$.

R_n, the internal plate resistance of the nth tube (a-c.)

$Y_n=(\mu_{n+1})$.

Z, the common impedance in the plate circuits of all the tubes.

Z_o, the value of Z which makes $D=O$, or which makes the circuit oscillate.

Z_n, the load impedance in the nth tube, exclusive of Z.

z_n, the total impedance in the plate circuit of the nth tube, also exclusive of Z, or $z_n=R_n+Z_n$.

Ψ_o, angle of Z_o

Ψ, angle of Z

θ_n, angle of z_n.

Φ_n, angle of Z_n.

SOME POSSIBILITIES AND LIMITATIONS IN COMMON FREQUENCY BROADCASTING

By

De Loss K. Martin,[1] Glenn D. Gillett,[1]
Isabel S. Bemis[1]

The congestion in the broadcasting frequency range is so great that consideration has naturally been given by various engineers to the possibilities of different stations using the same frequency for broadcasting. It is hoped that the following statements may be of some interest in the consideration of this question.

In common frequency broadcasting there are two cases which have to be considered as they are somewhat different in their requirements. The first is the case where two or more stations attempt to use the same frequency with their own separate programs. The second is the case where two or more stations attempt to use the same frequency for sending out a common program which is transmitted to them from a single source.

At the present time, in both cases a limitation on this type of broadcasting is the audible beat notes which are set up between the carriers of the different stations. In the first case if means are taken to keep the carrier frequencies of the different stations closely alike (say within a relatively few cycles), then the limitation becomes that of crosstalk between the separate programs. From the data given in the paper it would appear that stations separated by distances of no more than three or four hundred miles from each other could send out their separate programs in this way provided each station confined the field to which it catered to an area immediately surrounding the stations within a radius of perhaps twenty-five miles or less.

In the second case, if the carrier frequencies are held

---

[1] Department of Development and Research American Telephone and Telegraph Company.

*Received by the Editor, January 10, 1927. Presented before the I. R. E. Convention, New York, N. Y., January 11, 1927.

closely alike, the nature of the interference becomes somewhat different since each station is transmitting the same program. As in case one, each station, of course, could be satisfactorily heard in a small area immediately surrounding it. This area might be somewhat larger than that of case one since the interference limitations are probably not as exacting. However, in the broader areas between the stations, the wave interferences between the various stations become important and the paper gives some discussion of this fact. The work on which the paper is based was not carried, however, to the point where the limitations set up by such interferences can be predicted.

It is entirely outside the scope of this paper to attempt to draw any conclusions as to the practical force of the limitations imposed by the use of common frequencies in broadcasting or as to what use, if any, should be made of such common frequency broadcasting. The subject merits careful consideration in any case in which stations are sufficiently close in frequency and in distance so that beat notes between their carriers become objectionable.

INTERFERENCE BETWEEN STATIONS

To consider the matter somewhat more in detail, in both cases above, it is evident that if the carrier frequencies of the various stations are held to a common value and not allowed to depart from it by an amount which will produce audible frequency beat notes between the various carriers, such beat notes cannot exist. In other words, it would seem possible by more accurate frequency adjustment to avoid the principal difficulty that has been met with in the past in endeavoring to operate two stations on the same nominal frequency with any other than a very wide geographical separation. If in this way interfering noises due to the interaction of two carriers are avoided, the next difficulty would appear to be that of interference of one program to another.

Since with two stations with different programs on the same frequency it is impossible to separate the programs by any selective tuning arrangements, the relative signal strengths of different stations at a given point would determine whether the program from any one of them could be satisfactorily received. In order to obtain satisfactory reception, the signals from the desired station must necessarily be of much greater amplitude than those from the interfering stations.

The range of a station would, for satisfactory results, be limited to that area within which it was capable of producing signals which were stronger than the signals of any other station on the same frequency by whatever amount might be felt to be necessary for satisfactory freedom from crosstalk interference.

If carriers of the various stations differed by, perhaps, a few cycles per second, it is obvious that when the points of the carrier field strengths are not widely different in amplitude, the net strength of the received carrier signal would pulsate or flutter. Within the range of a station as determined by crosstalk considerations, it is not to be expected that this flutter would be of any material importance, since the amount of flutter or variation is determined by the adding and subtracting of the two carrier signals and if one of these is a great deal less than the other, the fluctuation would probably be imperceptible. It can be shown by mathematical analysis that even where the local signal amplitude flutters by only an extremely small amount the amplitude of the distant signal will flutter between zero and its maximum amplitude synchronously with the local signal. The complete flutter of the distant signal would probably so entirely destroy its identity that the crosstalk from it would be a substantially unintelligible noise. As to what the condition would be outside of the limited crosstalk free service areas of the stations, it is impossible to predict with assurance, since almost no experimental data are available. It seems likely, however, that the program crosstalk between stations and the fluttering of signal amplitude, combined with ordinary fading, would cause a very unsatisfactory situation.

Now consider the case where a number of stations on the same carrier frequency transmit a *common program*. The principal difference between this and the case just discussed is that the same program is transmitted from all stations in unison and it seems possible that more interference between programs could be tolerated due to the fact that no audible signal would be present during silent intervals of the program. If this is true, satisfactory reception might be obtained in areas where one signal dominated the others by a lesser amount than is required for the case where different programs are transmitted. If the program was distributed to the various stations over long wire telephone circuits, or in some other way which might, due to transmission delay, cause an appreciable lack of simultaneity in the transmission of the program from different stations, it might be that various signals would arrive at a given receiving station so much out of step with each other as to be nearly as objectionable as would be the case with entirely different programs.

It is of interest to consider what might occur if the various carrier frequencies of stations transmitting the same program were held to exactly the same value with a high degree of precision. This would mean that instead of having a flutter, the frequency differences would be so small that the flutter would be slowed down to something which would be more like fading. The interfering signals from the distant station would then become more intelligible and less objectionable. The extent to which this would increase the satisfactory range of the station before other limiting factors became of importance, can be determined only by experiment. It seems certain, however, that at points which are well away from any one of the stations, that is, where the signals from two or more of them are of approximately the same amplitude, continual fading variation of the signals, due to these slight frequency changes, would exist. Superimposed upon this there would no doubt be variations due to ordinary fading of the individual signals themselves. In addition not only would carrier frequency signals of the various stations interact in this way, but each individual side-band frequency would be similarly affected and no two frequencies would be necessarily affected in the same way at the same instant. In other words, the phenomena would be comparable with those which result from selective fading, and selective fading is known to cause damage to quality. It is a question which can be determined only by experiment whether this combination of variations would be so annoying as to completely prohibit satisfactory reception, or whether, on the other hand, the averaging effect of all the variations might produce a resulting signal, which would have no more annoying net variation than would the signals received from any one of the stations alone, presuming the others to be silent.

FREQUENCY CONTROL

In the practical case of two or more common frequency broadcast stations the carrier frequency could be determined by a single centrally located control-oscillator or some or all of the stations could have independent oscillators carefully standardized against each other.

In the case where a central control oscillator is to be used, it is desirable that the frequency of the oscillator be relatively low. The carrier frequency of the broadcast stations could be derived as a harmonic of this signal after it had been sent to the stations over wire circuits.

As the transmission characteristics of wire circuits change with the temperature and weather conditions the phase relation of the control signal at the sending and receiving terminals of the wire circuit would vary. The changes in phase of the control signal would be relatively small, but they would be multiplied in magnitude in the radio signal in proportion to the order of the harmonic used to obtain the radio carrier signal. For example, suppose a 1000 kc. carrier signal is to be obtained from a 1 kc. control signal sent over a wire line, then the phase changes in the 1 kc. control signal would be magnified a thousandfold in the carrier signal.

The significance of such phase changes is that while they are going on they are in effect frequency differences. Thus if the phase of one station changes with reference to that of another station at a rate of 360° per second the two station frequencies actually differ at that time by one cycle per second.

It seems likely that a central control-oscillator system would be necessary if it were desired to attain the greatest possible precision in synchronizing the various stations. On the other hand it is probable that independent oscillators, for instance those of the piezo-electric crystal type, could be standardized with sufficient exactness to avoid audible beat notes between stations.

Quite aside from other limitations there must be practical limits to the number of stations transmitting on one common frequency, due to the fact that cities in which stations might be located are not spaced at uniform intervals over the country and also to the fact that the power radiated from the various stations might not be equal.

It is evident that the existence of one common frequency broadcasting channel used simultaneously by a number of stations does not exclude the possibility of there being other common frequency channels as well, nor does it in any way alter the necessity for adequate frequency spacing between stations serving the same area on different channels.

Experimental Data

To illustrate a little more concretely the nature of the problems involved in common frequency broadcasting, use is made of the data obtained from a preliminary survey which was made during the spring of 1926, of the signal distribution from stations 2XB New York City and WCAP Washington, D. C. while these stations were transmitting on their normal frequencies. This permitted estimating the

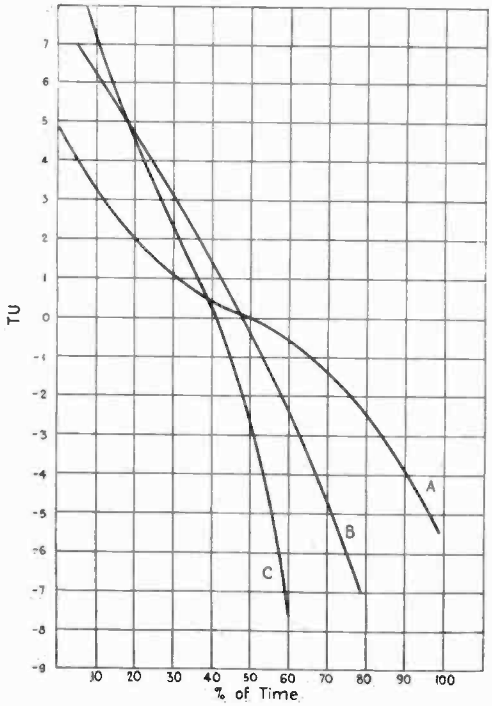


Figure 1. Variation in amplitude of audio-signal from the mean value caused by fading, in terms of percentage of the total observing time the signal exceeded these levels. Station 2XB.

A. Observed at Philadelphia, Pa.
B. Observed at Baltimore, Md.
C Observed at Washington, D. C.

effective ranges that would be obtained from these stations should they operate on a common frequency.

It was found that in the daytime the signal intensity from these stations remained substantially constant. At night graphic records of the variations in the signal intensity due to fading were made for each station at each of the observing points.

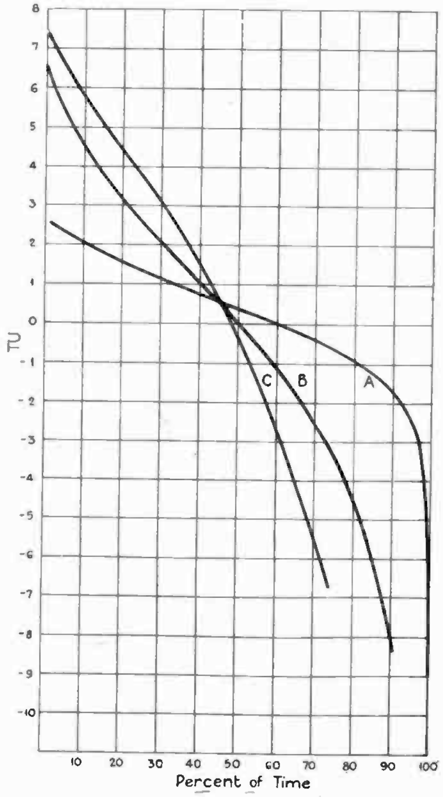


Figure 2. Variation in amplitude of audio-signal from the mean value caused by fading, in terms of the percentage of the total observing time the signal exceeded these levels. Station WCAP.

A. Observed at Baltimore, Md.
B. Observed at Philadelphia, Pa.
C. Observed at New York, N. Y.

From the graphic records it was possible to obtain mean values of the equivalent audio signal intensity and also to obtain an estimate in terms of per cent of the total observing time that the audio signal exceeded values which departed from this mean by any given amount. Figures 1 and

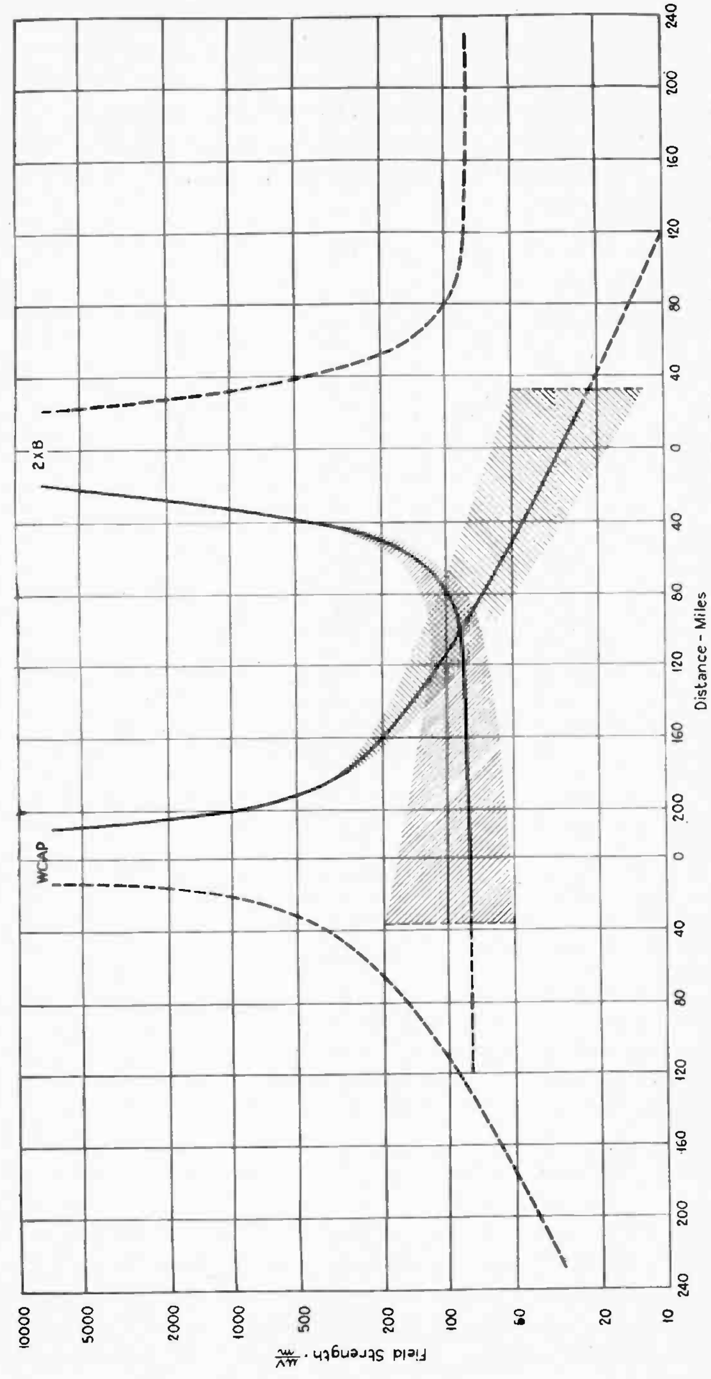


Figure 3. Measured variation of field intensity with distance for 2XB and WCAP. The shaded part indicates roughly the magnitude of the signal variation due to fading. From these curves an estimate of program interference may be obtained.

2 illustrate the characteristics of the variation in the signals recorded on these nights. The curves are representative of the variations taken from several graphic records, each extending over a period of from 10 to 20 minutes and taken at intervals of an hour or so. A very interesting fact brought out by the data on field intensity measurements is that the values of the steady daytime signal intensity and the mean of the signal intensity measured at night are substantially equal. This is true except for one set of observations on the 2XB signal made at Washington.

In Figure 3 the daytime signal field intensities are plotted for both stations against distance, and the observed ranges of variation in field intensity are shown approximately by the limits of the cross-hatched areas above and below the curves of the daytime signal.

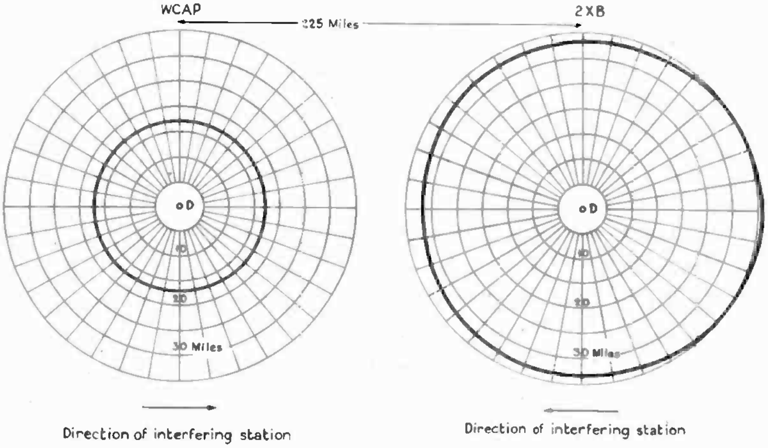


Figure 4. Effective ranges of 2XB and WCAP as they would be limited by program interference if both stations transmitted on the same frequency. Based on measurements made at night during May, 1926.

For the purposes of making an estimate of the effective range areas of these two stations if they were to be operated on a common frequency, it was assumed that the signal distribution was symmetrical about the stations as shown by the curves. This assumption is only partly true but is necessary to simplify consideration of the analysis.

From the data given in Figure 3 and on the basis of a ratio of about 30 to 1 between the desired carrier signal and the interfering carrier signal (a ratio which is perhaps too lenient) the range areas shown in Figure 4 were obtained. These range limits correspond to those that would be obtained during the day and under average night conditions.

However, in this experimental case the upper limit of the fading night-time signals differs so little from their mean value that the range is not materially reduced by the fading.

The range shown in Figure 4 for 2XB was compared with theoretical range calculated on the simple assumption that the field strength from both stations varied inversely with the distance. It was found that this calculated range had a radius about two-thirds as large as that derived from the experimental data. This is not sufficient evidence to warrant recommending the use of such calculations as a conservative method of estimating ranges but it suggests that for interstation distances of about two hundred miles the calculation might give a first approximation which would be of use for some purposes. It is interesting to compare these ranges with those estimated on the basis of noise interference as at present experienced.

The effective range of a broadcasting station is limited by the ratio of the intensity of the noise interference to the intensity of the desired signal.

It has been suggested[1] that with existing noise conditions, the outer boundary of the service range of a station lies between one and ten millivolts per meter and in general is nearer the latter value. From the field intensity contour maps of 2XB and WCAP which have been published,[2] the ranges for different field strengths can be determined. It is found that even for one millivolt per meter the ranges are of the same order of magnitudes as those shown on Figure 4.

We do not wish to infer from this comparison that the ranges of 2XB and WCAP would not have been materially affected if they had been placed on a common frequency to broadcast a common program. The assumptions underlying the above comparison are not sufficiently well supported to justify such a conclusion. On the other hand the fact that it comes out as a comparison rather than a contrast indicates that the subject is one which merits further and more exhaustive investigation. It should also be borne in mind that outside the ranges as determined for the common frequency case, reception of either station might be hopeless at all times, whereas with the stations on different frequencies it is known that they are frequently received with material satisfaction at distant points.

REFERENCES

1. Reduction of Interference in Broadcast Reception. A. N. Goldsmith. Proc. I. R. E. October, 1926, page 582.

2. Radio Broadcast Coverage of City Areas. L. Espenschied Jr., A. I. E. E., January, 1927, page 27.

Distribution of radio waves from broadcasting stations over city districts. R. Bown and G. D. Gillett, Proc. I. R. E., Aug., 1924, page 409.

THE INSULATION OF A GUYED MAST*

BY

H. P. MILLER, JR.,

(Federal Telegraph Company, Palo Alto, California.)

In planning to use guyed masts for supporting the antennas of high power transmitting stations, the question arises as to the advisability of insulating the masts and guys. Under certain conditions this will increase the effective height and efficiency of the antenna giving a power saving that is worth more than the cost of the insulation and the increase in mechanical hazard. Under other conditions the increase in antenna efficiency may be insufficient to make the insulation worth while.

Among the factors affecting the antenna efficiency some, such as the resistance of the antenna, can be improved after the antenna has been built. The mast and guy insulation, however, must be decided before erecting the masts and it is important to determine beforehand, (a) the most efficient arrangement of insulation, (b) the maximum voltage duties to be expected on the insulators, and (c) the economic value of the insulation. No fixed rules can be given in this regard since each design of antenna and mast system offers a different problem. An attempt will be made, however, to point out in this paper, with the aid of a characteristic example, certain fundamental considerations and experimental methods that will assist in the economical insulation of guyed masts.

THEORETICAL CONSIDERATIONS

A general idea of the effect of mast and guy insulation on antenna effective height can be obtained by considering the properties of an ideal antenna. If a large flat antenna plate of fixed area float in air above a flat ground plate of infinite extent, the capacitance of the antenna will depend

---

*Received by the Editor, September 22, 1926.

upon the height of the plate above ground, or its effective height. The greater the effective height, the less the capacitance and, contrarywise, the greater the capacitance, the less the effective height.

The characteristics of the electrostatic field around such an antenna are shown in Fig. 1. This is a vertical section through one side of the antenna plate and gives the approximate traces of the equipotential surfaces. It is seen that these surfaces are close together between the antenna plate and ground, but spread out beyond the edge of the plate.

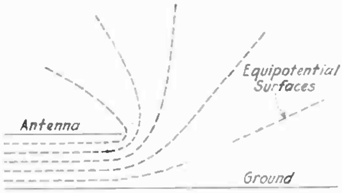


Figure 1—Ideal Antenna

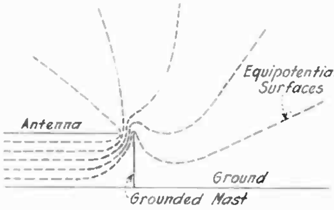


Figure 2—Antenna with Grounded Self-supporting Mast

If a grounded self-supporting mast be moved up close to the edge of the antenna, the equipotential surfaces will be distorted in the manner shown in Fig. 2. This distortion occurs only at the mast, the equipotential surfaces at some distance in front and back of the mast remaining as in Fig.

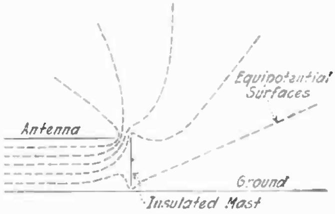


Figure 3—Antenna with Insulated Self-supporting Mast

1. The mast, therefore, has the effect of crowding the equipotential surfaces between its top and the edge of the antenna plate.

With the mast insulated at the ground, the distortion is not so great (see Fig. 3), the insulation at the base of the mast allowing one of the equipotential surfaces to pass underneath the mast.

The effect of crowding the equipotential surfaces is to increase the electrostatic flux and hence the capacitance between the antenna and ground. The grounded mast of Fig. 2, therefore, increases the total capacitance of the antenna and decreases its effective height. With the insulated mast of Fig. 3, there is less crowding of the equipotential surfaces, less increase in capacitance, and less decrease in effective height. If the mast were also insulated at its middle point, an approach would be made to the ideal condition shown in Fig. 1.

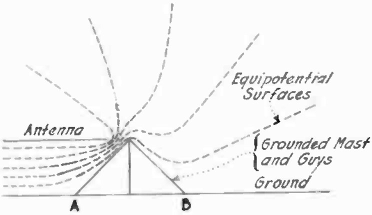


Figure 4—Antenna with Grounded Guyed Mast.

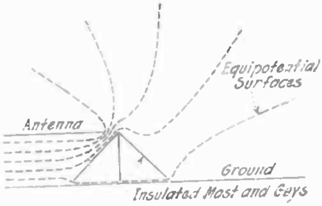


Figure 5—Antenna with Insulated Guyed Mast

The use of guys on a mast decreases the effective height still further. Fig. 4 shows the effect of uninsulated guys on a grounded mast. It is seen that the equipotential surfaces are crowded more than in Fig. 2.

If, in the case of Fig. 4, Guy A were insulated at a point near the ground, none of the equipotential surfaces could pass in through the insulator unless they also came out through it. The voltage duty on the insulator would, therefore, be zero. Insulating all the rest of the guys and the mast near the ground, would permit some of the surfaces to pass under the entire structure as shown in Fig. 5. The crowding of the surfaces would, however, be greater than in the case of Fig. 3.

With an insulator in each end of Guy A, the equipotential surfaces could pass in through one insulator and out through the other. The more surfaces that would pass through the guy insulators, the less crowded would be the surfaces between the antenna and guy system and the closer would be the approach to the condition of Fig. 2, where there are no guys.

The ideal guy would be one made up entirely of insulation. This would allow the equipotential surfaces to pass through it as though there were no guy and give the maximum value of effective height. Since the greatest possible number of surfaces would pass through the guy insulation the total voltage duty on the guy would be greater than in any case where it is not made up entirely of insulation. For maximum effective height, it is, therefore, necessary to have the total voltage duties on the insulators in each guy a maximum. The voltage duties on the mast insulation should also be kept high for the same reason.

It is not usually practicable to insulate a mast and its guys at very many points, but it is possible to insulate the guys at a few points so as to obtain such a large percentage of the maximum total voltage duty, that the addition of more insulation would cause very little increase in the total voltage duty. This is the economic condition desired in the arrangement of the insulation.

A simple relationship exists that is of great help in studying this problem. It was shown above that with two insulators in Guy A of Fig. 4, the equipotential surfaces can pass in through one insulator and out through the other. Since the same number of surfaces pass through each insulator, the voltage duty on each must be the same. In the same way, if three insulators are placed in the guy a certain number of surfaces pass through one insulator which must pass out through the other two. The voltage duty on the first insulator must then be equal to the sum of the voltage duties on the other two insulators.

Another way of looking at this relationship is to consider the potential above ground of the insulated section or sections of the guy. With an insulator in each end of a guy on a grounded mast, one side of each insulator will be connected to ground. The other side will be connected to a section of guy cable in which there is practically no potential drop. The sides next to the cable must, therefore, be at the same potential above ground so that the voltage duty on each insulator is the same. When there are three insulators in the guy, one of the insualted guy sections must be at a higher potential above ground than the other. The drop in voltage between the ends of this high-potential section and ground must be the same so that the sum of the insulator voltage duties above it must equal the sum of the insulator voltage duties below it. If then, the voltage duties be given signs according to whether they occur above or below the high-potential section, the algebraic sum of all the voltage duties in the guy must equal zero.

The same relationship occurs when the mast is insulated. In this case, the high-potential section can be the insulated section of the mast or a guy section. In the example shown in Fig. 14, the high-potential sections are in some cases in the guys and in other cases in the mast. In each case, the sum of the insulator voltage duties on one side of the high-potential section are equal and opposite to the sum of the duties on the other side.

The actual voltage duties on the insulators will depend on the position of the guys and masts with reference to the antenna. Insulators in guys close to the antenna will be subjected to high potentials on account of the large number of equipotential surfaces which can pass through them. Those in guys away from the antenna or shielded by other guys, will be subjected to very low potentials. The actual values for a given antenna and mast system can be obtained by measurement on the antenna or on an accurately scaled model. The best arrangement of insulators can best be determined on a model.

Another possible use for mast and guy insulation, is in the control of capacitance currents. It was pointed out above that if Guy A, of Fig. 4, were insulated near the ground, the voltage duty on it would be zero. An insulator at this point, however, would have a high reactance so that any capacitance currents in the guy would flow off to ground through the mast. This arrangement has an advantage in case a better ground connection is available at the mast than at the guy. Its value would depend upon the type of ground system used and can be estimated sufficiently accurately before the masts are erected.

EXPERIMENTAL DETERMINATIONS

In order to show how these theoretical considerations work out in a practical case, the results of certain voltage duty measurements made on the model of a typical high-power transmitting antenna will be given. These measurements were mainly to determine the best location for the insulators and the voltage duties to be expected. They did not include any effective height measurements which would permit a determination of the economic value of the insulation nor measurements which would indicate its value in the control of capacitance currents.

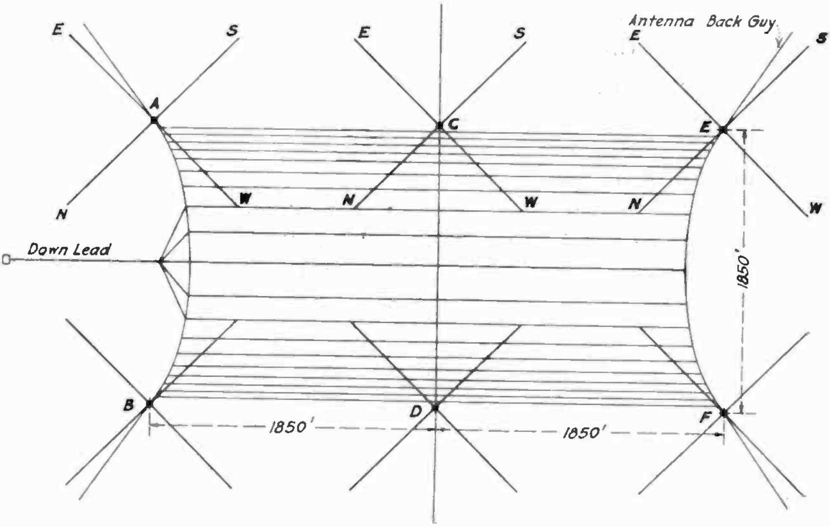


Figure 6—Plan of Antenna

The voltage duty measurements were made on a 1-50th-scale model of the antenna shown in Fig. 6. This antenna was designed for use with six steel masts each 1000 feet high and guyed in four directions in the manner shown in Fig. 7.

The antenna model was built in an open field as accurately to scale as possible. The masts were 20-ft. lengths of

1¼-inch galvanized iron pipe held in place by guys of No. 12 iron wire, stretched tight with turnbuckles. They were also insulated from ground by means of small porcelain tubes about 1½ inches long, jumpers being provided for shorting this insulation when desired. Each guy anchor was well grounded by soldered connections to a metallic stake and a common ground strip.

The guy insulators consisted of short lengths of ½ by ¼-inch bakelite, with hooks inserted in each end, the creepage distance between hooks being one-half inch. They were the same length as the sphere gaps used for measuring the voltage duties, and were placed at every point in the guys where measurements were desired. Any unused insulators were simply short-circuited out with short lengths of spring wire.

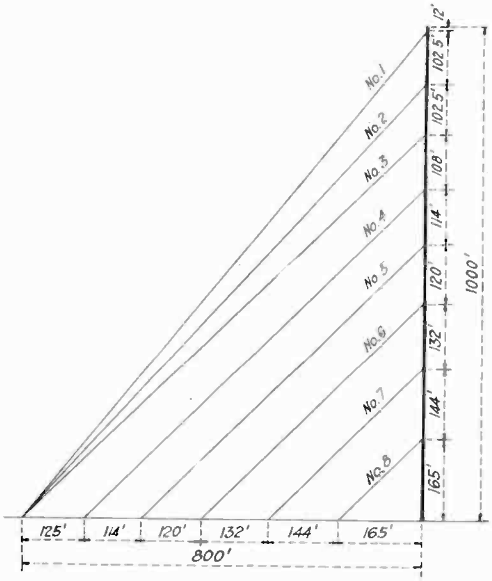


Figure 7—Guy Arrangement for 1,000-Foot Mast

The antenna was made of No. 22, B. & S. gage copper wire stretched over catenaries of ⅛-inch diameter flexible iron cable. It was insulated with ⅜-inch diameter pyrex rod insulators having two-inch diameter corona shields spaced to give a flashover distance of three inches.

Voltage duty measurements on the antenna model were made by means of a sphere gap. This was put either across or in place of the insulator whose duty was to be measured and adjusted so as to flash over when a high potential was applied to the antenna. Since the flashover voltage of the gap was the insulator duty at the instant of flashover, the ratio between the gap voltage and the antenna voltage required for flashover was the ratio between the duty on the insulator and the antenna voltage. This ratio would be the same for both the model and full sized antennas. By assuming a given antenna potential (150 kilovolts was used in these tests) it was possible to reduce all readings to a common basis.

In the preliminary tests, radio frequency potentials were applied to the antenna, flashover being detected visually through a surveyor's transit. Voltage control at the frequency used (35,000 cycles) was not simple so that the readings were erratic and not reliable. Extensive tests then showed that 60-cycle potentials could be used with greater constancy in results and in agreement within 0.6 per cent., with observations made over a wide range of radio frequencies. It was not possible to see the flashovers, however, so that it was necessary to listen for them. When the gap was used close to the ground, the observer could get within easy hearing distance but for high positions a long rubber listening hose had to be attached to the gap. Some measurements have since been made on larger models where the gaps were so high off the ground as to make a hose impracticable. In this case a short wave loop receiver was used which tuned quite sharply to the flashover at about 40 meters.

The desired 60-cycle potentials were obtained with a 110/33,000-volt potential transformer using a voltage control rheostat in the 110-volt supply circuit. Meters for measuring the antenna voltage were also placed in this circuit since tests showed that the voltage ratio on the transformer remained constant under the conditions of these tests. Antenna potentials above 30,000 volts could not be used on account of the antenna model going into corona.

The sphere gap adopted after considerable development is shown in Fig. 8. It consisted of a piece of natural bakelite tubing with brass inserts in each end through which the spheres (turned from ¼-inch brass screws) were inserted. Lock nuts were used to fix the length of the gap. On one side of the bakelite tube was inserted a smaller bakelite tube for attaching the rubber listening hose. On the other side a hole was left so as to expose the gap to the atmosphere. The distance between hooks on this unit was the same as on the guy insulators.

Three of these sphere gaps were used, each being set with a different gap length. Wherever possible the largest gap was used since this was the easiest to hear and gave the most consistent results. The smallest gap was used where the insulator duty was low. In some cases the duties were so very low that it was impossible to get a reading even with this gap.

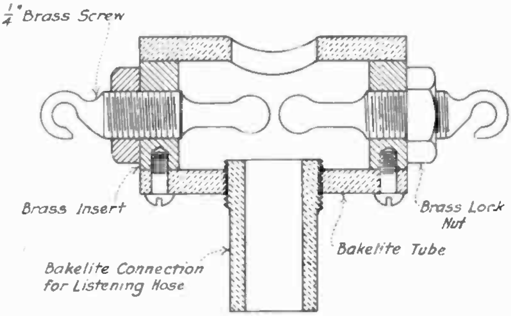


Figure 8—Sphere Gap for Voltage Duty Measurements

After a set of observations had been made on the model guys, the gaps were calibrated directly across the terminals of the transformer. The best results were obtained when the gaps were polished and calibrated frequently.

ARRANGING THE INSULATORS

To get a preliminary idea as to the best locations for the insulators in the mast guys, measurements were made on a single guy attached to the top of Mast C and extending under the antenna at an angle of 90 deg. to its edge. The the guy, moving the second one up the guy increased the results of the tests with two insulators in this guy are shown in Fig. 9. With one insulator fixed at the bottom of duty on each of them, reaching a maximum relative value of 6.4 near the top. Leaving the second insulator close to the mast, the first one was moved up the guy. This increased the duty on each one to 9 at a point about half way up the guy. Above this point the duties dropped off and became zero when the two insulators were again merged into one.

This test showed that the best electrical arrangement for two insulators in a single guy is to have one near the mast and the other about the middle of the guy. From a practical standpoint, however, it is preferable not to have an insulator where it will increase the tension on the guy due to its weight or to wind pressure on its surface. It was, therefore, considered advisable to keep the insulators close to the ends of the guys where maintenance would be easier.

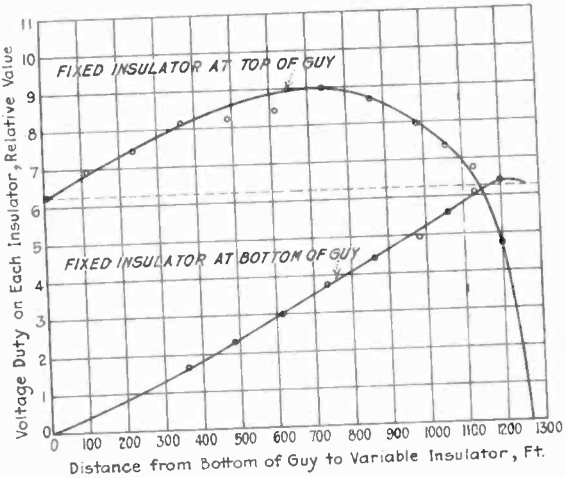


Figure 9—Curves Determining the Best Positions for Two Insulators in Single No. 1 Guy Placed at 90 degrees with Edge of Antenna on Mast C.

Further tests showed that the addition of a third insulator in the guy increased the total voltage duty enough to make its use worth considering. Fig. 10 shows the results of tests made to determine the best position for a third insulator. One insulator was fixed at the bottom of the guy, another one was fixed at the top, while the third one was moved between the two. The curves show the variation in voltage duty on the three insulators. They also illustrate the summation principle outlined above. Up to the point where the middle insulator has zero duty, the duty on the top insulator is numerically equal to the sum of the duties on the other two insulators. Above this point, the duty on the bottom insulator is equal to the sum of the other two. Although the curve for the middle insulator was obtained from the other curves by difference, enough check measurements were made to make sure that this procedure is correct.

The fact that the duty on the top insulator for most cases was equal to the sum of the other two, permits this curve to be used in determining the best location for the middle insulator. The total duty on the guy is twice the duty on the top insulator so that maximum duty on the guy occurs with maximum duty on the top insulator. It is interesting to note that this point of maximum duty occurs when the duty on the bottom and middle insulators is the same.

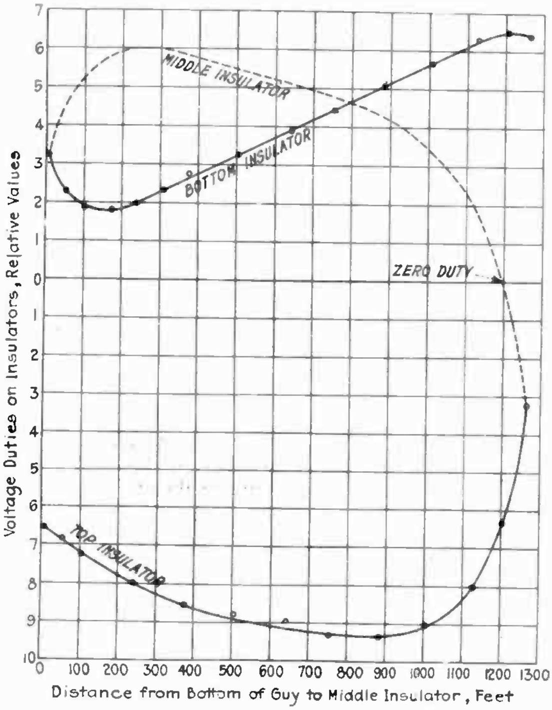


Figure 10—Curves Determining the Best Position for Third Insulator in Single No. 1 Guy Placed at 90 degrees with Edge of Antenna on Mast C. Insulators Fixed at Top and Bottom. Position of Middle Insulator varied.

Results of similar measurements for a more practical case are given in Fig. 11. In this case eight guys were in place at a small angle with the edge of the antenna, as position CN of Fig. 6. All the guys were insulated at each end. The position of the middle insulator of the top guy was changed and the voltage duties in that guy measured. The curve shows that the maximum guy duty occurred when the middle insulator was about 70 per cent up the guy.

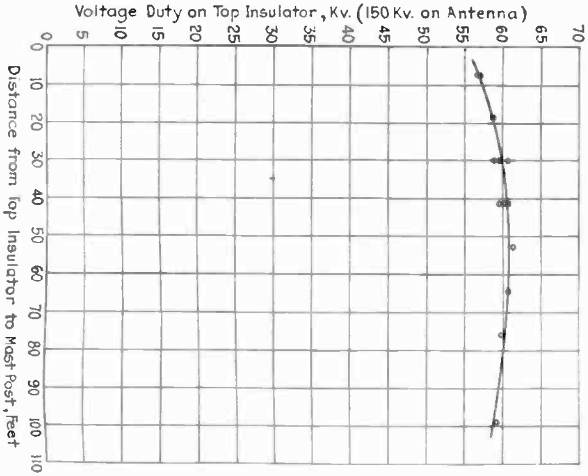


Figure 11—Curve Determining the Best Position for Third Insulator in No. 1 Guy at Position CN with all Guys in Place and Insulated. Top Insulator 42 Feet from Mast. Bottom Insulator 45 Feet from Ground.

With the same guy arrangement, Fig. 12 shows the results of leaving the bottom and middle insulators fixed and moving the top insulator. It is seen that the position of this insulator is not critical, but that maximum duty on the top insulator occurs when it is about 50 feet away from the mast post. Since the duty on this insulator is half the total guy duty, maximum duty also occurs with the top insulator fifty feet from the mast post. For this test the antenna was the equivalent of about 125 feet from the face of the mast.

INSULATOR VOLTAGE DUTIES

As a preliminary study, all guys were insulated at the top and bottom, and voltage duty measurements made at six characteristic guy positions with the masts both grounded and insulated. The results are given in Table 1. As might have been expected, maximum duties occurred on the inside position CN (See Fig. 6.) Minimum duties occurred in position AE with the masts grounded, and in position EW with the masts insulated.

The duties at positions CN and CE are shown also in Figs. 13 and 14 and have been used for plotting traces of the equipotential surfaces. It will be noted that separate duties are indicated at the bottom of the three upper guys. This is because the guys are insulated separately and not with one insulator as shown. These figures furnish a good check on the theoretical and experimental results previously outlined. In the case of the grounded mast (Fig. 13), four equipotential surfaces enter the guy system at the left through the bottom insulator of the top guy. After spreading out through the guy system, they come together again and pass out through the top insulator in the top guy. On the other side of the mast two of the surfaces enter the guy system at the top and pass out again at the bottom. The fact that the equipotential surfaces on both sides of the guy system bend down in passing through the bottom insulators shows that it would be better to move these in-

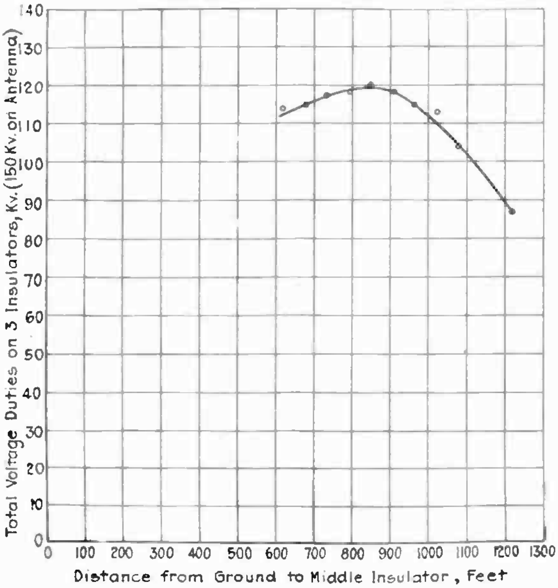


Figure 12—Curve Determining the Best Position for Top Insulator in No. 1 Guy at Position CN with all Guys in Place and Insulated. Middle Insulator 835 Feet from Ground. Bottom Insulator 45 Feet from Ground.

sulators up the guys as was indicated by the curves in Fig. 9.

When the C mast was insulated (see Fig. 14) some of the equipotential surfaces passed underneath the mast as in Fig. 5. It would appear, however, that an improvement in the location of the guy insulators could be made in this case. For instance, lowering the top insulators in the five lower guys would cause less distortion of the equipotential surfaces.

TABLE I

Voltage Duties with Insulator at Top and Bottom of Each Guy.

MASTS GROUNDED							
Guy No.	Insulator Position	Kv. Duty on Insulator (150 kv. on Antenna)					
		AN*	AE*	AW*	CN*	CE*	EW*
1	Top or bottom	21.3	12.2	36.4	44.1	23.7	18.3
2	" " "	18.1	10.2	28.9	37.0	20.6	15.5
3	" " "	15.6	8.4	24.4	29.9	17.6	12.4
4	" " "	10.6	5.8	16.7	19.7	13.5	9.5
5	" " "	7.8	4.7	11.6	14.8	10.0	7.3
6	" " "	5.6	3.5(e)	7.6	10.0	7.1	5.1
7	" " "	4.5	2.5(e)	4.5(e)	5.4	4.1	4.0(e)
8	" " "	2.5(e)	1.5(e)	2.5(e)	4.0(e)	2.5(e)	2.5(e)
	½ Total Duties	86.0	48.8	132.6	164.9	99.1	74.6
	Total Duties	172.0	97.6	265.2	329.8	198.2	149.2
MASTS INSULATED							
1	Top	3.5	4.5	18.5	18.8	0.5	1.8
	Bottom	23.5	15.5	38.2	46.3	28.0	19.8
2	Top	1.2	5.3	13.1	11.5	2.6	0.2
	Bottom	21.2	14.7	33.1	39.0	24.9	17.8
3	Top	0.8	6.0	8.5	6.5	4.7	2.2
	Bottom	19.2	14.0	28.5	34.0	22.8	15.8
4	Top	5.3	7.7	0.1	3.5	9.5	5.2
	Bottom	14.7	12.3	19.9	24.0	18.0	12.8
5	Top	8.0	8.8	5.5	8.2	11.8	7.6
	Bottom	12.0	14.2	14.5	19.3	15.7	10.4
6	Top	10.2	9.4	8.4	13.0	14.6	9.0
	Bottom	9.8	10.6	11.6	14.5	12.9	9.0
7	Top	12.6	9.5	11.7	16.4	17.5	11:0
	Bottom	7.4	10.5	8.3	11.1	10.0	7.0
8	Top	13.4	9.6	14.0	18.9	19.3	12.6
	Bottom	6.6	10.4	6.0	8.6	8.2	5.4
	Total Duties	169.4	160.0	239.9	293.6	221.0	147.6
Mast Duties: A equals 20.0 kv. C equals 27.5 kv. E equals 18.0 kv.							

(e) equals estimated.

* For notation of guy positions see Fig. 6.

In studying the results given in Table 1, it was seen that the voltage duties on some insulators were so low as to make them uneconomical, and on others were so high as to make additional insulation advisable. The insulators in the underneath guys of Fig. 13 for example, were practically unused while those in the top guy under the antenna

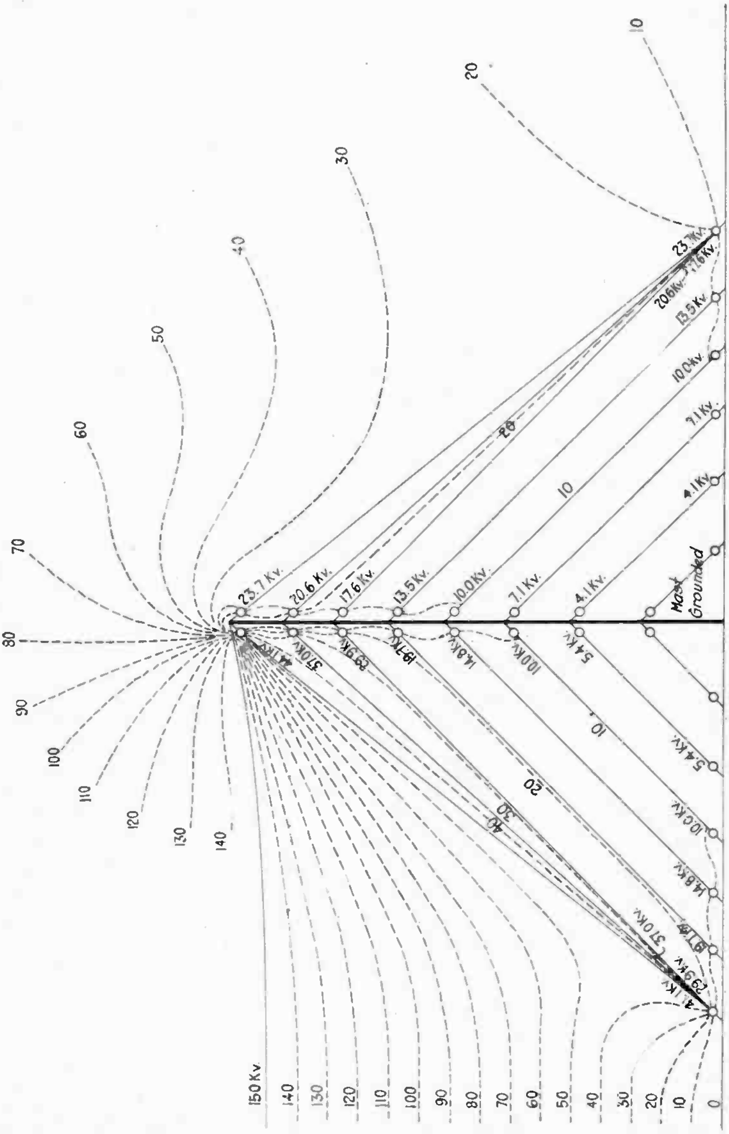


Figure 13—Insulator Duties and Electrostatic Field with two Insulators per Guy. Guy Positions NCS—Mast Grounded

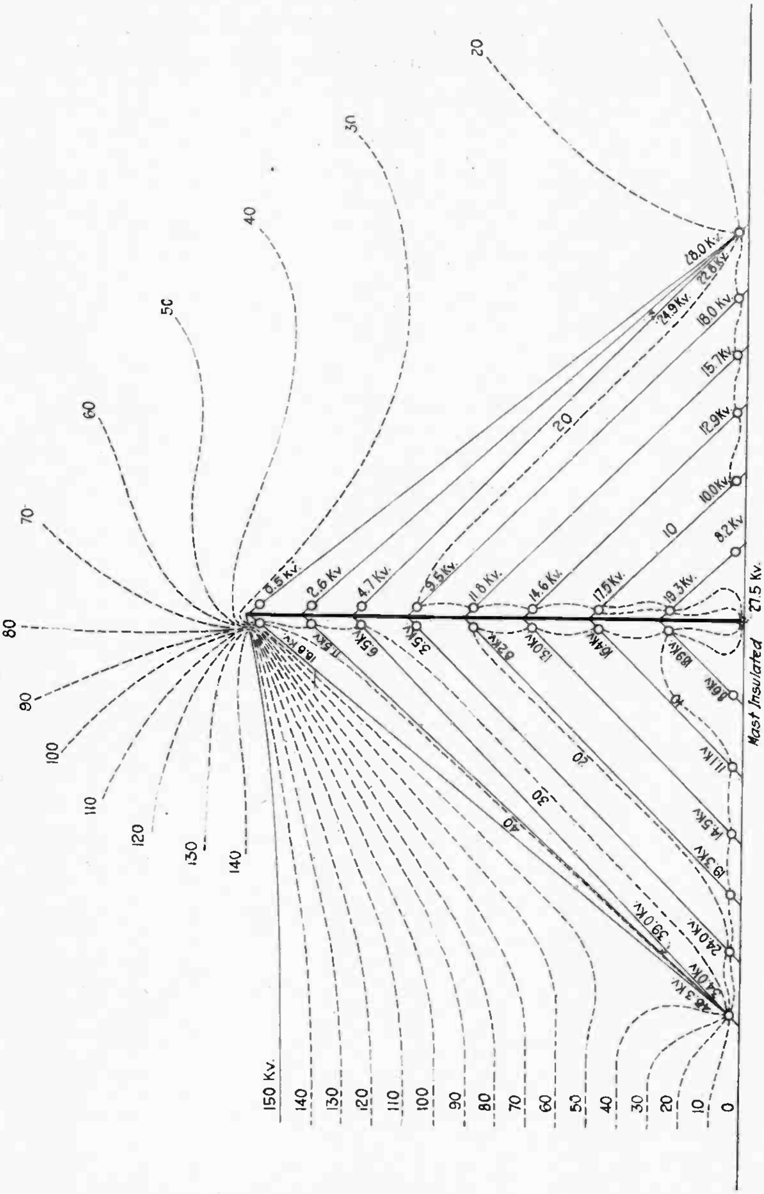


Figure 14—Insulator Duties and Electrostatic Field with 2 Insulators per Guy. Guy Positions NCS—Mast Insulated.

had very high duties. The question then arose as to where to eliminate insulation and where to increase it. The answer to such a question depends fundamentally on the corresponding change in effective height, but it is also influenced by the size of insulator units available. For example, it would not be economical to use insulator units where they carry only a small part of their rated duty.

TABLE II

Voltage Duties with Minimum Total Duty per Guy equals 10 kv.—Masts Grounded.

Guy No.	Insulator Position	Kv. Duty on Insulator (150 kv. on Antenna)					
		AN*	AE*	AW*	CN*	CE*	EW*
1	Top	27.6	12.2	44.7	57.8	31.1	23.3
	Middle	13.8	Out	22.3	28.9	15.5	11.6
	Bottom	13.8	12.3	22.4	28.9	15.6	11.7
2	Top	23.3	10.2	34.3	47.0	27.4	19.0
	Middle	8.6	Out	12.7	17.4	10.1	7.0
	Bottom	14.7	10.2	21.6	29.6	17.3	12.0
3	Top	15.8	8.4	24.4	38.2	22.8	12.4
	Middle	Out	Out	Out	11.6	7.0	Out
	Bottom	15.8	8.4	24.5	26.6	15.8	12.4
4	Top	10.5	5.8	16.7	26.1	13.5	9.5
	Middle	Out	Out	Out	10.0	Out	Out
	Bottom	10.5	5.8	16.7	16.1	13.5	9.5
5	Top	7.6	Out	11.5	14.7	10.0	7.3
	Bottom	7.6	Out	11.6	14.8	10.0	7.3
6	Top	5.5	Out	7.6	10.1	7.1	5.1
	Bottom	5.5	Out	7.6	10.0	7.1	5.1
7	Top	Out	Out	Out	5.4	Out	Out
	Bottom	Out	Out	Out	5.4	Out	Out
8	Top	Out	Out	Out	Out	Out	Out
	Bottom	Out	Out	Out	Out	Out	Out
	Total Duties	180.6	73.3	278.6	398.6	223.8	153.2

* For notation of guy positions see Fig. 6.

It was, therefore, assumed inadvisable to insulate a guy where the total duty (with 150 kv. on the antenna) was less than 10 kv. or to increase the number of insulators in a guy when the total guy duty was increased less than 10 kv. In working out such an arrangement it was found that three insulators per guy was the largest number desirable. Four or five insulators per guy had very little more total duty than three insulators.

The results of an arrangement worked out on this basis are given in Table II and Fig. 15. No measurements were made with the mast insulated since at the time of the measurements it was not considered worth while to insulate the masts.

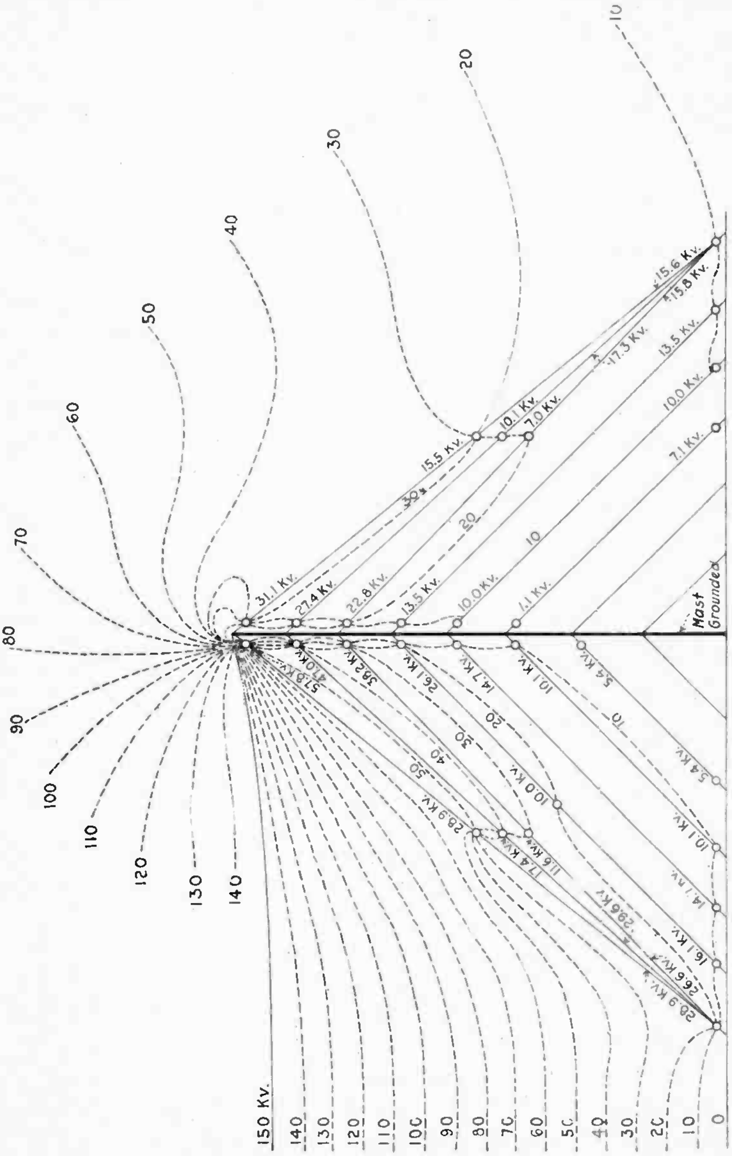


Figure 15—Insulator Duties and Electrostatic Field with 10 Kv. Minimum Guy Duty. Guy Positions NCS—Mast Grounded

The electrostatic field in Fig. 15 is very similar to that shown in Fig. 13, but it will be noted that a more economical insulation arrangement has been effected. With only two additional insulators the total insulator duties for the entire mast have been increased from 1054 kv. (Fig. 13) to 1245 kv. (Fig. 15), a change of 18 per cent. In spite of this large increase it is seen that a still greater increase could have been obtained if the middle insulators of Fig. 15 had been arranged in a horizontal row instead of in a vertical row.

CONCLUSION

The final decision as to the value of mast and guy insulation will depend upon an economic study of the costs. The change in effective height caused by using a particular insulation arrangement can be measured on a model such as that described above and used to determine the saving in power effected. Balancing this saving against the cost of the insulators will show the value of the insulation. The various factors involved differ so much with the station and its location that such a balance for the example given above would be of interest only and of little practical value.

ACKNOWLEDGMENTS

The writer is indebted to Dr. Harris J. Ryan of Stanford University for his many helpful suggestions in connection with this investigation and to Mr. C. H. Suydam for his assistance in making the measurements.

DISCUSSION ON RADIATION RESISTANCE OF A VERTICAL ANTENNA —(LEVIN AND YOUNG)

Stuart Ballantine: With reference to the computation of radiation resistance at the base of a vertical antenna with excitation at unloaded harmonics, I should like to observe that these special values are very simply and accurately derived from the general formulae given in my paper (Proceedings, 12, 823, 1924), particularly (18) in conjunction with the asymptotic developments (20) and (21) of the special functions $S_1(x)$ and $S_2(x)$ there employed. For odd harmonics $n=1, 3, 5, \ldots\ldots$, all the terms of (18) drop out except one so that the expression of the resistance at the antenna base is in this case reduced to the following simple form:

$$R_0=15\ S_1(2\pi n)\ \text{ohms}\ \textit{(odd harmonics)} \qquad (1)$$

The functions $S_1(x)$ is related to the cosine-integral function, and has the following asymptotic development, useful for large values of n:

$$S_1(x) \sim \log x + .5772 - \frac{1}{x^2} + \frac{6}{x^4} - \ldots\ldots\ldots \qquad (2)$$

For values of n above the first we may with considerable accuracy disregard the series, so that:

$$R_0=15(\log n+2.416)\ \text{approximately} \qquad (3)$$

In view of the simplicity and accuracy of this formula, already published, I do not quite see why Messrs. Levin and Young were willing to undertake the somewhat tedious work connected with the derivation of their approximate formula. It may be of interest to compare the results given by the authors in their Table I with the values computed from (3); this tabulation follows:

Odd Harmonic (n)	Levin & Young	Comp. from (3)
1	37	36.2
3	52	52.7
5	60	60.2
7	65	65.4
9	68	69.2
11	71	72.2
13	73	74.9
15	75	76.9
17	77	77.7

*Received by the Editor October 11, 1926.

For excitation at even harmonic frequencies the current at the base of the antenna is nominally zero and the values of radiation resistance which are frequently of the most interest in these circumstances are those corresponding to the point where the current amplitude is maximum. These values were previously designated as *R (loop)* and in the present case are given by:

$$R\ (loop) = 60\left[S_1(\pi n) - \frac{1}{4}\,S_1(2\pi n)\right],\ \text{ohms} \qquad 4$$

where n—$2, 4, 6, \ldots\ldots$ Now in view of (2) this may be written:

$$R\ (loop) \sim 45\left[\log n + 1.491 + \frac{5}{4}\ \frac{1}{(\pi n)^2} - \ldots\ldots\ldots\ldots\right] \quad (5)$$

or, with excellent approximation,

$$R\ (loop) \sim 45[\log n + 1.491].\ \textit{even harmonics} \qquad (6)$$

Messrs. Levin and Young do not furnish numerical values for the even harmonics; the following computations from (6) may therefore be of interest.

Even Harmonic (n)	2	4	6	8	10	12	14
R (at current loop)	99.5 o	129	149	161	171	179	186

These values, together with those previously published, furnish us with the comprehensive picture of the variation of loop radiation resistance over the whole range of frequencies shown in Fig. 1. The loading necessary to produce resonance at the various frequencies is assumed to be inserted at the base, and the lower end of the vertical antenna is connected to a perfectly conducting earth. Due to the concentration of load at the base the maxima and minima of resistance do not coincide exactly with the unloaded harmonic frequencies. The divergence is greatest at low frequencies, decreasing as the frequency increases as would be expected, until the envelopes of the extermals are the dotted curves given by the equations (3) and (6).

As I have previously suggested (PROCEEDINGS, 13, 255, 1925), when the antenna is erected over poorly conducting earth it is of some advantage to operate at an even harmonic, thus avoiding a great deal of earth loss. For short distance signaling by means of the direct earth ray the second *($n=2$)* is suitable, while if the fourth *($n=4$)* is employed the energy is radiated at an elevated angle of about 50 degrees and may cover greater distances by upper-atmospheric reflection. Some very excellent results with this mode of excitation have been reported to me in a private communication by B. A. Ostroumov, of the Radio Laboratory, Nijni-Nowgorod, Russia. In these tests, using a 15 k. w. Bontch-Broojewitch tube to supply a vertical antenna of 78 meters (or 95 meters) height at Moscow, Mr. W. W. Tatarinov used, according to my earlier prescription, a wavelength of about 83 meters. Signals of considerable strength were reported at Porto-Rico and India.

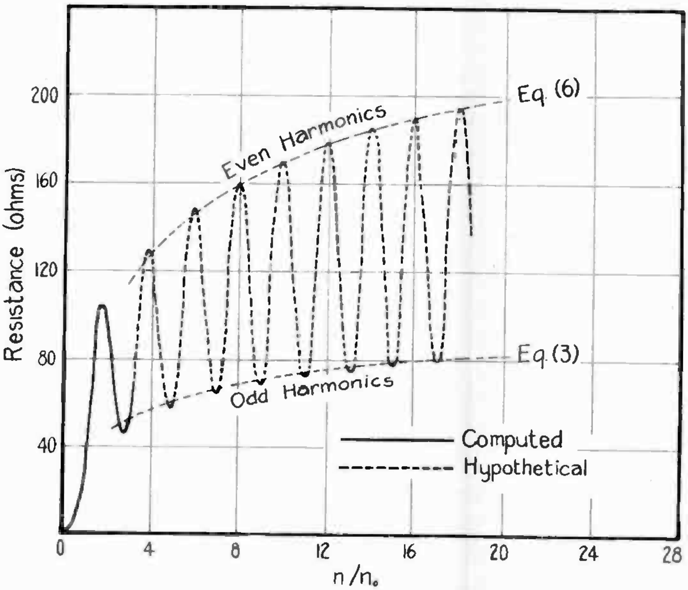


Figure 1—Radiation Resistance (at Current Loop) of Vertical Antenna over Perfect Earth and Loaded at Base as a Function of Operating Frequency, Fundamental Frequency.

In this note the term *harmonic* is employed in a strictly mathematical sense in which the fundamental is the first harmonic. This seems the best way to avoid the confusion which is current regarding the use of these terms. The term *harmonic* was originally borrowed from mathematics, whereas the physicist had been accustomed to referring to a *fundamental* and *overtones*. The *second harmonic* and *first overtone* are therefore synonymous, and so forth.

Some reference might have been made in this paper to the early work of Balth. van der Pol, Jr. on this subject.

DISCUSSION ON THE OUTPUT OF CHACTERISTICS OF AMPLIFIER TUBES.—(Warner and Loughren)

D. F. Whiting: I wish to take the opportunity that this occasion affords of emphasizing the importance to the radio engineer of the general subject with which the paper by Messrs. Warner and Loughren deals.

Mr. Warner has already pointed out to you that the development and use of improved loud speakers, which introduce less distortion of themselves and thereby allow the effects of tube overloading to be observed, has increased the need of amplifiers of considerably greater power.

To illustrate the similar effect of improvements in transformer design, let me say that puzzled radio-enthusiasts have often told me that, after replacing their old and supposedly inefficient audio-frequency transformers by those of improved design which are now appearing upon the market, they were must disappointed in the result of the change upon the quality of reproduction from their receiving sets. Upon questioning them regarding the type of tubes used and the conditions of use, such as grid and plate voltages, type of loud speakers used and volume of sound, it was at once apparent that they were badly overloading their amplifiers, which resulted in the poor quality that they had observed. The transformers which they had previously used cut off the low frequency where most of the energy of the original speech and music is concentrated, allowing the higher frequencies, to pass without serious overloading of the tubes. When transformers which were efficient at the low frequencies were substituted, the high energy of the low frequencies passed through the transformers to the tubes, overloaded them and produced the objectionable effect.

The obvious answer is to use not only a good loud speaker and good audio-frequency transformers, but also an amplifier possessing adequate power capabilities, the lat-

---

*Received by the Editor December 15, 1926.

ter requirement being the subject of the paper under discussion.

Since the procedure for determining the optimum conditions and the maximum power output for a vacuum tube according to the method outlined in the paper involves the use of curves which are not easily obtainable by the average radio enthusiast, it might not be inappropriate to indicate, a few simple relations which will serve as a guide to the optimum conditions. These relations are partly theoretical and partly empirical; and, although absolute exactness is not claimed for them because of many minor effects which must be neglected, they are sufficiently accurate for most practical purposes, and the results obtained through their use have been found to agree fairly well with the results of careful tests.

Neglecting the case in which the power is limited by the energy radiation from the plate, a condition which is not usual in receiving equipment, and assuming that the filament is capable of emitting a copious supply of electrons, the grid bias E_c may be obtained from the expression

$$E_c = \frac{E_b}{2\mu}$$

where μ is the amplification constant and E_b is the potential at the plate of the tube, the negative filament terminal being considered the zero of potential. In case the amplification constant of the tube is unknown, a good value for E_c can be found by getting an indication of the plate current with E_c—0 and E_b, normal and then increasing E_c until the plate current is reduced to about one-third of this value.

When using the proper value of grid bias, as determined above, and when operating into a resistance load equal to about twice the plate impedance, the maximum undistorted output power, $P_{max.}$, is approximately as follows:

$$P_{max.} = \frac{E_b^2}{36 r_p}$$

where r_p is the plate impedance at the plate and grid potentials chosen. In case the plate impedance is not known, $P_{max.}$ can be approximated in this way:

$$P_{max.} = \frac{E_b I_b}{10}$$

when I_b is the plate current which flows with a plate potential of E_b and a grid bias of E_c.

I am not certain just how closely these relations will be found to agree with the method outlined in the paper, and it is not my purpose to provoke any controversy over their relative merits. Conditions are so affected by the criteria assumed for full load that exact comparison may be difficult. I believe however that these relations will be found useful even to those in possession of complete tube data; and I state them here to add to the discussion as an expression of this important subject.

A. V. Loughren: Mr. Whiting's quasi-empirical rules are of considerable interest and are quite useful when the operating conditions are those for which any particular rule was developed. Unfortunately however the introduction of an apparently minor change in the circuit may sometimes be sufficient to invalidate the rule. The authors have employed such rules to some extent in practice, but feel that their proper sphere is the checking roughly of a design quantity obtained from the more rigorous methods set forth in the body of the paper.

DISCUSSION ON
VACUUM TUBE NOMENCLATURE. (CHAFFEE)

Geo. R. Metcalfe: The system of nomenclature proposed by Prof. Chaffee has undoubted advantages for both the writer and the readers of mathematical articles. These are very clearly set forth in his paper. When manuscripts of this character reach the printer and publisher, however, numerous disadvantages become apparent which are not generally appreciated by the layman. The writer does not wish by any means to deprecate the value of mathematical papers, as many of the most fundamental contributions to engineering literature are couched in highly mathematical language. Unfortunately such papers are very expensive to print, consume an extraordinary amount of time in their mechanical preparation, and generally, when printed, appeal to a very small fraction of the membership of the societies by which they are published.

As an example of the expense of publishing an article using a nomenclature similar to that suggested in the paper under discussion; a forty-page paper of this character, recently published, cost for composition alone, $440.00 and for its complete publication about $800.00. If this paper was read and appreciated by twenty members of the society (and this is probably a liberal estimate) it cost the society forty dollars apiece to place the paper in the hands of these twenty members. In general, it may be safely estimated that a highly mathematical paper costs about five times as much as the same length of plain text, and in view of its very high cost and the relatively small number of readers, it is always a question as to how much money a society is justified in spending on a mathematical article. It certainly should be a paper of outstanding merit to warrant its publication at all.

From the foregoing it will be evident that in adopting a nomenclature the practical requirements of the printer should be given at least equal consideration with the convenience of the reader, in order not to stifle the production of technical literature by prohibitive costs. From this point of view the proposed nomenclature is unfortunate, because the use of one or two dashes above or below the letters and of caret signs and tildes over the letters doubles and triples the work of the compositor. A complicated equation with these various appendages attached to certain letters may, involve two or three hour's work and at the current rate of $3.50 per hour may bring the cost of five or six lines of type up to approximately $10.00. Such an equation consists of hundreds of different sized types all of which must be "justified" or fitted together so that the block may be lifted as a whole with each individual type tight in place.

From the standpoint of publication, any system of notation should be confined for the sake of economy to Roman, Italic and bold face capitals and small letters, and Italic superior and inferior English and Greek capitals and small letters and figures. These, with the necessary mathematical symbols, are sufficiently difficult to handle without introducing any further complications.

An incident occurred some years ago that illustrates the attitude of printers toward complicated mathematical nomenclature. A very important mathematical paper was presented before an engineering society and it contained quite a few special characters for which special matrixes had to be cut. In order to expediate the typesetting the manuscript was divided between two experienced compositors. The first one looked over his part and resigned his job at once. The second man worked until noon and then gave notice that he would leave the job that night. It took over six weeks to set that manuscript in type with less experienced compositors.

It is felt that anything that can be done to simplify the nomenclature is of distinct advantage to engineering, as the production of engineering literature will surely be curtailed by making it too expensive for the engineering societies to publish.

DIGEST OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY

By John B. Brady

1,608,047—ALBERT H. TAYLOR and LEO C. YOUNG, Washington, D. C. Filed Jan. 7, 1925, issued Nov. 23, 1926. Assigned to Wired Radio, Inc.

RADIO SIGNALING APPARATUS wherein a radio transmitter may be located at a substantial distance from the transmitting antenna and the high frequency supplied to the antenna over a trunk line extending for a substantial distance.

1,608,048—ALBERT H. TAYLOR, Washington, D. C. Filed Jan. 23, 1926, issued Nov. 23, 1926. Assigned to Wired Radio, Inc. Assigned to Wired Radio, Inc.

PIEZO-ELECTRIC CRYSTAL CONTROL SYSTEM for frequency control of transmitting stations wherein a protective circuit is provided for preventing undue strain upon the piezo-electric crystal element in the event that the current should rise through the piezo-electric crystal circuit below a predetermined safe value.

1,608,083—JAMES C. DALEY, Chicago, Ill. Filed Aug. 10, 1925, issued Nov. 23, 1926. Assigned to Jefferson Electric Mfg. Co.

MEANS FOR RECONDITIONING RADIO TUBES comprising an apparatus into which an electron tube may be inserted for successfully imposing high and low voltages upon the filament for predetermined periods of time for restoring the tube to operating condition.

1,608,085—H. A. DOUGLAS, Bronson, Michigan. Filed June 1, 1922, issued Nov. 23, 1926.

CONDENSER of variable capacity in which the disc-like plate may be moved within a cup shaped enclosure with respect to a stationary plate.

1,608,110—W. O. MEISSNER, Chicago, Ill. Filed Dec. 18, 1925, issued Nov. 23, 1926.

LOOP AERIAL in which a frame is provided with a plurality of apertures therearound and the conductors secured on the frame by members passing through the apertures.

1,608,146—A. M. TROGNER, Rakoma Park, Maryland. Filed Feb. 27, 1922, issued Nov. 23, 1926. Assigned to Wired Radio, Inc.

ELECTRICAL PROTECTIVE ARRANGEMENT for automatically disconnecting the plate potential in a high power electron tube transmitter should the antenna or other load accepting circuit fail to function.

1,608,272—P. E. GILLING, East Orange, N. J. Filed Mar. 19, 1925, issued Nov. 23, 1926. Assigned to Wireless Specialty Apparatus Co.

ELECTRICAL CONDENSER where a stack is secured under compression by means of U shaped clamps which slide over opposite ends of the condenser.

1,608,292—H. I. BECKER, Schenectady, N. Y. Filed Feb. 4, 1920, issued Nov. 23, 1926. Assigned to General Electric Co.

MEANS FOR PRODUCING ALTERNATING CURRENTS wherein a two element tube is provided with an external magnetic field control winding arranged in the oscillatory circuit.

1,608,146—A. M. TROGNER, Washington, D. C. Filed June 4, 1926, issued Nov. 23, 1926. Assigned to Wired Radio Inc., of New York.

MULTIPLE PIEZO-ELECTRIC HOLDER wherein a plurality of piezo-electric crystal elements of different frequency characteristics are mounted upon a rotatable frame which may be moved to selective positions for effectively positioning a desired piezo-electric crystal in the transmitter circuit.

1,608,311—ALVARADO L. R. ELLIS, Swampscott, Mass. Filed Jan. 5, 1926, issued Nov. 23, 1926. Assigned to General Electric Co.

OSCILLATOR where a piezo-electric crystal element is connected to an electron tube circuit and the circuit tuned in response to a change in condition of the piezo-electric element for the control of a transmission circuit.

1,608,316—A. W. HULL, Schenectady, N. Y. Filed Jan. 29, 1920, issued Nov. 23, 1926. Assigned to General Electric Co.

METHOD OF AND MEANS FOR PRODUCING ALTERNATING CURRENTS which consists in producing a stream of electrons in substantially radial paths between an electron emitting cathode and a cooperating electrode and periodically substantially interrupting the electron stream between cathode and anode by means of a magnetic field which is in a direction substantially at a right angle to the paths of the electrons and which is produced by current carried by said electron stream.

1,608,317—AUGUSTUS C. HYDE, Perivale, England. Filed May 26, 1925, issued Nov. 23, 1926.

THERMIONIC VALVE having a cathode which is formed by coating a core of refractory metal by applying a solution of tungstic acid mixed with finely powdered thorium which is heated to at high temperature for forming the cathode.

1,608,429—C. E. RILEY, Charlestown, Indiana. Filed May 18, 1925, issued Nov. 23, 1926.

CRYSTAL DETECTOR HOLDER where a plurality of contact points in overlapping staggered relation are arranged to grip a crystal element therebetween.

1,608,472—J. J. AURYNGER, Brooklyn, N. Y. Filed Dec. 1, 1922, issued Nov. 23, 1926.

CONDENSER having a set of stator plates and two sets of rotor plates independently adjustable with reference to the stator plates.

1,608,504—G. W. HEATH, Newark, New Jersey. Filed April 15, 1924, issued Nov. 30, 1926.

ELECTRIC CONDENSER PLATE in which the surface of the plate is stippled with indentations for increasing the area of one plate with respect to the adjacent plate.

1,608,526—E. F. POTTER, Glencoe, Illinois. Filed Oct. 23, 1922, issued Nov. 30, 1926. Assigned to Kellogg Switchboard and Supply Company.

CONDENSER having a set of rotor and stator plates and a separate set of verier plates controlled by a concentrically positioned operating shaft.

1,608,535—P. SCHWERIN, New York, N. Y. Filed Dec. 30, 1921, issued Nov. 30, 1926. Assigned to Western Electric Co.

ELECTRIC DISCHARGE DEVICE in which the electrodes within the tube are supported on wire members flattened at selected points for positioning the electrodes in definite relation.

1,608,551—C. D. DEMAREST and R. K. BONELL, of Ridgewood and East Orange, New Jersey, respectively. Filed Dec. 30, 1925, issued Nov. 30, 1926. Assigned to American Telephone & Telegraph Co.

RADIO SIGNALING SYSTEM for linking line wire telephone systems with radio transmission and reception circuits with special circuit arrangements for indicating at a central station the particular secondary station which may be signaling the central station.

1,608,580—S. CABOT, Brookline, Mass. Filed Nov. 19, 1924, issued Nov. 30, 1926.

RADIO RECEIVING SYSTEM embodying a method of tuning a radio-receiving system of the radio-frequency amplifier type to the point of greatest sensitiveness for any wave length within the range of said system which consists, first, in simultaneously changing in opposite direction the impedance of the input and output circuits of a vacuum tube as wave length varies whereby any local oscillations that may be created in said system will be of substantially uniform intensity for any wave length within the range of said system, and, second, reducing the intensity of such local oscillations to as low a value as desired.

1,608,821—W. M. Sullivan, deceased; late of Newark, N. J. Filed Jan. 26, 1921, issued Nov. 30, 1926. Harriet Sullivan Payne, Administratrix.

SPARK GAP STABILIZER consisting of a member of conducting material disposed laterally of the path of rotation of the rotary electrode and connected to ground the rotary electrode being driven in synchronism with with the a-c. supply source of the set.

1,608,922—W. A. BOCKIUS, Wilmette, Ill. Filed June 6, 1925, issued Nov. 30, 1926. Assigned to H. F. Tideman, H. H. Whetter, and W. A. Bockius, of Chicago, Illinois.

ELECTRICAL CONDENSER comprising a pair of sets of interleaved plates, pivoted to swing on different axes, and means for conjointly shifting the sets comprising a cam wheel connected to shift said sets.

1,608,969—H. W. WEBBE, Columbus, Ohio. Filed June 18, 1923, issued Nov. 30, 1926.

DIFFERENTIAL RADIOCONTROL wherein a transmitter may be modulated under selective control of tuning forks while tuning forks at the receiver may be similarly controlled for closing particular circuits.

1,608,974—A. S. BLATTERMAN, of Vail, Little Silver, N. J. Filed Jan. 29, 1921, issued Nov. 30, 1926. Assigned to Murad Radio Corp.

APPARATUS FOR CONTROLLING THE DIRECTIONAL RECEPTION CHARACTERISTICS OF LOOP OR COIL ANTENNAE consisting of a plurality of sets of parallelly arranged conductors said conductors being of substantially equal length and arranged closely adjacent to a portion of the loop antenna to provide an electrical shield to said loop antenna. Means are provided for optionally connecting and disconnecting both sets of the parallel conductors with one another and ground, or only one set of said sets of parallel conductors with the receiver, the other set of conductors being in this instance entirely disconnected.

1,609,006—C. D. Tuska, Hartford, Conn. Filed Jan. 17, 1922, issued Nov. 30, 1926. Assigned to The C. D. Tuska Co.

VARIABLE CONDENSER wherein the rotatable shaft has a frictional bearing at one end consisting of a yielding strip anchored upon one of the insulated end plates of the condenser.

1,609,116—J. H. HAMMOND, Gloucester, Mass. Filed Aug. 17, 1922, issued Nov. 30, 1926.

METHOD AND SYSTEM FOR COMMUNICATION BY RADIANT ENERGY in which oscillations at the transmitter have periodic variations of relatively lower but supersonic frequency impressed thereon and varied in accordance with the signal at the receiver a special circuit is provided for transforming the energy into oscillations having a frequency intermediate between the frequency of the original oscillations and the frequency of the variations.

1,609,118—C. HARDY, New York, N. Y. Filed Dec. 10, 1925, issued Nov. 30, 1926. Assigned to Amsco Products, Inc.

ELECTRICAL CONDENSER MANUFACTURE where the plates of a condenser are keyed to a shaft by locking the plates within grooves formed in the shaft.

1,609,152—F. C. CARMEL, Pittsfield, Mass. Filed Feb. 9, 1925, issued Nov. 30, 1926. Assigned to A. H. Rice Co.

ANTENNA comprising a flat sheet of fabric including a plurality of braids laid parallel to each other and of insulating material and a conductor woven progressively forward in a zigzag manner across the sheet alternately between the strands of the sheet.

1,609,162—W. F. DIEHL, Jamaica, N. Y. Filed Dec. 19, 1924, issued Nov. 30, 1926.

RADIO RECEIVING APPARATUS of the superheterodyne type wherein there is a receiving circuit for the incoming electric wave, a second circuit adapted to be tuned to a frequency differing from the frequency of the first circuit, and a third circuit having a variable tuning element mechanically connected in such relation to a variable tuning element of the first circuit, as to maintain the third circuit, throughout the frequency range of the system, tuned to a frequency other than that at which the second circuit is designed to operate for the desired signal and differing from that of the first circnit by an amount equal to the frequency difference between the first and second circuits.

1,609,222—J. M. TAYLOR, Bridgeport, Pa. Filed Oct. 28, 1921, issued Nov. 30, 1926. Assigned to Diamond State Fibre Co.

INSULATED CONDUCTING ELEMENT for constructing condensers consisting of a body of metal foil with at least one sheet of parchmentized fibre applied thereto and extending through openings in said metallic foil.

1,609,398—C. E. BRIGHAM, of East Orange, N. J. Filed July 16, 1924, issued Dec. 7, 1926. Assigned to Brandes Laboratories, Inc.

VISUAL TESTING SYSTEM FOR ELECTROMAGNETIC SOUND REPRODUCERS by which the loud speakers may be tested both as to sensitivity and volume by observing their characteristics in an electrical circuit.

1,609,931—S. COHEN, New York, N. Y. Filed Oct. 30, 1923, issued Dec. 7, 1926.

ELECTRICAL CONDENSER of the fixed stack type where a baked coating of metallic oxide is formed directly upon the dielectric plates for forming the condenser.

1,610,051—GUY HILL, Washington, D. C. Filed May 16, 1921, issued Dec. 7, 1926. Assigned to Wired Radio, Inc.

SUPPORTING PLATE FOR ELECTRICAL CONDENSERS in which a semi-circular metallic plate is embedded in an insulated plate and arranged to coact with movable plates for adjustment of capacity.

1,610,073—E. F. W. ALEXANDERSON, Schenectady, N. Y. Filed April 10, 1922, issued Dec. 7, 1926. Assigned to General Electric Co.

HIGH FREQUENCY SIGNALING SYSTEM in which two high frequency alternators are arranged to supply energy simultaneously to the same antenna circuit under control of separate modulator circuits without interference between the channels.

1,610,090—V. A. Hendrickson, Springdale, Conn. Filed Nov. 14, 1922, issued Dec. 7, 1926. Assigned one-third to Fred Berg and one-third to J. Edward Brown.

GENERATING AND CONTROLLING SYSTEM FOR RADIO TELEPHONES in which the anode circuit of the oscillator is provided with separate inductors which are coupled on opposite sides to the radiating inductance.

1,610,122—L. EDENBURG, Brooklyn, N. Y. Filed June 10, 1924, issued Dec. 7, 1926. Assigned to Dubilier Condenser & Radio Corp.

ADJUSTABLE CONDENSER comprising a helically wound strip which may be adjusted with respect to a correspondingly shaped strip for changing the capacity of the condenser.

1,609,366—FREDERICK A. KOLSTER, Washington, D. C. Filed Nov. 26, 1920, issued Dec. 7, 1926. Assigned to Federal Telegraph Company.

RADIO APPARATUS consisting of a closed circuit including an inductance and a capacity area where the capacity area constitutes a conductor which is a part of the inductance in the signaling circuit.

1,610,208—LESLIE R. McDONALD, Westmount, Quebec, Canada. Filed Oct. 31, 1925.

VACUUM TUBE VIBRATION DAMPER in the form of a rubber cup which snugly grips the bulb of the tube for damping vibration.

1,609,748—J. WEINBERGER, New York, N. Y. Filed Sept. 20, 1921, issued Dec. 7, 1926. Assigned to Radio Corp. of America.

RADIO TELEPHONE TRANSMITTING SYSTEM where alternating current above the limit of audibility is supplied to the plate filament circuit of an oscillator and the supply to the oscillator modulated in accordance with speech.

1,609,805—W. N. FANNING, Vallejo, Calif. Filed Jan. 23, 1922, issued Dec. 7, 1926.

RADIO RECEIVING SYSTEM wherein a relay is acted upon by both signal and static and the effect of static balanced out for the control of the relay by the signal.

1,610,258—A. E. CHAPMAN, London, England. Filed June 4, 1923, issued Dec. 14, 1926.

ELECTRICAL VARIABLE CONDENSER wherein two groups of plates are pivotally mounted spaced in position on a support with a third group of plates pivotally mounted adjacent the first two groups and all adjustable for controlling the tuning of an electrical circuit.

1,610,316—W. A. E. QUILTER, London, England. Filed Feb. 26, 1921, issued Dec. 14, 1926. Assigned to Radio Corp. of America.

THERMIONIC DEVICE wherein a grid electrode constructed in a plurality of metal parts, each part having apertures and being capable of movement for the adjustment of the size of the apertures for the control of electron discharge.

1,610,329—P. F. SHIVERS, Racine, Wis. Filed Oct. 19, 1922, issued Dec. 14, 1926. Assigned to Western Electric Co.

RADIO APPARATUS wherein the frequency of the transmitting station may be varied and a corresponding change effected at a receiving station for the secret transmission of signaling energy.

1,610,371—H. H. HAMMOND, JR., Gloucester, Mass. Filed (original) March 21, 1914; renewed July 24, 1923, issued Dec. 14, 1926.

GASEOUS DETECTOR OF RADIANT ENERGY AND METHOD OF CONTROL THEREOF, in which circuits are provided for the automatic interruption of the cathode and plate circuits of an electron tube system at a predetermined rate.

1,610,417—A. BOEDEKER and J. S. WENTWORTH, of Cincinnati and Norwood, Ohio, respectively. Filed March 7, 1925, issued Dec. 14, 1926. Assigned to Grandtone Radio Corp.

RADIO CONDENSER in which sets of plates are slidable with respect to each other in a frame of special construction for varying the capacity of the condenser system.

1,610,425—E. L. CHAFFEE, Belmont, Mass. Filed Sept. 3, 1918, issued Dec. 14, 1926. Assigned to John Hays Hammond, Jr.

TRANSMISSION SYSTEM FOR RADIANT ENERGY wherein high frequency oscillations are produced, amplified, and then increased in frequency for impression upon a transmitting antenna circuit.

1,610,551—I. W. Eisenberg, Alhambra, Calif. Filed Mar. 28, 1923, issued Dec. 14, 1926.

RADIO EQUIPMENT wherein a variable condenser is arranged with a set of rotor plates and sets of alternately positioned stator plates. The stator plates are arranged in separate series, each insulated one from the other and separately connected to an electron tube system.

1,610,560—F. S. McCULLOUGH, Wilkinsburg, Pa. Filed Oct. 24, 1922, issued Dec. 14, 1926.

VACUUM TUBE FILAMENT CONSTRUCTION AND METHOD OF MANUFACTURING SAME for use in power tube devices. A pitted surface is provided for the cathode for increasing rigidity and strength for high power operation.

1,610,615—W. SCHAFFER, Berlin, Germany. Filed Oct. 28, 1924, issued Dec. 14, 1926. Assigned to Gesellschaft fur Drahtlose Telegraphie. M. B. H.

ARRANGEMENT FOR MAINTAINING ANODE VOLTAGE CONSTANT IN TUBE TRANSMITTERS, where a rectifier supplies the output circuit of an oscillator with capacity and loading devices traversed by the rectified current for maintaining the circuit anode potential steady.

1,610,704—S. D. PADDOCK, San Francisco, Calif. Filed Mar. 9, 1925, issued Dec. 14, 1926. Assigned to Paddock Engineering Corp.

MEANS FOR INCREASING THE CAPACITY OF RADIOAERIALS by providing metallic extension members upon a conductor comprising the antenna.

1,610,783—A. W. HULL, Schenectady, N. Y. Filed Dec. 18, 1920, issued Dec. 14, 1926. Assigned to General Electric Co.

ELECTRON DISCHARGE APPARATUS in which an electrode auxiliary to the normal three electrodes is employed and a positive potential applied for giving the device a negative resistance characteristic.

1,610,837—W. C. WHITE, Schenectady, N. Y. Filed Mar. 6, 1923, issued Dec. 14, 1926. Assigned to General Electric Co.

RECTIFIER CIRCUITS for obtaining uni-directional current from polyphase alternating current wherein individual rectifiers are provided in the separate phases and the effect of the rectifier integrated for the production of rectified current.

1,610,875—E. MAYER, Berlin, Germany. Filed Dec. 5, 1922, issued Dec. 14, 1926. Assigned to Gesellschaft fur Drahtlose Telegraphie.

ARC LAMP GENERATOR FOR PRODUCING AND AMPLIFYING ELECTRICAL OSCILLATIONS where a grid electrode is provided for controlling the passage of current between the anode and cathode.

1,610,919—E. BERLOW, East Orange, N. J. Filed Mar. 2, 1925, issued Dec. 14, 1926.

RADIO APPARATUS in which a hollow base is provided for receiving apparatus within which all of the wiring for the equipment within the received may be enclosed.

1,610,980—S. Silberman, Porz-on the Rhine, Germany. Filed July 18, 1925, issued Dec. 14, 1926.

ELECTRICAL CONDENSER built up in the form of a cable having a plurality of metallic sections each insulated one from another.

1,611,848—E. H. ARMSTRONG, New York, N. Y. Filed Dec. 13, (original) 1913; divided application filed May 8, 1926, issued Dec. 21, 1926. Assigned to Westinghouse Electric & Mfg. Co.

RADIO RECEIVING SYSTEM FOR CONTINUOUS WAVES consisting of a resonant receiving circuit upon which received waves are impressed, the resonant receiving circuit being coupled with a resonant detector circuit by which oscillations in the detector circuit react for effecting an audible signal in the receiving circuit.

1,611,990—C. E. BONINE, of Melrose Park, Pa. Filed May 28, 1924, issued Dec. 28, 1926.

ELECTRICAL CONDENSER in which a plurality of folds are provided for housing the plates of a condenser with an adjustable pressure device for regulating the special relation of the folds.

1,611,101—H. J. J. M. De R. DE BELLESCIZE, Paris, France. Filed August 29, 1921, issued Dec. 28, 1926.

RADIO SIGNALING SYSTEM for the transmission and reception of telegraph signals by a system of impulses which will make deciphering by a receiver not equipped with the special apparatus required for this system extremely difficult.

1,611,182—WILLIAM H. FRASSE, Newark, N. J. Filed Dec. 4, 1924, issued Dec. 21, 1926.

RESISTANCE COUPLING which consists of a plurality of spaced terminals with resistance elements and an interposed condenser in series mounted in position with respect to the terminals for providing a coupling unit for radio receiving circuits.

1,611,183—WILLIAM H. FRASSE, Newark, N. J. Filed Dec. 4, 1924, issued Dec. 21, 1926.

GRID LEAK AND CONDENSER MOUNTING wherein a pair of spring arms are arranged to engage a condenser and a grid leak connecting the elements in shunt relationship.

1,611,215—A. P. McARTHUR, Bogoto, N. J. Filed Jan. 4, 1926, issued Dec. 21, 1926.

RADIO RECEIVING APPARATUS in which radio receiving apparatus is mounted upon a panel and arranged to be readily removed to a position within a cabinet or removed from the cabinet, at the same time establishing electrical connection with apparatus connected within the cabinet.

1,611,224—HARRY NYQUIST, Jackson Heights, N. Y. Filed Dec. 19, 1923, issued Dec. 21, 1926. Assigned to American Telephone and Telegraph Company.

METHOD AND APPARATUS FOR MEASURING FREQUENCY which consists in combining a given electro-motive force with an electro-motive force of slightly different standard frequency to produce a current whose frequency is the difference of the two electro-motive force frequencies. The magnitude of this difference may then be measured.

1,611,264—L. G. BURKWEST, Chicago, Ill. Filed Aug. 14, 1924, issued Dec. 21, 1926.

ADJUSTABLE CONDENSER in which a flexible metallic plate may be pressed in varying degrees with respect to a stationary plate for changing the effective value of the condenser.

1,611,313—W. LATRAVERSE, Montreal Canada. Filed Dec. 24, 1925, issued Dec. 21, 1926.

CONDENSER in which a plurality of variable condensers may be simultaneously operated through a system of gears with balancing plates for each condenser which may be adjusted with respect to each of the variable condensers.

1,612,134—C. V. LOGWOOD, San Francisco, Calif. Filed March 10, 1921, issued Dec. 28, 1926.

RADIO RECEIVING SYSTEM including an electron tube system having coupled grid and plate circuits with a mechanical interrupter arranged in the circuits in the form of a chopper.

1,612,259—W. R. BULLIMORE, Highbury Grove, London, England. Filed July 21, 1925, issued Dec. 28, 1926.

THERMIONIC VALVE wherein the capacity between the connecting pins of an electron tube is reduced by providing air dielectric between the pins.

1,612,284—J. H. HAMMOND, JR., Gloucester, Mass. Filed Oct. 14, 1922, issued Dec. 28, 1926.

SECRET RADIANT TELEPHONE where the transmitting station emits energy of varying character and the receiving station is provided with circuits which respond to the transmitted energy of varying character for piecing together the transmitted signals regardless of the disassociated arrangement of the signals which would be received upon any normal receiver.

1,612,285—J. H. HAMMOND, JR., Gloucester, Mass. Filed Oct. 31, 1922, issued Dec. 28, 1926.

SYSTEM OF SECRET RADIANTTELEPHONY where a transmitting station emits energy over a variable range of frequencies and means are provided in the receiving station for integrating the effects of the received energy upon an observation circuit.

1,612,414—W. C. BRUMDER, Milwaukee, Wis. Filed July 31, 1922, issued Dec. 28, 1926.

ADJUSTABLE CONDENSER including a pair of adjustable drums which may be actuated for varying the position of one condenser plate with respect to another condenser plate.

1,612,427—H. FLURSCHEIM, Paris, France. Filed Nov. 13, 1923, issued Dec. 28, 1926.

RADIO WARNING SYSTEM FOR USE ON VEHICLES consisting of a receiving installation for movable vehicles which will be actuated upon approach to a signaling station which might be located upon another movable vehicle for warning the occupant of the first vehicle of his approaching a position of danger.

1,612,440—F. L. HUNTER, JR., Towaco, New Jersey. Filed Oct. 29, 1924, issued Dec. 28, 1926. Assigned to DeForest Radio Company.

ELECTRON DISCHARGE DEVICE where an insulated member is provided for supporting the electrodes within a tube, the insulating member being resiliently mounted within the tube.

1,612,448—M. LATOUR, Paris, France. Filed May 3, 1924, issued Dec. 28, 1926. Assigned to Latour Corp.

ELECTRICAL SIGNALING SYSTEM AND METHOD where a group of signaling stations are arranged to receive on a certain wave length and transmit on another wave length in cooperation with another group of stations with selective means for arranging the particular stations which are to be operated.

1,612,473—E. G. SHALKHAUSER, Peoria, Ill. Filed Aug. 27, 1926, issued Dec. 28, 1926.

VARIABLE CONDENSER in the form of a rotatable member which is screw threaded into a stator member in varying amounts for changing the capacity of the condenser.

1,612,476—W. K. THOMAS, Crafton, Pa. Filed Sept. 12, 1922, issued Dec 28, 1926. Assigned to Samuel A. Pickering.

RADIO RECEIVING SET in which a specific circuit arrangement is provided for impressing a positive potential on the grids of the tubes in the receiving circuit.

1,612,594—H. DE F. MADDEN, Newark, New Jersey. Filed Sept. 29, 1922, issued Dec. 28, 1926. Assigned to Westinghouse Electric & Mfg. Co.

MOUNT FOR ELECTRON EMISSION DEVICE in which a plate electrode is provided with side extensions which permit supports to be connected thereto where the supports extend in a vertical direction within the tube

GEOGRAPHICAL LOCATION OF MEMBERS ELECTED JANUARY 5, 1927

Transferred to Fellow Grade

Pennsylvania,	E. Pittsburgh, Westinghouse Elec. & Mfg. Co.	Conrad, Frank

Elected to Fellow Grade

Germany,	Berlin-Lankwitz, 1 Luisenstrasse	Wagner, Dr. K. W.

Transferred to Member Grade

Massachusetts,	Arlington Heights, 72 Oakland Ave.	Lamson, H. W.
	Cambridge, 5 Craigie Circle, Suite 6	McElroy, Paul K.
New Jersey,	Englewood, 279 Audubon Road	Gillett, Glenn D.
	Roselle, 276 East 3rd Ave.	Hanson, O. B.
New York,	Brooklyn, 144 Underhill Ave.	Drew, C. E.
	Brooklyn, 274 Linden Blvd.	Pease, R. M.
	Rochester, c-o Stromberg-Carlson Te. Mfg. Co.	Graham, V. M.
Ohio,	Cleveland Heights, 3223 Ormond Road	David, B. W.

Elected to Member Grade

Dist. Columbia,	Washington, 1314 Belmont St. N. W.	Heron, L. M.
	Washington, 405 Ninth St. N. W.	Loomis, M. T.
Illinois,	Chicago, Armour Inst. of Tech.	Freeman, E. H.
New Jersey,	Plainfield, 730 Park Ave.	Barbulesco, C. D.
	So. Orange, 257 So. Ridgewood Road	Rodman, I. P.
New York,	Buffalo, 15 Wilbury Place	Million, J. W.
	New York City, c-o E. H. Robinson, 79 Madison Ave.	Moore, E. J. T.
Pennsylvania,	Scranton, 820 Wheeler Ave.	Graf, J. J.
England,	Hampshire, Farnborough, Victoria Road	Barber, W. E.
Sudan,	Kartoum, General Post Office	Edgeworth, K. E.

Associates Elected

California,	Hollywood, 1316 N. Sierra Bonita	Rogers, M. E.
	Hollywood, 1242 Gordan St.	Wilson, G. L.
	Los Angeles, 3338 W. 27th St.	Comyns, W. L.
	Los Angeles, 1922 Hooper Ave.	Pfleger, R. A.
	Pasadena, 2157 Dolores St.	King, A. P.
	Pasadena, 614 N. Holliston Ave.	Logan, M. A.
	San Francisco, 525 Market St.	Dauforth, R. S.
	Sherman, 839 Elwood St.	Smith, W. H.
Colorado,	Denver, 6100 Montview Blvd.	Owen, R. H.
Connecticut,	Bridgeport, Bridgeport Herald	C. B. Kingston,
Dist. Columbia,	Washington, 6631 Harlan Place, N. W.	Waldo, G. V.
	Washington, 5503-33rd St. N. W.	Wheeler, H. A.
Illinois,	Berwyn, 3111 Grove Ave.	Wilkinson, L. G.
	Chicago, 6318 Kenwood Ave.	Andres, F. J.
	Chicago, 207 City Hall	Bronson, G. E.
	Chicago, 9551 Longwood Drive	Christ, J. F.
	Chicago, 2017 Grace St.	Cummings, G.
	Chicago, 716 Buena Ave.	Harries, H. M.
	Chicago, 5442 Race Ave.	Heasley, D. F.
	Chicago, 5480 Cornell Ave.	Hill, A. J.
	Chicago, 5005 W. Adams St.	Holmquist, C. T.
	Chicago, 1851 W. Adams St.	Howard, C. M.
	Chicago, 4607 Beacon St.	Jorgenson, H.
	Chicago, 2510 Lexington St.	Murphy, E. R.
	Chicago, 925 Wrightwood Ave.	Norene, R. E.
	Chicago, 24 S. Clinton St.	Pfeifer, P. S.
	Chicago, 6140 University Ave.	Temple, C. T.
	Chicago, 815 N. Pine Ave.	Trimble, L.
	Chicago, 3047 N. Robey St.	Weissmantel, C. H.
	Cicero, 2501 S. 61 Ave.	Zeithammel, A. J.
	Hinsdale, 37 N. Washington St.	Blair, W.
	Oak Park, 44 S. Maple Ave.	Blizat, C. R.
	Oak Park, 212 Marion St.	Phillips, L. E.
	Peoria, 507 Bigelow St.	Brewer, F. T.
	Sycamore, 307 N. Main	Boynton, F. L.

Indiana,	Valparaiso, 451 Greenwich St.	Piatt, F. W.
	Warsaw, 9 Times Bldg.	Franklin, T. U.
Iowa,	Council Bluffs, 2408 S. 12th St.	Kelly, E. L.
Kansas,	Manhattan, 1622 Houston St.	Whan, L. H.
Louisiana,	New Orleans, 844 Howard Ave.	Clemmons, W. A.
	New Orleans, 2211 Octavia St.	Green, W. H.
	New Orleans, 321 St. Charles St.	Nall, V.
	New Orleans, 6036 Patton St.	Nebe, H. G.
	New Orleans, 512 St. Peter St.	Pohl, J .A.
	New Orleans, 139 S. Rampart St.	Willoz, V. L.
Massachusetts,	Cambridge, M. I. T. Dormitories	Chinn, H. A.
	Cambridge, 984 Memorial Drive	Fahnestock, H., Jr.
	Cambridge, 34 Mass Ave.	Gebhardt, P. B.
	Winchester, 16 Wildwood St.	Allen, A.
Michigan,	Detroit, 1650 W. Gd. Blvd., Apt. 5,	Lyons, F. E.
	Detroit, 774 Casgrain Ave.	Waynich, A. H.
Minnesota,	St. Paul, 820 Gt. Nor. Bldg.	Rankine, J. C.
New Jersey,	Bayonne, 89 W. 26th St.	Dillenbeck, P. D.
	Elizabeth, 20 Rankine St.	Crowley, D. A.
	Glen Ridge, 5 Pierson Place	Umbach, W. R.
	Jersey City, 66 York St.	Henschel, E. B.
	Leonia, 8 Paulin Blvd.	Musterman, H. G. A.
	Montclair, 54 Hawthorne Pl.	Hervey, J. P.
	Wenonah, 109 E. Jersey Ave.	Beeler, E.
New York,	Brooklyn, 948 E. Parkway	Brody, M. M.
	Brooklyn, 2016 Greene Ave.	Grade, F. E.
	Brooklyn, 1705-77 St.	Hamre, F.
	Brooklyn, 88 Livingston St.	Michelson, C. D.
	Brooklyn, 255 Hull St.	Redfern, F .F.
	Brooklyn, 1907 Homecrest Ave.	Reynolds, J. B.
	Brooklyn, 195 Ocean Ave.	Shestacovsky, J.
	Brooklyn, 4821-11th Ave.	White, P. S.
	New York, 41 Park Row	Allyn, R. S.
	New York, 463 West St.	Anderson, W. H.
	New York, 10th Ave. & 36th St.	Baukat, H. W.
	New York, 453 W. 143rd St.	Brouthers, C. A.
	New York, 168 Washingtotn St.	Fernald, P. R.
	New York, 1055 Anderson Ave.	Grabar, J.
	New York, 195 Broadway	Green, E. I.
	New York, 1069 Gerard Ave.	Harvey, B. J.
	New York, 16 E. 40th St.	Henry, C. C.
	New York, 326 Broadway	Israel, J. J.
	New York, 233 Broadway	Melhuish, H. T.
	New York, 463 West St.	Mellor, W. N.
	New York, 1295 Madison Ave.	Purdy, F. R.
	New York, 136 Liberty St.	Schmetf, F. E.
	New York, 571 W. 130th St.	Turski, A.
	New York, U. S. S. Seattle. Care Postmaster	Whitaker, J. N.
	New York, 920 Prospect Ave.	Wright, H. M.
	Port Jefferson, 1207 Main St.	White, L. S.
	Schenectady, Radio Eng. Dept. G. E. Co.	Hultkrantz, J. G.
	Scotia, Route No. 2	Palmer, H. L.
	Syracuse, 412 S. Alvord St.	Blaich, J. R.
Ohio,	Cincinnati, Brunswick-Bulke-Collinder Co.	Albright, G. F.
	Cleveland, 8520 Carnegie Ave.	Calkins, W. G.
	Cleveland, 1101 Union Trust Bldg.	Covert, C. B.
	Cleveland, 2028 W. 99th St.	McCollister, D. R.
	Cleveland, 464 East 117th St.	Robertson, F. E.
Pennsylvania,	Altoona, 2629 Maple Ave.	Aughenbaugh, W. K.
	E. Pittsburgh, Westinghouse	Landon, V. D.
	Lansdowne, 79 S. Wycombe Ave.	Kimball, G. W.
	Norristown, 739 Noble St.	Sands, W. F.
	Philadelphia, 4912 Walnut St.	Kennedy, T. R.
	York, 434 N. Beaver St.	Gemmill, W. E.
Vermont,	Northfield, 11 Highland Ave.	Howes, D. E.
Virginia,	Arlington, Naval Radio Station	Freed, R. E.
W. Virginia,	Wheeling, 42 Poplar Ave.	Weimer, E. W.
Wisconsin,	Madison, 725 W. Dayton	Borden, F. G.
	Madison, 222 N. Orchard St.	Davis, R. J.
	Madison, Burgess Laboratories	Martin, T. J.
	Milwaukee, 747 Summitt Ave.	White, W. M.

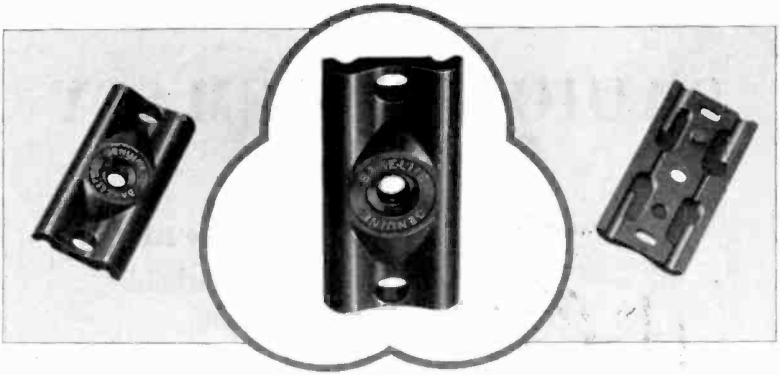
Associates Outside the U. S.

Brazil,	Sao Paulo, Mackenzie College	Weeden, E. H.
Canada,	Montreal, 497 Phillips Square	Crawford, J.
	Sudbury	Jessop, F. R.
	Toronto, 1936 Queen St.	Emes, K. C.
	Toronto, Apt. 16, "The Oaks"	De Grave, C.
	Toronto, Prince George Hotel	McClain, G. W.
China,	Shanghai, Commercial Press	Yu, Chia Chang

England,	Bournemouth, 1 Irving Rd., West Southbourne	Kilmister, G. W.
	London, 11 Brassie Ave., East Acton	Jervis, F. J.
	London, 27 Stanwick Road, West Kensington	Leathes, W. H. B. deM
	Natwich, Coppice Road, Fern Villa	Noden, J.
Mexico,	Mexico City, Gante No. 20	Domenzain, S.

Juniors Elected

Connecticut,	West Hartford, 111 South Highland Ave.	Wagner, R. P.
Georgia,	Decatur, 1127 Clairmont Ave.	Hamilton, J.
Illinois,	Chicago, 1407 Irving Park Blvd.	Imes, R. N.
Massachusetts,	Brookline, 62 Chestnut St.	Duffy, J. A.
New Jersey,	Clifton, 370 Clifton Ave.	Watts, I. B.
Pennsylvania,	Philadelphia, 2070 West 65th Ave.	Hutchby, G. E.
Texas,	Houston, 113 N. Palmer	Wheeler, H.
Wisconsin,	Madison, 2246 Talmadge St.	Zurian, P. D.



Bakelite molded cover for Sparks-Withington connector.
Made by Sparks-Withington Co., Jackson, Mich.

BAKELITE

---*a trade-mark that will protect manufacturer, dealer and consumer*

There is no chance for the substitution of inferior materials when radio parts are marked "Bakelite"—for it is a trade-mark that only those who are using the genuine material are allowed to use.

By insisting upon the use of the trade-mark "Bakelite", manufacturers are assured of molded parts of uniform quality, color and lustre. Through the use of this trade-mark the dealer is protected against imitation products, and the consumer may accept parts so marked with confidence in their genuineness.

Bakelite engineers and research laboratories are always ready to cooperate with radio manufacturers in adapting Bakelite to their own particular needs.

Write for Booklet 33

BAKELITE CORPORATION

247 Park Ave., New York, N. Y. Chicago Office: 636 W. 22nd St.
BAKELITE CORP. OF CANADA, LTD. 163 DUFFERIN ST., TORONTO, ONT.

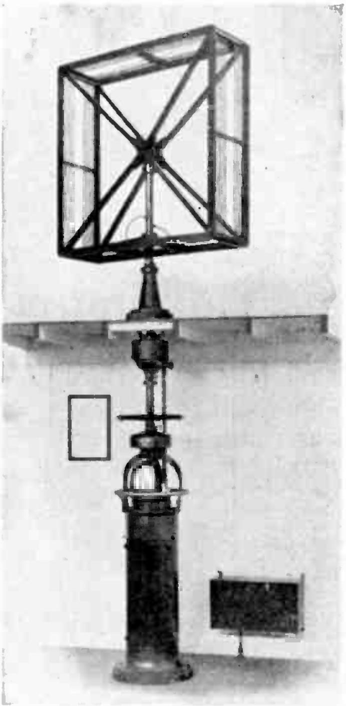
BAKELITE

REGISTERED U. S. PAT. OFF.

THE MATERIAL OF A THOUSAND USES

"The registered Trade Mark and Symbol shown above may be used only on products made from materials manufactured by Bakelite Corporation. Under the capital "B" is the numerical sign for infinity, or unlimited quantity. It symbolizes the infinite number of present and future uses of Bakelite Corporation's products."

RADIO SUPREMACY



This Kolster Radio Compass is an investment in safety of life and property at sea.

16 Years

of remarkable
radio
developments

Responsible for

—the development of the *continuous wave* arc converter for use on shipboard—

—the first successful commercial point-to-point radio telegraph system in the world—

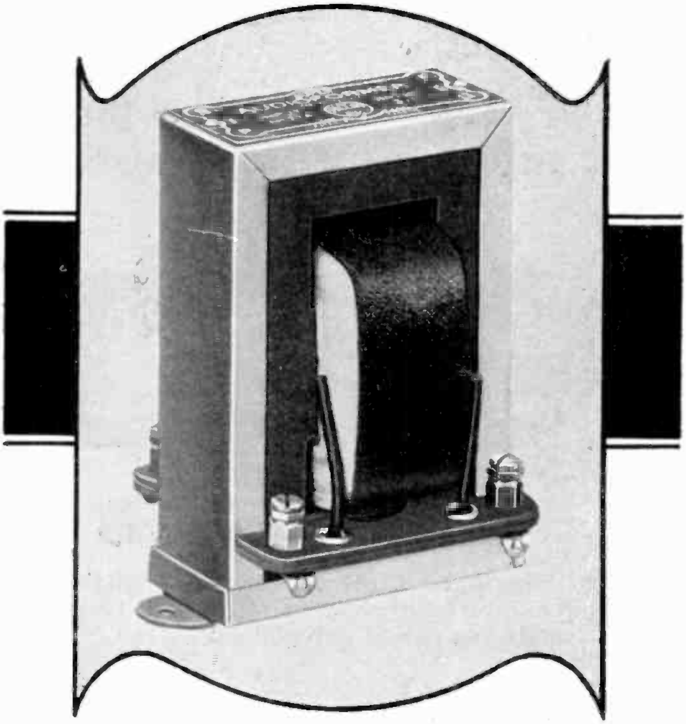
—the Kolster Radio Compass, the use of which permits the *safe* navigation of vessels during foggy or thick weather.

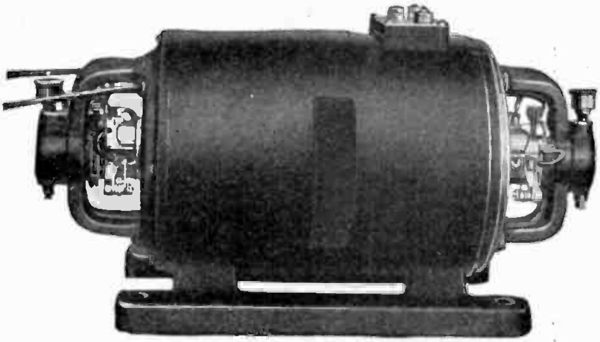
And most recently ---

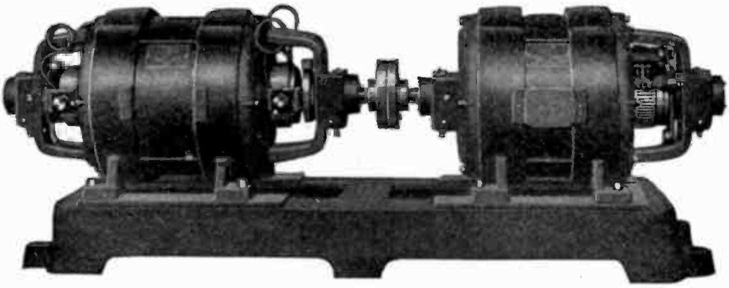
KOLSTER RADIO for the Home

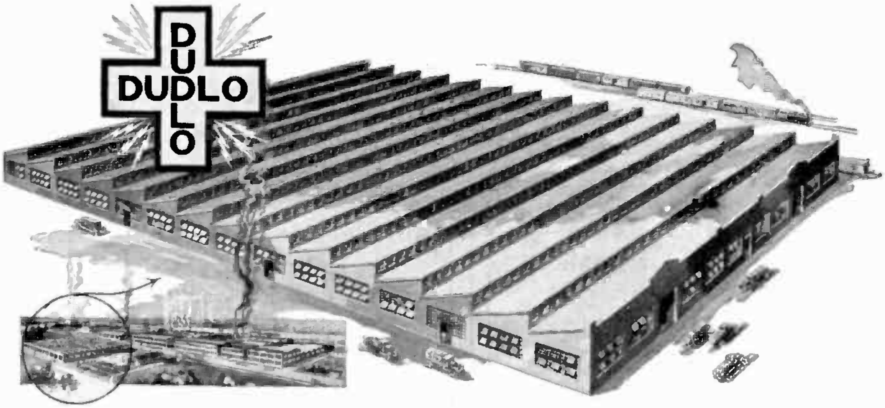
Engineers will be interested in the complete bulletins that are available upon request

FEDERAL TELEGRAPH COMPANY
SAN FRANCISCO
25 BEAVER STREET, NEW YORK CITY
Japan-China Representatives:
Sperry Gyroscope Co., Mitsui Building, Tokio









The circled part of the inset picture of all of the Dudlo Factories shows the new plant's location and relative size.

a NEW Wire Mill
a NEW Enameled Wire

New Method of Enameling---More Flexible---Greater Dielectric Strength---More Heat Resisting---More Enduring Better Looking

In the large and finely equipped new Wire plant, shown above, Dudlo Engineers are producing an improved enameled wire that sets a standard never before approached.

Dudlo special coated enameled wire now possesses an unheard of flexibility and elasticity.

It has greater dielectric strength, gives greater resistance to heat, is more enduring and better looking.

It can be bent without injury or cracking. High operating temperatures do not lessen its efficiency.

These qualities are due to the special Dudlo system of baking, improved materials and other new features of Dudlo development.

Dudlo enameled wire is made in sizes No. 10 to No. 44, American Wire Gauge.

One experience with Dudlo Enameled Wire will do more than anything else to explain to you why the world's leaders in the manufacture of electrical apparatus look to Dudlo as the unfailing source of supply of quality magnet wire and coils.

Dudlo Manufacturing Corporation, Fort Wayne, Indiana.

412 Chamber of Commerce Bldg.,
NEWARK, N. J.

160 North La Salle Street
CHICAGO, ILL.

4153 Bingham Ave.
ST. LOUIS, MO.

274 Brannan St.
SAN FRANCISCO, CALIFORNIA

PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in Radio and Allied Engineering Fields

The J. G. White Engineering Corporation

Engineers—Constructors

Builders of New York Radio Central

Industrial, Steam Power and Gas Plants, Steam and Electric Railroads, Transmission Systems.

43 Exchange Place New York

Electrical Testing Laboratories

Electrical, Photometrical, Chemical and Mechanical Laboratories

RADIO DEPARTMENT

80th St., and East End Ave.,
New York, N. Y.

Duskis Sales Company

Sales Entrepreneurs

Cable Address: RADIOPARTS
326 W. Madison St., Chicago, Ill.

Radio Engineers should consult us immediately regarding parts for set manufacturing, for popular and high-priced radio sets.

One of our factors builds radio Chassis (wired set minus cabinet) to order.

Do you get our bulletins?

WILLIAM W. HARPER

Consulting Engineer

CHICAGO

Research and design problems relative to improvements and cost reductions — production testing systems — development special research equipment — radio engineering service

161 EAST ERIE STREET
Telephone Superior 7614

John Minton I. G. Maloff

JOHN MINTON, Ph. D.

CONSULTING ENGINEER

for

Developing — Designing — Manufacturing

of

Radio Receivers, Amplifiers, Transformers, Rectifiers, Sound Recording and Reproducing apparatus.

Radio and Electro-Acoustical Laboratory

8 CHURCH ST. WHITE PLAINS, N. Y.

Engineers

Your card on this page will be seen by nearly 5000 readers — technical men, executives and others with important radio interests. Rate: Per year (12 issues) $30.00.

QRV
RADIO SERVICE, INC.

John S. Dunham, PRES. & TREAS.
J. F. B. Meacham, VICE-PRES. & SEC'Y

Service on Broadcast Receivers Exclusively

1400 BROADWAY NEW YORK

J. E. JENKINS & S. E. ADAIR

ENGINEERS

Broadcasting Equipment

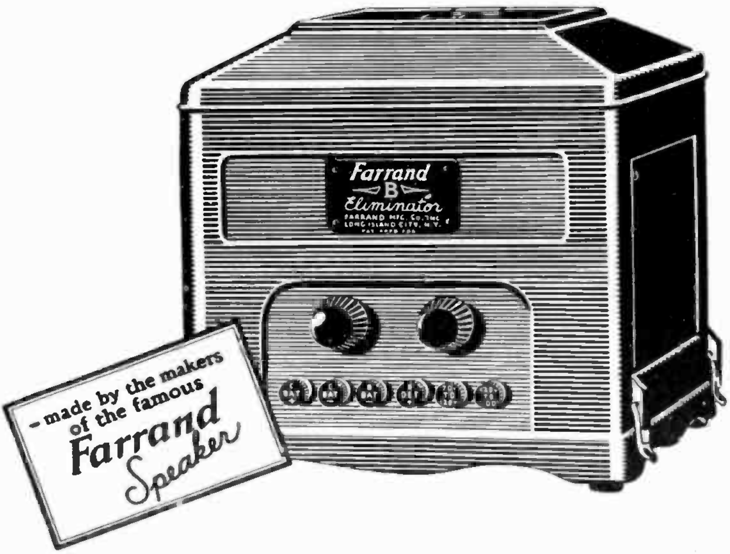
General Radio Telephone Engineering

1500 N. DEARBORN PARKWAY
CHICAGO, ILLINOIS

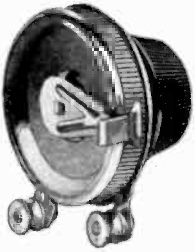
Farrand

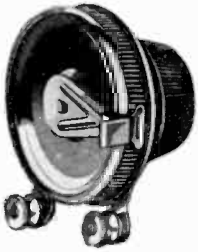
B

ELIMINATOR



KNOWN QUALITY





Centralab

CENTRAL RADIO CRL LABORATORIES

Rheostats

THESE Centralab Rheostats are designed and built to give accurate control of filament currents. They are a type which you can specify and recommend with perfect safety.

Centralab Rheostats always operate smoothly and noiselessly, for the resistance element is firmly clamped between insulated metal discs so that it cannot move or warp. Large metal area aids in dissipation of heat allowing more current carrying capacity.

Centralab Ribbon Wound Rheostats have an extra factor of safety for Heavy Duty Service.

YOUR PROBLEMS ARE OUR PROBLEMS

Send Your Specifications.

Wire Wound

Standard Wire Wound Rheostats have resistance values of 6, 10, 20 or 30 ohms and retail at $1.00.

Ribbon Wound

Standard Ribbon Wound Rheostats for Heavy Duty Service have resistance values of 2 or 3 ohms and retail at $1.25.

Central Radio Laboratories

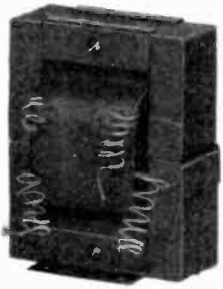
16 KEEFE AVENUE MILWAUKEE, WISCONSIN

Centralab Products are standard controls on sixty-nine makes of radio receivers.


HIGH
MED
LOW

--A new transformer with ideal performance!
---"B" *Eliminators that are proven!*

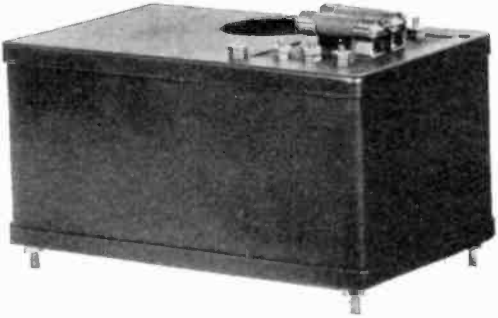
MODERN



Type M

We unqualifyingly pronounce this the finest audio transformer yet produced. The manufacturer striving to build the most perfect set possible is missing a big bet if he fails to test out his set using these transformers. 1st stage 3 to 1 Ratio, 2nd stage 4 to 1, output 1 to 1.

A response curve of the Type M Modern shows the same amplification at 30 cycles as at 3000 cycles, with a reduced amplification above 6400 cycles so that while the ordinary transformer over amplifies the high harmonics thus causing a hiss the Type M eliminates this undesirable reaction.



Modern "B" Eliminators

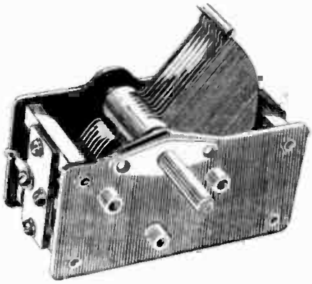
Modern "B" Battery eliminators are available for the set manufacturer in both the Raytheon and emission types, in the same high quality that made MODERN COMPACTS so efficient during the past season.

It is noteworthy that Modern "B" Compact went through the year with practically no returns or complaints.

As supplied to manufacturers MODERN eliminators are equipped with fixed resistances to meet the current requirements of the set, with no adjustment necessary by the operator.

The Modern Electric Mfg. Co. . . Toledo, Ohio

RADIO PARTS



In the swift development of Radio, Scovill engineers are blazing the trail of progress. Bring your problems to Scovill. Here are complete facilities for experimentation, exact manufacture and quantity output certain to strengthen your position in this highly competitive market.

A SCOVILL SERVICE

Scovill is the name of a broad service to industry. It places acres of factories, forests of machinery, hosts of skilled workmen, metallurgists, modern laboratories and trained representatives at the disposal of those who require parts or finished products of metal. Why not see how Scovill can serve you?

THESE ARE SCOVILL PRODUCTS

Made to Order: Condensers—Variable and Vernier and parts for same, Metal Stampings, Screw Machine Products, Switches, Decorated Metal Radio Panels, Parts from Brass, Steel and Aluminum. ***Carried in Stock:*** Butts and Hinges, Continuous Hinges, Machine Screws. ***Brass Mill Products:*** Sheet, rod, wire, tubing.

SCOVILL MANUFACTURING COMPANY
Waterbury Connecticut

New York, Boston, Chicago, Providence, Philadelphia, Cleveland, San Francisco, Los Angeles, Atlanta, Cincinnati

Stocks of Brass Mill Products at Waterbury, Providence, Chicago, San Francisco and Los Angeles.

Stocks of Cap Screws, Buttons and Fasteners at Waterbury and Chicago.

Member, Copper and Brass Research Association

Alphabetical Index to Advertisements

When writing the advertisers please mention The Proceedings of The Institute of Radio Engineers.


TOBE
AMER TRAN
POWER
PACK
1000 VOLTS D.C.

THE WHITLOCK PRESS, INC.
MIDDLETOWN, N. Y.