PRICE FIFTY CENTS

FM AND TELEVISION

OCT. 1946

PROGRESSIVE THINKING PAYS HIM DIVIDENDS

SEE PAGES 3 AND 36

N.A.B. Convention Issue

★ ★ Edited by Milton B. Sleeper ★ ★

THE 1-10A

The ONE-TEN-A is a complete redesign of the ONE-TEN, retaining all the proven design features of the older model but with improved performance and smoothness of control.

For many years the ONE-TEN has been the "standard" receiver for work in the range from one to ten meters. Although many advances in high frequency technique have been made since this little receiver was first introduced, it has easily held its place in the affections of experienced amateurs by its consistent dependability under actual operating conditions and its high usable sensitivity.

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The ONE-TEN-A is a fine receiver.

NATIONAL COMPANY, INC., MALDEN, MASS.

FM AND TELEVISION

FORMERLY: FM MAGAZINE and FM RADIO-ELECTRONICS

VOL. 6 | OCTOBER, 1946 | NO. 10

CONTENTS

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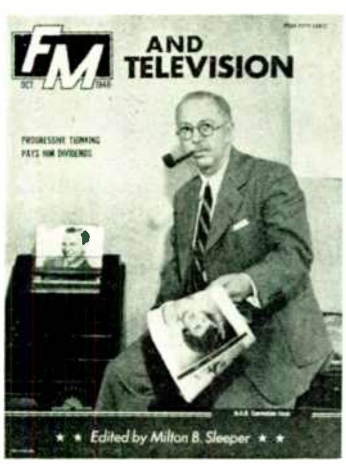
THIS MONTH'S COVER



"He made a success of broadcasting just by playing records." That has been said many times of John V. L. Hogan by those who think wishfully but not wisely about entering the FM field. It's true that John Hogan made a success of WQXR, and his station WQXQ may have the largest FM audience in New York City, but he didn't do this just by grinding out phonograph records. A top-ranking radio engineer long before he entered broadcasting, he succeeded in that venture by the use of an engineer's progressive, independent thinking. Disregarding methods of other stations, he chose the type of listeners he wanted, and consistently programmed WQXR-WQXQ to please them. Next step in his planning is to transmit facsimile by FM.

Entered as second-class matter, August 22, 1945, at the Post Office, Great Barrington, Mass., under the Act of March 3, 1879. Additional entry at the Post Office, Concord, N. H. Printed in the U. S. A.

MEMBER, AUDIT BUREAU OF CIRCULATIONS ABC

WHAT'S NEW THIS MONTH

1. Color Television
2. Is FM Expensive?
3. An Attainable Goal

1. CBS has now advanced their color television to the point of using live talent in place of the films shown in their first demonstrations, although wires are being used to connect the studios to receivers in the audition room.

When we received an invitation to witness a demonstration of live-talent color television, we decided that, rather than give our readers an engineer's reaction, we should publish a layman's report. Engineers inevitably have their pet peeves and enthusiasms which are reflected in their critical opinions. However, television's problem is to satisfy laymen, not engineers.

Accordingly, we asked Bill Mohrman, our advertising manager, to attend the CBS show, and to jot down his impressions immediately thereafter. The only instruction we gave him was to report on the matter of eye strain, and on any blur he might see when people moved across the screen. Here is his report, in his own words:

"There was no noticeable flicker when a white boy and a Negro boy sparred for a minute or two, and none was noticed when each one did some shadow boxing.

"However, if I concentrated on a certain part of the screen — say lower left hand corner — and then raised my eyes to the upper right or some other part of the screen, there was a flicker and also a jumble of colors. Or if I blinked naturally, there was also a jumble of color. Sometimes it would be a solid red or again it might be green. This also applies to close-ups.

"Colors were natural and, I think, despite what I said above, it is much better than Technicolor films.

"My eyes felt tired, and I believe this was caused by having to concentrate my gaze on a 10-in. screen. At times it seemed as if my eyes were being pulled.

"All details were good, even when people moved around. Facial expressions were good, particularly on close-ups.

"The actual demonstration lasted about 15 minutes, counting the time spent in moving the camera around the studio. — During that time the screen was dead.

"I hesitate to say how much I would pay for a television receiver. It would depend on the size of the screen. Personally,

(CONTINUED ON PAGE 78)

ADVERTISERS INDEX

about FM

Producing FM Home Receivers—NOW

Victrola*, Model 612V3... tunes in FM, AM, and short wave... separate built-in Magic Loop antenna for each band (plus provision for external single-wire or dipole antenna)... push-button tuning for AM or FM reception... FM receiver has tuned r-f amplifier ahead of first detector... second detector is of Seely ratio type providing low distortion and easy tuning... famous "Golden Throat" tone system... automatic record changer. A real sensation in beauty and performance.

8 FM MODELS—SIZABLE PRODUCTION

On July 15, at the NAMM Convention, in Chicago, RCA Victor's first postwar instrument for receiving FM . . . the Victrola* 612V3 (*above*)... was shown to an enthusiastic group of distributors.

This radio-phonograph is the forerunner of eight new models—all of which will incorporate RCA Victor's Advanced FM Circuit.

Initial instruments for demonstration to the public are expected to be on RCA Victor dealer floors during November.

Additional new RCA Victor FM receivers will reach full production early in 1947.

RCA Has Everything for FM—From transmitters right through to home receivers, broadcast stations can profit from the benefits of RCA's vast experience and latest developments in FM. If you are planning to build a new FM station, we believe that "RCA all the way" will help you to make it a *better* station. For further information write: Dept. 35-J, RCA, Camden, New Jersey.

*"Victrola"—T.M. Reg. U.S. Pat. Off.

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ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

In Canada: RCA VICTOR Company Limited, Montreal

FM station control

Accurate indication of station performance with the new G-E FM Station Monitor, simplified station control with the new G-E Control Console — here are important General Electric contributions designed to help keep your station performance at top efficiency. For the facts about these important units—call your G-E broadcast sales engineer or write to *Electronics Department, General Electric Company, Syracuse 1, N. Y.*

WITH THE NEW G-E FM STATION MONITOR TYPE BM-1-A

For your FM Carrier

G-E FM Station Monitor type BM-1-A

Better station operation begins with *accurate* measurements. General Electric, pioneer designer of FM monitors, announces the BM-1-A—the new FM monitor that meets *all* FCC requirements for measuring *all* FM transmitter functions.

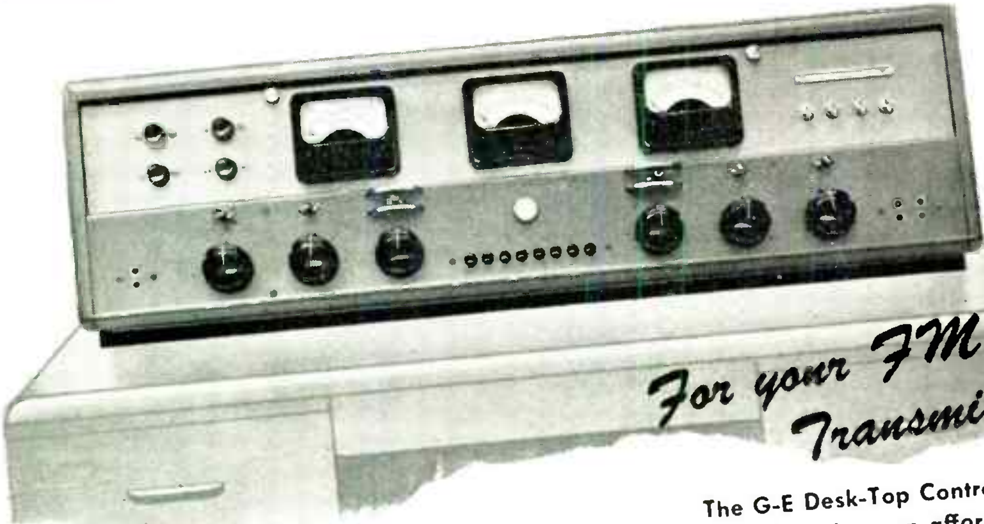
- **Center frequency indicator.** Direct-reading instrument measures carrier frequency over ±3000 c-p-s range, with or without modulation.
- **Modulation indicator.** Two-scale, direct-reading instrument shows frequency swing. Percentage scale, 0 to 133 percent. Decibel scale, −20 to +3 db range.
- **High-fidelity audio monitor.** Two volts output into 600-ohm balanced line. Frequency characteristic follows standard de-emphasis curve within ±0.5 db between 50 and 15,000 cps.
- **Over-modulation flasher.** Front panel control adjustable to indicate peaks exceeding any value between 50 and 120 per cent modulation.
- **Transmitter "proof-of-performance".** 20-volt high impedance audio output with less than 0.25 per cent distortion and noise level approximately 75 db below full modulation level. Will operate commercial distortion meters for FCC tests.
- **R-f input level indicator.** Approximately 1.0 watt in 50-ohm line, with indicator to show correct level.
- **Illuminated meter scales.**
- **Easy-to-get-at.** Hinged front panel provides ready accessibility.
- **Ready to operate.** Connect it to your transmitter. Plug it into your 115-volt, a-c line.
- **FCC approved.**

STUDIO AND STATION EQUIPMENT • TRANSMITTERS

GENERAL ELECTRIC

160-E10-8914

at a glance!



For your FM or AM Transmitter

The G-E Desk-Top Control Console that *every* station can afford, type BC-3-A

WITH THE NEW G-E DESK-TOP CONTROL CONSOLE TYPE BC-3-A

Flexible and compact, equipped with every mixing and switching facility required by the modern broadcast station—FM or AM—the new G-E Control Console centralizes all major station functions under instantaneous finger-tip control.

- Control provisions for 2 local turntables and 2 microphones.
- Mixer circuits connect either microphone with either turntable.
- 8-position, push-button control for audio monitoring.
- Illuminated VU meter.
- Jacks for (1) "proof-of performance runs", (2) transfer-line switching to control-room rack, and (3) routine a-f measurements.
- Line transfer switch makes it possible to use telephone line for order wire service—*without equalization.*
- Monitor amplifier and speaker transfer switch.
- Master gain control in 0.5-db steps.
- Input connections for two audio lines.
- 4 heavy-duty switches for tower lights, sleet melters, lightning trip circuits, carrier alarm, etc.
- High degree of flexibility to meet operational requirements. Accessible terminal board.
- Two-tone, blue-gray cabinet with sloping panel, only 12 inches high, 40 inches long.
- Full visibility of controls and transmitter.
- Easy-to-get-at. Designed with piano-hinged front panel.
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Have you placed your order yet?

G-E High-Fidelity Audio Facilities

Write for the complete data on General Electric's new line of quality speech—input units—pre-amplifiers, program amplifiers, line and isolation amplifiers, monitoring amplifiers, monitoring loudspeakers. De luxe in performance and appearance. Flexible, convenient, reliable. Yet at a price *every* station can afford.

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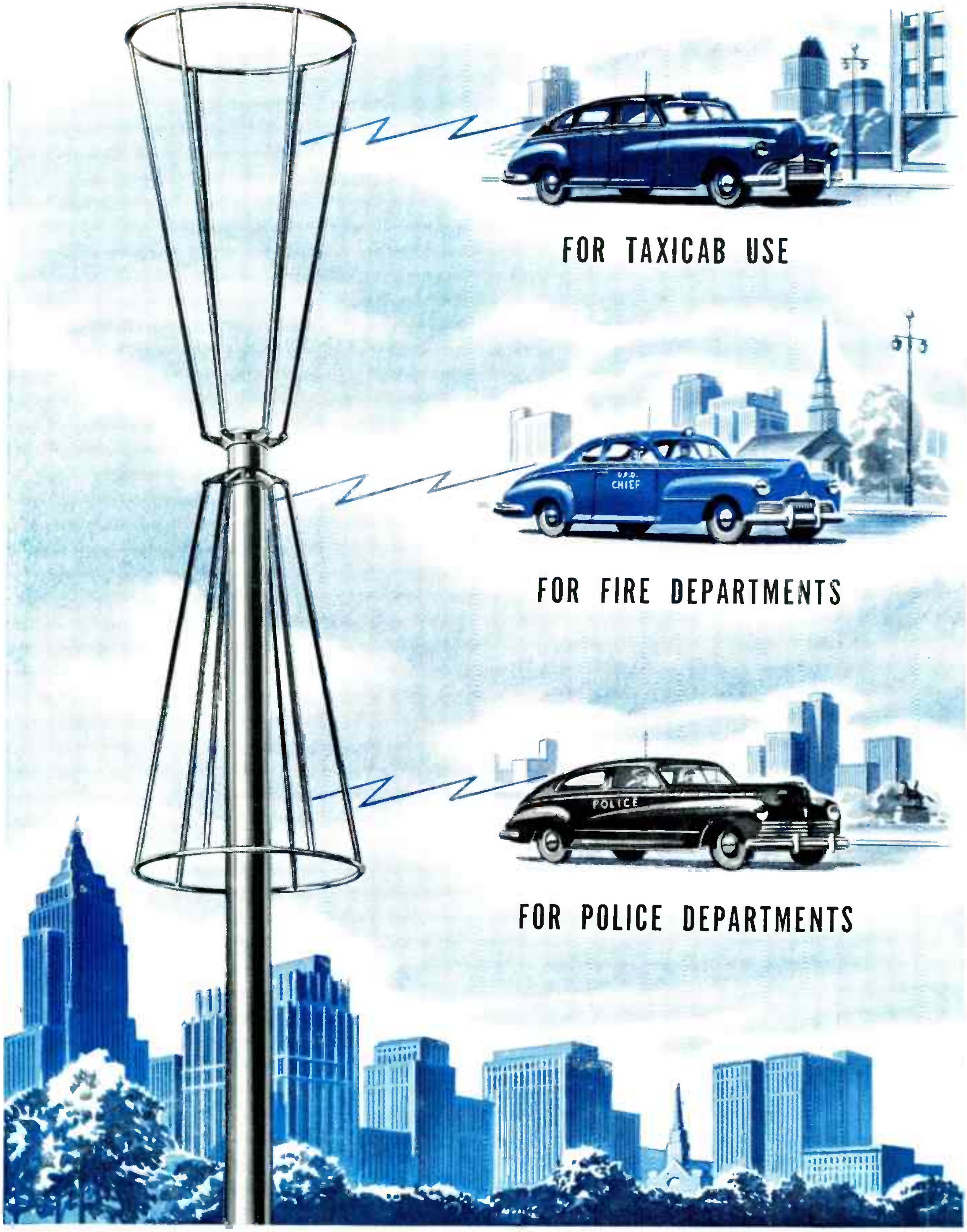

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BENDIX AVIATION CORPORATION
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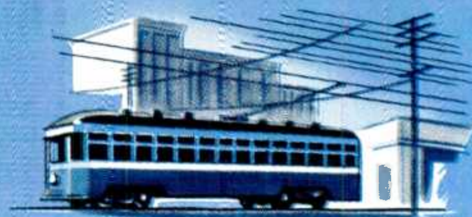

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Decatur 1234

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Consulting Radio Engineers
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MEtropolitan 4477

ANDREW CO.
Consulting Radio Engineers
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Triangle 4400

MAY & BOND
CONSULTING RADIO ENGINEERS
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Kellogg Building Republic 3984

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Consulting Radio Engineers
Earle Building
NATIONAL 6513
Washington 4, D. C.

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National Association of Broadcasters

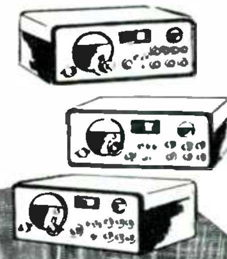
CHICAGO CONFERENCE, OCT. 21-24, 1946

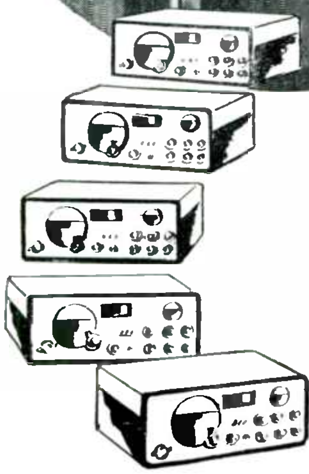
Directory of Exhibitors, Palmer House, 8th Floor

Amperex Electronic Corporation	860
Andrew Company	827
Associated Program Service, Inc.	810-811
Audio Devices, Inc.	816
Broadcasting Magazine	884-886
Broadcast Measurement Bureau, Inc.	804
Capitol Transcriptions, Inc.	842
Collins Radio Company	812-813
Daven Company	858
Fairchild Camera and Instrument Corp.	862
Featured Radio Programs, Inc.	817-818
Federal Telephone and Radio Corp.	847
FM and Television Magazine	881
Gates Radio Company	838
Goodman Radio Productions	834-835
Graybar Electric Co.	852-854
Hart & Co., Inc., Frederick	840-841
Kasper-Gordon, Inc.	804
Keystone Broadcasting System, Inc.	805
Langevin Company, Inc.	843-844
Lang-Worth Feature Programs, Inc.	882-883
MacGregor Electrical Transcriptions	826
Magnecord, Inc.	850
Matchlett Laboratories, Inc.	820
Mutual Broadcasting System	859
NAB Sales Managers Committee	875
NAB Small Market Stations Committee	865
NAB Staff Headquarters	807-809
National Broadcasting Co. (Radio Recording Dept.)	822-824
Neblett Radio Productions	876-877
Presto Recording Corporation	815
Program Buys	857
Radio Corporation of America	879-880
Radio Engineering Laboratories, Inc.	824
Radio-Television News	887
Raytheon Manufacturing Company	806
Rek-O-Kut Company	856
Sesac, Inc.	814
Sponsor Publications, Inc.	851
Standard Radio Transcription Services, Inc.	831-833
Sterling Insurance Company	839
Teleways Radio Productions, Inc.	861
Transcription Sales, Inc.	848-849
United States Recording Company	836
Universal Radio Productions	819
Universal Recording	878
Western Electric Company	852-854
Wilson, Herbert L.	825
Wincharger Corporation	802-803
World Broadcasting System, Inc.	864
Ziv Company, Frederic W.	828-829

THERE WILL BE ADDITIONAL EQUIPMENT EXHIBITS ON THE 4th FLOOR

As requested by the NAB Conference Committee, exhibits will be closed during the hours when meetings are in session





ALL-INDUSTRY FM ASSOCIATION IS PROPOSED

Views of Progressive FM Broadcasters and Set Manufacturers Favor an Association to Coördinate Plans for Better Home Radio Reception

BY MILTON B. SLEEPER

LATEST angle on proposals for a new association of FM broadcasters, discussed in the July and August issues of *FM* AND TELEVISION, brings up an entirely new slant on an all-industry organization. Here is the gist of the current thinking:

All-Industry Association ★ Until the advent of FM, plans and activities of the broadcasters and the equipment manufacturers were worked out as independently as if they were completely unrelated operations in totally different fields.

Now, as new FM stations are going on the air, the operators are suddenly faced with the need of having the coöperation of set manufacturers for, unless sets are shipped into their service areas, they cannot build audiences.

Moreover, the FM broadcasters have awakened to the fact that unless the sets deliver satisfactory performance, audience-building efforts will be stopped off before they start. A flood of FM sets giving reception at the AM performance level could do irreparable harm to a new FM station.

On the other hand, FM set manufacturers want to be sure that programs do justice to the capabilities of the receivers. They are also concerned about the extent of each station's service area, for that defines the territory in which sales should be made.

Thus, for the first time, it has been brought home to broadcasters and manufacturers alike that FM has given them the common responsibility for assuring genuine, high-quality FM reception in each listener's home. The extension of this thinking is that a joint association can do more to protect and promote the interests of FM broadcasters than NAB, and more for the manufacturers than RMA.

This new angle was brought up in discussions of an association of independent FM broadcasters, to which AM stations with FM affiliates and equipment manufacturers would be admitted only as non-voting associates. Opinions on this subject first favored the admission as voting members of AM stations that are going all out to promote their expansion into FM. Then the idea developed into plans for an all-industry association, to be directed by a board comprised of both broadcasters and manufacturers.

Such a setup would answer Walter Damm's objection[1] that an association of independent FM broadcasters would not have sufficient income to build an effective organization.

Organization Plans ★ With the NAB Conference opening in Chicago on October 21st, it has seemed advisable to postpone action on definite organization plans until there is time to see what will be done by NAB or by the remaining members of FM Broadcasters, Inc.

At this time of writing, it seems probable that executives of representative broadcasters and manufacturers will meet in November to draft tentative plans for an all-industry association, dedicated to raising the overall standards of home radio reception. The preliminary draft will then be submitted to a selected list, with invitations to attend a meeting at which formal action can be taken.

One very interesting proposal is that the work of the association should be in the hands of a board of directors comprising an equal number of broadcasting and manufacturing executives, with the president acting to correlate and coördinate the efforts of the bilateral board. Mentioned for the post of president are Gordon Grey, John V. L. Hogan, and Wayne Coy. Feeling so far expressed indicates preference for a man of wide experience within the industry, and in broadcasting rather than manufacturing.

NAB Situation ★ Although anything can happen at the NAB Conference in Chicago, some very drastic policy changes, calling for a virtual reorganization of this conservative association, would be required to meet the new conditions which face the broadcasters and the manufacturers. Postwar changes are not due to the advent of FM and facsimile alone for the roots of most industry problems reach back to the unorganized beginnings of broadcasting, following the first world war.

It is not so many years ago that sales of records and phonographs had almost ceased, because AM broadcasting met the demand for home entertainment. But the radio art, as well as public taste, were in a state of flux then, as they are now, and will be for years to come, until radio reaches the boundaries of technical advancement, as is the case with the theatre and motion pictures.

Consequently, the NAB, now constituted as guardian of the status quo, has set a limit on the progress of radio broadcasting, if not purposely, then by its failure to act in public interest to promote the expansion of FM and facsimile.[2]

So far, NAB has side-stepped these issues by ignoring them. Its action in taking over FMBI amounted to nothing more than burying an organization that had proved highly effective in setting up FM broadcasting. With FMBI tucked under its wing, NAB proceeded to reduce it to a few paragraphs in its weekly reprint of FCC reports. For this service, FM broadcasters were asked to pay $50 a year! To the dynamic and volatile radio industry, the NAB gives the outward appearance of a setting hen warming a nestful of unfertile eggs. All this may be changed at the Chicago Conference, but there is no outward manifestation of such intention at this time of writing.

RMA Situation ★ The Radio Manufacturers Association had every reason for heading up the swing to FM and, to implement such action, setting up a board to cooperate with the FM broadcasters. The reasons are all in the interests of the set and components manufacturers. They are, briefly:

1. FM sets are more profitable to produce and sell because the unit price is very much higher. This increased profit can be handed down the line to distributors, dealers, and servicemen.

2. By stabilizing prices, as has been done in the automobile industry, a second-hand market can be created for FM sets, to take care of listeners who cannot afford new, expensive models.

3. FM sets require components of higher quality than are used in AM table models. This means an increase volume of business in more profitable items.

4. The swing to FM will give listeners greatly improved service, and this must, inevitably, benefit the entire industry.

Mention of higher sales units brings up the question: Is it right and sound to increase the prices of radio sets to the public? The facts speak for themselves. The public has not gained in quality of service since 1929, when the average unit of sale was $175. Reception performance has been degraded as AM set prices were

[1] See *FM* AND TELEVISION, August, 1946, page 28.

[2] Reference is not made to television because this is an entirely separate development, well represented by associations of television broadcasters, engineers, and producers.

lowered. FM receivers will step up prices to the 1929 level, but they will deliver reception far above the performance levels of that period — despite subsequent increases in production costs.

And that is only half the story. The other half concerns the fact that, on the whole, radio set manufacturing had become, at the time of Pearl Harbor, an impoverished business. If we are to judge from financial statements for the first half of 1946, that condition is getting worse.

Yet the president of RMA announced recently, with considerable enthusiasm, that the industry's capacity seems to be 25 million sets a year instead of 13 to 14 million, as estimated originally. What RMA figures do not show is dollar volume. On that basis, the industry's postwar record stinks. And so do postwar AM receivers, in their performance and their intrinsic value. Why RMA has consistently concealed this industry situation by releasing only figures which misrepresent the true conditions has not been explained.

Against this situation, we can measure RMA's attitude toward FM-AM sets by its president's statement: "FM station operators who are advising listeners not to buy any radio receiver that does not have FM reception are doing the industry and the dealers no good."

In reply, one might ask: "How are the people going to feel toward dealers and manufacturers when, within the next few months, they have a chance to compare their new and very poorly-built AM sets with what they could hear on FM if they had waited just a little longer?" Already, in areas where FM set deliveries have been concentrated, dealers are trying to talk themselves out of that situation.

Perhaps RMA will suddenly do an about face, but right now that seems unlikely. As matters stand, RMA is not only fumbling the FM ball but is, in consequence, overlooking the new-business possibilities of FM-operated facsimile, despite the fact that a considerable number of broadcasters are keenly interested in getting it started.

The Job to Be Done ★ If it is true that both broadcasters and set manufacturers will benefit by raising the quality of home radio reception, it is also true that this is an all-industry undertaking, calling for carefully integrated efforts by all groups concerned.

In other words, it must be recognized that broadcast stations and home receivers are parts of the same circuit, and that the task of raising the level of radio service to the public calls for coördinated effort at both the output and the input ends.

From those who are interested in forming an all-industry association, we have collected suggestions as to matters of common interest to broadcasters and manufacturers, on which an all-industry association could take constructive action. They are set forth separately on this page. Because the idea of working together is a new angle to broadcasters and set manufacturers, these suggestions deserve the most careful consideration.

Of course, it is possible that an all-industry association, whatever its potential usefulness, cannot be set up. The radio business was built by rugged individualists of widely varying and sometimes opposing interests. On the other hand, the industry has passed the age of adolescence, and if it does not accept the responsibilities of maturity, the retrogression of AM radio service which had set in before Pearl Harbor will continue in the postwar period.

This much is clear: The shift to FM is under way. Having overcome every opposition to its establishment, nothing can stop FM now. The change may come slowly and painfully, in which case it will be costly. Or it may be worked out as a natural transition from the old to the new, and from what was good enough to launch the industry, to what is required to put it on a firm and stable basis, expanded in usefulness to a degree which the pioneers could not have foreseen 25 years ago.

If that is to be the case, no time should be lost in setting up an all-industry organization to ease and implement the shift from AM to FM, and to protect broadcasters, manufacturers, and the public from losses which all will suffer if battle lines are drawn between AM interests that would maintain the status quo, and the progressive proponents of FM.

There are still some very important figures in the industry who refuse to budge from the AM positions they have taken up, but they are only fighting a rear guard action in the face of certain, ultimate defeat. This recalls the old political axiom: If you can't lick your opponent, it's best to join him.

PROGRAM FOR AN ALL-INDUSTRY FM ASSOCIATION

The following suggestions have been offered as to ways in which FM broadcasters and set manufacturers can work together to further their common interests. These points constitute a tentative program for an All-Industry FM Association:

1. Plan for FM set production and deliveries to assure the availability of receivers in each area served by FM broadcasting.
2. Work out FM promotion which can be used in any area by broadcasters, and manufacturers, distributors, and dealers to assure maximum effectiveness. These would cover coöperative demonstrations of all kinds.
3. Plan methods whereby broadcasters and manufacturers can work together to educate distributors, dealers, and servicemen in the problems of demonstrating, installing, and servicing FM sets, to assure satisfactory performance.
4. Set up standards of FM performance as to fidelity and sensitivity, to protect purchasers against misrepresentation and substandard reception.
5. Explore the problems and possibilities of facsimile as an added public service, a means of additional revenue for broadcasters, and a new market for manufacturers. Also, consider methods of multiplexing sound and facsimile, and system standards.
6. Represent the industry before the FCC in matters pertaining to engineering standards and regulations.
7. Hold an annual conference for this discussion of program, operation, engineering, and policy problems.
8. Organize seminars for advertising executives and program directors, with discussions and demonstrations of FM program techniques.
9. Look into methods of 15,000-cycle FM program distribution by wire or relay systems, or by the use of recordings.
10. Finally, act as a clearing house for the exchange of information among FM broadcasters, set manufacturers, and contributing services, for the purpose of improving the standards of service rendered to radio listeners.

FM IN ENGLAND

Because of interference from European stations on the broadcast bands, the British Broadcasting Company has made exhaustive tests on FM, both at 45 and 90 mc. The complete text of their report and conclusions will be published in the November issue of *FM* and TELEVISION. Great significance attaches to this report, for it confirms in detail the advantages of FM which have been claimed for it by its proponents in the United States.

This investigation, it is expected, will mark the spread of FM broadcasting to other countries.

IMPORTANT MEETINGS AHEAD

National Association of Broadcasters
October 21–24, Palmer House, Chicago

FM Broadcasters, Inc.
October 22, Palmer House, Chicago

Associated Police Communications Officers
October 28–30, Hotel Statler, Buffalo
Chairman, Lawrence Geno, Police Department, Buffalo, N. Y.

Rochester Fall Meeting, IRE
November 11–13 Sheraton Hotel, Rochester, N. Y.

Association of American Railroads
Annual Communications Section Meeting, November 19–21, Hotel Statler, Detroit. Chairman, A. S. Hunt, 30 Vesey Street, New York 7, N. Y.

Winter Technical Meeting, IRE
March 3–7, 34th St. Armory. Chairman, Dr. James E. Shepherd, 330 W. 42nd Street, New York City

DYNAMIC NOISE SUPPRESSOR FOR RECORDINGS

A Development in Noise Suppression Employing Dynamic Bandwidth Control

BY H. H. SCOTT*

FIG. 2. THE AUTHOR WITH A DYNAMIC NOISE SUPPRESSOR SET UP TO WORK WITH TRANSCRIPTIONS AT WEEI

ONE of the world's most important cultural treasures is the vast library of recorded music, including definitive performances of all of the greatest compositions. All classical and modern composers are represented, and the artists and orchestras include the most famous names of the past two decades. There are recordings of symphonies, operas, and other extended musical works performed in their entirety, and much of the modern and popular music conducted or performed by the composer himself or by the artist who made it famous.

Noise Is Limiting Factor ★ This library of recorded music is available at low cost to every broadcast station and to every phonograph owner, and the number of selections is so large that the listener need never be bored by too frequent repetition. The standard of the music and the standing of the artists are so high as to require no apology from any program director. In the past, however, the use of phonograph records has always been characterized by the presence of annoying background noise which could be reduced only at the sacrifice of fidelity of reproduction, and which has become increasingly objectionable as transmitters and receivers have been improved.

Particularly FM, with its inherent capabilities of combining high fidelity with low noise level, has placed recorded music at a serious disadvantage. Many FM stations are local in character and have to rely upon recorded material for a large percentage of their program time, and yet, with common methods of utilizing such material, the results in terms of fidelity and noise level are far below the standard expected of FM systems. Furthermore, in the home, the ordinary FM-AM radio-phonograph combination provides a tremendous contrast between the fidelity and quietness of live talent FM reception and the ordinary reproduction of phonograph records.

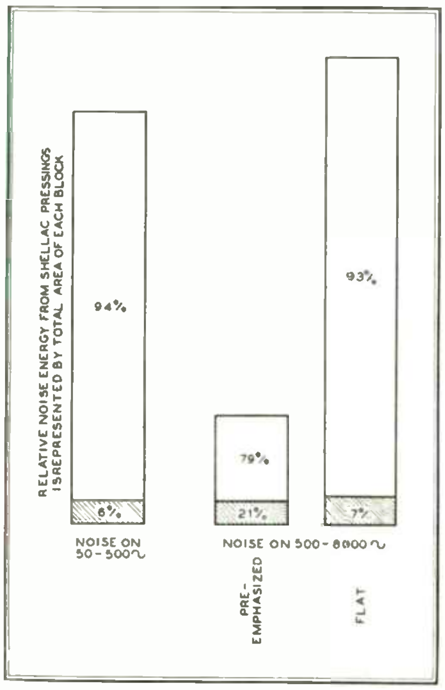


FIG. 1. EXTENT OF NOISE SUPPRESSION

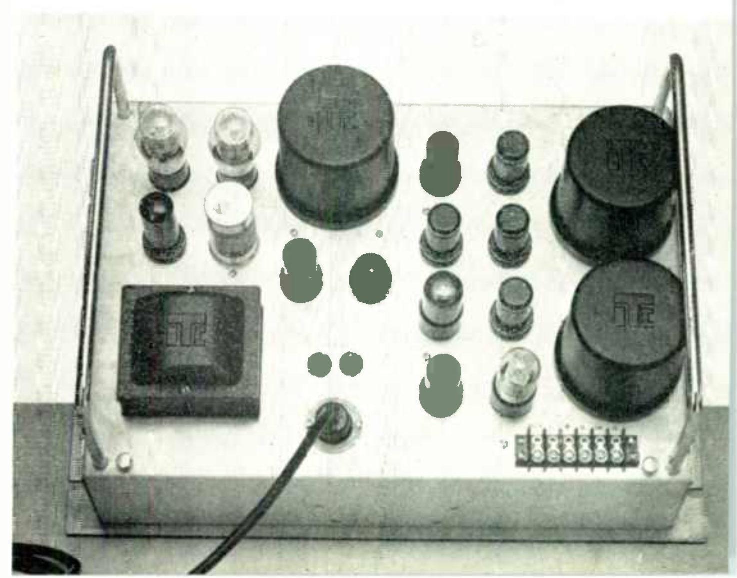
The Dynamic Noise Suppressor ★ Recent developments have made possible a distinct improvement in the reproduction of music from phonograph records, allowing practical utilization of the complete frequency range engraved upon the records, with a lower background noise than has heretofore been possible, even in systems of severely restricted response characteristics. The Dynamic Noise Suppressor developed by Technology Instrument Corporation, represents the results of an extended investigation and development program expressed in circuits that are relatively simple and can be adapted to many commercial applications.

The method of operation of the dynamic noise suppressor is based upon a practical electronic application of fundamental principles of acoustics and physiology. The threshold of hearing for the normal ear, that is, the lowest-level sound which can be heard, varies with frequency, with the result that the normal human being can hear extremely low and high frequency tones only at fairly high intensity levels. The ability of the ear to hear a given musical tone or overtone depends, therefore, upon its frequency and loudness. The orchestra or other source of music generates air vibrations which vary in frequency and amplitude, depending upon the type of instrument, the type of

(CONTINUED ON PAGE 60)

* President, Technology Instrument Corporation, 1058 Main Street, Waltham 54, Mass.

FIGS. 3 AND 4. FRONT AND REAR VIEWS OF THE DEVICE WHICH EMPLOYS DYNAMIC BANDWIDTH CONTROL TO REDUCE NEEDLESS NOISES



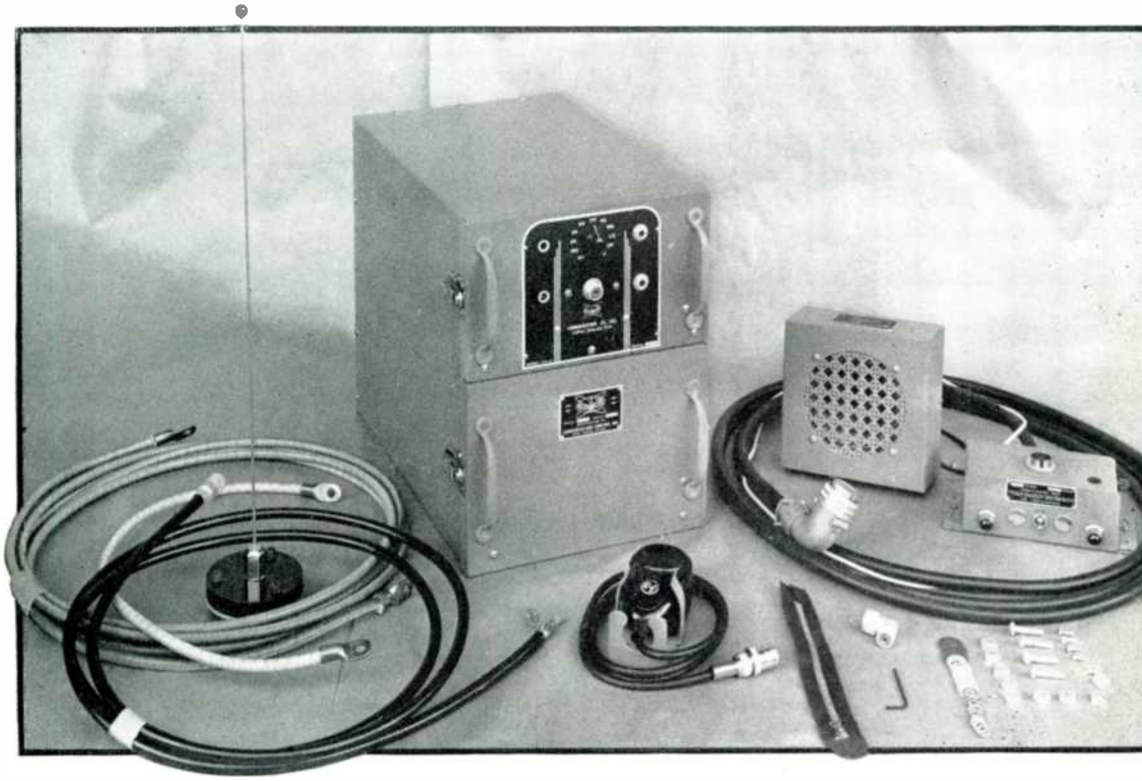


FIG. 1. THE FM COMMUNICATIONS UNIT AND THE COMPLETE COMPONENTS FOR A CAR INSTALLATION

NEW EQUIPMENT FOR MOBILE SERVICES

Units Developed by Comco Take Advantage of Operation at 152 to 162 Mc.

BY DONALD E. ANDERSEN*

FOR nearly two years, Communications Company, Inc. has been producing FM railroad radio equipment [1] for the 152- to 162-mc. band. Now we have developed and are delivering mobile units for the new band which are designed around the special needs of taxi, transportation, and police systems. In addition, we have simplified the installation of the equipment by working out a standard group of associated components, Fig. 1, which can be put into any kind of car or truck with the minimum of cutting and fitting.

The transmitter-receiver chassis and the power supply chassis are separate, as Fig. 1 shows, but they lock into a single steel case occupying only 1.1 cu. ft. The power supply, Fig. 2, fits in at the bottom, while the transmitter-receiver, Fig. 5, goes at the top.

From the point of view of service, we have found this separation to be the most practical. Also, in anticipation of an increasing demand for selective calling, we have allowed ample space for the relay assembly on the power supply chassis.

Fig. 3 gives a block diagram of the transmitter. The crystal-controlled oscillator section of the 3A5 tube supplies RF voltage to the 2E25 balanced modulator grids. The plates of the modulator tubes are connected in parallel, and the output circuit is tuned to that of the crystal. The output of the audio section of the 3A5 is fed to the modulator grid, through a network. It will be seen that the AF voltage so impressed on the grids causes a relative phase shift in the output frequency of the modulators.

The next three stages, using 2E25 tubes, produce an overall frequency multiplica-

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[1] See "100- to 165-Mc. Mobile Units, by G. A. Leap, *FM* AND TELEVISION, May, 1945, and "Progress Report on Railroad FM" by Arnold C. Nygren, *FM* AND TELEVISION, December, 1945.

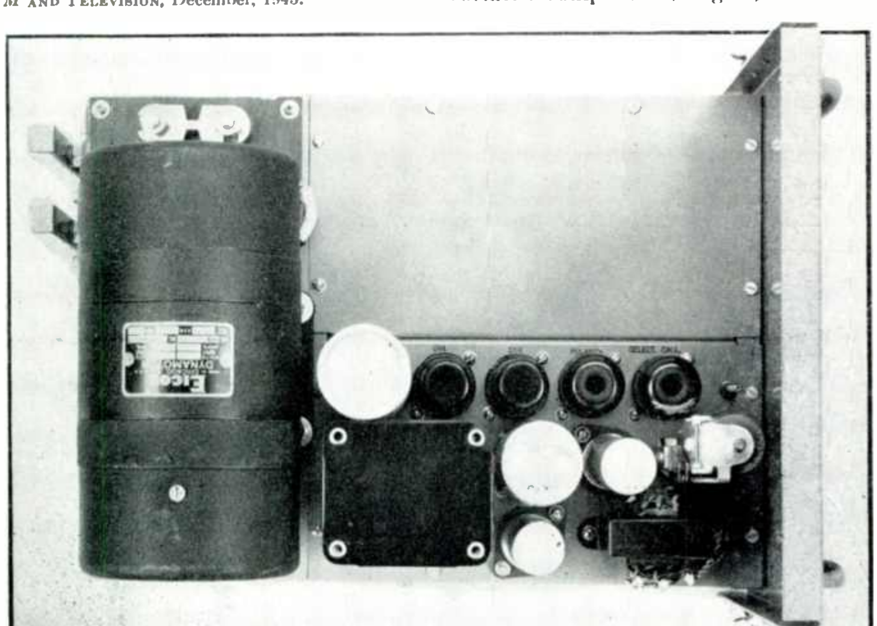


FIG. 2. TOP VIEW OF THE POWER SUPPLY

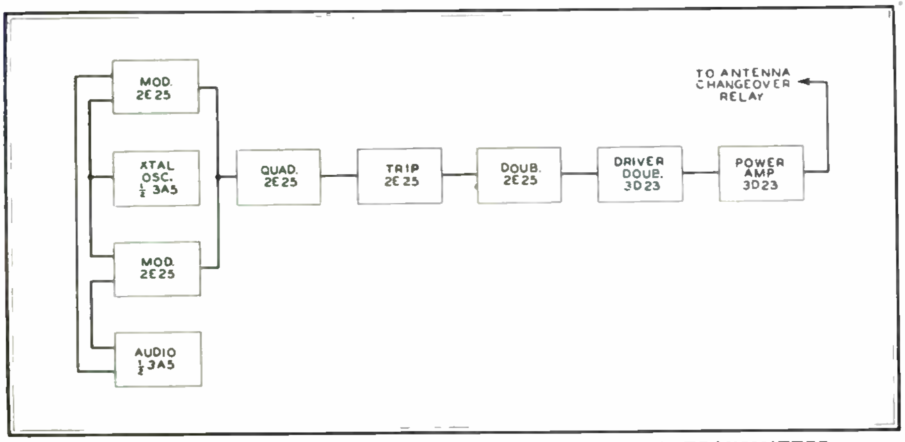


FIG. 3. BLOCK DIAGRAM OF THE 15-WATT 152- TO 162-MC. TRANSMITTER

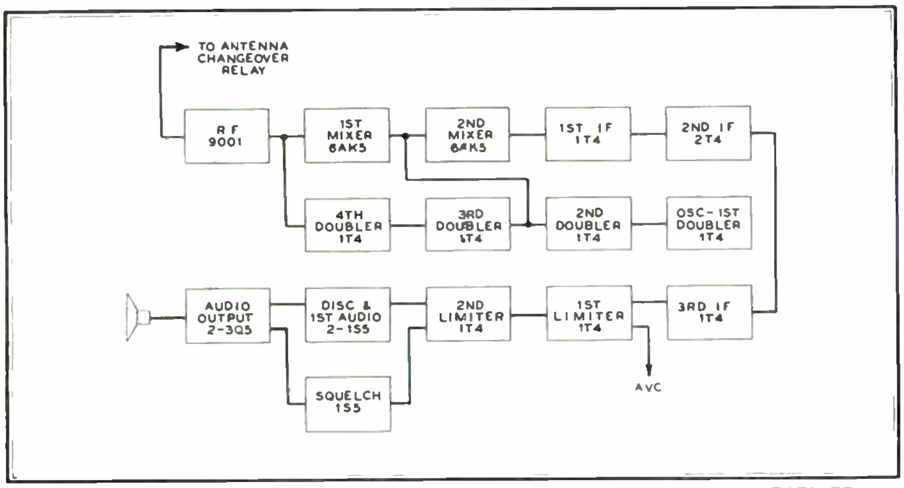


FIG. 4. THIS DIAGRAM SHOWS INTERESTING REFINEMENTS IN THE RECEIVER

tion of 24 times. The next stage, a 3D23 driver, also doubles the frequency and provides excitation to the final 3D23 power amplifier. This stage, delivering 15 watts output, connects to the antenna through a transmit-receive relay.

Meter shunt resistors are connected in the grid returns of the various stages and, with a selector switch, permit the use of a single meter for checking grid drive and the tuning of all circuits except the antenna.

Fig. 4 shows the block diagram of the receiver. The amplified signal from the 9001 RF stage is impressed on the first mixer, using a 6AK5. Proper injection voltage is obtained from the 1T4 fourth doubler stage at a frequency 16 times that of the 1T4 crystal oscillator. The output from the first mixer is coupled to the second 6AK5 mixer, which obtains its injection voltage from the second doubler.

The crystal frequency for a particular signal frequency, and the values of IF frequencies are found as follows:

$$IF_1 = 4f_x - 4.32 \text{ mc.}$$

also $$IF_1 = f_s - 16f_x$$

then $$f_x = \frac{f_s + 4.32}{20} \text{ mc.}$$

where f_x = crystal frequency
f_s = signal frequency
IF = first IF
4.32 mc. = second IF

Output from the second mixer is amplified through 3 IF stages, using 1T4 tubes. The third IF stage is coupled to the first 1T4 limiter, from which point is obtained AVC voltage to apply to the 2 mixer and 3 IF stages. Overall gain from the antenna to the first limiter grid is sufficient to provide saturation of the grid by the internal set noise.

The second limiter is transformer-coupled to the diode plates of the two 1S5 tubes. The pentode sections of these tubes serve as push pull amplifiers for the out-of-phase audio voltage developed across the diode load resistors. Two 3Q5 tubes serve in the push-pull AF output.

The squelch circuit is of the noise-operated type. In the absence of a signal, the limiters are saturated by set noise, and considerable AF noise voltage is developed in the plate circuit of the second limiter tube. This noise voltage is coupled through a high-pass filter to the grid of the 1S5 squelch tube. This filter removes the audio components below 12,000 cycles, preventing the possibility of carrier modulation tripping the squelch. After amplification by the pentode section of the 1S5 squelch tube, the noise voltage is applied to the 1S5 diode. The negative voltage developed across the diode load resistor is used to bias the push-pull 3Q5 AF tubes nearly to cutoff.

A signal of sufficient strength to override the noise level causes the noise voltage from the second limiter to disappear. Thus the cutoff bias is removed, and the 3Q5 tubes are restored to normal bias and operating conditions. Positive squelch is further obtained by means of a relay in the plate and screen supply circuit of the 3Q5 tubes. It operates when the bias is applied from the squelch circuit. In the squelched condition, the relay is open, and the contacts short the speaker voice coil to ground. When a signal is received, the relay is closed and, in addition to removing the ground from the voice coil, it

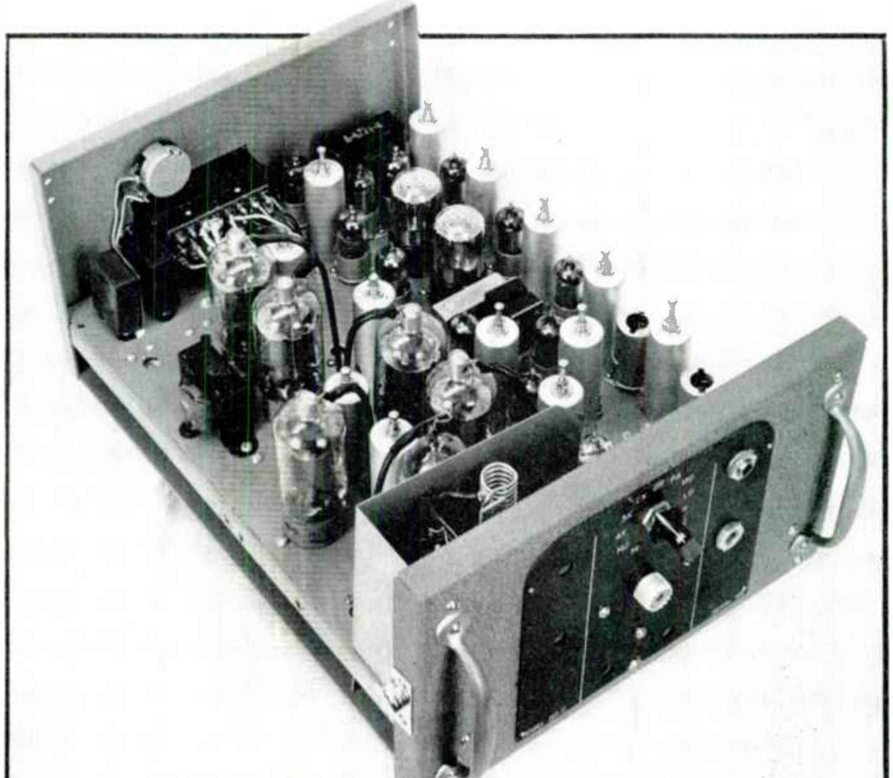


FIG. 5. TRANSMITTER-RECEIVER CHASSIS

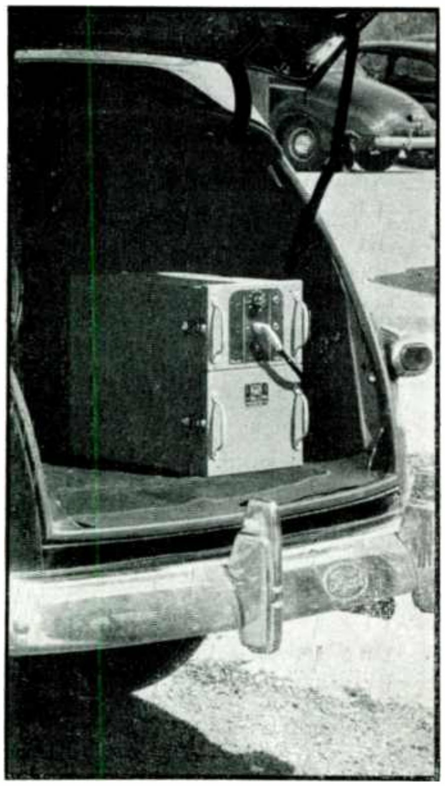


FIG. 6. TYPICAL CAR INSTALLATION

closes the circuit to a red indicator lamp on the control panel.

Since quick-heater tubes are used, the battery drain is zero in standby position and 58 amperes when transmitting. Receiver drain is 3.8 amperes on standby and 4.2 when signals are being received. Audio output is .7 watt.

42 TO 44 AND 72 TO 76 MC.

ON July 19th, the FCC announced allocations for various services in the bands from 42.02 to 43.98 mc. and from 72.02 to 75.98 mc. These are shown in the accompanying tables. The assignments in both bands are predicated on the initial use of channels 40 kc. wide.

According to the FCC announcement concerning allocations for 42 to 44 mc., this band is to be cleared of FM broadcast stations not later than January 1, 1947. Depending upon the availability of FM home radios for 88 to 108 mc., the Commission will consider before the end of this year whether FM broadcasting stations now operating between 42 and 44 mc. shall be authorized temporarily to continue low-band operation by shifting to the 44- to 50-mc. band. This would still leave the door open for the assignment of 44 to 50 mc. as an additional FM broadcast band if there will not be room for all applicants between 88 and 108 mc.

The IRAC has requested the FCC to maintain an 800-kc. guard band around the aeronautical marker located at 75 kc. during the interim period of its continued use. When new air navigation aids are completely developed it is expected that the 800-kc. guard band will be available for non-government fixed and mobile services.

ASSIGNMENTS IN THE 42– TO 44–MC. BAND

As of July 19, 1946

POLICE—24 Channels
PROVISIONAL & EXPERIMENTAL—1 Channel
MARITIME MOBILE & GEOPHYSICAL—5 Channels
GENERAL HIGHWAY MOBILE—19 Channels

POLICE	42.78	GENERAL HIGHWAY MOBILE[1]
42.02	42.82	43.22
42.06	42.86	43.26
42.10	42.90	43.30
42.14	42.94	43.34
42.18		43.38
42.22		43.42
42.26		43.46
42.30	PROV. & EXPERIMENTAL	43.50
42.34	42.98	43.54
42.38		43.58
42.42		43.62
42.46		43.66
42.50	MARITIME MOBILE & GEOPHYSICAL	43.70
42.54		43.78
42.58	43.02	43.82
42.62	43.06	43.86
42.66	43.10	43.90
42.70	43.14	43.94
42.74	43.18	43.98

NOTE: To avoid interference with FM stations still operating in the band from 42 to 44 mc., each such FM station will be protected until January 1, 1947, by the provision of an 800-kc. guard band about its center frequency in the area in which it is located.

[1] May provide radio communication service to all types of mobile units such as marine, land vehicles, aircraft, etc. Pending final determination of the best method of operation of this service, these channels will be assigned on an experimental basis — 12 for development on a common carrier basis, 4 for trucks, and 4 for buses, except in those cases where it is shown that a different distribution is more desirable.

ASSIGNMENTS IN THE 72– TO 76–MC. BAND

As of July 19, 1946

FIRE—12 Channels
FORESTRY & CONSERVATION—8 Channels
POLICE—36 Channels
POWER, PETROLEUM[2]—6 Channels
SPECIAL EMERGENCY, PROVISIONAL[1]—10 Channels
URBAN TRANSIT, FORESTRY & CONS.—6 Channels

FOR. & CONS.—URBAN TRANSIT	FOR. & CONS.—URBAN TRANSIT	73.94
72.02	72.62	73.98
SPECIAL EMERGENCY—PROV.[1]	SPECIAL EMERGENCY—PROV.[1]	74.02
72.06	72.66	74.06
72.10	FIRE	74.10
FOR. & CONS.—URBAN TRANSIT	72.70	74.14
72.14	72.74	74.18
PROV. & EXPERIMENTAL	72.78	74.22
72.18	72.82	74.26
72.22	72.86	74.30
FOR. & CONS.—URBAN TRANSIT	72.90	74.34
72.26	72.94	74.38
SPECIAL EMERGENCY—PROV.[1]	72.98	74.42
72.30	73.02	74.46
72.34	73.06	74.50
FOR. & CONS.—URBAN TRANSIT	73.10	74.54
72.38	73.14	74.58
SPECIAL EMERGENCY—PROV.[1]	POLICE	POWER—PETROLEUM[2]
72.42	73.18	75.42
72.46	73.22	75.46
FOR. & CONS.—URBAN TRANSIT	73.26	75.50
72.50	73.30	SPECIAL EMERGENCY—PROV.[1]
SPECIAL EMERGENCY—PROV.[1]	73.34	75.54
72.54	73.38	POWER—PETROLEUM[2]
72.58	73.42	75.58
	73.46	75.62
	73.50	75.66
	73.54	FOR. & CONS.
	73.58	75.70
	73.62	75.74
	73.66	75.78
	73.70	75.82
	73.74	75.86
	73.78	75.90
	73.82	75.94
	73.86	75.98
	73.90	

[1] Includes Highway Maintenance.
[2] Including other classes of stations requiring similar radio service.

COÖPERATION IS BUILDING FM AUDIENCES

How Zenith Radio Is Working with Broadcasters, Distributors, and Dealers to Publicize FM's Advantages Over AM

BY EDWARD R. TAYLOR*

THE old "build a better mousetrap" story may be sound in theory. As an advertising man, however, I have always felt that the inventor's door would be far more heavily besieged if he paved the road to it with advertising telling of the superiority of his product.

FM is the "better mousetrap" of the radio industry — with features so outstanding and superior that most people will ultimately become aware of them and will want FM radios. Right now, they do not appreciate fully what FM can do, why it is better than AM, and to what extent it can increase their enjoyment of broadcast reception. We have been disturbed for some time by this obvious lack of knowledge about FM on the part of the general public. Potential buyers are not the only ones who have little or no idea of FM reception. In our surveys we discovered that long-established radio dealers were in the dark about this new kind of radio broadcasting. This was true even in the city of Chicago — which has had FM broadcasting for more than six years — where FM has been publicized with thousands of words in the local newspapers — a city where actual demonstrations of FM's features have been held for thousands who attended broadcasts in the audience studios of one of the city's largest AM stations.

With the realization of this lack of knowledge and appreciation of FM, we have taken the first steps toward a broad educational program. In our house-organ for Zenith dealers, we recently published a complete and non-technical description of FM broadcasting — just what it is, and why reception sounds so much better. This article created tremendous interest in FM on the part of our dealers and is helping them get the story across to the prospects they contact.

However, the entire educational program that must be carried out, if FM is to reach the popularity we anticipate, is far too big a job for us to do alone, or in coöperation with our dealers. If this kind of a program is to be thoroughly successful, the coöperation of all those engaged in FM — broadcasting, manufacturing and sales — is essential.

As a step in this direction, we have recently released to all of our distributors a comprehensive program containing our suggestions for coöperative plans to be followed out in cities throughout the country, wherever an FM station is operating or is preparing to go on the air. Included in this program are definite things to be done by the distributors and by the dealers in whose territory the FM station is located. These activities are designed to focus attention of radio listeners throughout the territory on the new FM station and to increase the sale of FM radios by building a desire to hear FM broadcasts.

EDWARD R. TAYLOR SELLS FM SETS BY HELPING TO BUILD FM AUDIENCES

We suggest that dealers hold open house in their showrooms, with the FM station presenting special programs highlighting the advantages of this new kind of broadcasting. We suggest that dealers and distributors place FM receivers in hotel and theatre lobbies and similar places, tuning them to the local FM station.

Many other suggestions for radio dealers and distributors are included in the program. What we consider the most important parts of the outline, however, are the promotional ideas for our distributors to present to the FM stations themselves. Among these ideas are the following:

We have prepared a series of newspaper articles, written in non-technical language, explaining the advantages of FM, and emphasizing each of its features of superiority over standard AM radio. It is our suggestion that this series of general articles be supplemented by a feature story about the local station, telling of its program plans, the personnel, and the transmitter and studios. This article should be written by the station promotion man or by a newspaper reporter. Because FM is new, and because the public is interested in learning more about it, these articles have definite news value, and will be gladly accepted by the local newspaper editors.

We suggest that FM stations arrange with local papers for a daily editorial feature in the form of an FM Question Box, to appear on the radio page. Each day, one of the questions frequently asked about FM can be answered.

Since one of the greatest advantages of FM is its high fidelity, we suggest that stations arrange for a series of broadcasts by a prominent local orchestra or musical group.

Music teachers, aware of the comparatively poor fidelity of standard radio, are highly enthusiastic about FM when they learn about the finer reception it makes possible. FM stations should send mailings to all music teachers in their respective service areas, explaining this new kind of broadcasting. These teachers, who have much to do with influencing community thinking along musical lines, should be invited to visit radio dealers for demonstrations of FM reception, and conducted tours of the broadcasting stations should be held at their convenience.

Many local theatres are glad to participate in demonstrations of FM reception. A tried-and-true stunt is that of having an FM receiver and a live musician on the stage, playing the same selections. This gives the audience the opportunity of comparing the FM broadcast and the "in person" performance, and of recognizing the true fidelity provided by FM receivers.

FM stations are finding music stores to be most coöperative. We suggest that a program be worked out in which the music store features FM receivers and publicizes the station, which, in turn, calls attention to the fact that the records being broadcast are obtainable at the coöperating music store.

These are but a few of the promotional stunts any FM station can use to build an interested audience in a short time.

The coöperative program we have outlined is based upon our own experience in the field. We are not recent converts to FM. Our interest in this kind of broad-

(CONCLUDED ON PAGE 76)

*Director of Advertising, Zenith Radio Corporation, 6001 Dickens Avenue, Chicago 39, Ill.

WILL NEWSPAPERS SELL THEIR PRESSES?

If Facsimile Is Planned for Most Effective Public Service, It Will Not Compete with Newspapers

BY MILTON ALDEN*

YES, you read the headline correctly. In view of the possibility that news will soon be delivered to homes directly by facsimile, should newspapers replace old presses now, or invest in new printing equipment?

At a publishers' meeting in Washington, publicity was given to the fine delivery record, percentagewise, made by newspapers during the past year, despite a full share of trying difficulties. Does the wide publicity given to this report mean that the publishers are already on the defensive against wire and radio facsimile delivery of news as a substitute for the physical delivery of the paper itself? Probably not, but in some quarters the question is being asked: Should we stop expanding our printing plant equipment?

My answer to the question would be No, because I believe that the net effect of facsimile will be to whet the public appetite for better newspapers, and to create new *layers* and *areas* of readers that do not exist today.

I presume to offer an opinion because my interest in transmitting pictures over wires or wireless, as it was then known, goes back to the 1907–08 era when vacuum tube amplifiers were unknown and the coherer and electrolytic detector were in vogue. Forty years ago, my concept of sending pfctures was to use a halftone plate with a microphone and needle for pickup at the sending end, and a converted telephone receiver with cutting stylus for the reproducer at the receiving end. This early interest, although only academic and experimental, was revived about ten years ago when I coöperated with other early workers in the facsimile field by taking a workable laboratory model of a facsimile recorder and advancing it to a more presentable model for demonstration and possible manufacture.

This early work gave me the opportunity to observe and follow the experimental facsimile tests conducted by newspapers and, subsequently, to meet many people from all over the world whose interest has been aroused by the possibilities of this development.

This early interest in facsimile and a knowledge of its ultimate possibilities motivated the initial program set up at Alden Products Company at the time we first undertook the development and manufacture of facsimile equipment. Behind this plan was the purpose of preparing to take an active part in the field if and when the associated facilities were available to provide facsimile service on a large scale.

It will be seen, therefore, that I have reason to be pro-facsimile.

In our varied work during the war, we participated in, and were able to observe in operation, the correlation of technical problems that had stymied prewar facsimile. In the light of this experience, we feel that there appear to be no technical obstacles or other serious difficulties to putting home facsimile in operation.

Such problems as remain lie more in *human nature, psychology, inertia,* and *non-technical factors.*

Many years ago, in the early experimentation by *The Milwaukee Journal,* Walter Damm made the observation that *the success of facsimile lies entirely in the program.*

Here lies the crux of the whole matter, now that the technical obstacles have been hurdled, and the FCC has given facsimile its blessing.

The more facsimile is studied, the more apparent it becomes that it will not replace newspapers, although we are building equipment that will duplicate full-size newspaper pages. From the use tests with this equipment, it appears to be an excellent means of sending sections or the complete format of publications by micro-wave relays to distant cities for reproduction. It does not, however, seem logical to send a full-size newspaper, as is, into the home.

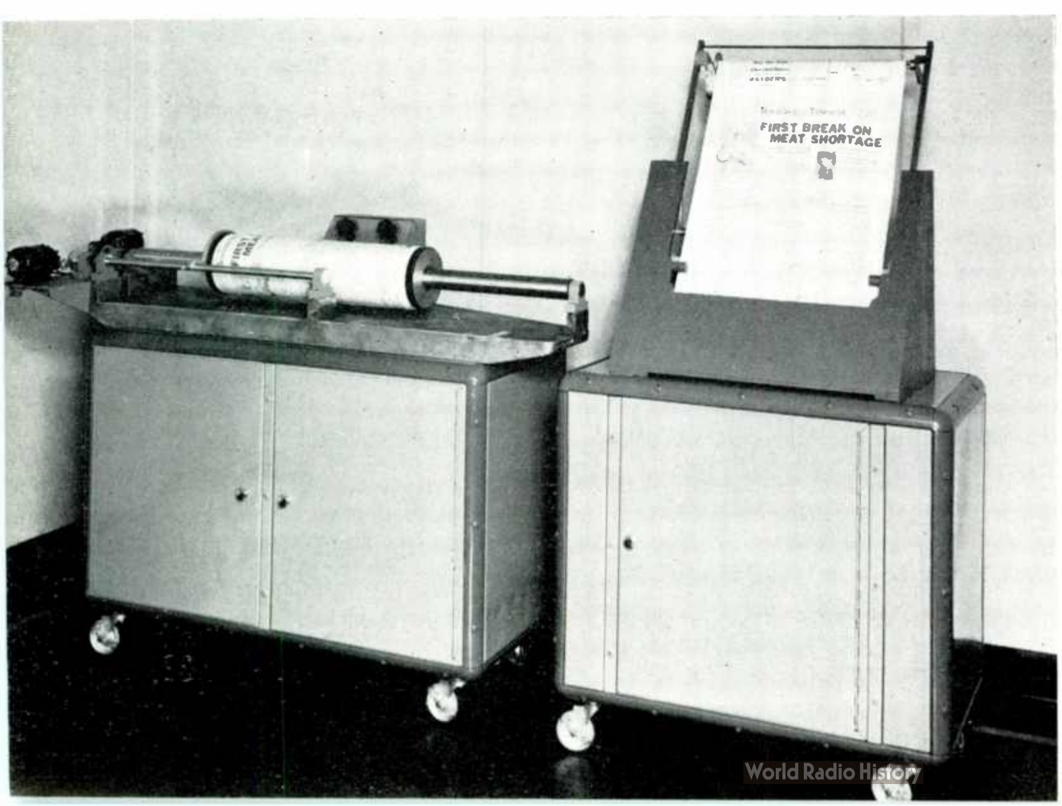
However, one researcher has advocated this. He considers the facsimile recorder one more home utility, perhaps located in the kitchen or hall where the milkman or some other serviceman can keep the recorder loaded with blank paper. However, using the most optimistic possible figures for paper, service, and capital investment, it does not seem to add up. Of course, someone may easily disprove the above conclusion by doing it; but it does not seem immediate or country-wide in its possibilities.

Whatever the ultimate decision as to the proper format for home facsimile, there is no limitation inherent in equipment already developed to the point where it can be put into quantity production at any time. If it should transpire that different facsimile services will be required to meet the needs of separate groups, equipment can be furnished as soon as specifications are prepared.

The range of available equipment is shown in the accompanying illustrations. At the left is the scanner and recorder for handling standard 8-column newspaper pages. At the right is a model of a chairside radio receiver and 4-in. facsimile recorder. This was built in the course of our investigation of audiences reactions, to determine preferences for different types of installations, for wide and narrow format, and for various kinds of program material.

*President, Alden Products Company and Alfax Programs, Inc., Brockton, Mass.

FACSIMILE SCANNER AND RECORDER CAPABLE OF HANDLING 8-COLUMN SHEETS



Once again, the more facsimile programs are studied, the more it becomes self-evident that the successful programming that will pay off will be less like newspapers and more like women's magazines.

Logically, facsimile should be transmitted simultaneously with sound programs, using one broadcast transmitter and the same home receivers for both services. Generally, facsimile and sound program material would be related, but not necessarily. This calls for a whole new art of programming, as different from present sound programs as talking picture production is from that of silent pictures.

The programs must and will be so intensely vital to women and children that they will feel they cannot miss those which appeal to their favorite interests and tastes. With the proper feature programs, the "hours of use" of radio sets will exceed anything previously known.

Facsimile must offer more than mere news service. Experimental programs clearly showed indifference to news sent at night over facsimile.

Unusual spot news, of course. Everyone would like that. It can and should be a featured part of any facsimile operation, but only as one element of the program plan. Facsimile recording can easily deliver twice as many words per minute as a news commentator, or the same number of words plus an advertisement or an illustration recorded alongside the news column at the same time. This can be done by our smallest home unit using 4-in. paper, a size favored because of convenience and low paper cost. This news service alone, however, would not assure the commercial success of facsimile. In fact, facsimile service would be seriously limited if it were planned as direct competition with newspapers.

Facsimile offers a totally new kind of service supplementing newspapers and sound broadcasting, but replacing neither. In the home, it can be used simultaneously with sound programs, or it can be left unattended to record transmission during the owner's absence.

In the former capacity, facsimile makes possible illustrated sound broadcasting. It can create in the home innumerable program adjuncts, from pictures of star performers or public figures, to sporting events or news shots and maps, to say nothing of illustrating products and packages and furnishing coupons or contest blanks. Coördinated voice and facsimile can even produce and read funnies for the children!

Operated independently, facsimile can furnish printed programs and preview shots of the day's broadcast features, with sponsors' names and product pictures added, thereby increasing the effectiveness of sound broadcasting. News flashes, sports bulletins, and photos can be put on the air without interrupting audio programs. Stock market quotations, racing results, ball scores, and other information which, if reported by voice, are forgotten if not recorded, come naturally within the scope of facsimile service.

Illustrated articles on various special subjects, short stories, and condensed novels similar to those in *Reader's Digest* can be transmitted during off-peak hours. The most important functions of facsimile, it will be noted, are more competitive with magazines than newspapers, yet the preparation of material for transmission would not follow the style of either medium. No, facsimile is indeed a completely new kind of public service, and one which opens so many new avenues that its ultimate success is already assured.

The problems, however, do not stop with programs. Our present research is being directed also to the study of reactions to facsimile chairside sets, wall models and service models. We're more concerned about making it easy for the average person to put paper in the machine, the question as to what size type he likes, and the best illustrating technique, than we are about any of the engineering technical difficulties. For this research we are producing prototype universal scanners. These can send copy of any width at any number of lines per inch, and can handle any kind of program material. For the receiving end, we are making recorders of various widths. With such equipment, actual listener-reader reactions can be determined.

Alfax Programs, Inc. has been organized to conduct this research, and to prepare and provide high-grade feature programs for the day and night. It is also working out techniques that can be handed on to the local stations, so that local programs will equal the standards of feature programs supplied to them. In this connection, it is important to note that facsimile programs of all types can be transcribed, and the discs can be distributed by mail or express.

The object of our research is to obtain facts for creating programs which will pay, without too much initial trial and error.

Preliminary research indicates that such programs will probably not be in columns, or follow newspaper technique but, because of the continuous paper, will read directly across the page, at least in the 4-in. width.

Facsimile, in my estimation, will never replace the newspaper. It may give some people all the news they want, much as the present radio does. However, to offset this loss, many people who now are not news-conscious will become so, and want complete information on subjects that facsimile can only handle in bulletin style.

Facsimile may hurt the inferior magazines but, in general, it will accentuate interest and desire for the colors and fine illustrations of well-printed publications.

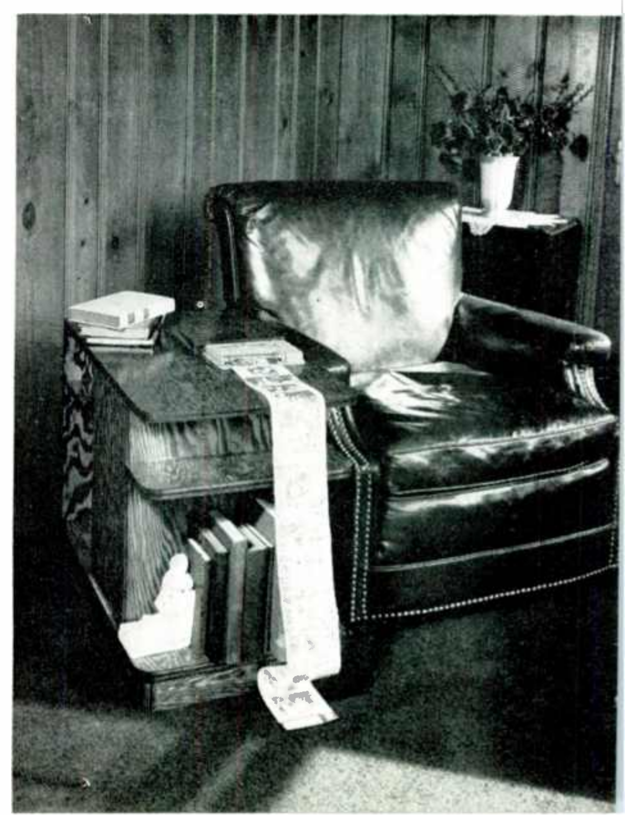
Facsimile can easily raise the national standards of literacy and culture, benefiting all media. Because people eat more dairy products than formerly, it does not mean they have cut their meat bills. Statistics show that people now eat more and better food, and that health and the total food expenditure have increased. Radio broadcasting did not kill the phonograph record business, but it expanded into a multi-million-dollar industry.

Facsimile will have its broadening influence and will stimulate wants, but in the metropolitan areas it can never take the place of newspapers with all their detailed news reports, and large-space advertising. In the suburban and rural communities the personal, local gossip and the quality of advertising in the local weekly papers, plus features corresponding to the large dailies, have such a definite place that facsimile will never replace them, although it can serve to develop community interest.

The cost of facsimile advertising per dollar of results can be much lower than in newspapers because of the lower production and delivery costs. Moreover, facsimile advertisements are much more effective per square inch of area because attention is focused on a narrow page, and not distracted by a large area of competing text and advertising.

Altogether, while this discussion does not spell out in specific detail exactly what lies ahead in facsimile, it is certain that there are so many possibilities offered by facsimile that successful operation is inevitable. Further, the many phases of facsimile applications which need study can be worked out in any area by the simple method of transmission over existing FM broadcast stations, and rotating a small number of recording machines among families selected from different occupational and income groups.

4-IN. FACSIMILE AND RADIO RECEIVER



SPOT NEWS NOTES

Items and comments, personal and otherwise, about manufacturing, broadcasting, communications, and television activities

FMBI: There will be a meeting of FM Broadcasters, Inc. at the NAB Chicago Conference on October 21st at 3:00 p.m. This is a most important meeting, for its purpose is to determine the future course of FMBI. Members should make a special effort to attend.

J. E. Brown: Zenith Radio's chief engineer, speaking of AM receiver performance: "When a radio manufacturer designs an AM radio receiver for widerspread sale over the U. S., he must provide in that receiver adequate selectivity to secure satisfactory reception in the present broadcasting structure where stations are spaced 10 kc. apart. This will automatically limit the fidelity of the receiver to the point where there's essentially nothing left at 5,000 cycles. There is very little out of the receiver at 4,000 cycles."

Everett L. Dillard: Head of Commercial Radio Equipment Company says: "FM means Folding Money because FM offers the greatest opportunity in the history of radio to sell more higher-price radio set units with less sales cost or sales resistance."

APCO Conference: Most important meeting of the year for communications men is the annual conference of the Associated Police Communications Officers, October 28th to 30th, at Hotel Statler, Buffalo, N. Y. Chairman is Lawrence Geno, of the Buffalo Police Department. *FM* AND TELEVISION will have booth 53, just outside the conference room.

Technical Data: Publication of *The Collins Signal* has been resumed by Collins Radio Company, Cedar Rapids, Ia. Under the editorship of Lew H. Morse, articles will cover subjects of interest to broadcast, communications, and airlines engineers, and radio experimenters. Those desiring to be put on the mailing list should send their names to the Collins Signal Office.

Dale Pollack: Former vice president in charge of engineering at Templetone Radio has opened an engineering office and laboratory at 352 Pequot Avenue, New London, Conn. He will handle engineering and design problems of FM receivers and transmitters, and complete communications systems.

V-2 Rocket: Telemetering equipment, built by Wilmotte Manufacturing Company, Washington, D. C., successfully recorded cosmic ray data from Geiger Tube telescopes mounted in a V-2 rocket, up to a height beyond 400,000 ft.

FM Engineering Clinic: A 3-day engineering clinic, organized by Radio Engineering Laboratories, Long Island City, will convene on December 2nd. Sessions will cover a review of FM theory, a study of equipment and operating techniques, laboratory work, and a round table discussion of practical problems. Sessions will be conducted by Frank A. Gunther, assisted by outstanding engineers in the FM broadcasting field.

It's Different Now: Announcement that Beckley, W. Va., has an FM station on the air brings to mind the last time we spent the night there. Equipped with a high-power AM portable, we pulled in a dial-full of squeals, squawks, and co-channel interference, but the only intelligible reception came from the Fort Worth Star Telegram's station!

NEW YORK DEPARTMENT STORES OFFER THIS U. S. TELEVISION MODEL AT $1995

Voice from the Dark: Speaking at Washington on September 18th, RMA president Cosgrove confessed: "The three FM sets in this room are the first I've seen." Then he said: "I deplore the fact that some FM stations advise the public not to buy radio sets until they have FM. What about the 1,500,000 AM sets produced last month?"

This reminds us of Major Armstrong's remark: "If they haven't sense enough to get into FM, let 'em go broke!" Apparently Mr. Cosgrove sees some such handwriting on the wall for, referring to the present deluge of AM table model production which is beginning to back up on dealers' shelves, he warned of the danger in the present "profitless prosperity" resulting in operating loss of more than $1,000,000 at each of three major producers of AM sets.

NAB Conference: We shall be on hand to greet our old friends and to meet new ones in Room 881, where the exhibits will be set up in the Palmer House. Our room is next door to RCA.

Television Receivers: Full-page advertisement in *The New York Times* offered television receivers with 21-in. viewing screen at $1995, with 15-in. screen at $1495, and with 10-in. direct-view tube at $745. These models, from U. S. Television Mfg. Corporation, 3 W. 61st Street, New York City, were put on sale at Macy's, Bloomingdale's, Abraham & Straus, and at Bamberger's, all offered for immediate delivery.

David Sarnoff: Speaking at a dinner on September 30th, commemorating his 40 years in radio: "Unfortunately, in the social and political spheres, our imaginations cover a rather limited radius. Many men will risk their lives to solve a scientific problem; few will risk their comfort or security to solve a social or political problem. Therefore, the most important problem of all is the selection of courageous, competent and wise leaders. That kind of leadership calls for more than mere exercise of authority; it calls for imagination, initiative, direction and guidance."

FM in England: The British Broadcasting Company has completed very thorough field tests of FM broadcasting at 45 mc. and 90 mc., including comparisons with AM and pulse modulation on the same frequencies. These tests covered transmission from Alexandra Palace, in London, and at Moorside Edge, near Huddersfield, in hilly country.

The findings of this extensive investigation have been presented in the *B.B.C. Quarterly* by H. L. Kirks, Head of Research Department, B.B.C. Engineering Division. Because this report presents a totally independent point of view, arrangements have been made through the British Information Service to publish the findings in full in a forthcoming issue of *FM* AND TELEVISION.

On the Air: Up to September 16th, 15 upper-band 1-kw. FM transmitters and one 250-watt type had been installed by REL. The stations are W2XMN, Alpine, W1NX, Washington, D. C., WDRC-FM and WTIC-FM Hartford, WENA Detroit, WNBF-FM Binghamton, WGTR Paxton, WMIT Winston-Salem, WIL-FM St. Louis, WRCM New Orleans, WRAL

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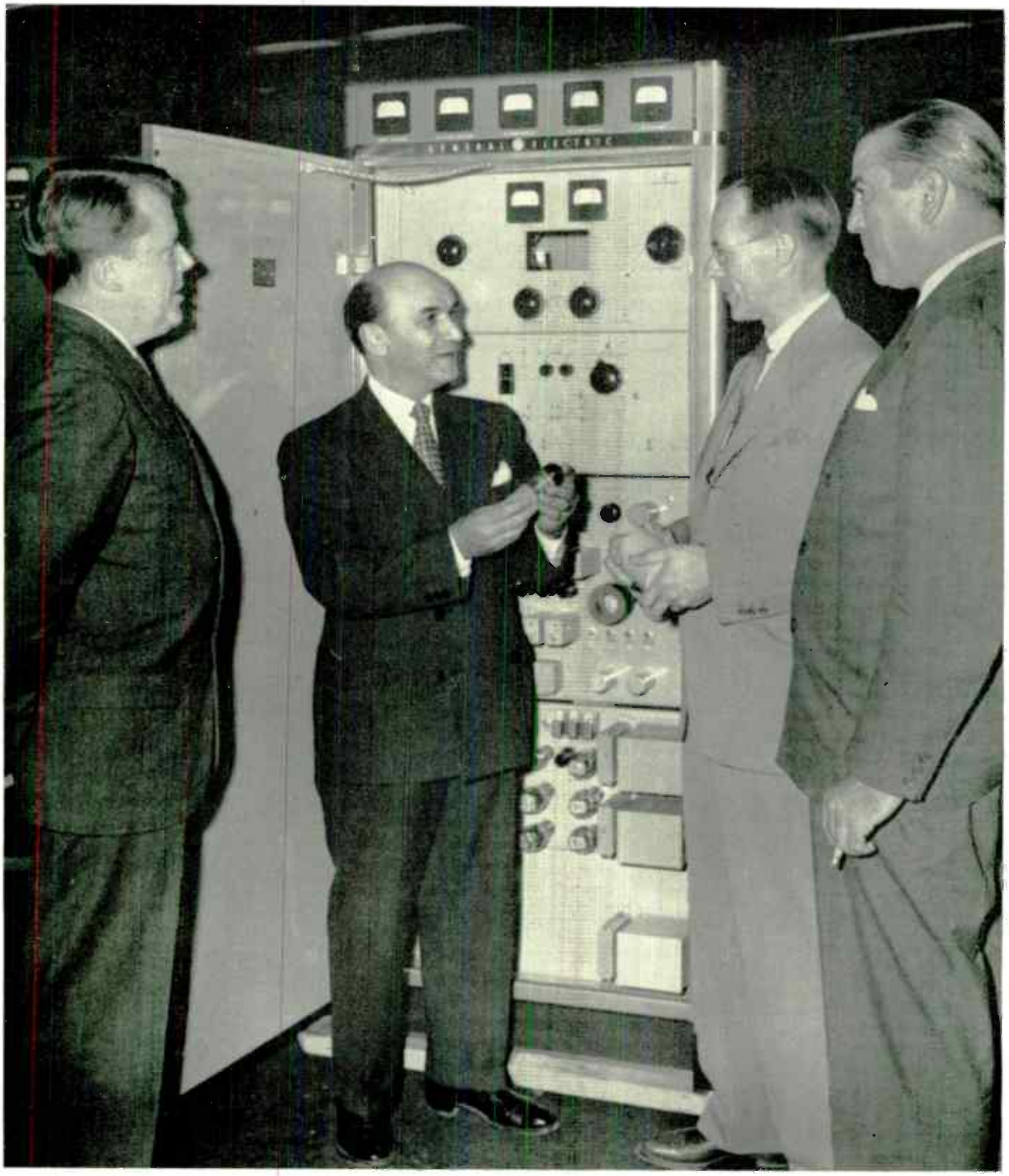

NEWS PICTURE

SHIPMENT of the 50th General Electric new-band FM transmitter marked an important milestone for G. E.'s Syracuse plant, and for the progress of FM broadcasting. The 50th transmitter, shown here, went to Battling Len Asch, whose Schenectady station WBCA, holds top rank among the FM independents.

From left to right in this picture are Col. E. C. Page, vice president in charge of engineering for Mutual Broadcasting System; Leonard Asch of WBCA; W. R. David, G. E.'s broadcast equipment sales manager; and Howard Mandernach, New York district manager for electronics.

All of the 50 transmitters shipped so far have been 250-watt installations. Now, 3-kw. amplifiers, to be driven by the basic 250-watt units, are in production, and deliveries will start in October. The first will go to WGY, Chicago, and the second to the Canadian Broadcasting Company's Montreal station. Others will be shipped in rapid succession.

Each 250 watt transmitter provides service to another market for FM receivers. These 50 installations will create a demand for new sets by the thousands.

WHAT WQXQ NEW YORK IS DOING

An Account of the Present Activities and Future Plans for WQXR's FM Affiliate

BY JOHN V. L. HOGAN*

WQXQ is the FM affiliate of standard broadcasting station WQXR, in New York. Like WQXR, it is licensed to Interstate Broadcasting Company, owned by *The New York Times* and managed by Elliott Sanger and myself. The transmitter is located on the 54th floor of the Chanin Building, at 42nd street and Lexington avenue, with the antenna more than 600 ft. above sea level. With a high-gain antenna at this height, the power of the new Western Electric transmitter now being installed will permit WQXQ to give outstanding service on its new frequency of 97.7 mc.

This upper-frequency service could begin tomorrow, since the driver unit of the new high-power transmitter is already delivered, except for the fact that there is not yet enough 60-cycle power available at the Chanin roof to permit simultaneous operation of the new 97.7-mc. unit and the old 45.9-mc. REL 1-kw. transmitter.

We have our choice of operating one or the other, but not both. In this area, it is more important to serve the listeners who have FM receivers that will tune to 45.9 mc. than to radiate our programs on the new frequency alone, since there are still relatively few receiving sets here that will bring in FM programs on the 88- to 108-mc. band. Consequently, WQXQ continues to send out its programs on 45.9 mc. from five o'clock in the afternoon to after midnight weekdays and Sundays. FM listeners within something like a 50-mile radius can continue to hear the news and good music on programs that are characteristic of WQXR.

For the most part, WQXQ transmits simultaneously the programs that originate in our WQXR studios. Whether this practice will be continued after a substantial audience has been developed on the new FM frequencies, or whether WQXQ will be programmed separately from WQXR, has not yet been decided. Our studio facilities are adequate to permit completely independent program operation of the two stations, but under today's conditions it appears best to run the same program on both WQXR and WQXQ. In the future, it may well become more desirable to appeal to two completely different sets of listeners by using different programs on the two stations.

Whatever the program policy may be from year to year, Interstate and *The New York Times* intend to push the service possibilities of FM to the limit. We all feel that FM has great potentialities, as I myself have believed from the days of Major Armstrong's first developments, and we propose to provide public services that will make use of the new facility as fully as possible. In the foreseeable future, we believe that FM will be found able to provide a better service than can be had from AM stations on any regional or local channel. We think that this should result in an abandonment by AM stations of local and regional positions, and a shift to FM. This cannot happen, however, as we see it, until there are enough new-band FM receivers in use to provide a potential audience as large as today's potential or actual audience for the local and regional AM stations.

> **H**OW much money and how much time are needed to start an FM station and develop it to the point of profitable operation? That question is being asked right now by many individuals and organizations who have started or are preparing to start in the FM broadcast field.
>
> In this connection, the success of John V. L. Hogan's New York AM station WQXR has drawn much attention. This venture was started with a shoe-string investment to carry a minimum of personnel and to acquire a record library and a low-power transmitter. Consistently breaking all the rules for success by programming the station for an audience above the intellectual level to which most broadcasting is directed, John Hogan created an equity which he sold to "The New York Times" not long ago for about one million dollars.
>
> He accomplished more than that. Largely in recognition of the distinctive service performed by WQXR, the FCC granted him successive power increases and protection of his frequency.
>
> Because John Hogan is also a pioneer in FM, we asked him to bring our readers up to date on the present activities and future plans of WQXR's FM affiliate, WQXQ. Specifically, we asked him what is going to be done with WQXQ under "The Times'" ownership and his management. His reply is presented here.

Since AM station WQXR on the 1560-kc. cleared channel, sharing only with KPMC in Bakersfield, California, is not subject to a night-time interference limitation by co-channel stations, we expect to continue its development for serving listeners within WQXR's primary or daytime area and also those within the Eastern third of the USA, where WQXR now has thousands of night-time sky-wave listeners. The 1,500- to 1,600-kc. sky-wave develops useful intensities at considerable distances almost immediately after sunset, and offers great opportunity to deliver programs to suburban and rural listeners who do not get FM service at this time. Thus, we feel that with a cleared channel station we are committed to continue its expansion, but this does not in any way restrict our enthusiasm for carrying forward the most intensive development of our FM broadcasting to supply high-fidelity programs to still more families in the metropolitan New York area.

Another FM service that WQXQ plans to provide is facsimile broadcasting directly to the home. WQXQ was one of the pioneer participants in the Broadcasters' Facsimile Analysis, organized by WOR and Radio Inventions, Inc. We are now awaiting delivery of standard facsimile equipment from the General Electric Company. As soon as it is available, which we anticipate will be early in 1947, we plan to use WQXQ for the scheduled transmission of facsimile news and magazine features. We have not yet made final plans for this initial facsimile programming, for much will depend upon the division of time on WQXQ between aural programs and visual facsimile.

As of today, it looks to us as though we would put out several four-page, 15-minute editions of a facsimile magazine every day, perhaps at 4-hour intervals, beginning at 8 A.M. and ending at midnight. Later, of course, the 97.7-mc. channel will have to carry at least 17 hours of sound programs every day, as WQXR does now on its 1,560-kc. AM channel. Our facsimile magazine will either go out over a second FM transmitter on a different frequency or else on 97.7 mc. by means of multiplex.

It seems reasonable to believe that, by that time, someone will have solved the facsimile-sound multiplex problem to the satisfaction of the Federal Communications Commission. In our view, the FCC is very reasonable in requiring that facsimile-sound multiplex 1) shall not degrade the high-fidelity transmission of sound on FM, and 2) shall not require the users of FM sound receivers to pay for or install special filters to exclude the facsimile signals. But when these requirements are met, we foresee a tremendous expansion of FM by reason of the possibility of coördinating facsimile and sound programs on a single FM channel.

In a word, we at WQXQ–WQXR are

(CONCLUDED ON PAGE 66)

* President, Interstate Broadcasting Co., Inc., 730 Fifth Avenue, New York City.

MAGNETRON: GENERATOR OF CENTIMETER WAVES

The Theory of the Magnetron, and Its Development as a Practical Means for Generating Centimeter Waves—1st Installment

BY J. B. FISK, H. D. HAGSTRUM, AND P. L. HARTMAN*

THE development of Magnetron tubes, one of radio's greatest contributions to military equipment for both defensive and offensive warfare, promises to be equally important in peacetime communications. Types now available can be used as continuous wave generators of frequencies between 600 mc. and 60,000 mc., handling from 100 kw. at 30,000 mc. up to 3,000 kw. at 3,000 mc. Moreover, they can be used in Frequency Modulation circuits.

Now that peacetime applications of magnetrons are being explored, radio engineers should be fore-armed with an understanding of these tubes. Handling high power at the upper limit of radio frequencies, they open up many new possibilities for point-to-point and relay services. They may be the eventual answer to television transmission, and perhaps to an ultimate broadcasting system in which one central station at each service area will supply a choice of audio and television programs, plus facsimile reports of business and general news, and magazine features.

Accordingly, by permission of the American Telephone and Telegraph Company, we present here the first installment of a paper on magnetron tubes by Drs. Fisk, Hagstrum, and Hartman, originally published in "The Bell System Technical Journal" of April, 1946. Written by three members of Bell Telephone Laboratories' physical research department who were engaged in the development of magnetrons during the war, this paper may well be considered a classic exposition, and of continuing value for reference purposes.

Permission to publish this paper was obtained through the courtesy of Dr. J. O. Perrine, co-editor of "The Bell System Technical Journal."

INTRODUCTION

LATE in the summer of 1940, a fire control radar operating at 700 mc. was in an advanced state of development at the Bell Telephone Laboratories. The pulse power of this radar was generated by a pair of triodes operating near their upper limit of frequency. Even when driven to the point where tube life was short, the generator produced peak power in each pulse of only 2 kw., a quantity usable but marginal. Although the triodes employed had not been designed for high voltage pulsed operation, they were the best available. This is an example of how development of radar in the centimeter wave region was circumscribed by the lack of a generator of adequate power and reasonable life expectancy. Moreover, the prospects of improvement of the triode as a power generator at these wavelengths and extension of its use to shorter wavelengths were not bright. Solution of the problem by means of power amplification was remote. A new source of centimeter wave power was urgently needed.

For the British, who were at war, the problem was even more urgent. They had undertaken a vigorous search for a new type of generator of sufficiently high power and frequency to make airborne radar practicable in the defense against enemy night bombers. They found a solution in the multiresonator magnetron oscillator, admirably suited to pulsed generation of centimeter waves of high power.

In the fall of 1940, an early model of this magnetron operating at 10 cm. was brought to the United States for examination. The first American test of its output power capabilities was made on October 6, 1940, in the Bell Telephone Laboratories' radio laboratory at Whippany, N. J. This test confirmed British information and demonstrated that a generator now existed which could supply several times the power that our triodes delivered and at a frequency four times as great. The most important restraint on the development of radar in the centimeter wavelength region had now been removed.

A number of pressing questions remained to be answered, however. Could the new magnetron be reproduced quickly and in quantity? Was its operating life satisfactory? Could its efficiency and output power be substantially increased? Could one construct similar magnetrons at 40 cm., at 3 cm., even at 1 cm.? Could the magnetron oscillator be tuned conveniently? One by one, during the war years, all of these questions have been answered in the affirmative. In many instances, but not without detours and delays, results have been better than hoped for or expected.

The British magnetron was first reproduced in America at the Bell Telephone Laboratories for use in its radar developments and those at the Radiation Laboratory of the National Defense Research Committee which was then being formed at the Massachusetts Institute of Technology. Since that time, extensive research and development work has been carried on in our Laboratories, in other industrial laboratories, and in the laboratories of the National Defense Research Committee. Several manufacturers have produced the resultant designs. Magnetron research and development was also carried on in Great Britain by governmental and industrial laboratories. There has been continuous interchange of information among all these laboratories through visits and written reports. Magnetron and radar developments have been greatly accelerated by this interchange.

Multicavity magnetron oscillators are now available for use as pulsed and continuous wave generators at wavelengths from approximately 0.5 to 50 cm. The upper limit of peak power is now about 100 kw. at 1 cm., 3,000 kw. at 10 cm. Operating voltages may be less than 1 kilovolt or more than 40 kilovolts. The magnetic fields essential to operation range from 600 to 15,000 gauss. Tunable magnetrons now exist for many parts of the centimeter wave region. The tuning range for pulsed operation at high voltage is about ±5%. It is as much as ±20% for low voltage magnetrons. Magnetrons may now be tuned electronically, making frequency modulation possible. Present magnetron cathodes are rugged and have long life. Even for high-frequency magnetrons where current density requirements are most severe, research has made available rugged cathodes with adequate life. Magnetrons are built to withstand shock and vibration without change in characteristics. Designs have been compressed and in some cases the magnet has been incorporated in the magnetron structure in the interest of light weight for airborne radar equipments.

PART 1 of this paper is a general discussion of present knowledge concerning the magnetron oscillator. As such, it is largely a discussion of what has come to be common knowledge among those who have carried out wartime developments. It brings together in one place results of work done by all the magnetron research groups including that at our Laboratories. PART 1 supplies the background necessary to understanding the discussion in PART 2 of the magnetrons developed at the Bell Laboratories during the war. More complete presentations of the experimental and theoretical work done on the magnetron during the war are soon to be published by other research groups.

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The material written up during the war has appeared as secret or confidential reports issued by the British Committee on Valve Development (CVD Magnetron Reports), by the Radiation Laboratories at the Massachusetts Institute of Technology and at Columbia University, and by the participating industrial laboratories. No attempt has been made in PART 1 to indicate the specific sources of the work done since 1940. To fit the wartime development of magnetrons into the sequence of previous developments, specific references are made to publications appearing in the literature prior to 1940.

The nature and scope of PART 2 of the paper are discussed more fully in its introductory Section, 11. GENERAL REMARKS.

PART 1—THE MAGNETRON OSCILLATOR

1. General Description ★ 1.1 *Description*: The multicavity magnetron oscillator has three principal component parts: an electron interaction space, a multiple resonator system, and an output circuit. Each of these is illustrated schematically in Fig. 1. The electron interaction space is the region of cylindrical symmetry between the cathode and the multisegment anode. In this region electrons emitted from the cylindrical cathode move under the action of the DC radial electric field, the DC axial magnetic field, and the RF field set up by the resonator system between the anode segments. These electronic motions result in a net transfer of energy from the DC electric field to the RF field. The RF interaction field is the fringing electric field appearing between the anode segments, built up and maintained by the multicavity resonator in the anode block. RF energy fed into the resonator system by the electrons is delivered through the output circuit to the useful load. The output circuit shown in Fig. 1 consists of a loop, inductively coupled to one of the hole and slot cavities, feeding a coaxial line.

To operate such a magnetron oscillator, one must place it in a magnetic field of suitable strength and apply a voltage of proper magnitude to its cathode, driving the cathode negative with respect to the anode. This voltage may be constant or pulsed. In the latter case, the voltage is applied suddenly by a so-called pulser or modulator for short intervals, usually of about 1 microsecond duration at a repetition rate of about 1,000 pulses per second. With suitable values of the operating parameters, the magnetron oscillates as a self excited oscillator whenever the DC voltage is applied. The energy available at the output circuit may be connected, as in a radar set, to an antenna or, as in a laboratory experimental setup, may be absorbed in a column of water.

1.2 *Analogy to Other Oscillators:* In its fundamental aspects, the magnetron oscillator is not unlike other and perhaps more familiar oscillators. In particular, instructive analogies may be drawn between the magnetron oscillator, the velocity variation oscillator, and the simple triode oscillator. In Fig. 2 is depicted schematically the parallelisms between these types of oscillators and a simplified equivalent lumped constant circuit.

In the triode of Fig. 2 (a), as in the gap of the second cavity of the velocity variation tube of Fig. 2 (b) and in the interaction space of the magnetron oscillator of Fig. 2 (c), electrons are driven against RF fields set up by the resonator or *tank circuit*, to which they give up energy absorbed from the primary DC source. In each type of oscillator there is operative a mechanism of *bunching*, which allows electrons to interact with the RF field primarily when the interaction will result in energy transfer *to* the RF field. In the triode oscillator this is accomplished by the grid, whose RF potential is supplied by the tank circuit in proper phase with respect to the RF potential on the anode. In the velocity-variation oscillator, bunching is accomplished by variation of the electron velocities in the gap of the first cavity, followed by drift through the intervening space to the second gap. The first cavity is driven in proper phase by a feed back line from the second cavity. In the magnetron oscillator, as is to be described in detail later, electron interaction with the RF fields is such as to group the electrons into bunches or *spokes* which sweep past the gaps in the anode, in phase for favorable interaction with the RF fields across the gaps. The bunching field is thus the same field as that to which energy is transferred. In this sense, the magnetron oscillator is perhaps more properly analogous to the reflex type of velocity variation oscillator, in which a single cavity is used both as *buncher* and *catcher;* the electrons, after traversing the gap once, are turned back in the proper phase in the drift space so as to pass through the gap again in the opposite direction.

Each type of oscillator has a resonator in which energy is stored and which synchronizes the flow of energy from the electrons into it by the means of self excitation. In each type, energy is extracted from the resonator by an output circuit at a rate which, under steady state conditions, equals that of influx from the electron interaction, minus the losses in the resonator itself.

1.3 *Use of Equivalent Circuits:* In many instances the understanding of electromagnetic oscillators is made easier and analytic treatment made possible by use of an equivalent circuit with lumped constants. Of several possible types, one of the simpler and more frequently used for the magnetron oscillator is shown in Fig. 2. This may appear in the case of the multicavity magnetron to be an oversimplification, as it does not account for the fact that the resonant frequency of the magnetron resonator system is many-valued. A magnetron resonator, being made up of a number of coupled resonating cavities, is capable of supporting several modes of oscillation. These modes of oscillation have different resonant frequencies and correspond to different configurations of the electromagnetic fields. By means to be discussed, however, magnetron resonators can be made to oscillate cleanly in one of these modes, and may thus be represented for many purposes by a simple LC circuit having a single resonance.

The output circuit of the oscillator is also amenable to treatment by equivalent lumped-constant circuits which account for its behavior with accuracy. More general, four-terminal network theory has also been applied in the study and design of impedance transformations in this part of the oscillator.

Finally, the electrons, which in a sense are connected to the circuit formed by the resonator and the load, can also be treated by circuit concepts. The electrons moving in the space between the cathode and anode, by virtue of their presence and motion, induce charge fluctuations on the anode segments. The time derivative of these fluctuations is equivalent to an RF current flowing into the anode from the

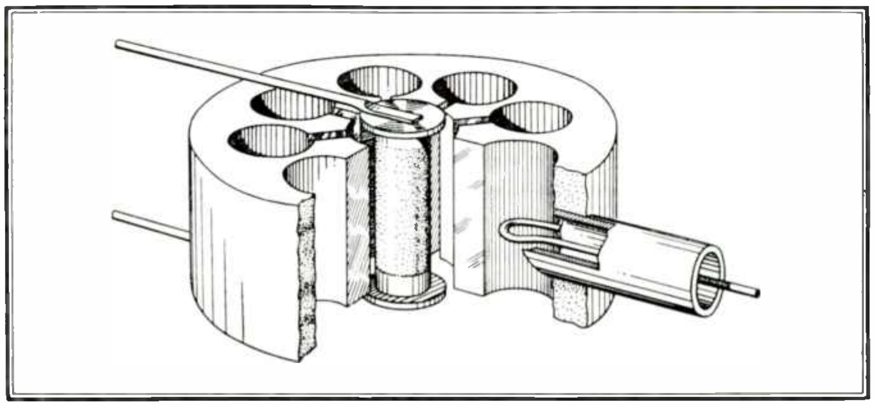


FIG. 1. A schematic diagram designed to show the principal component parts of a centimeter wave magnetron oscillator. The resonator system and output circuit each represents one of several types used in magnetron construction.

interaction space. This current and the RF voltage on the anode, bearing a definite phase relationship, make possible the definition of an admittance called the average electronic admittance, $Y_e = G_e + jB_e$. Since the electrons are being driven against RF fields in the interaction space, this admittance looking into the electron stream has a negative conductance term. Unlike usual circuit admittances, the electronic admittance is nonlinear, being a function of the voltage amplitude of oscillation, V_{RF}, as well as of other parameters governing the electronic behavior of the oscillator, such as voltage and magnetic field. It is not known *a priori*, but may be deduced from measurements on the operating oscillator and its circuit.

A necessary condition for oscillation, applicable to the magnetron as to any oscillator, is that, on breaking the circuit at any point, the sum of the admittances looking in the two directions is zero. Thus, if the circuit is broken at the junction of electrons and resonator, as is convenient, the electronic admittance Y_e, looking from the circuit into the electron stream, must be the negative of the circuit admittance Y_c, looking from the electron stream into the circuit.

With these remarks, of general applicability to all types of electromagnetic oscillators, the discussion will be continued for the centimeter wave magnetron oscillator in particular. As far as is possible, the electronic interaction space, resonator system, and output circuit of the device will be taken up in that order. The function and operation of each part will be described; then the principles of its design, and its relation to previous magnetron development will be indicated.

1.4 *Electron Motions in Electric and Magnetic Fields — The DC Magnetron:* Before beginning the discussion of the electronics of the magnetron oscillator, it would be well to review briefly electron motions in various types and combinations of electric and magnetic fields, and the operation of the DC magnetron.[1]

An electron, of charge e and mass m, moving in an electric field of strength E, is acted upon by a force, independent of the electron's velocity, of strength eE, directed oppositely to the conventional direction of the field. If the field is constant and uniform, the motion of the electron is identical to that of a body moving in a uniform gravitational field.

[1] The cylindrical DC magnetron was reported by A. W. Hull, *Phys. Rev.* 18, 31 (1921).

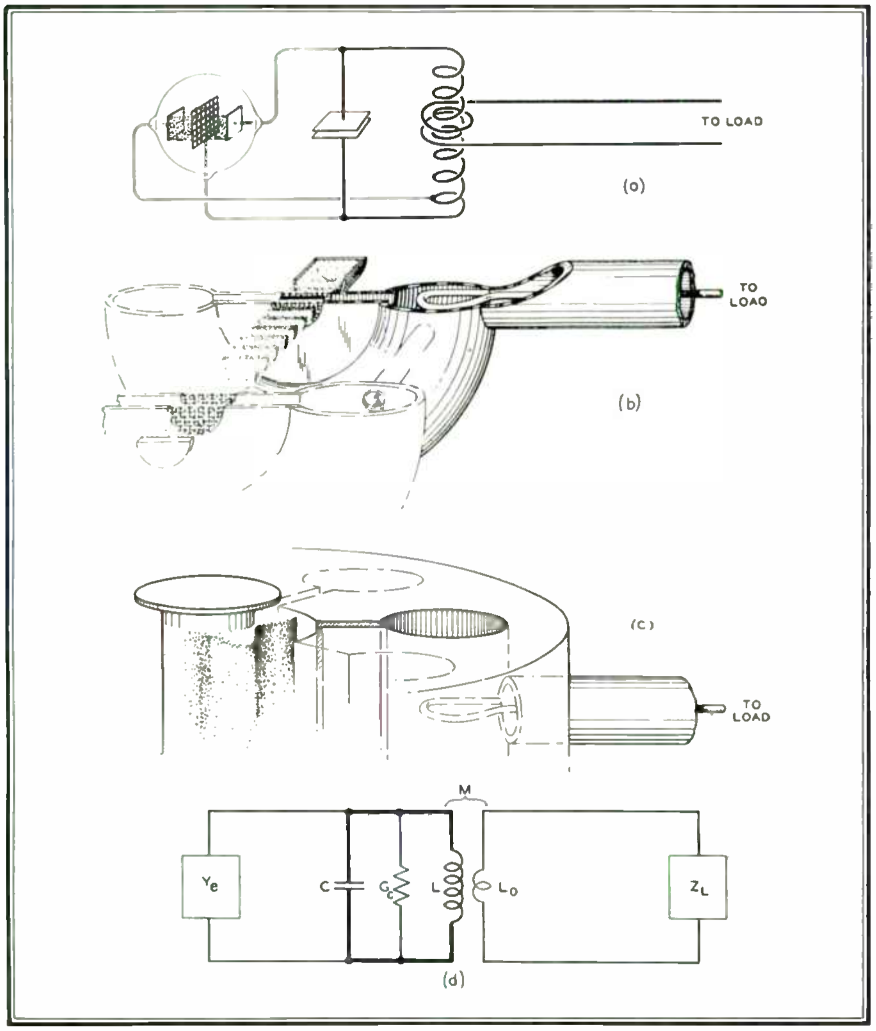


FIG. 2. A schematic diagram depicting the parallelism among the conventional triode oscillator, the velocity-variation oscillator, the centimeter wave magnetron, and an equivalent lumped constant circuit. In the figure an attempt is made to align corresponding parts vertically above one another.

An electron moving in a magnetic field of strength B, however, is acted upon by a force which depends on the magnitude of the electron's velocity, v, on the strength of the field, and on how the direction of motion is oriented with respect to the direction of the field. The force is directed normal to the plane of the velocity and magnetic field vectors, and is of magnitude proportional to the velocity, the magnetic field, and the sine of the angle θ, between them. Thus the force is the cross or vector product of $\vec{v}$ and $\vec{B}$,

$$\vec{F} = e[\vec{v} \times \vec{B}], \qquad F = Bev \sin \theta.$$

An electron moving parallel to a magnetic field ($\sin \theta = 0$) feels no force. One moving perpendicular to a uniform magnetic field ($\sin \theta = 1$) is constrained to move in a circle by the magnetic force at right angles to its path. Since this force is balanced by the centrifugal force, the radius ρ of the circular path depends on the electron's momentum and the strength of the field; that is,

$$Bev = \frac{mv^2}{\rho},$$

yielding

$$\rho = \frac{mv}{eB}. \qquad (1)$$

The time T_c, required to traverse the circle, is independent of the radius and hence of the velocity of the electron; $T_c = 2\pi\rho/v = 2\pi m/eB$. Thus, the angular frequency of traversing the circular path, the so-called cyclotron frequency, depends on the magnetic field alone and is given by,

$$\omega_c = 2\pi f_c = 2\pi \frac{1}{T_c} = \frac{e}{m} B. \qquad (2)$$

In the magnetron, electron motion in crossed electric and magnetic fields is involved. Consider first such motion between two parallel plane electrodes, neglecting space charge. If, as in Fig. 3, the electric field is directed in the negative y direction and the magnetic field in the negative z direction, the equations of motion of the electron are:

$$\left.\begin{aligned} \frac{d^2x}{dt^2} &= \frac{eB}{m}\frac{dy}{dt}, \\ \frac{d^2y}{dt^2} &= \frac{e}{m}\left(E - B\frac{dx}{dt}\right), \\ \frac{d^2z}{dt^2} &= 0. \end{aligned}\right\} \qquad (3)$$

The particular case of most interest here is that for which the electron starts from rest at the origin. The equations of motion then yield a cycloidal orbit given by the parametric equations

$$x = v_c t - \rho_c \sin \omega_c t = \rho_c(\omega_c t - \sin \omega_c t), \quad y = \rho_c(1 - \cos\omega_c t), \tag{4}$$

in which:

$$v_c = \frac{E}{B}, \tag{5}$$

$$\rho_c = \frac{m}{e}\frac{E}{B^2}, \tag{6}$$

$$\omega_c = \frac{e}{m}B. \tag{7}$$

This motion may be regarded as a combination of rectilinear motion of velocity v_c in the direction of the x axis, perpendicular to both E and B, and of motion in the xy plane about a circular path of radius ρ_c, at an angular frequency ω_c, the cyclotron frequency. Fig. 3 shows the resulting cycloidal path and its generation by a point on the periphery of the rolling circle. In the case of cylindrical geometry, it is often convenient to think in terms of the plane case.

In the case of cylindrical geometry with radial electric and axial magnetic fields, the electron orbit, neglecting space charge, approximates an epicycloid generated by rolling a circle around on the cylindrical cathode. The orbit is not exactly an epicycloid because the radial motion is not simple harmonic, which state of affairs arises from the variation of the DC electric field with radius. The approximation of the epicycloid to the actual path is a convenient one, however, because the radius of the rolling circle, its angular frequency of rotation, and the velocity of its center, for the epicycloid, all approximate those for the cycloid of the plane case. These approximations improve with increasing ratio of cathode to anode radii. Several electron orbits in a DC cylindrical magnetron are shown in Fig. 4 for several magnetic fields.

It is clear from this simplified picture of the orbits in a DC cylindrical magnetron without space charge, that, at a given electric field, an electron orbit for a sufficiently strong magnetic field may miss the anode completely and return to the cathode. The critical magnetic field at which this is just possible is called the cut-off value, B_c. For a given voltage between cathode and anode, as the magnetic field is increased, the current normally passed by the device falls rather abruptly at B_c. A current versus magnetic field curve, together with electron orbits corresponding to four regions of the curve, are shown in Fig. 5. For the case of parallel plane electrodes, the cut-off relation between the critical anode potential V_c, and magnetic field B_c, and the electrode separation d, for the parallel plane case, is obtained by equating the electrode separation to the diameter of the rolling circle. Thus,

$$d = 2\frac{m}{e}\left(\frac{V_c}{d}\right)\frac{1}{B_c^2},$$

from which $V_c = \dfrac{eB_c^2 d^2}{2m}$.

For the cylindrical case, the relation may be shown to be

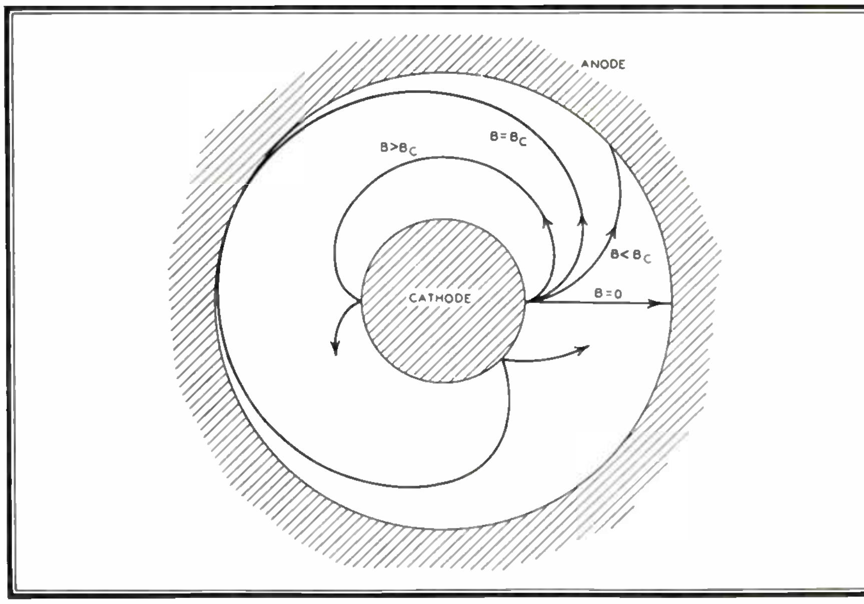


FIG. 4. Electron paths in a cylindrical DC magnetron at several magnetic fields above and below the cut-off value, B_c. The electrons are assumed to be emitted from the cathode with zero initial velocity.

$$V_c = \frac{eB_c^2 r_a^2}{8m}\left[1 - \left(\frac{r_c}{r_a}\right)^2\right]^2, \tag{8}$$

in terms of cathode and anode radii r_c and r_a.

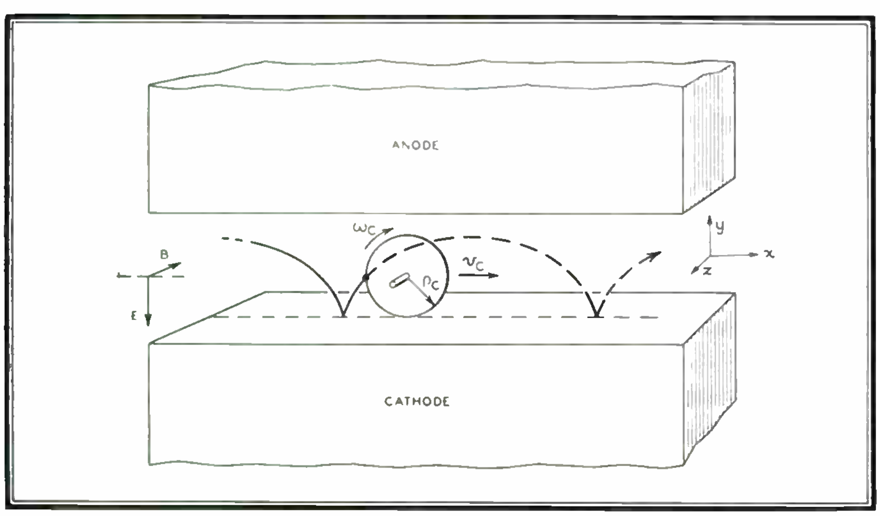


FIG. 3. The cycloidal path of an electron which started from rest at the cathode in crossed electric and magnetic fields for the case of parallel plane electrodes. The mechanism of generation of the orbit by a point on the periphery of a rolling circle is depicted.

2. Types of Magnetron Oscillators ★ 2.1 *Definitions:* The DC magnetron can be converted into an oscillator, suitable for the generation of centimeter waves, by introducing RF fields into the anode-cathode region. This can be done by applying between anode and cathode RF voltage from a resonant circuit, in which case the electrons interact with the superposed radial RF field. Or it can be done by splitting the magnetron anode into two or more segments between which the RF voltage is applied. Then the electrons interact with the fringing RF fields existing between the segments. The problem of understanding the electronics of the multicavity magnetron oscillator is that of understanding how an electron, subject to the constraints placed upon its motion by the DC axial magnetic and DC radial electric fields, can move so as to interact favorably with the RF field; how an electron interacting unfavorably is rejected; and why, on the average, the electrons transfer more energy to the RF field than they take from it.

On the basis of the nature of the electronic mechanism by means of which energy is transferred to the RF field, it is now convenient to distinguish three types of magnetron oscillators.[3] The *negative resistance magnetron oscillator* depends on the existence of a static negative resistance characteristic between the two halves of a split anode.[3] The *cyclotron frequency magnetron oscillator* operates by virtue of resonance between the period of RF oscillation and the period of the cycloidal motion of the electrons (rolling circle or cyclotron frequency).[4] The *traveling wave magnetron oscillator* depends upon resonance, that is, approximate equality between the mean translational velocity of the electrons and the velocity of a traveling wave component of the RF interaction field.[5]

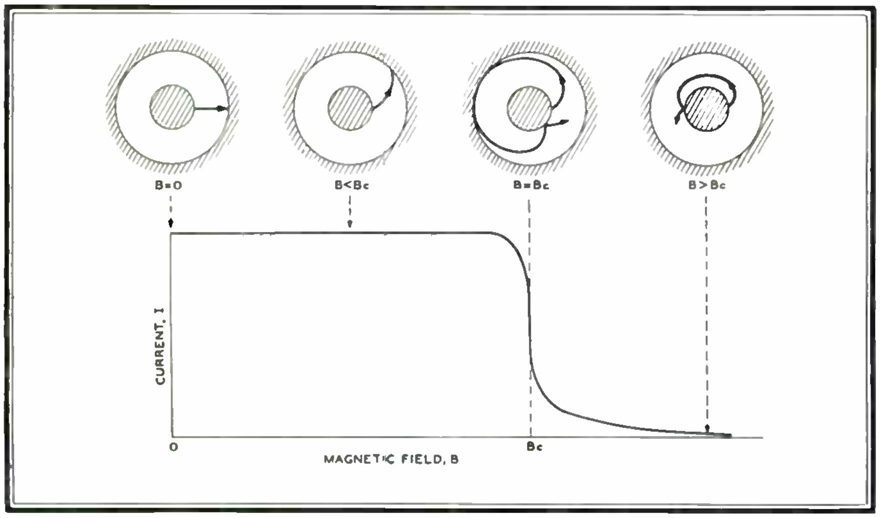


FIG. 5. Variation of current passed by a cylindrical DC magnetron at constant voltage, plotted as a function of magnetic field. The orbits of electrons occurring at four different magnetic fields are shown above the corresponding regions of the current characteristic.

The magnetron oscillator with which this paper is primarily concerned is of the traveling wave type. The other magnetron types are discussed briefly for the sake of completeness and because an understanding of them enhances one's grasp of the entire subject and places the traveling wave magnetron oscillator in its proper historical perspective.

2.2 The Negative Resistance Magnetron Oscillator — Type I: In the negative resistance magnetron oscillator,[6] the anode is split parallel to the axis into two halves, between which the RF circuit is attached. The electrons emitted by the cathode must move under the combined action of the DC radial electric and DC axial magnetic fields together with the RF electric field existing between the two semicylinders forming the anode. The transit time from cathode to anode is not involved in the mechanism except that it must be small relative to the period of the RF oscillation. The static negative resistance characteristic arises from the fact that under certain conditions the allowable orbits for the majority of electrons terminate on the segment of lower potential, irrespective of the segment toward which they start. These electrons, being driven against the RF component of the field, give energy gained from the DC field to the RF field.

In Fig. 6 are shown the paths, plotted by Kilgore,[7] of two electrons starting initially toward opposite segments but both striking the segment of lower potential. Each path is completely traversed in a time during which the RF field changes little. Thus it is possible by applying DC potential differences between the anode segments to measure a negative resistance between them. As can be seen from the orbits of Fig. 6, magnetic fields considerably above the cut-off value are used. With magnetrons of this type, power output up to 100 watts at 600 mc. at an efficiency of 25% has been attained.[7] Oscillations of frequency as high as 1000 mc. (30 cm.) have been produced.[8] Because a large number of orbital loops are required, however, making $\omega \ll \frac{eB}{m}$, this type of magnetron oscillator demands the use of high magnetic field in the centimeter wave region and is thus less desirable than other types.

2.3 The Cyclotron Frequency Magnetron Oscillator — Type II: Not long after the invention of the DC magnetron, oscillations between anode and cathode were found to occur near the cut-off value of magnetic field.[9] These were found to be strongest for wavelengths obeying a relation of the form:

$$\lambda = \frac{\text{constant}}{B}. \qquad (9)$$

Later, it was shown that the oscillation period is equal to the electron transit time from the vicinity of the cathode to the vicinity of the anode and back. This made it possible to calculate a value for the constant in the above equation in good agreement with experiment.[10] The oscillation frequency is that of the rotational component of the electronic motion, that is, approximately the cyclotron frequency of equation (7).

The mechanism must be explained in terms of electrons moving in the DC radial electric and axial magnetic fields and the superposed RF radial electric field. This may be done as follows: An electron leaving the cathode in such phase as to gain energy when moving from the

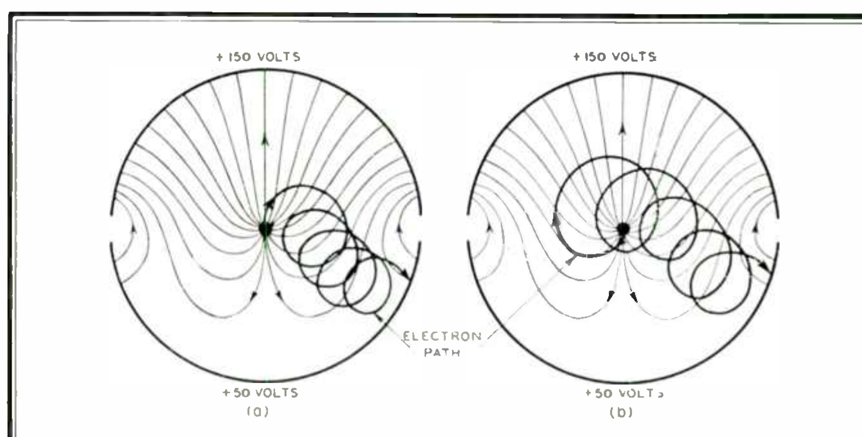


FIG. 6. Electron paths plotted by Kilgore for the negative resistance magnetron oscillator, Type I. During the time the orbits shown are being executed, the cathode is at zero potential and the anode segments at the potentials indicated. Lines of electric force on an electron are plotted in this figure. The two orbits are those of electrons which start initially toward opposite anode segments. It should be noted that in either case the electron is driven to the segment of lower potential against the RF field component.

[3] The magnetron oscillator discussed by Hull, in which the magnet winding is coupled to the plate circuit, is not considered, as it is essentially an audio frequency device. K. Okabe in his book, "Magnetron-Oscillations of Ultra Short Wavelengths" (Shokendo, 1937), distinguishes five types, but it is not clear just how his types C and E are to be identified.

[4] These oscillations have been called by Habann quasi-stationary, or dynatron oscillations, and correspond to Okabe's type D.

[5] These oscillations have been called electronic oscillations by Megaw, transit time oscillations of the first order by Herriger and Hülster, and correspond to Okabe's type A.

[6] These oscillations are the running wave type discussed by Posthumus, the transit time oscillations of higher order of Herriger and Hülster, and correspond to Okabe's type B.

[6] This type was disclosed by Habann, *Zeit. f. Hochfrequenz.* 24, 115 and 135 (1924).

[7] G. R. Kilgore, *Proc. I.R.E.* 24, 1140 (1936).

[8] E. C. S. Megaw, *Journ. I.E.E.* (London) 72, 326 (1933).

[9] A. Zacek, *Cas. Pro. Pest. Math. a Fys.* (Prague) 53, 578 (1924). A summary appeared in *Zeit. f. Hochfrequenz.* 32, 172 (1928).

[10] K. Okabe, *Proc. I.R.E.* 17, 652 (1929).

cathode toward the anode will also gain energy during its return, striking the cathode with more energy than it had when it left. There, such an electron is stopped from further motion during which it would continue to absorb energy from the RF field at the expense of the oscillation. The electron will execute an orbit something like that of Fig. 7 for the plane case. An electron leaving the cathode in the opposite phase, on the other hand, loses energy when moving toward the anode and again on its return toward the cathode. As is shown in Fig. 8, it reverses its direction after the first trip without reaching the cathode surface and starts over on a second loop of smaller amplitude, remaining in the same phase and continuing to lose energy to the field. This process continues until all the energy of the rotational component of the electron's motion has been absorbed by the RF field. If the electron is not removed at this stage, in its subsequent motion the rotational component will build up, extracting energy from the RF oscillation. Means such as tilting the magnetic field or placing electrodes at the ends of the tube have been used to remove the electrons from the interaction space when all the rotational energy has been absorbed. It is possible to maintain the oscillations and extract energy from them because electrons which give energy to the field can do so over many cycles, whereas electrons of opposite phase can gain energy over only one cycle before they are removed.

Magnetrons oscillating in this manner have been built with split anodes.[10,11] Here the RF field with which the electron interacts is more tangential than radial but the criterion for oscillation is the same, namely, resonance between the field variations and the rotational component of the electron's motion. Operating efficiencies of 10 to 15% have been obtained. It was with a magnetron of this type having an anode diameter of 0.38 mm. that radiation of wavelength as low as 0.64 cm. was generated.[12]

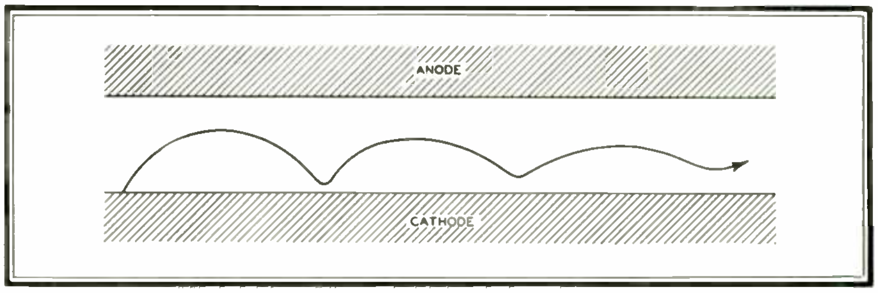


FIG. 8. An approximate orbit of an electron which loses energy to the RF field in a cyclotron frequency or Type II magnetron oscillator, shown for the plane case. If the electron after losing all its rotational energy remains in the interaction space, it gains energy from the RF field, and its orbit builds up cycloidal scallops in a manner directly the reverse of that shown here. The DC electric force on the electron is directed from cathode to anode.

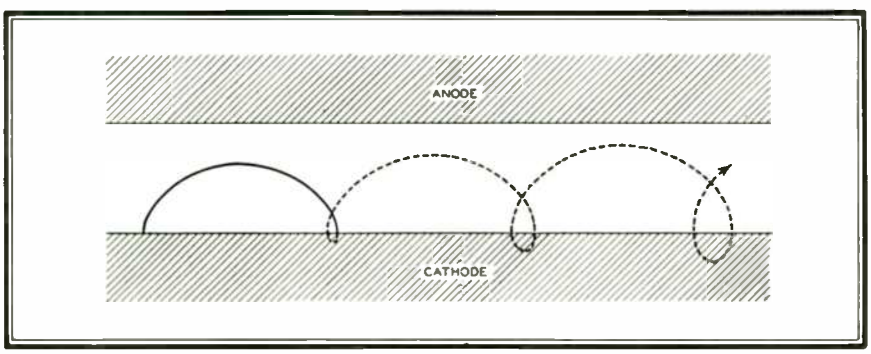


FIG. 7. An approximate orbit of an electron which gains energy from the RF field in a cyclotron frequency or Type II magnetron oscillator, shown for the plane case. The orbit is continued as a dashed line indicating how it would be traversed were it not stopped by the cathode. The DC electric force on the electron is directed from cathode to anode.

The cyclotron frequency magnetron oscillator has been almost entirely superseded by the traveling wave magnetron oscillator as a generator of centimeter waves. In the main this is the result of the impossibility of removing electrons emitted from an extended cathode area from the interaction region at the proper stage in their orbits. This inherent drawback is not shared by the traveling wave magnetron oscillator which can be operated at higher efficiency without critical adjustment of orientation in the magnetic field or of the potential of auxiliary electrodes.

2.4 *The Traveling Wave Magnetron Oscillator — Type III:* Oscillations have been found to occur in the magnetron which are independent of any static negative resistance characteristic and which can occur at frequencies widely different from the cyclotron frequency. In 1935,[13] the electronic mechanism of these oscillations was correctly interpreted as an interaction of the electrons with the tangential component of a traveling wave whose velocity is approximately equal to the mean translational velocity of the electrons. Later,[14] the role of the radial component of the rotating electric field in keeping the electrons in proper phase was recognized. Magnetrons of wavelength as short as 75 cm., operating at better than 50% efficiency, were built prior to 1940, but performance such as was later to be attained with this type of magnetron at much shorter wavelengths was not achieved then, perhaps primarily because of the lack of a good resonator. It was a magnetron of this type which the British brought to the United States in 1940. The British magnetron was a 10-cm. oscillator, intended for pulsed operation, having a tank circuit consisting of eight resonators built into the anode block as shown in Fig. 1.[15]

3. Electronic Mechanism ★ 3.1 *Electronic Interaction at Anode Gaps:* The electrons in the interaction space of the magnetron oscillator are the agents which transfer energy from the DC field to the RF field. As such, they must move subject to the constraints imposed by the DC radial electric and DC axial magnetic fields, considering, for the moment, the RF fields to be small. Under these conditions, as has been seen for the DC cylindrical magnetron (see Fig. 4 for $B > B_c$), electrons follow approximately epicycloidal paths which progress around the cathode. The mean velocity of this progression, that of the center of the rolling circle, depends upon the relative strengths of the electric and magnetic fields as indicated by equation (5) for the plane case. By proper choice of DC voltage V between cathode and anode and of magnetic field B, the mean angular velocity of the electrons can be set at any desired value.

The RF electric fields in the interaction space, with which the electrons moving as described above must interact, are the electric fields fringing from the slots in the anode surface. These fields are provided by the N-coupled oscillating cavities of which the magnetron resonator system is composed. As will be discussed in more detail later, such a system of resonators can oscillate in a number of different modes, in each of which the oscillations in adjacent resonators, and

[11] H. Yagi, *Proc. I.R.E.* 16, 715 (1928).
[12] C. E. Cleeton and N. H. Williams, *Phys. Rev.* 50, 1091 (1936).
[13] K. Posthumus, *Wireless Engineer* 12, 126 (1935).
[14] F. Herriger and F. Hülster, *Zeit. f. Hochfrequenz.* 49, 123 (1937).
[15] The use of such internal resonators is reported in the literature by N. T. Alekseieff and D. E. Maliaroff, *Journ. of Tech. Phys.* (U.S.S.R.) 10, 1297 (1940); republished in English, *Proc. I.R.E.* 32, 136 (1944). A. L. Samuel has obtained U. S. Patent No. 2,063,342 Dec. 8, 1936, for a similar device.

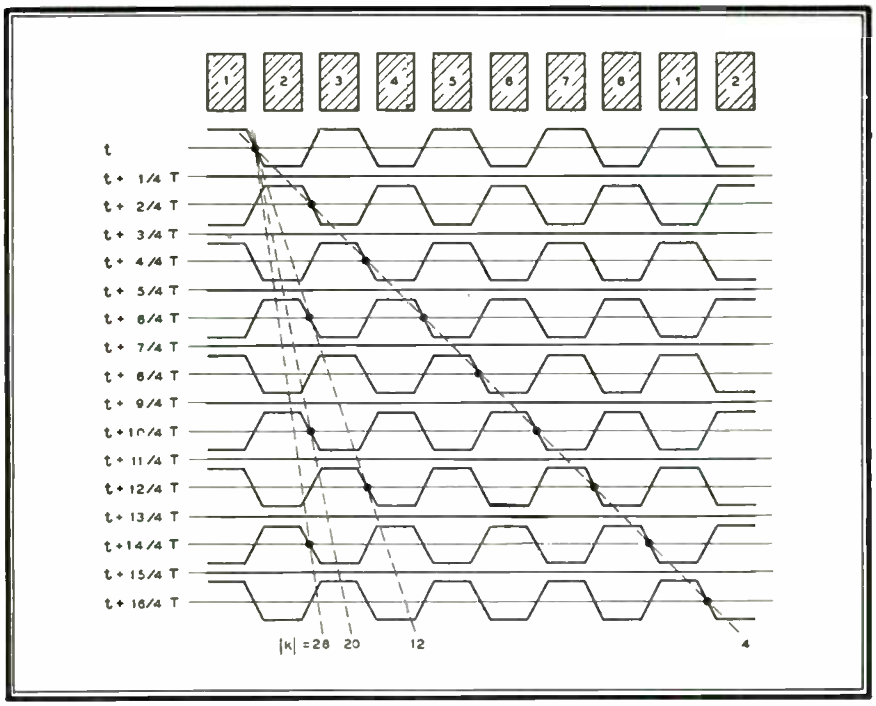


FIG. 9. A plot showing the π mode anode potential wave at several instants in an eight resonator magnetron and the mean paths of electrons which interact favorably with the RF field. The plot is developed from the cylindrical case, the shaded rectangles at the top representing the anode segments. The anode potential variation is a standing wave, shown here for a sequence of instants one quarter period ($T/4$) apart. Note that the potential is constant across the anode surfaces and varies linearly between them. Electrons interacting favorably with the RF field cross the anode gaps when the field there is maximum retarding as indicated by the filled circles. The lines for $|k| = 4, 12, 20, 28, \ldots$ represent mean paths of electrons traveling with mean angular velocities $2\pi f/4$, $2\pi f/12$, $2\pi f/20$, $2\pi f/28$, . . . around in the interaction space. Since the field is a standing wave, it is clear that electrons possessing these velocities in either direction may interact favorably with the RF field.

thus the fields appearing across adjacent anode slots, bear a definite phase relationship. For a system of N resonators, it will be seen that the phase difference between adjacent resonators may assume the values $n\,2\pi/N$ radians, n being the integers 0, 1, 2, . . . , $N/2$.

Adopting another point of view, one may consider the potentials placed upon the anode segments by the resonators. The variation of the potential from one segment to the next depends upon the mode of oscillation of the system as a whole. The restriction on the phase difference stated above requires the sequence of anode segment potentials at any instant to contain n complete cycles in one traversal of the cylindrical anode, n still denoting the integers 0, 1, 2, . . . , $N/2$. In general, these anode potential waves can be standing waves or waves traveling around the anode structure in either direction with angular velocity $2\pi f/n$ radians per second, where f is the RF frequency. For the two modes in which adjacent resonators are in phase ($n = 0$) and π radians out of phase ($n = N/2$, the so-called π mode), however, only standing potential waves on the anode are possible. As examples of standing and traveling anode potential waves in an anode structure having eight resonators ($N = 8$), the standing wave for $n = 4$ and standing and traveling waves for $n = 2$ are shown in Figs. 9, 10, and 11 respectively.

From what has been said about the RF field and the electronic motion in the interaction space of the magnetron oscillator of Type III, it is possible to understand its fundamental electronic mechanism. As in any oscillator, the criterion for oscillation is that more energy shall be transferred to the RF field by electrons driven against it than is taken from the RF field by electrons accelerated by it. This can be accomplished in the traveling wave magnetron oscillator only if the mean angular velocity of the electrons is such as to make them pass successive gaps in the anode at very nearly the same phase in the cycle of the RF field across the gaps. Then it is possible for an electron which leaves the cathode in such phase as to oppose the tangential component of the RF field across one anode gap to continue to lose energy gained from the DC field to the RF field at successive gaps. Electrons which gain energy from the RF field are driven back into the cathode after only one orbital loop and are removed from further motion detrimental to the oscillation. This process of selection and rejection of electrons forms the groups of bunches, shown in Fig. 2 (c), which sweep past the anode slots in phase to be retarded by the RF field component. The criterion that the electron drift velocity shall be such as to keep these bunches in proper phase is analogous to the condition that the drift angle in a velocity variation oscillator, Fig. 2 (b), be such as to cause the bunches to cross the gap of the second or catcher cavity in phase to lose energy to the RF field across the gap.

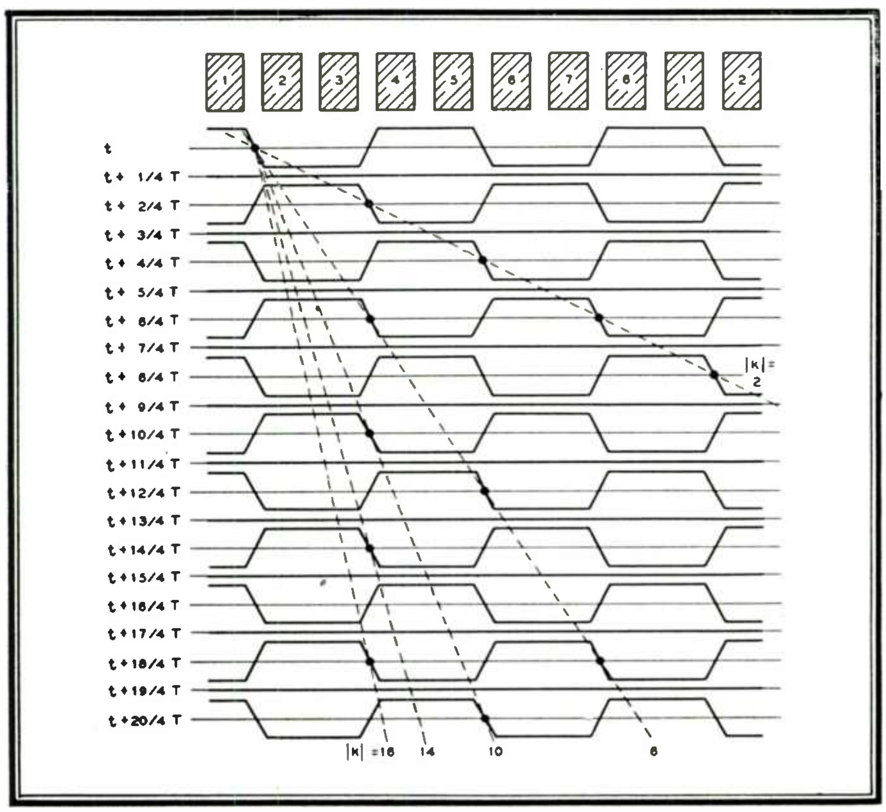


FIG. 10. A plot similar to that of Fig. 9 for the standing wave component of anode potential of periodicity $n = 2$ in a magnetron having eight resonators. Electrons which interact favorably have mean angular velocities $2\pi f/2$, $2\pi f/6$, $2\pi f/10$, $2\pi f/14$, . . . in either direction in the interaction space.

The condition placed upon the mean angular velocity of the electrons can be discussed more readily by reference to Figs. 9, 10, and 11. Consider first, however, only Fig. 9 for the standing potential wave of the $n = 4$ mode, and focus attention on an electron which crosses the gap between anode segments 1 and 2 at the instant t when the RF field is maximum retarding, that is, the potential on segment 1 is maximum and on segment 2 minimum. It is clear that this electron can cross the next gap in the same phase if the time required to reach it is $(|p| + \frac{1}{2})\,T$, in which p is any integer and T is the period of RF oscillation. In Fig. 9, four lines are drawn representing the mean paths of electrons moving with such velocities as to make $p = 0, 1, 2$, and 3. Each line crosses a gap when the RF field is maximum retarding, that is, when the potential has the maximum negative slope at the center of the gap. As will be seen later, a more convenient parameter, to be called k, is that whose absolute magnitude $|k|$ specifies the number of RF cycles required for the electron to move once around the interaction space. $|k|/N$ is then the number of cycles between crossings of successive anode gaps, which for the π mode of Fig. 9 must take on the values:

$$\frac{|k|}{N} = |p| + \frac{1}{2}, \qquad p = 0, \pm 1, \pm 2, \cdots,$$

or the values given by the more general expression, applicable to any mode:

$$\frac{|k|}{N} = |p| + \frac{n}{N}, \qquad p = 0, \pm 1, \pm 2, \cdots.$$

In this expression, n/N is the phase difference between adjacent resonators, expressed as a fraction of a cycle. k may thus assume the values given by

$$\left.\begin{aligned} k &= n + pN, \\ p &= 0, \pm 1, \pm 2, \cdots. \end{aligned}\right\} \quad (10)$$

The mean angular velocity which the electrons must possess is then given by

$$\frac{d\theta}{dt} = \frac{2\pi}{kT} = \frac{2\pi f}{k}, \qquad (11)$$

in which θ is the azimuthal angle.

For the π mode ($n = N/2$) it is seen that the negative integers p give the same series of values for $|k|$ as do the positive integers including zero. The sequence is $|k| = 4, 12, 20, 28, \cdots$. Reference to Fig. 9 indicates that electrons can travel in either direction around the interaction space and interact favorably with the RF field, provided their mean angular velocity is given by equation (11) with values of k specified by equation (10). That this should be so is clear from the fact that the anode potential wave is a standing wave with respect to which direction has no meaning. Fig. 9 also makes clear how an electron, moving with velocity different from that corresponding to the lines shown, will fall out of step with the field and, on the average, be accelerated as much as it is retarded, thus effecting no net energy transfer.

In Figs. 10 and 11, diagrams for the $n = 2$ mode similar to that of Fig. 9 for the π mode are shown. Fig. 10 is for electronic interaction with a standing wave of periodicity $n = 2$, and Fig. 11 for a traveling wave of the same periodicity. Again, as in the case of the π mode, the values of k for favorable electronic interaction are given by equation (10).

The sequence of positive integral values of p (including zero) and the sequence of negative integral values of p do not each give the same sequence of values for $|k|$, as was the case for the π mode. For $p \geqq 0$, $|k| = 2, 10, 18, \cdots$; and for $p < 0$, $|k| = 6, 14, 22, \cdots$. For the standing potential wave, Fig. 10, each of these values of $|k|$ does specify the velocity of possible electron motion in *either* direction for favorable interaction with the field. For the traveling potential wave, Fig. 11, on the other hand, only the positive values of k ($p \geqq 0$) correspond to electron motion in the same direction as the traveling wave, the negative values of k ($p < 0$) corresponding to electron motion in the direction opposite to the traveling wave. The sign of k has significance. If the electrons are moving with velocities specified by equation (11), with the negative values of k from equation (10), and are thus moving counter to the traveling RF field wave, the electrons are said to be driving a *reverse* mode.

The actual electron orbits do not correspond to simple translation but, as has been discussed, to rotation superposed on translation. The epicycloid-like scallops in the orbit are of no significance to the fundamental electronic mechanism. It is the mean velocity of the electron motion around the interaction space, specified by the relative values of V and B, that is of importance. The magnetron can operate, for example, at such high magnetic field, provided V has the proper value, that the scallops become relatively small variations in an otherwise smooth orbit, Fig. 18.

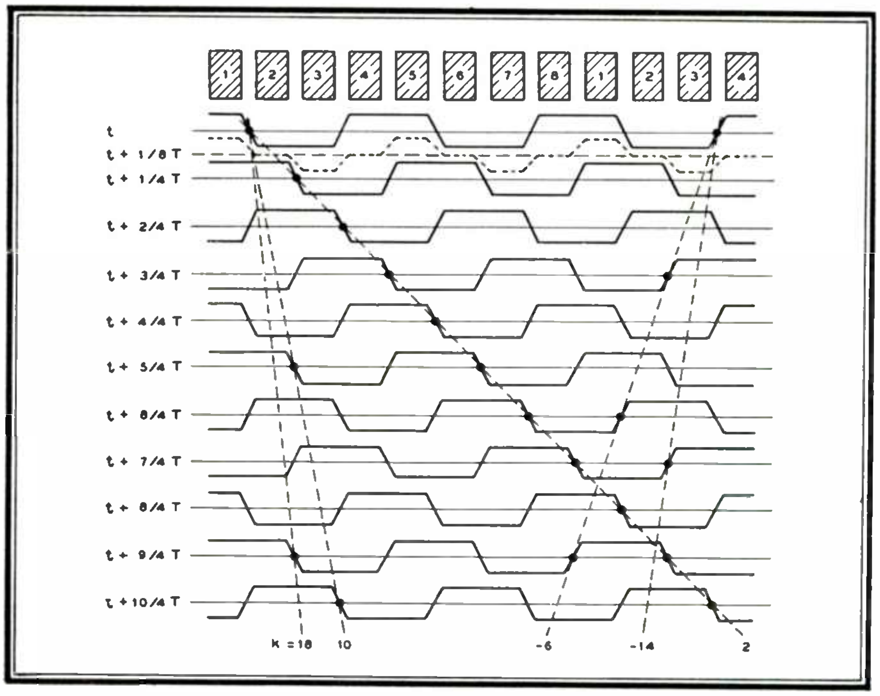


FIG. 11. A plot similar to those of Figs. 9 and 10 for the rotating wave of anode potential of periodicity $n = 2$ in a magnetron having eight resonators as indicated by equation (13) in the text. The field at the instant $t + \frac{1}{8}T$ is plotted as a dashed line to show that the traveling wave does not preserve its shape at all instants. Whereas the wave travels in one direction with the angular velocity $2\pi f/2$, electrons which travel with velocities $2\pi f/2$, $2\pi f/10$, $2\pi f/18$, . . . in the same direction or with velocities $2\pi f/6$, $2\pi f/14$, . . . in the opposite direction interact favorably with the RF field. Directions of electron motion must now be distinguished. Electrons whose velocity is opposed to that of the rotating field are said to be driving a "reverse" mode.

In the cylindrical magnetron, the radial variation of the DC electric field, resulting in a decrease in the mean angular velocity of the electrons as they approach the anode, would make it impossible for an electron to keep step with the fields across the anode gaps were not a mechanism of phase focusing operative. That such focusing is inherent in the interaction of electrons and fields will be seen later.

3.2 *The Interaction Field:* The electronic mechanism which has been discussed in terms of electron motions through the fields at the gaps in the multisegment anode can be discussed also in terms of the traveling waves of which the RF interaction field can be considered to be composed. The RF interaction field corresponds to anode potential waves like those plotted in Figs. 9, 10, and 11. The interaction fields for the several modes of oscillation of the resonator system are thus to be distinguished by the number, n, of repeats of the field pattern around the interaction space. Since the potential at the anode radius is nearly constant across the faces of the anode segments and varies primarily across the slots, the azimuthal variation of the field cannot be purely sinusoidal, but must involve higher order harmonics.

For a mode of angular frequency $\omega = 2\pi f$, corresponding to a phase difference between adjacent resonators of

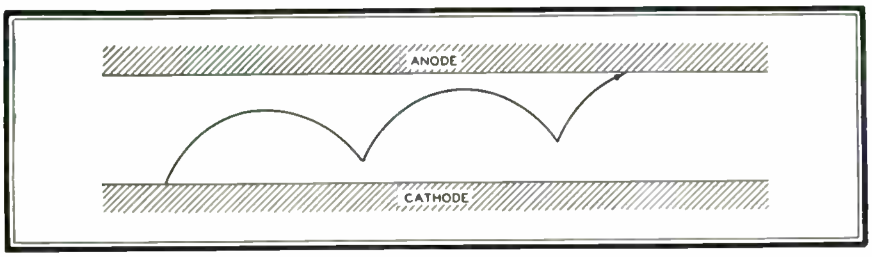


FIG. 12. An approximate orbit of an electron which is losing energy to the RF field in a traveling wave or Type III magnetron oscillator, shown for the plane case. Here the energy loss is potential energy of the electron in the DC field. Compare this with the orbit in Fig. 8 where the energy loss is rotational energy of the electron. The DC electric force on the electron is directed from cathode to anode.

$n\,2\pi/N$, the anode potential wave is of periodicity n around the anode and can be written as a Fourier series of component waves traveling in opposite directions around the interaction space:

$$V_{RF} = \sum_k A_k e^{j(\omega t - k\theta + \gamma)} + \sum_k B_k e^{j(\omega t + k\theta + \delta)}, \qquad (12)$$

$$k = n + pN, \quad p = 0, \pm 1, \pm 2, \cdots.$$

Note that the summations are taken over all integral values of k given by equation (10).

The interaction field for any mode of periodicity n is thus represented by two oppositely traveling waves, whose fundamentals are moving with angular velocities $\omega/n = 2\pi f/n$, and whose component amplitudes, A_k and B_k, in general are not equal. γ and δ are arbitrary phase constants. The expression (12) can be reduced to the form:

$$V_{RF} = \sum_k (A_k - B_k) \cos(\omega t - k\theta + \gamma) + \sum_k 2B_k \cos\left(\omega t + \frac{\gamma+\delta}{2}\right) \cos\left(k\theta - \frac{\gamma-\delta}{2}\right), \qquad (13)$$

$$k = n + pN, \quad p = 0, \pm 1, \pm 2, \cdots,$$

which shows that the complete field pattern can be considered to consist of a rotating wave superposed on a standing wave, each having a fundamental component of periodicity n.

The fact that the periodicities k of the harmonics in the expressions (12) or (13) are those for which k has the values given by (10) can be determined from a Fourier analysis of the complete anode potential waves like those of Figs. 9, 10, and 11. Only those harmonics which specify the same pattern of potentials at the centers of the anode segments as the fundamental are admitted in the analysis.

As has been mentioned before, the complete field patterns for $n = 0$ and $n = N/2$ are standing waves. Thus, for these modes of oscillation, $A_k = B_k$ in the expressions (12) and (13). For the other modes, $n = 1, 2, 3, \cdots, (N/2) - 1$, the electrons may interact with the traveling field component of expression (13) or with the standing field components which, in case $A_k = B_k$, is the only component present. See Figs. 10 and 11 for the case $n = 2$, $N = 8$.

The terms in expressions (12) and (13) for which $|k| = n$ are the fundamental components; those for which $|k| \neq n$ are

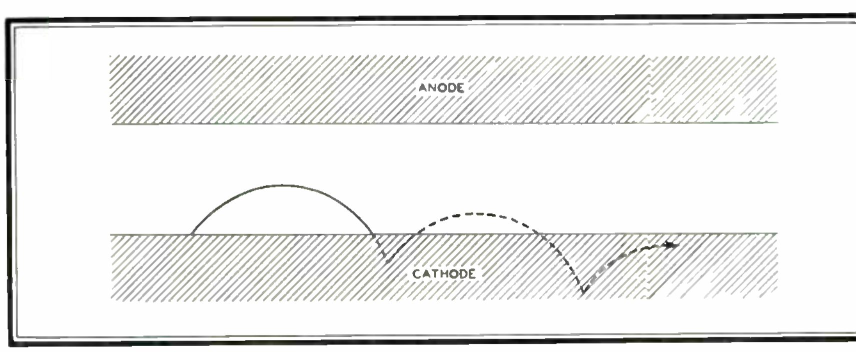


FIG. 13. An approximate orbit of an electron which gains energy from the RF field in a traveling wave or Type III magnetron oscillator, shown for the plane case. The orbit is extended as a dashed line as though the cathode were not there. The energy gained is potential energy of the electron in the DC field. Compare this with the orbit in Fig. 7 where the energy increase is in the rotational energy of the electron. The DC electric force on the electron is directed from cathode to anode.

called the Hartree harmonics. The components of field strength corresponding to these harmonics in the interaction field pattern fall off in intensity from anode to cathode more rapidly the higher the value of k. The variation with radius is of the form $(r/r_a)^k$. Thus the farther from the anode one samples the field, the more like the fundamental sinusoidal pattern it appears.

For each value of k in expression (12), whether or not $A_k = B_k$, there are two oppositely traveling sinusoidal wave components of periodicity k. Since each requires k cycles of the RF oscillation to complete one trip around the interaction space, the linear velocity at the anode surface is $2\pi f r_a/k$ corresponding to an angular velocity of $2\pi f/k$. Thus, as seen in Fig. 11 for the instant $t + T/8$, the change of shape of the total traveling wave indicates that the components of which it is composed travel with different velocities. In Fig. 23 will be shown instantaneous RF interaction field patterns for the fundamental components ($p = 0$) of the $n = 1, 2, 3$, and 4 modes of an anode block having eight resonators.

3.3 *The Traveling Wave Picture:* It is instructive to discuss the operation of the Type III magnetron oscillator in terms of electron interaction with the traveling wave components present in the interaction field. This might at first appear to be difficult in view of the many components of several possible modes. By mode frequency separation, as discussed later, it is generally possible, however, to restrict oscillation to only one mode, usually the π mode. Further, the fact that the electronic motion in crossed DC electric and magnetic fields results in a mean drift of electrons around the interaction space enables one to restrict one's attention to a single traveling wave corresponding to the fundamental or a single Hartree harmonic of the field of this mode; for it is possible, in principle at least, by proper adjustment of V and B to equate the mean angular velocity of the electrons to the angular velocity $2\pi f/|k|$ of *any* one of the traveling field components. When this is true, only the field of this component has an appreciable effect upon the electron's motion. With respect to the fields of the oppositely traveling component of the same harmonic (same k), and the components of all other harmonics (different k), the electron finds itself drifting rapidly through regions of accelerating and decelerating field with no net energy transfer. From the point of view of the electron, the fields of the other components vary so rapidly as to average out over any appreciable interval of time. The only exception to these statements occurs when a harmonic of periodicity k' of another mode of frequency f' has the same angular velocity as the harmonic of periodicity k, that is, when

$$\frac{2\pi f'}{|k'|} = \frac{2\pi f}{|k|}.$$

The effect on magnetron operation of this coincidence of angular velocities will be discussed further in a later section. In the calculation of electron motions, the restriction to the field of a single traveling wave component has been called the *rotating field approximation.*

The consideration of the electronic mechanism has thus been reduced to that of the motion of electrons under the combined influence of the radial DC electric field, the axial DC magnetic field, and a sinusoidal field wave traveling around the interaction space. From what has been said thus far, it is clear that for energy to be transferred to the RF field it is necessary that the mean electron velocity very nearly equal that of the traveling wave. Then an electron leaving the cathode in such phase as to find itself moving in a region of decelerating tangential component of the RF field may continue to move with this region and lose energy to the field. In contrast to the Type II magnetron oscillator, the energy transferred to the RF field in this case is the potential energy of the electron in the radial DC electric field. The energy in the rotational component of the motion remains practically unaffected, and the electron orbit from cathode to anode looks something like that plotted in Fig. 12 for the case with plane electrodes. On the other hand, an electron which leaves the cathode in such phase as to gain energy in a region of accelerating tangential RF field is removed at the cathode after only one cycle of the epicycloid-like motion. If this did not occur, the electron would continue to move with the field and absorb energy. An approximate orbit is shown in Fig. 13. It is instructive to compare the orbits of the two categories of electrons in the traveling wave magnetron oscillator with the orbits of corresponding electrons in the cyclotron frequency type of magnetron oscillator, Figs. 7 and 8. In each case, it is the fact that *favorable* electrons may interact for a considerably longer time than *unfavorable* electrons which makes possible a net energy transfer between the DC and RF fields

One can now compare the traveling wave picture of the electronic mechanism with that presented earlier in which the motion of electrons past the gaps in the anode structure is considered. An electron moving so that

$$\frac{|k|}{N} = |p| + \frac{n}{N} \text{ cycles}$$

of the RF oscillation elapse between its crossing of two successive anode gaps is thus moving around the interaction space in synchronism with a traveling component of the *kth* harmonic of the interaction field. Both points of view are of value. That involving the motion of electrons past the anode gaps is more fundamental physically. That in terms of a traveling wave component, on the other hand, is more convenient in calculations of electron orbits including space charge effects where, by transformation to a coördinate system rotating with the field, it is possible to treat of motions in static fields.

3.4 *Phase Focusing:* It has been seen from two points of view how groups of electrons which move around the interaction space of the magnetron oscillator are formed by a process of selection and rejection of electrons by the tangential component of the RF field. However, space charge debunching and the discrepancy at all but one radius between the mean velocity of translation of the electrons and the velocity of the interaction field would tend to disperse these groups and prevent efficient interaction, were it not for the phase focusing provided by the radial component of the RF field.

The mechanism of the phase focusing can be discussed either in terms of the interaction of electrons with the actual fields existing at the anode gaps, or in terms of the traveling wave picture of the electronic mechanism. The fundamental mechanism involved depends upon the effect of the radial component of the RF field in aiding or opposing the radial DC field in determining the mean drift velocity of the electron around the interaction space. If the radial RF field increases the net radial field in which the electron finds itself at any instant, the mean velocity of the electron increases, as can be seen from equation (5) for the plane case. Similarly, a decrease in the net radial electric field, caused by the RF radial component, results in decreased electron translation velocity. These changes in the electron's velocity operate so as to keep the electron near the position in which it can interact most favorably with the tangential component of the RF field.

Consider an electron which crosses an anode gap at the instant the RF field there is maximum retarding, that is, an electron which is to be found on the plane marked M in Fig. 14 at this instant. It experiences about as great an increase of velocity by virtue of the radial component aiding the DC radial field before crossing the gap as decrease by virtue of the radial component opposing the DC radial field after crossing the gap. Another electron which is lagging behind the electron just considered is to be found opposite a positively charged anode segment, as at P in Fig. 14, when the RF field passes through its maximum value. Since the RF field component decreases with time after this instant, the effect of the radial component of the field on the electron's velocity after crossing the gap will be less than its effect before crossing the gap, the net effect being one of increasing the mean velocity of translation, bringing the electron more nearly into the proper phase. An electron which leads the electron first considered, on the other hand, will be found opposite the negatively charged anode segment beyond the gap when the RF field is maximum, and for it the net effect of the radial component is to reduce the mean velocity of the electron, bringing it also more nearly into the proper phase.

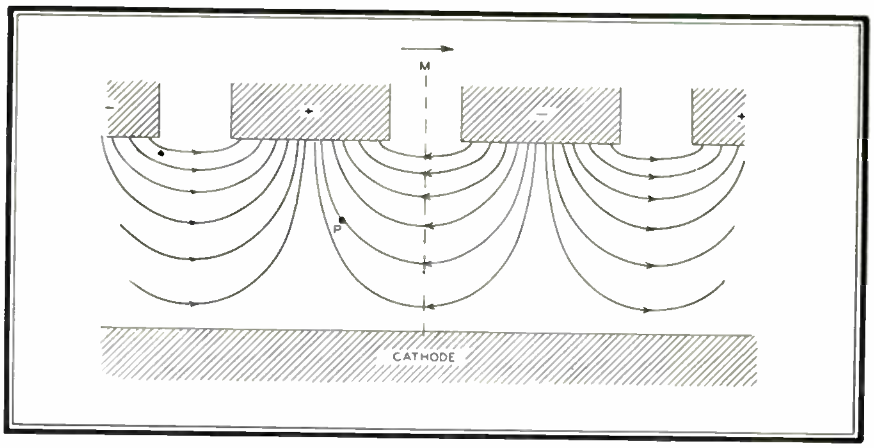


FIG. 14. A plot of lines of electric force on an electron, drawn for the plane case, for the fundamental of the π mode. It is shown for the purpose of explaining the phase focusing property of the radial field component. The plane of maximum opposing force on the electron intersects that of the figure along the line M. The arrow shown above the line M indicates the direction of electron motion. The force on the electron due to the DC electric field is directed from cathode to anode. The force lines shown may be considered to be those of the total fundamental field component at the instant the field is maximum. Then an electron at the point P will cross the center of the anode gap after the instant of maximum retarding force. Or the lines shown may be considered to be those of the traveling component of the fundamental moving in the same direction as the electrons. In this case an electron at the point P is lagging behind the maximum of the retarding tangential field.

In discussing the mechanism of phase-focusing from the traveling wave point of view, the field lines of Fig. 14 can be considered to be those of the traveling wave component with which the electrons are intereacting. Then the whole field pattern indicated moves to the right as shown by the arrow above the plane of maximum retarding tangential field at M. An electron which falls behind the position M to the point P, for example, finds itself in a stronger net radial electric field which increases its mean translational velocity tending to bring it back to the position M. The reverse holds for an electron which runs ahead of the plane M.

on the basis of this space charge distribution can then be compared with that assumed. This cycle of calculations is repeated, each time using the calculated field of the previous cycle as that in which the electrons move, until a field is obtained which is consistent with that used in calculating the electron orbits. This method will be recognized as that used in the calculation of electron orbits about the nucleus in atoms.

The result of one such calculation is shown in Fig. 15. The orbits of four electrons which were emitted from the cathode in different phases are plotted in a set of coördinates rotating with the RF

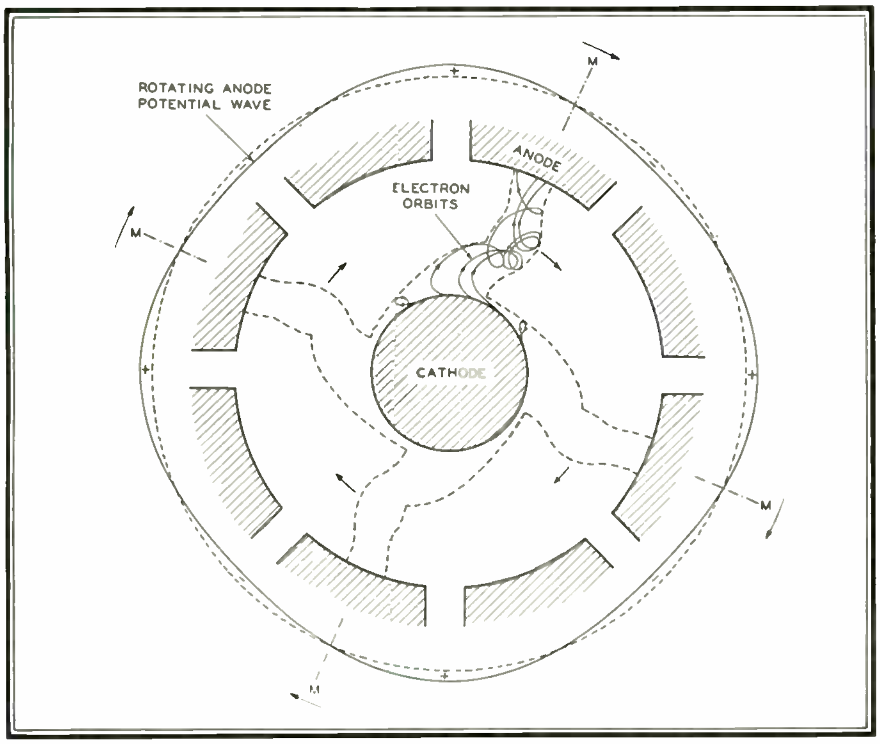


FIG. 15. The orbits of four electrons which left the cathode in different phases, plotted in a coördinate system rotating with the anode potential wave. These orbits have been calculated by the self consistent field method which includes space charge effects. In this frame of reference the orbits exhibit loops, whereas in a stationary frame they would more nearly exhibit cusps. The dashed lines inclose the orbits of the electrons and hence delineate the boundaries of the space charge cloud which rotates around the cathode in synchronism with the anode potential wave. Planes of maximum retarding tangential field are represented by the lines M in Fig. 14. This figure is reproduced by courtesy of the British Committee on Valve Development (CVD) and is taken from the CVD Magnetron Report No. 41.

3.5 *Space Charge Configuration:* The over-all picture of the electronic mechanism in the Type III magnetron oscillator thus presents a spoke-shaped space charge cloud of electrons wheeling around the cathode in synchronism with the anode potential wave, each spoke in a region of maximum retarding field. This picture of what is happening has been very handsomely confirmed by actual orbital calculations taking account of space charge. The calculations have been carried out by the so-called self consistent field method, using the rotating field approximation mentioned earlier. In this method, orbits of electrons are calculated in an assumed field, and the space charge due to these electrons determined. The field calculated

field component. One electron is returned to the cathode, and the other three reach the anode. The boundaries of the space charge cloud are shown as dashed lines. The spoke-shaped structure is clear, and its position with respect to the rotating anode potential wave is as expected. The number of spokes of the cloud is equal to the periodicity of the component of the mode with which the electrons are interacting. In the case of Fig. 15 there are four spokes, since the magnetron is operating in the fundamental of the $n = 4$ mode ($k = 4$, $p = 0$).

3.6 *Induction by the Space Charge Cloud:* Another view of the mechanism by which the electrons drive the resonator system can be obtained by considering the effect of the space charge spokes in inducing current flow in the anode segments themselves. For example, the oscillation of the resonator block in its π mode corresponds to the periodic interchange of electric charge from each anode segment around a resonating cavity to the next anode segment. This oscillation is maintained, much in the manner of a pendulum escapement drive, by the space charge spoke appearing in front of an anode segment at that instant in the oscillation cycle when it can aid in building up the net positive charge on the segment. At the same instant, the adjacent segments, being opposite a gap in the space charge wheel, may build up a negative charge.

The RF current I_{RF} induced in the anode structure thus results from the motion of the spoke-shaped space charge cloud in the interaction space. It is not to be confused with the total circulating RF current in the resonator system. Whereas I_{RF} must be in a phase with the space charge cloud, it need not be in phase with the RF voltage V_{RF} between the anode segments. In terms of the electron motions, this means that the spokes of the space charge cloud may lead or lag the maxima in the tangential field. In general, the electronic admittance defined by the ratio of I_{RF} to V_{RF} may thus include a susceptance as well as a conductance. The product of V_{RF} and the in-phase component of I_{RF}, integrated over a period of one cycle of RF oscillation, equals the energy per cycle which is delivered to the load. This amount of energy is twice that transferred in the half-cycle during which the spokes of space charge move against the field from positions in front of one set of alternate anode segments to similar positions in front of the adjacent anode segments.

In each spoke of the electron space charge cloud, individual electrons progress from cathode to anode. The DC current I, passed by the magnetron, is made up of electrons which strike the anode from the ends of the space charge spokes. Quite apart from its dependence on other parameters, this DC current is directly proportional to anode length h. If the magnetron is driven at greater DC current, the space charge in the interaction space increases, but the phase of its structure with respect to the traveling anode wave does not change to a first approximation. Thus both the in-phase and quadrature components of I_{RF} increase with no change in electronic admittance. The second order effects which do arise from small shifts in the phase of the rotating space charge structure will be discussed in Section 10.4 *Electronic Effects on Frequency*.

EDITOR'S NOTE: This paper will be published in six installments. The second installment will appear in our November issue.

THE W. E. SERIES OF FM TRANSMITTERS

Engineering Information on Western Electric FM Transmitters of 1, 3, and 10 Kw., and Advance Data on Designs for 25 and 50 Kw.—Part 2

BY JOHN H. GANZENHUBER

1-Kw. Transmitter ★ The essential circuits of the 1-kw. type 503B-2 transmitting equipment are given in the system schematic in Fig. 10. In addition, a more detailed schematic of each section is provided, along with its accompanying description in this text.

Oscillator-Modulator ★ Fig. 11 is the detailed schematic of the oscillator-modulator panel. The source of the radio frequency oscillation is the balanced push-pull oscillator circuit V1A, primary of L3A, and C10, 11, 12, and 13A, which operate at a mean frequency *f* (carrier)/16. Some of the energy of this circuit is taken by the secondary of L3A to a 90° network, L5A, C14A, C15A, and R7A. The output voltage of the 90° network, constant in amplitude, is supplied in parallel to the grids of the reactance control tubes V2A, the plate circuit of which is common with that of the oscillator tubes. Negative feedback is introduced in the cathode circuit of V1A by the potentiometer P1A and inductance L9A. This negative feedback stabilizes the amplitude of the output and also provides an easy method for adjusting the 90° phase network accurately. The adjustment is made by connecting headphones to jack J1A and adjusting C14A and C15A for zero tone. Any audio tone present at this point represents amplitude variations which can cause FM distortion. Therefore, this easy adjustment eliminates any distortion that might be possible from inaccurate phasing.

The output voltage of the 90° network is applied to the grids of the reactance control tubes V2A, and creates a component of radio frequency current in its plate circuit in quadrature with the RF voltage across the oscillatory circuit. These "reactance tubes," therefore, appear to the oscillatory circuit as a reactance. The audio voltage from the input transformer T3A is superimposed on the bias voltage of V2A. The radio frequency current in the plate circuit, in other words the effective reactance of the tube, is proportional to the audio input voltage. Therefore, the mean frequency is varied by an increment proportional to the amplitude of the audio signal, and at a rate proportional to the audio frequency. As mentioned before, the circuit is operated at the optimum point for linear modulation, since no limitation on biasing is imposed by a frequency-control function.

RF voltage from L3A is also supplied to the grid of the buffer amplifier stage V3A. The output of this stage drives the grid of the first doubler stage, V4A, and also supplies the input to the frequency divider panel through the coupling circuit C30A, C31A, and T2A. The first doubler stage provides the modulated RF output to the doubler panel at a mean frequency of *f* (carrier)/8.

Frequency Doubler Panel ★ The frequency doubler panel, Fig. 12, includes three additional doubler stages, V1B, V2B, and V3B. Thus the input mean frequency, *f*/8, is increased so that the output of this panel is at the assigned carrier frequency.

The plate circuit inductance L1B, and plate tuning capacitor C15B are adjustable by means of front panel controls.

Pow3r Amplifier Panel ★ The input energy to the two-stage power amplifier, shown in Fig. 13, is at carrier frequency. The first stage, V4C, has two tubes in push-pull. The plate circuit is tuned by condenser C1C, which is adjustable from the control panel. Variable condensers C2C and C8C are used to minimize the series impedance between the screens and ground, thus providing optimum isolation between the grids and plates of the tubes.

The final stage has two Western Electric type 357 tubes in push-pull. The tubes are neutralized by inductance L9C and L10C. Variable coupling is provided between the output of this stage and the load.

Variable condenser C17C, in a sealable container, provides a means of adjusting the transmission line voltmeter M4M. After adjustment of C17C, the cover is sealed in place to prevent unauthorized tampering.

A pick-up loop provides a sample of the output for monitoring purposes.

Frequency Divider Panel ★ A part of the frequency-modulated output of the buffer stage V3A is supplied to the balanced input of the frequency divider panel, shown in Fig. 14. In this panel the signal passes through ten frequency divider stages operating on the principle of regenerative modulation. Each stage, consisting of a balanced modulator such as RV5H and a regenerative amplifier such as V5H, produces an output frequency of half that applied to the input terminals. The last stage, V11H, is an untuned amplifier stage without frequency division. The output frequency of the frequency divider panel is, accordingly, *f* (carrier)/16,384. The balanced modulators of stages 1 to 7 inclusive use rectifiers of the germanium crystal type. Stages 8 to 10 inclusive use rectifiers of the copper oxide type.

The features of the divider stages are:

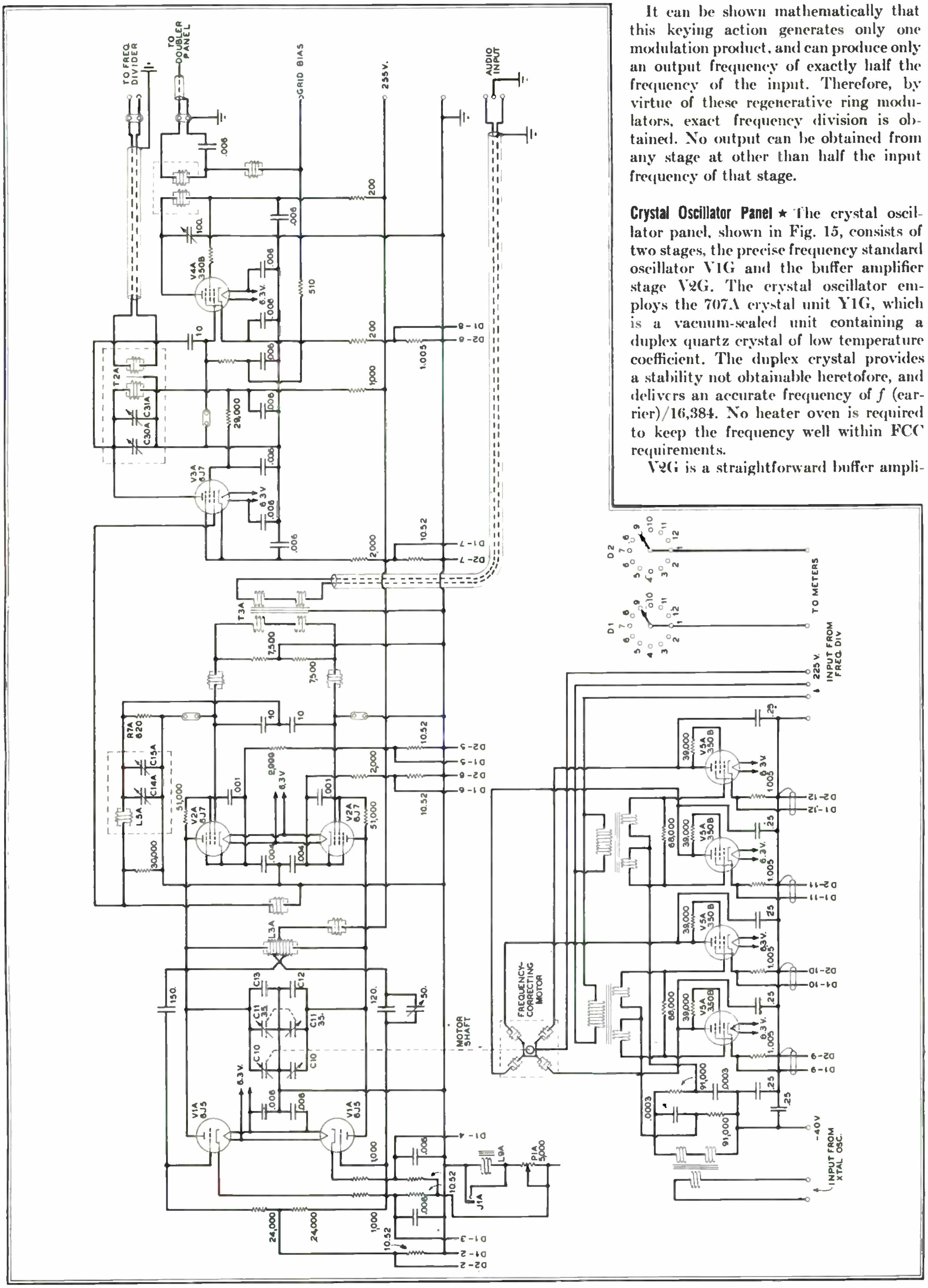
1. The input frequency is suppressed by virtue of the switching effect of the balanced ring modulators.

2. Regenerative feedback can occur only when an input current is present and the feedback is at half the input frequency. For this reason the output frequency of these divider stages can be only one frequency, i.e., either half the input frequency or nothing. It is therefore impossible for the circuit to produce an erroneous output frequency.

The amplitude modulator networks are rectifiers connected all in direct series, so to speak, "around a ring." Taking the first stage in Fig. 14 as an example, it is possible for DC to flow in RV1H from 1 to 4 to 3 to 2 and back to 1.

The input frequency, applied across terminals 2 and 4 of RV1H, effectively keys or modulates the feedback from T1H which is applied to the junction points of R96H-R97H and R98H-R99H. The plate circuit of the tube is tuned to half the frequency of the output, and a portion of this half-frequency energy is fed back to the modulator RV1H in the grid circuit. At such times that there is no input frequency, two balanced paths are available for this feedback voltage which effectively applies equal voltages of opposite phase to resistors R98H and R99H. Under these conditions, the net voltages applied between grid and ground are zero.

When the input voltage is applied, this balance is disturbed by the input current flow. During the half-cycle of the input current, when terminal 2 is positive, input current will flow from terminal 4 to 3 to 2. This current flow will be modulated with the feedback voltage ($f/2$) thus effectively applying the feedback voltage to R98H in the grid circuit of the tube. During the other half-cycle, when terminal 2 is negative, current will flow from terminal 2 to 1 to 4, thus applying the modulated voltage to R99H, but in reverse phase. This switching action effectively suppresses the input frequency and provides an output frequency of $f/2$.



It can be shown mathematically that this keying action generates only one modulation product, and can produce only an output frequency of exactly half the frequency of the input. Therefore, by virtue of these regenerative ring modulators, exact frequency division is obtained. No output can be obtained from any stage at other than half the input frequency of that stage.

Crystal Oscillator Panel ★ The crystal oscillator panel, shown in Fig. 15, consists of two stages, the precise frequency standard oscillator V1G and the buffer amplifier stage V2G. The crystal oscillator employs the 707A crystal unit Y1G, which is a vacuum-sealed unit containing a duplex quartz crystal of low temperature coefficient. The duplex crystal provides a stability not obtainable heretofore, and delivers an accurate frequency of *f* (carrier)/16,384. No heater oven is required to keep the frequency well within FCC requirements.

V2G is a straightforward buffer ampli-

FIG. 11. DETAILED SCHEMATIC DIAGRAM OF THE OSCILLATOR-MODULATOR PANEL, ALSO SHOWING CENTER FREQUENCY CONTROL

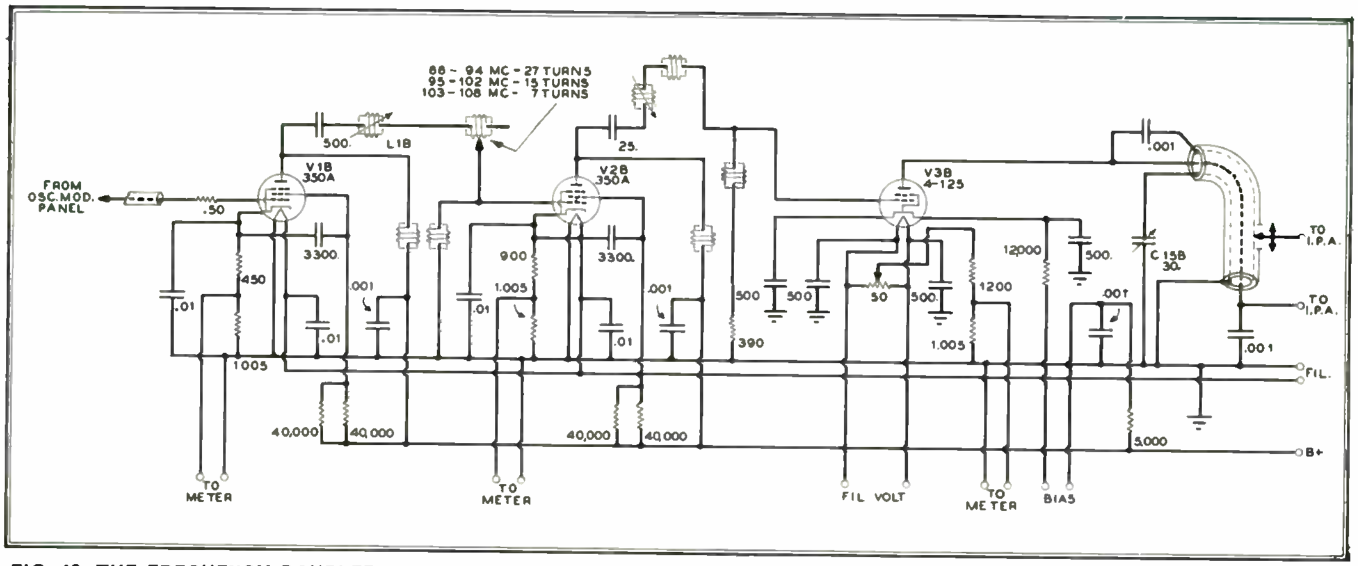


FIG. 12. THE FREQUENCY DOUBLER PANEL, COMPRISED OF THREE DOUBLER STAGES. OUTPUT IS AT THE CARRIER FREQUENCY

fier. Jack J1G provides a means for measuring the input, while jack J2G and potentiometer P1G provide means for measuring and adjusting the output. The output of this panel is applied to the automatic frequency control circuit.

AFC Circuit ★ The automatic frequency control circuit is shown on the oscillator-modulator panel schematic, Fig. 11. Tubes V5A are paired, each pair being part of one balanced modulator circuit, as shown in the schematic wiring diagram. The plates of each pair of tubes are connected to opposite field coils of the motor whose shaft is connected to the frequency-controlling condenser. The voltage from the output of the frequency divider panel is applied to the grids of one tube in each pair in like phase, and in opposite phase to the other tube in each pair.

The voltage from the crystal oscillator panel is divided into two voltages by the circuits made up of the input transformers and associated resistors and condensers. These two voltages are identical except that they are in phase quadrature. One phase is applied to the grids of third and fourth tubes, and the other to the grids of first and second tubes.

All of the tubes are biased approximately to cut-off. Also note that the plate-to-ground bypass condensers on the V5A automatic frequency control tubes provide low-impedance paths for the high-frequency components. The currents flowing in the motor fields winding are dependent upon the phase relation existing between the two voltages applied to the

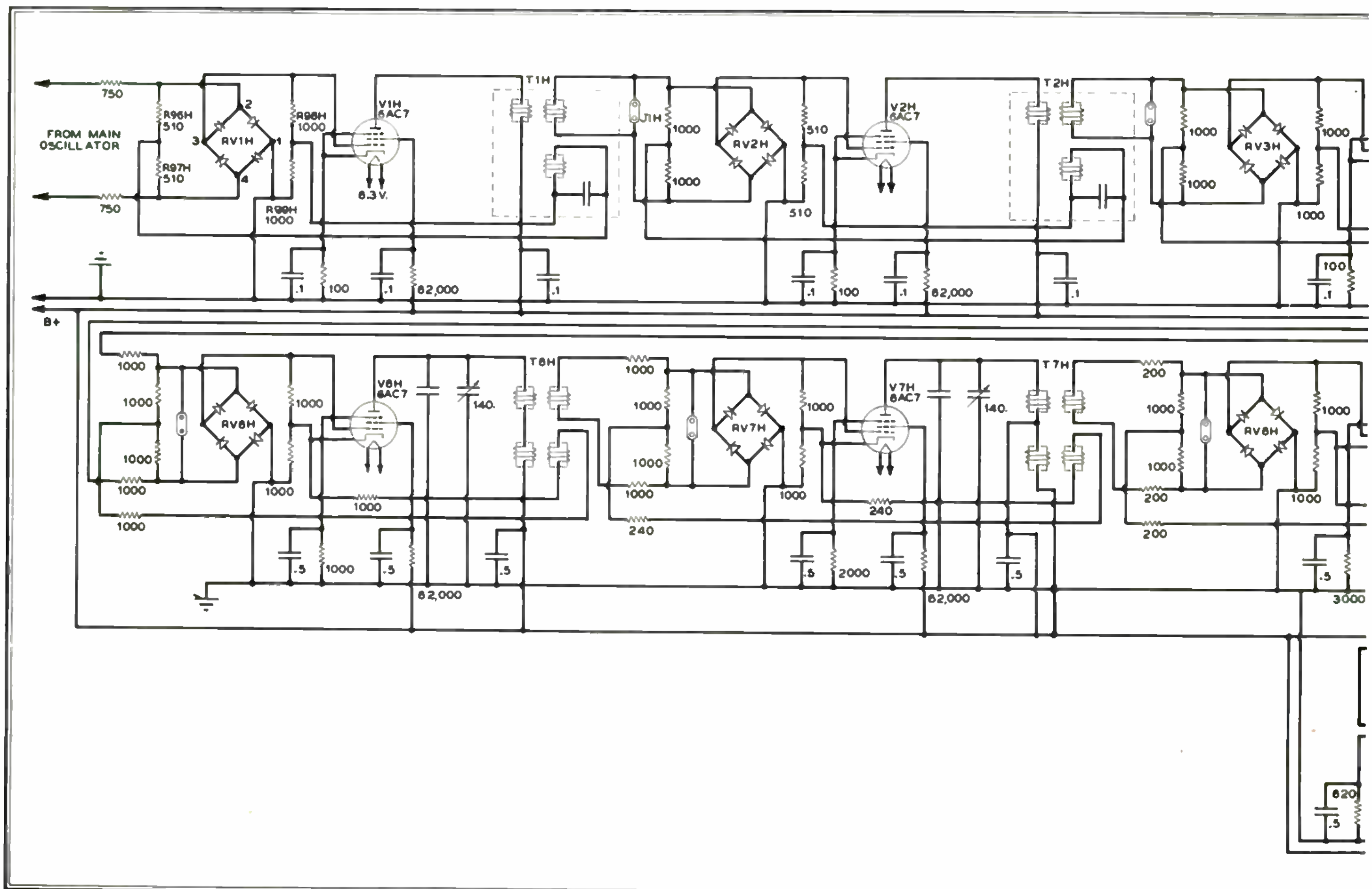


FIG. 14. PART OF THE FREQUENCY-MODULATED OUTPUT OF BUFFER STAGE V3A, FIG. 11, IS FED TO THE INPUT OF THIS

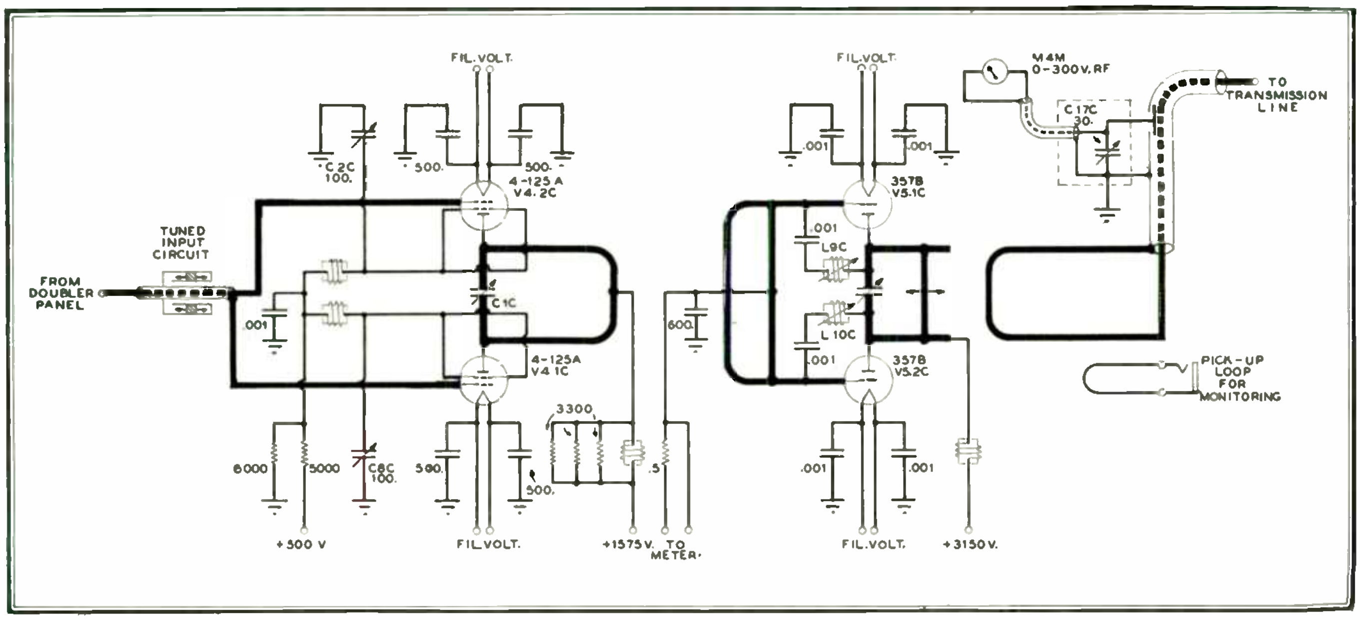


FIG. 13. SCHEMATIC DIAGRAM OF THE 1-KW. POWER AMPLIFIER, USING TWO 357B TUBES IN PUSH-PULL FOR THE OUTPUT

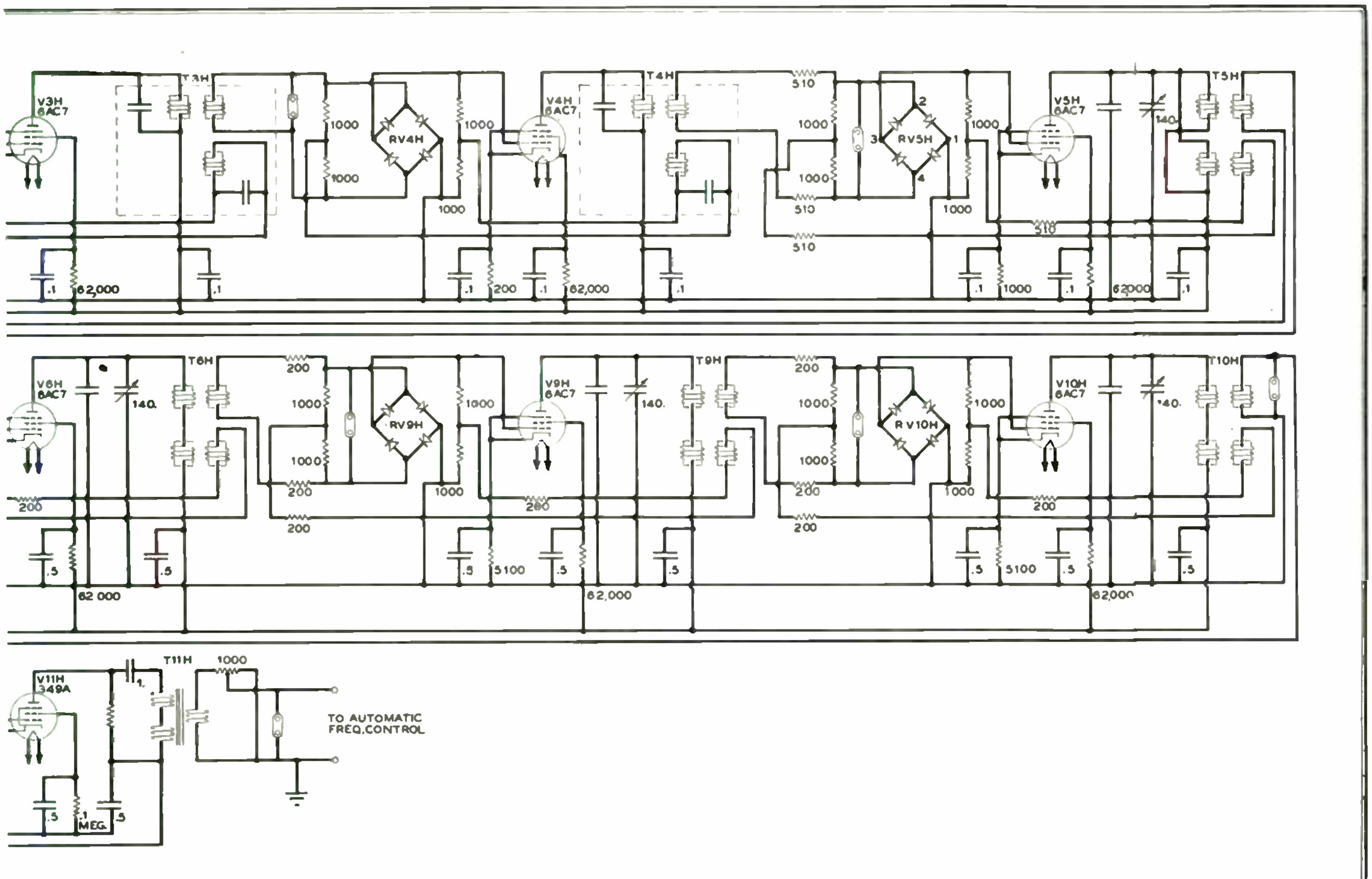
grids of the associated tubes. If the phase of one of the voltages varies with respect to the other, the resultant field in the motor will rotate. The rate of rotation varies in proportion to the frequency difference, and its direction depends upon the relative phase of the two voltages.

With exact synchronization, the resultant currents will be at zero frequency and no action will take place. When a frequency difference exists, a beat frequency results, and the rotating field will cause the armature to drive the mechanically-coupled variable condenser in the oscillator circuit in such a direction that its capacity will be decreased if the carrier frequency is low, and increased if the frequency is high.

The rate of rotation is approximately proportional to the angular velocity of the rotating field. Hence a large frequency difference will be quickly reduced to a small value.

3-Kw. Transmitter ★ The 3-kw. type 504B-2 transmitter is distinguished by its simplicity and straightforward design. The basic frequency modulation and driver circuits for the final power amplifier are provided by the 1-kw. transmitter just described. The final power stage for providing the 3-kw. output is a single-tube, single-stage grounded grid amplifier.

In this particular transmitter, since 1 kw. of driving power is available, high



FREQUENCY DIVIDER PANEL. THE OUTPUT, AT 1/16384TH THE CARRIER FREQUENCY, IS FED TO THE FREQUENCY CORRECTOR, FIG. 11

18, the stray plate capacitance to ground is in parallel with the grounding condenser C1, used to block the DC path to ground of the plate supply, and thus has no effect on the operation of the circuit. Only the capacitance of the filament to ground need be considered with this arrangement, and this capacitance is very much smaller than that between the plate and ground.

The filament of the tube is at high RF potential. It is very essential to supply filament current without the necessity of operating the filament transformer at this high potential above ground. It is also necessary to supply RF driving potential between the grid and filament from the driver unit, one side of which is at ground potential. A method of obtaining these two objectives is shown schematically in Fig. 18.

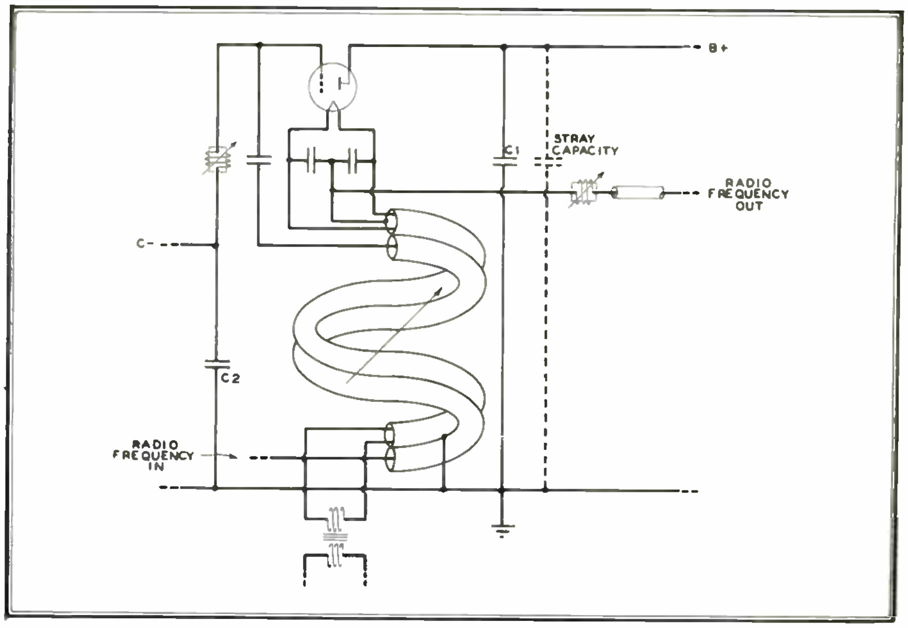


FIG. 18. DIAGRAMATIC REPRESENTATION OF W.E. GROUNDED PLATE AMPLIFIER

The plate tuning coil of Fig. 17 is replaced in this new circuit by a coil between filament and ground. If this coil is formed by a pair of copper tubes in parallel, as indicated in the illustration, the filament leads may be threaded through the bore of one of the tubes, and the grid driving potential supplied through an inner conductor of the other. At the filament end of this coil, the copper tubes are connected to the filament through condensers as

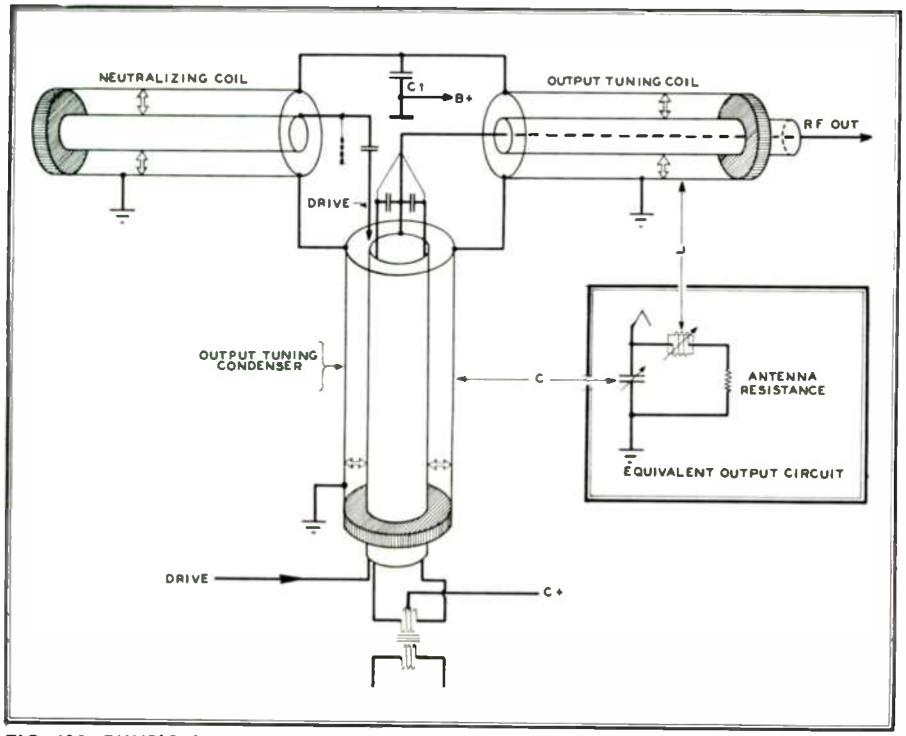


FIG. 19A. PHYSICAL ARRANGEMENT OF ADJUSTABLE COAXIAL TRANSMISSION LINE IN THE 10-KW. AMPLIFIER. FIG. 19B, INSERT, EQUIVALENT OUTPUT CIRCUIT

shown, and the other end of the coil is grounded. Thus, the filament current and grid driving voltage are delivered at the required circuit locations with the sources — driver and filament transformers — maintained at ground potential.

The necessity of being able to adjust the reactance of this inductance introduces numerous mechanical difficulties if an attempt is made to employ a coil as shown schematically in Fig. 18. These difficulties are avoided by the use of a coaxial transmission line section whose length can be varied to adjust the net reactance from filament to ground to the proper value required for tuning the output circuit.

The physical arrangement of such a structure to replace the tuning coil of Fig. 18 is shown schematically in Fig. 19A. Here both the grid drive and filament leads are carried through the inner conductor of a variable section of transmission line fitted with a movable short-circuiting slug which permits the proper adjustment of the net filament-ground reactance, shown as C in Figs. 19A, and 19B. The output tuning coil, L of Fig. 19A, is likewise a variable length of transmission line less than ¼ wavelength long, and hence inductive in reactance. Its exact value is determined by the position of its short-circuiting slug.

Fig. 19B shows in schematic form the equivalent output circuit and, in conjunction with Fig. 19A, illustrates the unique manner in which a completely shielded output circuit is obtained without the attending embarrassment of unwieldy lead lengths or exposed coils and condensers. Moreover, it will be observed that the output tuning coil, commonly referred to as a bazooka, provides the very useful function of effectively transferring the antenna resistance from between points of high RF potential to the low end of the coil where one side of the transmission line can be grounded. This is most convenient when it comes to the matter of an actual installation in the field.

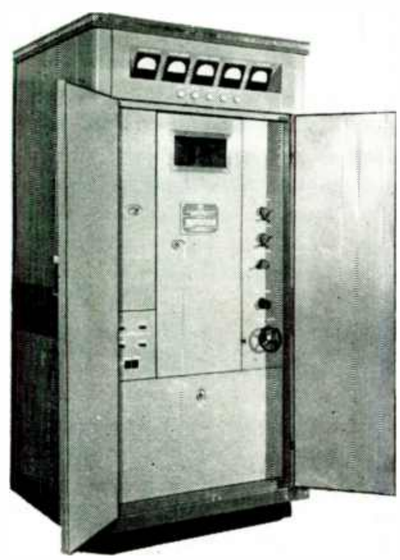
The neutralizing coil, like the other tuning elements previously described, consists of a section of transmission line with the inner conductor connected to the grid and the outer conductor grounded. The position of the short-circuiting slug, therefore, determines the amount of inductance for coil neutralization and is, of course, adjusted to a value such that its inductive reactance just balances the capacitive grid-plate reactance of the tube at the operating frequency.

The physical arrangement of circuit elements employed in the 506B-2 amplifier is no less unique than the extremely straight-forward and simple electrical circuits themselves. In fact it is because of the utter simplicity of the electrical circuits that such a neat and simple mechanical arrangement is possible.

The 10-kw. air-cooled tube is located in a cylindrical tube socket 9 ins. in diameter at the base of which is an insulating support. This makes contact with the fin

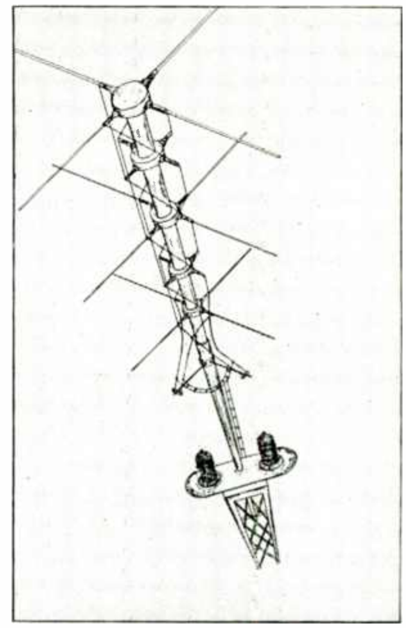
(CONCLUDED ON PAGE 74)

YOUR FM CAN BEGIN WITH THIS!— AND QUICKLY, TOO!



TRANSMITTER • Rel 518 DL
* 1 KW FM Transmitter

Many Broadcasters have begun FM programming economically with the REL equipment illustrated. Our long experience in FM insures prompt delivery and reliable commercial operation from the start.



ANTENNA • REL 642 3-element Interim Turnstile Antenna

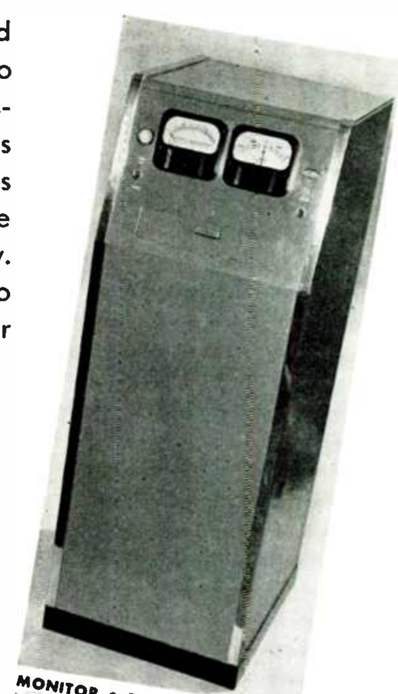
Remember! There are now 20 new REL-equipped FM Broadcast Stations on the air daily with regular schedules.

None of this equipment need be replaced when you go to higher power. In the REL Transmitter line, the 1-kw. drives 10 kw., which can be used as the driver for 50 kw. The 250-watt unit drives 3 kw. which, in turn, can be used to drive other high-power amplifiers.

CONSOLE • REL 603 Speech Input Console

REL

RELIABLE
ENGINEERING
LEADERSHIP



MONITOR • REL 600 FM Frequency and Modulation Monitor

* or on REL 549 DL 250-watt transmitter

RADIO ENGINEERING LABS., INC.
Long Island City, N.Y.

COMPLETE AUDIO FACILITIES WITH

Only 2 Types of AMPLIFIERS VACUUM TUBES

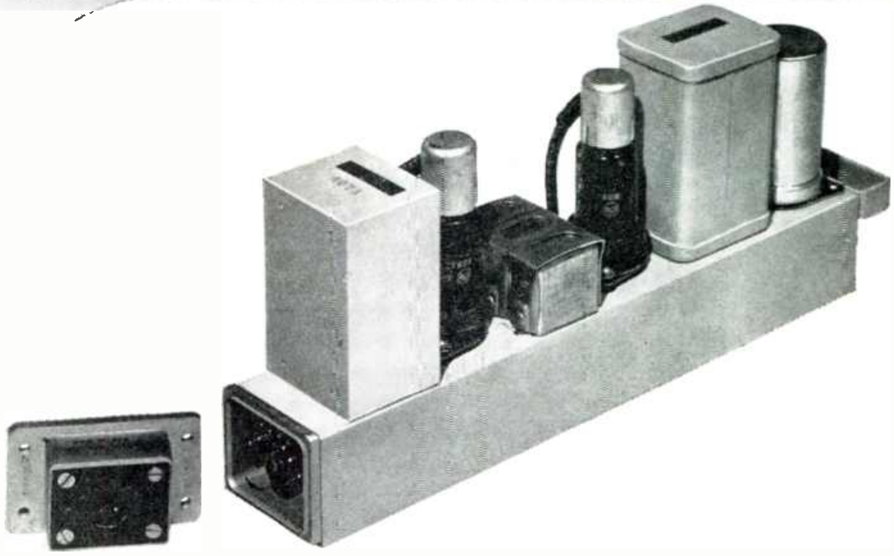
. . . AND ALL PLUG-IN

The Langevin Types 116-A and 117-A Plug-in Amplifiers were developed in collaboration with the General Engineering Department of the Columbia Broadcasting System.

We believe these amplifiers fulfill the desire of many broadcast engineers to simplify their audio facilities. With only these two types of amplifiers even the largest system can be fabricated. Further—in the interest of simplicity—only two types of tubes are required in the operation of both these units (the accompanying power supply uses a selenium rectifier). A replaced amplifier can be serviced when convenient at a test bench, with the aid of a simple service unit designed for that purpose.

Many lessons learned during the War have been incorporated in these amplifiers: They are simple, compact, rugged and of high quality; they are replaceable in a matter of seconds WITHOUT THE USE OF TOOLS; they are designed for easy servicing. And they can be either rack or console mounted; fittings are available. These units are connected into the circuit by means of a plug especially designed for them by Cannon—employing gold plated contacts and a shielded TWIN-AX input connection.

A COMPLETE SYSTEM USING THESE AMPLIFIERS WILL BE BETTER IN ALL RESPECTS THAN THE F.C.C. RECOMMENDATIONS FOR FM.

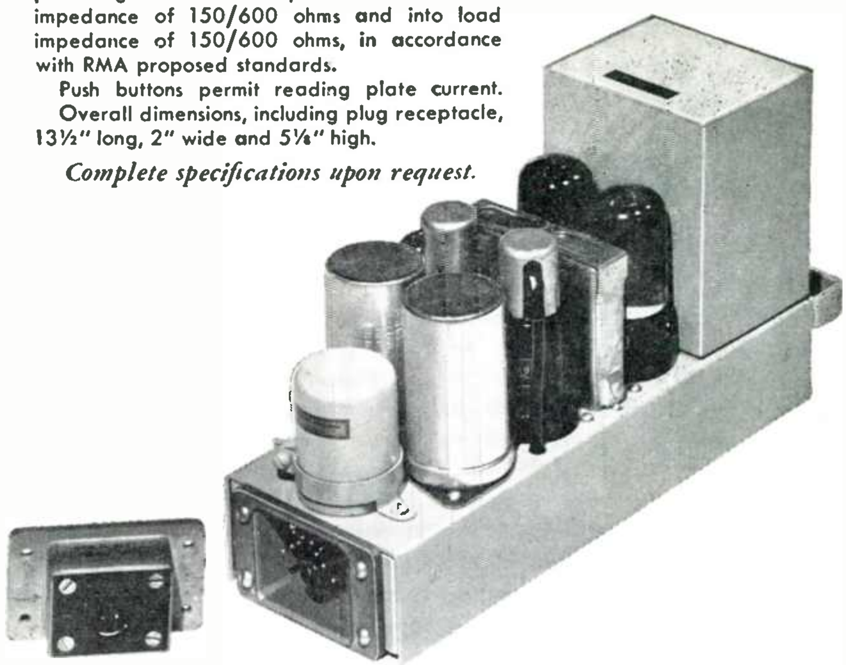


The Type 116-A has been designed for use as a microphone preliminary and as a booster amplifier—gain 36 db. Operates from source impedance of 150/600 ohms and into load impedance of 150/600 ohms, in accordance with RMA proposed standards.

Push buttons permit reading plate current.

Overall dimensions, including plug receptacle, 13½" long, 2" wide and 5⅛" high.

Complete specifications upon request.



The Type 117-A has been designed as a program or monitor amplifier—gain 55 db. Operates from source impedance of 150/600 ohms and into load impedance of 150/600 ohms, in accordance with RMA proposed standards.

Push buttons permit reading plate current.

Overall dimensions, including plug receptacle, 11" long, 3¼" wide and 5½" high.

Complete specifications upon request.

The Langevin Company

INCORPORATED

SOUND REINFORCEMENT AND REPRODUCTION ENGINEERING

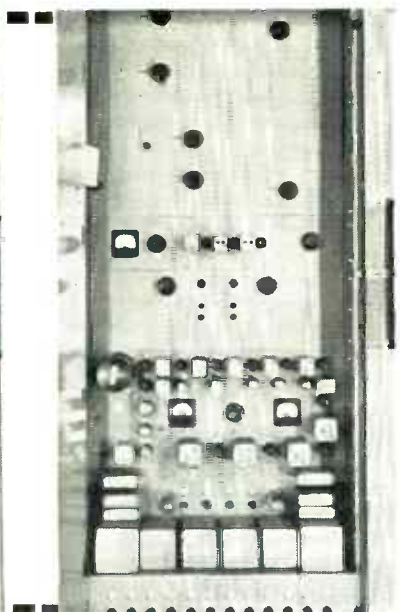
NEW YORK, 37 W. 65 St., 23 • SAN FRANCISCO, 1050 Howard St., 3 • LOS ANGELES, 1000 N. Seward St., 38

RAYTHEON'S 250 WATT FM TRANSMITTER

INCORPORATING THE NEW

Cascade PHASE SHIFT MODULATION

250 Watt FM Transmitter, also standard exciter unit for all higher power.



Thorough tests in actual competition with all other systems of modulation have proved the superiority of the Cascade Phase Shift Circuit—in signal quality, simplicity and dependability.

Raytheon's Cascade Phase Shift Modulation is a basically direct circuit which adds the phase shift of six simple stages to produce the required phase shift needed for high fidelity modulation—at an *inherently* lower noise level. This extremely simple circuit eliminates the major faults of other systems and brings important advantages never before possible (See features).

Carefully compare and you will buy Raytheon. *Place YOUR order now for Fall delivery.*

Above—Complete Cascade Phase Shift Modulator.
Left—Front control panel of Transmitter

YOU WILL WANT EVERY ONE OF THESE TEN IMPORTANT FEATURES . . . ONLY RAYTHEON CAN GIVE THEM TO YOU

1. **Simplified circuit design** thru the *Cascade* system gives stability and efficiency to Raytheon FM.

2. **Direct Crystal Control,** independent of modulation, gives positive and automatic control of the mean carrier frequency. No complicated electronic or mechanical frequency stabilizers are used. A single high quality crystal does the job.

3. **An inherently lower noise level** is achieved by Cascade Phase Shift Modulation which adds the phase shift of six simple stages.

4. **Very low harmonic distortion**—less than 1.0% from 50 to 15,000 CPS with 100 KC frequency deviation.

5. **Conservatively operated circuits** prolong tube life—prevent program interruptions.

6. **No expensive special tubes.** The modulator unit uses only inexpensive receiver type tubes of proven reliability.

7. **Unit construction.** There is no obsolescence to Raytheon FM Transmitters. Add an amplifier later to give the desired increase in power. All units are perfectly matched in size, styling and colors.

8. **Simple, very fast tuning.** Circuit can be completely tuned up in two or three minutes without external measuring instruments.

9. **Lasting economy.** Low first cost—low power cost—advanced engineering design—plus modern styling, guarantee years of satisfaction.

10. **Easy to service.** Excellent mechanical layout, vertical type chassis and full height front and rear doors make servicing fast and easy.

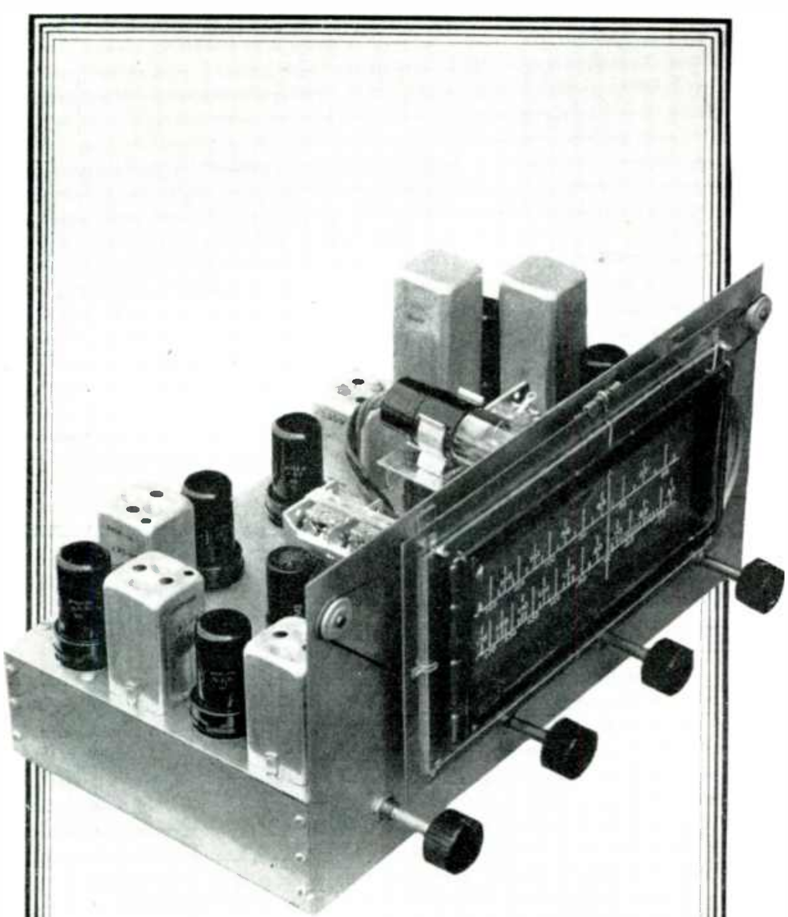
RAYTHEON MANUFACTURING COMPANY
Broadcast Equipment Division
7517 No. Clark Street, Chicago 26, Illinois

RAYTHEON
Excellence in Electronics

DEVOTED TO RESEARCH AND MANUFACTURE FOR THE BROADCASTING INDUSTRY

BROWNING UNIVERSAL TUNER:

UNIVERSAL TUNER, MODEL RJ-12................$114.50
RACK PANEL FOR LABORATORY, MODEL RJ-14..$134.80
POWER SUPPLY UNIT, MODEL PF-12.............$ 14.75



"PERFORMANCE": That is Frequency Modulation's challenge to the radio industry. BROWNING LABORATORIES' answer to that challenge is embodied in the RJ-12 BROWNING Universal Tuner.

This instrument, licensed under the Armstrong patents, affords every advantage in high-quality reception which FM has come to represent. In addition, a high-sensitivity AM section covers the regular broadcast band.

This particular dual-band facility brings to the user the utmost in radio reception, plus control circuits for playing phonograph records. Since the BROWNING Universal Tuner is not complicated by the addition of short-wave circuits, performance on the FM and AM broadcast bands is correspondingly improved.

Here, indeed, is the realization of the promised postwar improvement in radio broadcast reception.

BROWNING LABORATORIES, INC.

Engineers and Manufacturers

WINCHESTER • MASSACHUSETTS

Canadian Representatives
Measurements Engineering, 61 Duke St., Toronto

FM RECEPTION AT ITS BEST

DESIGNED TO MEET THE NEEDS OF ALL TYPES OF INSTALLATIONS AT THE LEAST COST FOR FINEST FM-AM PERFORMANCE

SPECIFICATIONS AND DATA ON THE RJ-12 TUNER

1. TUNING RANGE: 88 to 108 mc. on FM, and 535 to 1650 kc. on AM. These are the tuning ranges for FM and AM established by the Federal Communications Commission.

2. SENSITIVITY: On FM, complete noise-limiting action is obtained with signals of 15 microvolts. AM circuits respond to signals of 1 microvolt.

3. FM CIRCUITS: A separate high-frequency FM section employs tuned antenna and RF stages feeding a mixer, and using a separate oscillator tube. Image interference is minimized by operating the local oscillator at a frequency higher than that of the incoming signals.

The output of the mixer is fed through two IF stages to a dual limiter, where static and other amplitude disturbances are removed. The output of the limiter is applied to the discriminator which produces a demodulated audio signal for feeding into a separate power amplifier.

4. AM CIRCUITS: An independent AM section provides a tuned antenna and RF stage to eliminate image response. This is followed by a converter stage, a high-gain IF stage, and a diode detector which furnished AVC voltage and the audio output to the separate power amplifier. FM and AM output levels are approximately the same.

5. PHONOGRAPH: Terminals for connections from a phonograph pickup are at the rear of the chassis. A third position on the band switch cuts in the phonograph, and its volume is regulated by the FM-AM volume control.

6. NEW TUBES: Miniature tubes are used in the FM section to obtain maximum efficiency.

CONTROLS: Single-knob FM and AM tuning, on-off switch, volume control, and FM-AM phonograph band switch.

TUBE COMPLEMENT: The following tubes are furnished in the Universal Tuner: one 6BE6, one 6C4, one 6BA6, three 6SG7, two 6SJ7, one 6H6, one 6SA7, one 6SF7, and one 6E5.

DIMENSIONS: Height 7⅜ ins., width 13½ ins., depth 9 ins.

POWER REQUIREMENTS: To operate the Universal Tuner, a separate power supply is needed to furnish 250 volts DC at 65 milliamperes, and 6.3 volts AC at 4 amperes.

OUTPUT: High-impedance output is designed to feed any high-fidelity audio amplifier.

ANTENNA: FM antenna input of 300 ohms is intended for use with the new twin-lead cable. The FM antenna is also used for AM reception. No separate AM antenna is needed.

MODEL RJ-14 UNIVERSAL TUNER FOR LABORATORY USE

When it is desired to employ this unit as a laboratory instrument to monitor quality of modulation, harmony of appearance of associated equipment is obtained through the use of an engraved aluminum rack panel 19 by 8¾ ins., finished in black leatherette. Sufficient space has been allowed for mounting a power supply. This laboratory type is designated as Model RJ-14.

MODEL PF-12 POWER SUPPLY FOR THE TUNER

To make the Universal Tuner adaptable to the widest possible range of cabinets and methods of mounting, it has been reduced in size by the use of a separate power supply. This unit, using a 5Y3GT rectifier, is only 6 ins. high, 3½ ins. wide, and 8 ins. deep. Operating on 115 volts, 60 cycles, it furnishes adequately-filtered DC, and the AC required for the tubes in the Tuner. Current consumption is approximately 0.7 ampere.

AMPLIFIER AND LOUDSPEAKER

Any amplifier and loudspeaker can be used with the Universal Tuner, depending upon the audio quality and power required. This also permits experimentation with amplifiers and speakers to suit the needs of special installation.

THE BROWNING Universal Tuner, as the name implies, is designed to suit each individual installation for use in the home, the broadcast studio, the laboratory, or the advertising agency audition room.

Therefore, it is furnished without power supply, audio amplifier, or loudspeaker. This enables the individual purchaser to work out his own ideas as to the audio system and method of installation, depending upon whether the installation is for a small room, a public auditorium, a skating rink or a dance hall, or some other special purpose. The BROWNING Universal Tuner will deliver undistorted, static-free FM signals, plus AM and record-playing, to whatever audio system you select. The use of the Universal Tuner provides high-quality performance at the lowest cost, since it is necessary to add only the accessories needed at a given installation.

BROWNING LABORATORIES, INC.

Engineers and Manufacturers

WINCHESTER • MASSACHUSETTS

Canadian Representatives

Measurements Engineering, 61 Duke St., Toronto

pace in Microphone Development

1931: Bell Telephone Laboratories developed the Western Electric moving coil or dynamic microphone. The first of its kind, it was rugged, noiseless, compact, and needed no polarizing energy. Many are still in use.

1935: The first non-directional mike — the famous Western Electric 8-Ball, designed by Bell Laboratories. Small, spherical, it provided top quality single mike pick-up of speech or music from every direction.

1936: Directional with slide-on baffle, non-directional without it, the Western Electric Salt Shaker gave highest quality pick-up at new low cost. Widely used in studios and remotes as well as in high quality sound distribution.

1946: No larger in diameter than a quarter, the 640 Double-A condenser mike (shown with associated amplifier) is ideal for single mike high fidelity pick-ups. It was originally designed as a laboratory test instrument.

What is a microphone? Fundamentally it's a device which converts sound into electrical energy—just what Bell's original telephone did for the first time away back in the seventies.

Today's Western Electric mikes—the Salt Shaker, Cardioid and 640 Double-A—are a far cry from the first crude, close-talking telephone transmitter. But they're its direct descendants.

Year after year, Bell Telephone scientists—through continuing research—have developed finer and finer telephones and microphones.

Year after year, Western Electric has manufactured these instruments, building quality into each one.

Together these teammates have been responsible for almost every important advance in microphone development.

Whether you want a single mike, a complete broadcasting station, or radio telephone equipment for use on land, at sea or in the air, here's the point to remember:

If Bell Telephone Laboratories designed it and Western Electric made it, you can be sure there's nothing finer.

BELL TELEPHONE LABORATORIES

World's largest organization devoted exclusively to research and development in all phases of electrical communications.

Western Electric

Manufacturing unit of the Bell System and the nation's largest producer of communications equipment.

WHAT WQXQ IS DOING

(CONTINUED FROM PAGE 36)

optimists as to the future of FM, both for sound and for facsimile programs. We are no less optimistic as to the service that cleared-channel AM can deliver for many years to come. We intend to press forward on all three fronts, and to continue, on FM, the forward-looking policy that is a natural outgrowth of our having initiated the first regular FM program service in New York.

WQXQ, under the experimental call letters W2XQR, began its operations on November 8, 1939. Except for a close-down of about a week in order to move the transmitter from my Long Island City laboratory to the Chanin Building, the FM station has been on the air with WQXR programs every day since its opening. We don't know much about the size of WQXQ's audience today, but we do know that two surveys made in 1942 showed that by June of that year it had more listeners than any other FM station in New York. We intend to do all that we can to establish and maintain a similar position on the new channel, both as to our sound and our facsimile programs. The timetable for our progress in putting new plans into effect will be determined, to a large extent, by production of FM receivers.

SPOT NEWS NOTES

(CONTINUED FROM PAGE 34)

Raleigh, WMTW Mt. Washington, KTHT Houston, WGAL Lancaster, and WMFR High Point, N. C.

W. R. G. Baker: Addressing the RMA Transmitter Section at Harrisburg on April 30th: "What is the absolute end result of any engineering effort? . . . It is very simple to state, but not too easy to realize. This objective is to make a profit for someone. . . It is unfortunately too true that this simple truth is not appreciated and understood by many engineers. That such is true is evidenced by the fact that, by-and-large, lawyers, accountants, and candle-stick makers manage the business of the Country. Too many engineers emulate the ostrich who sticks his head in a pile of sand to avoid reality. Too many engineers stick their heads in the sands of science to avoid the facts of life.

Expansion: Initial production started on September 24th at Philco's new 3-story plant adjoining the main factory. Total floor space of this addition is 300,000 sq. ft.

Television Plans: Bendix is preparing to produce both black-and-white and color television receivers, the latter under CBS license. Television development will be headed by A. C. Omberg, with a staff including Frank K. Norton, W. B. Wilkins, and Dr. H. Goldberg.

WBT-FM: Construction of an $80,000 FM transmitter has been started by WBT-FM on Spencer Mountain, 16 miles from Charlotte, N. C. The complete plant, to cost $250,000, is scheduled to be in operation next January. The finished transmitter will have an output of 160 kw. from an antenna 1,836 ft. above sea level.

Facsimile on WJJD: Chicago station WJJD will transmit daily facsimile programs during the NAB Conference. Finch Telecommunications will have recorders in operation at the Continental Hotel, 505 N. Michigan Avenue.

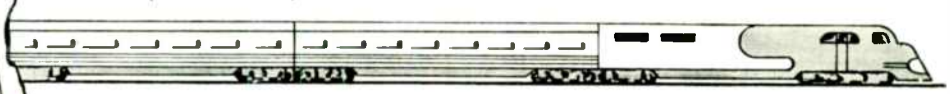
WGYN: New York's first station to operate on full power at the new band is now operating full time, from 7 A.M. to 10 P.M. weekdays and 9 A.M. to 10 P.M. Sundays.

Philip M. Baker: Washington radio attorney, formerly associated with Andrew G. Haley and Major General Myron C. Cramer, has opened offices at 1101 Earle Building, Washington, D. C. From 1941 to 1944, Mr. Baker was an attorney for the FCC.

New Tubes: Raytheon is now in production on two new miniature cathode-type tubes

(CONTINUED ON PAGE 68)

All aboard...to music!



Santa Fe Trains To Get Radio, Music Systems

In announcing forthcoming installation of musical wire reproducers, radio and public address systems on their passenger trains, Fred G. Gurley, president of the Atchison, Topeka, and Santa Fe Railway, yesterday disclosed that individual outlets will be placed in sleeping cars.

Each roomette, bedroom, compartment, and drawing room will be equipped with push-button selector, a loud speaker, and volume control, so that occupants may have their choice of radio or wire-reproduced popular or semi-classical music, Mr. Gurley stated. A pilot lamp, lighting automatically when the announcement system is in use, will be installed so that passengers may turn the system on if they so desire.

As a forerunner of this innovation, wire reproducing units providing programs of various types of music, will be placed on the Santa Fe dining car 1450 when it goes into transcontinental service on March 10. As soon as equipment and labor are available, the railroad president declared, similar installations will be made on both new and old dining cars, as well as sleeping, chair, and club-lounge cars.

Speakers will be placed in the ceiling of these cars to provide an even distribution of low-level sound throughout the car. The volume will be set at an advantageous point for both the listener and conversationalist, it was stated.

Farnsworth Television and Radio Corporation of Fort Wayne, Indiana, designed the over-all integrated system.

Reprinted from the Chicago Journal of Commerce, March 4, 1946.

New Program Distribution Systems Make Rail Travel More Pleasant; Will Increase Passenger Traffic!

Systems Produced by Pioneers in Quality Sound Reproduction, Communications and Television.

Music now brings its magic to the railway passenger — and gives railroads another tool with which to sell travel by rail!

In announcing the first modern electronic program distribution systems for railroads, the Farnsworth Television & Radio Corporation takes a logical step forward. Known for its superlative phonograph-radios, including The Capehart, for its pioneering in the fields of tonal reproduction, television and other forms of electronics, Farnsworth now extends its engineering knowledge and manufacturing skill to the field of passenger entertainment.

These new systems will meet the varying tastes of passengers and the specific operating conditions of individual roads. Based upon the knowledge secured from railroad-conducted surveys, the most complete Farnsworth system provides four channels for individual selection: one for classical and one for popular music; a third for radio programs; and a fourth for train announcements and travel talks. More simplified Farnsworth Systems are also available.

Farnsworth engineering has met and overcome the problems peculiar to pleasing sound reproduction in passenger cars, including the need for uniform, low-level distribution and automatic compensation for varying ambient noise levels.

With these comprehensive, flexible systems, railroads can now provide passengers with the same standard of entertainment and comfort they expect in their own homes. Farnsworth Television & Radio Corporation, Fort Wayne 1, Indiana.

Farnsworth

MAKERS OF

THE CAPEHART • THE PANAMUSE BY CAPEHART

Other Products Include: Farnsworth Radio and Television Receivers and Transmitters • Aircraft Radio Equipment • Farnsworth Television Tubes • Halstead Mobile Communications and Traffic Control Systems for Rail and Highway • The Farnsworth Phonograph-Radio

FM TRANSMITTERS

(CONTINUED FROM PAGE 54)

structure of the air-cooled plate and through it the DC plate potential is supplied. The entire tube, except for filament and grid connectors, is enclosed by the tube socket. The tube is insulated from the socket by a cylinder of Pyrex glass. Silver plating on the glass forms one plate of the condenser C1, Figs. 18 and 19A, thereby helping to connect the plate RF-wise to ground potential. The three coaxial tuning elements of Fig. 19A are arranged in a closely packed vertical arrangement which extends some 3 ft. above the top of the tube structure. The latter just projects above the top of the tube socket. An electrically tight cylindrical screen, some 6 ins. high, joins the top of the tube socket to the tuning pipes. Thus, the whole structure is completely shielded from the outside and from unwanted interaction between the neutralizing coil, output circuit, and input circuit. Moreover, the whole structure is at ground potential and entirely free from hazard to operating personnel.

The unique tube socket design and the small size of the tube make it possible for one operator to change the tube quickly and easily. The grill covering is readily lowered by loosening a clamp. The grid and filament leads are then disconnected and the whole tubular housing for the tube slides forward on rails. The tube is easily lifted out of the housing. A tube can be installed just as quickly by simply reversing this procedure.

A blower to supply forced air cooling to the plate and grid structure is located in the base of the amplifier cabinet. The cooling air first passes over the grid and filament seals and then through the fin structure, exhausting downward.

With these novel features, both electrical and mechanical, the new transmitter is unusual in appearance as well as in design. All tuning and amplifier controls are motor-operated to eliminate long or intricate mechanical linkages, and all contactors are controlled by DC to insure quiet operation. By means of interlocks and time delays, all potentials are applied in the proper sequence at starting, and a complete complement of safety devices provides full protection for the operating personnel. The complete 10-kw. transmitter includes the driving unit already referred to, the 10-kw. amplifier unit, and a power-supply circuit arranged in a cabinet of similar appearance. This assembly is completely self-contained, and requires a minimum of floor space.

In actual practice it is often desirable to install FM transmitters in unusual locations such as on the upper floor of an office building, in which case compact design is a necessity. These transmitters provide this compactness and at same time are constructed for maximum ease and economy of operation and accessibility for maintenance.

SPOT NEWS NOTES

(CONTINUED FROM PAGE 68)

speaking as a member of the radio audience: "We, the public, need a critical review of radio programs, both of news and entertainment, just as discriminating and just as independent as are the dramatic and music reviews in our best newspapers."

D.C.K. & J.: New law firm of David, Courtney, Krieger and Jorgensen has been formed by ex-officials of the FCC. Nathan H. David was assistant general counsel; Jeremiah Courtney, assistant general counsel, safety and special services; Seymour Krieger, chief of field section; and Norman E. Jorgensen, assistant to the general counsel and previously assistant to the Chairman. Address is 1707 H Street, N. W., Washington 6. D.C.

Lester N. Hatfield: Has been appointed chief engineer of Press Wireless Mfg. Corporation. After 2 years as a lieutenant in the electronics division of the Bureau of Ships, he joined Press Wireless in January, 1945. For the 10 years previous, he was a member of the CBS engineering staff.

Dr. R. O. Curry: Has been appointed audio and acoustical engineer at Farnsworth Television & Radio Corporation. A native of England, he holds a Ph.D. degree from the English University of Durham.

IMSA Conference: Police and municipal officials will gather at Miami for the 51st annual meeting of the International Municipal Signal Association, November 11 to 14 inclusive. Headquarters will be at Hotel Alcazar. Information can be obtained from Irvin Schulsinger, 8 E. 41 Street, New York, 17.

Facsimile: We find that facsimile is decidedly more dependable than the operation of the airlines! When Finch scheduled a demonstration of facsimile reception in an air liner, the plane in which the equipment was to be installed was fog-bound at Pittsburgh. Next day, the plane reached Newark, but the control tower refused clearance for it to take off because of bad weather. However, the facsimile equipment in the plane worked perfectly even though the antenna, mounted under the fuselage, was only a few feet off the ground. Signals were transmitted from the Finch FM station WGHF in New York City.

Pilot Glass Plant: Corning Glass Works has set up a plant of 11,000 square feet to handle pilot runs of new glass products and to check new manufacturing methods. Located at Corning, N. Y., the new plant will serve as a connecting link between the research laboratory and factory production.

BUILDING FM AUDIENCES

(CONTINUED FROM PAGE 31)

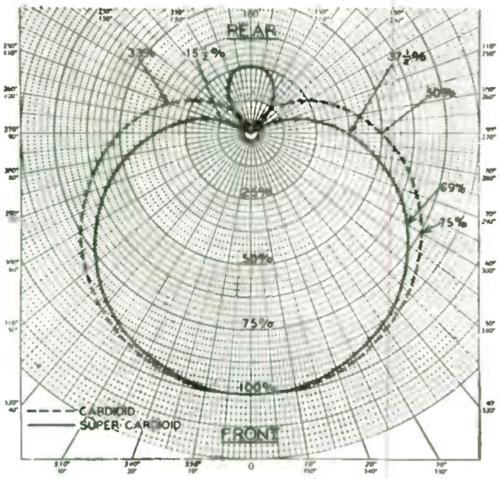
casting dates back to Major Armstrong's first announcements of FM's development, and our engineers have worked closely with him since that time to develop compact, moderately-priced FM receivers. For more than six years we have operated our FM station WEFM, in Chicago.

From this broad experience has come a tremendous enthusiasm about this new and better kind of radio — an enthusiasm that is reflected in our production quotas, our sales policies, and our advertising. Because we do believe in FM, we are anxious to do everything in our power to increase public interest in FM broadcasting and to broaden the market for FM receivers. Undoubtedly, most other set manufacturers feel much as we do about it. After all, this is only good merchandising. FM receivers are more expensive radios, with a greater dollar return to the manufacturer, the distributor, and to the dealer. Furthermore, the owner of an FM set is more certain to be thoroughly satisfied with his purchase — usually so enthusiastic as to become a booster for FM.

The FM station operator has just as great a stake in creating interest in and the desire for FM receivers, since the value of his broadcasting time will increase as the size of his audience grows. It would seem, then, to be good strategy for all of us to work together toward the common goal of getting across to listeners the advantages of FM over AM reception.

In the past, networks, independent stations, set manufacturers, radio dealers, and listeners have had their own separate and distinct ideas about what constituted sound policies for the radio industry as a whole. Many of the difficulties that have beset AM have come about because of this lack of coördinated thinking. FM can avoid these pitfalls by intelligent planning. As a step toward that end, I would like to suggest that FM station operators look up the distributors of leading FM set lines in their territories. These distributors are alert, progressive business men. Generally speaking, they are well aware of the fact that FM is *the* coming thing in radio. Because they are aggressive merchandisers, they are receptive to new ideas, they are coöperative, and they have much experience to contribute to plans that will expand the local FM audience.

Obviously, FM operators are sold on FM. We are, too, and so are our dealers. But the fact is that we are all "hollering down a well" until the millions of radio listeners become as much aware of FM's advantages as we are. And they aren't going to ask about those advantages. We must *tell* them and *sell* them. Whether it takes a few years or many years for FM to become the chief source of radio music and entertainment for the American public depends upon the efforts all of us put forth now.



. . . do you know these important performance advantages of the SHURE Super-Cardioid?

The improvement in unidirectional operating characteristics of the SHURE Super-Cardioid Microphone over the cardioid is indicated by the comparative pickup patterns shown above.

★ Maximum sensitivity (100%) is achieved by sounds entering the front of the Microphone.

★ A wide range of pickup is indicated by the fact that the Super-Cardioid is practically as sensitive as the cardioid at a 60° angle. (69% against 75%).

★ Beyond the 60° angle, the directional qualities of the Super-Cardioid become rapidly apparent. At 90°, the Super-Cardioid is 25% more unidirectional. At a wide angle at the back (110° to 250°) the Super-Cardioid is more than twice as unidirectional.

★ The ratio of front to rear pickup of random sound energy is 7:1 for the cardioid; 14:1 for the Shure Super-Cardioid.

For critical acoustic use, specify the Shure Super-Cardioid Broadcast Dynamic.

MODEL	IMPEDANCE	CODE
556A	35 ohm	RUDOM
556B	200 ohm	RUDOP
556C	High	RUDOR

List price . . . $82.00

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Microphones and Acoustic Devices

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WHAT'S NEW THIS MONTH

(CONTINUED FROM PAGE 4)

I can't say I enjoy a small screen as it requires too much concentration, with the result that the eyes tire very easily.

"All receiving was done while the studio had several lamps lit. These were end lamps at the sides of two divans.

"The receiver was a custom built job, and no one would venture a guess as to its cost."

We shan't add to these comments because we think they are of greater value as an appraisal of the state of color television than any engineering opinion could be.

2. Elsewhere in this issue, the statement is made that genuine FM receivers seem high in price only because current AM designs have been so cheapened in mechanical and electrical design, and so degraded in performance.

Just how true this is can be seen by checking prices of sets prior to 1929, when AM sets were really well constructed. Of course, they were subject to all the interference and background noise heard on present day AM receivers, so that their performance did not equal the new FM sets. Moreover, manufacturing costs have risen enormously since those days. Here are some actual figures from 1924:

For example, the famous Grebe table model CR-12, described as a 4-tube receiver combining regeneration and tuned RF, cost $175 without tubes, loudspeaker, or batteries.

The Paragon model III, a long-distance record-holder, was also priced at $175, with tubes, batteries, and speaker or earphones extra.

Slightly lower in price, and also a table model, was the de Forest Reflex Radiophone type D10. It was described as "a 4-tube set with a range on indoor loop of 3,000 miles, record range 5,000 miles. It has the reputation for the clearest reception of broadcast in existence. Uses either headphones or loudspeaker. The simplest long-distance set made, low in first cost; economical to operate. Price for set and loop $150. Batteries, tubes, phones, or speaker extra."

Still farther down in the price range was a little Crosley number. Identified as model X-J, the manufacturer said: "We believe that for bringing in distant stations it cannot be equalled. Price, $65. Cost of necessary accessories from $40 up."

Kennedy made some very fine equipment in those days. We find the table model V described as "an entirely new development in radio science — it is unusually simple to operate, very selective, has high electrical efficiency, presents a pleasing appearance, and sells for $125 complete with all tubes, dry batteries, Kennedy 3,000-ohm phones, with plug."

Cutting and Washington were among the first to produce console models.

(CONTINUED ON PAGE 79)

WHAT'S NEW THIS MONTH

(CONTINUED FROM PAGE 78)

Here is their description of one type:

"The Console Model, a highly selective 4-tube receiver, is a beautiful furnishing for your home, as well as a wonderful means of entertainment and pleasure. Completely self-contained in a handsome walnut finish, Early English Period Console, with tubes, batteries, and a Magnovox speaker all in cabinet. — Finest materials, simple sturdy construction, an efficient, moderate-priced instrument, $325."

No review of early receivers, however brief, should omit the Radiola Super-XIII, the number that signalled the shift from tuned RF to the superheterodyne. RCA had this to say about the console model: "With *no antenna* and no ground connection, it receives far distant stations even while local ones are operating. Loudspeaker built in — *Complete* with six UV-199 Radiotrons — everything except batteries, $425."

There are many other examples, but these suffice to show how much more radio listeners get in a $400 FM-AM phonograph console than they did when consoles costing about that much had 4 to 6 tubes, operated on dry cells and storage batteries, had perhaps ½ watt undistorted output, and didn't include automatic phonographs!

3. While we were looking up the preceding references, we came across an article on amplifier design written by Dorman Israel, now the engineering genius behind Emerson radio receivers. Here are his introductory remarks:

"In designing a speech amplifier for broadcast equipment, it is necessary to consider frequencies from 25 to 20,000 cycles. The lower limit is determined by the fact that certain musical instruments such as the organ or double bass operate as low as 25 cycles. The upper limit is, of course, above the range of the normal ear so far as the fundamental is concerned, but when it is remembered that harmonics are present which play a vital part in the peculiar characteristics and qualities of instruments, the reason for setting the limit at 20,000 cycles is obvious. . . . If a violin is playing a 2,000-cycle note, its eighth harmonic will be 16,000 cycles. Without the reproduction of these harmonics, the violin would sound like a tuning fork, for only the fundamental would be present."

What Dorman Israel wrote 20 years ago is as true today as it was then. The trouble is that, in the intervening years, we accepted the audio limitations imposed by background noise, static, and the increasingly crowded condition of the AM band. Now, however, there is already a renaissance of interest in high fidelity because FM has made it an attainable goal.

FREQUENCY *Link* MODULATION

BROADCAST TRANSMITTERS

250 WATT • ONE KW • THREE KW

WITH THE SAME HIGH STANDARDS THAT HAVE MADE *Link* THE RECOGNIZED LEADER IN EMERGENCY RADIO COMMUNICATIONS EQUIPMENT

TYPE 250 FMB

Specifications

Frequency Range: 88 to 108 mc.

Center Frequency Stability: Within ± 2000 cycles of assigned frequency.

Modulation: Phase modulation (Armstrong system).

Audio Input: Standard 600/150 ohm line.

Deviation: Standard ± 75 KC.

Frequency Response: Within ± 1 DB of standard 75 microsecond pre-emphasis curve from 50 cycles to 15,000 cycles.

Distortion: Less than 1.0% rms from 100 to 7500 cycles; less than 1.5% rms from 50 to 100 and 7500 to 15,000 cycles at ± 75 KC swing.

FM Noise Level: At least 65 DB below ± 75 KC swing within the band of 50 to 15,000 cycles when measured in conjunction with a demodulator of standard 75 microsecond de-emphasis characteristic.

AM Noise on Carrier: At least 50 DB below the equivalent of 100% AM modulation level within the band of 50 to 15,000 cycles.

RF Harmonics: At least 60 DB below fundamental frequency output level.

Audio Monitor: Built-in.

External Monitoring: Jacks are provided for operating external carrier and frequency swing monitors.

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