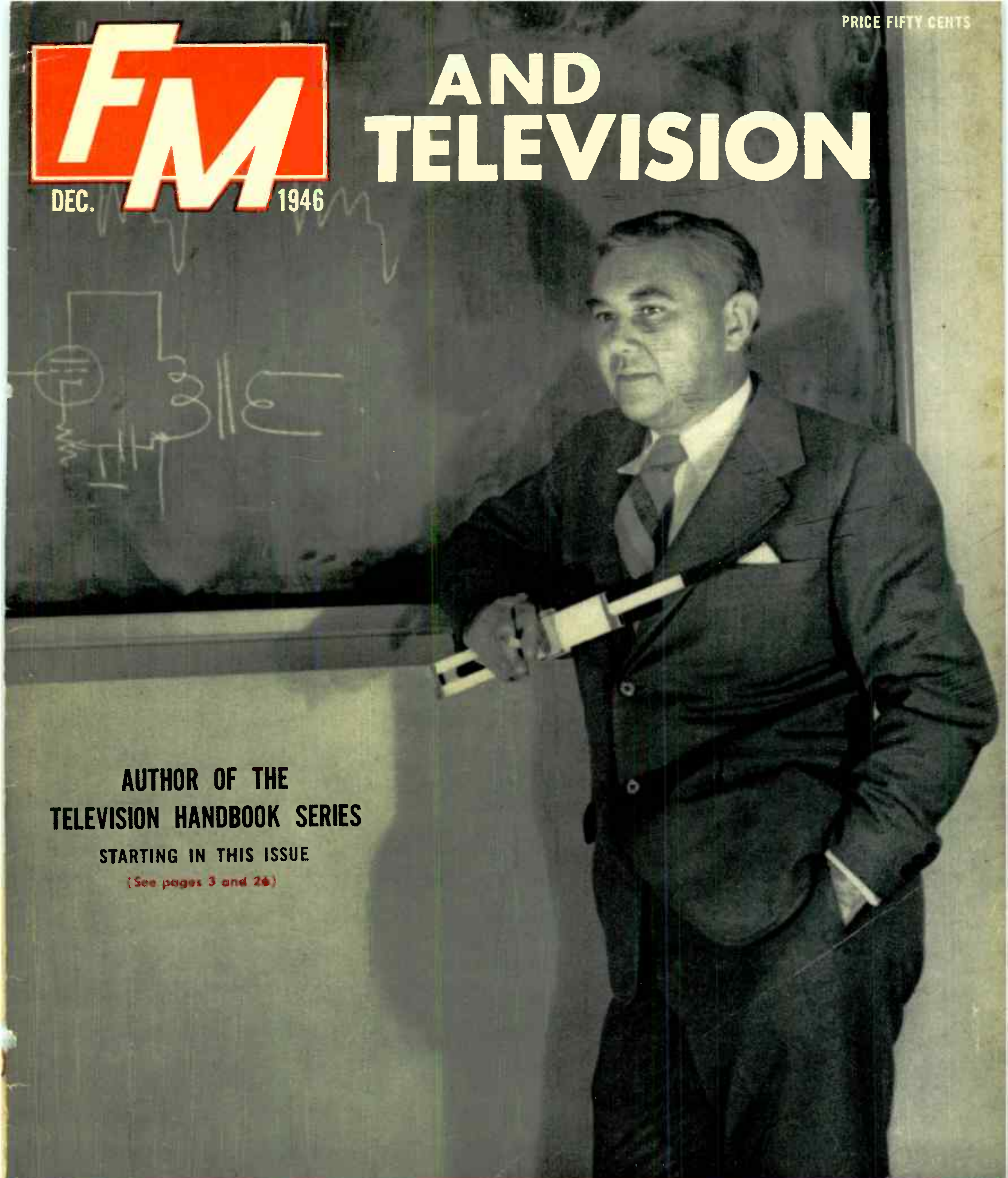
PRICE FIFTY CENTS

FM AND TELEVISION

DEC. 1946



AUTHOR OF THE TELEVISION HANDBOOK SERIES

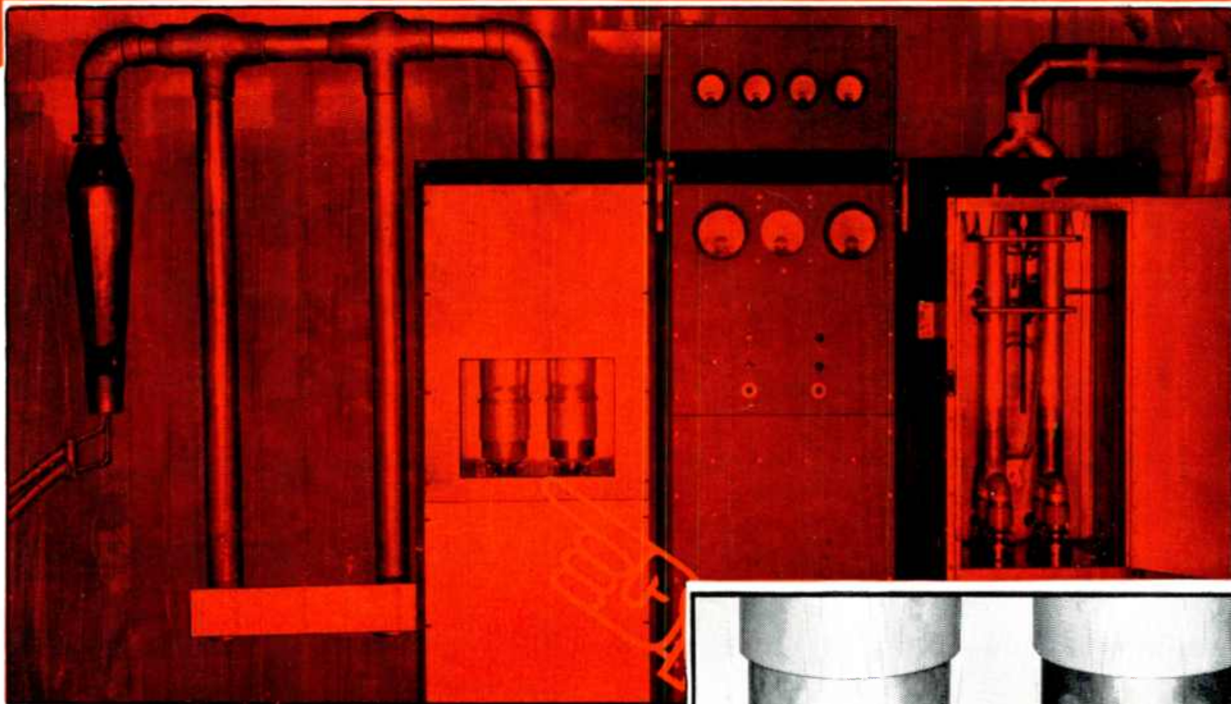
STARTING IN THIS ISSUE

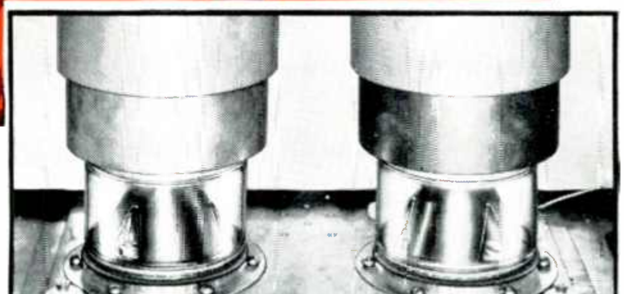
(See pages 3 and 26)

★ ★ Edited by Milton B. Sleeper ★ ★

REG. U.S. PAT. OFF.

COMPACT VERSATILITY for 10 KW at 110 MC





● Experimental 12½ kw 110 mc amplifier, above, and detail of Eimac 3X2500A3 triodes in final stage. Combination plate lines and air ducts simplify cooling.

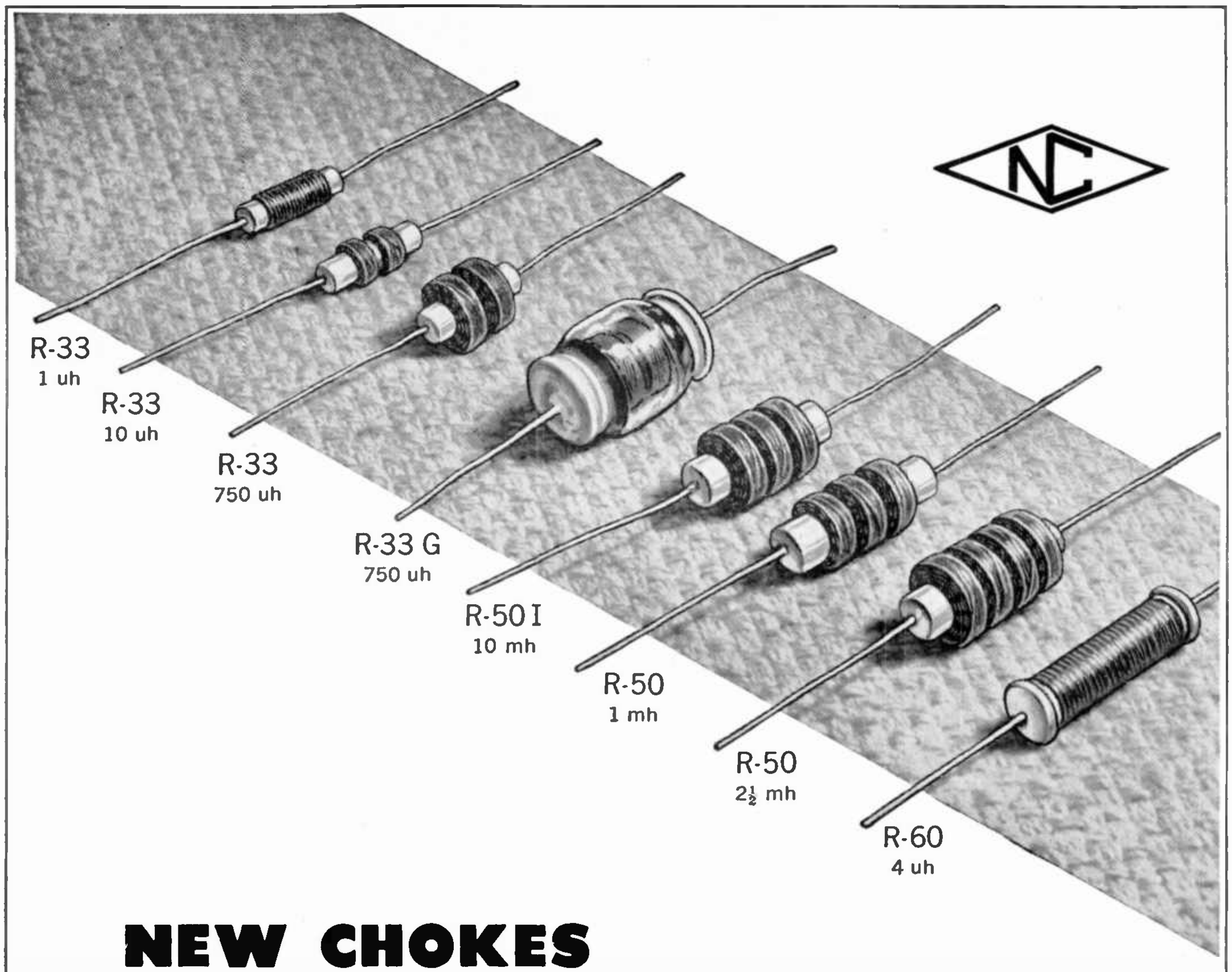
Mounted in a 19-in. relay rack as illustrated above, two Eimac 3X2500A3 triodes are regularly pushing more than 10 kw of useful output power into a water-cooled load in the Eimac testing department. As measured, 12,500 watts is being delivered at 110 mc. The tubes are operating class C in a grounded-grid circuit, which requires no neutralizing and gives an apparent overall efficiency of 90 per cent. Circuit losses are reduced to a minimum by the use of low plate voltage. The 3X2500A3's deliver 12.5 kw at only 3500 plate volts.

So compact are the 3X2500A3 triodes (see inset closeup) that the entire final amplifier and driver can be housed in the equivalent space of two five-foot racks. The driver section, as shown at the right, provides 3 kw of driving power with four of Eimac's new 4X500A tetrodes in a push-pull parallel circuit. The low plate-voltage requirements of the 3X2500A3 also permit use of a common power supply for driver and amplifier.

Simple compact transmitter design is now made possible in the higher power brackets of the new f-m band. The Eimac 3X2500A3 offers a number of design advantages such as low driving power, low plate voltage, functional electrode terminations, and tool-less installation and removal. Write for full particulars.

EITEL-McCULLOUGH, INC., 1363L San Mateo Ave., San Bruno, Calif.
Export Agents: Frazar and Hansen, 301 Clay Street, San Francisco 11, Calif., U.S.A

Follow the Leaders to
Eimac TUBES
REG. U.S. PAT. OFF.



NEW CHOKES

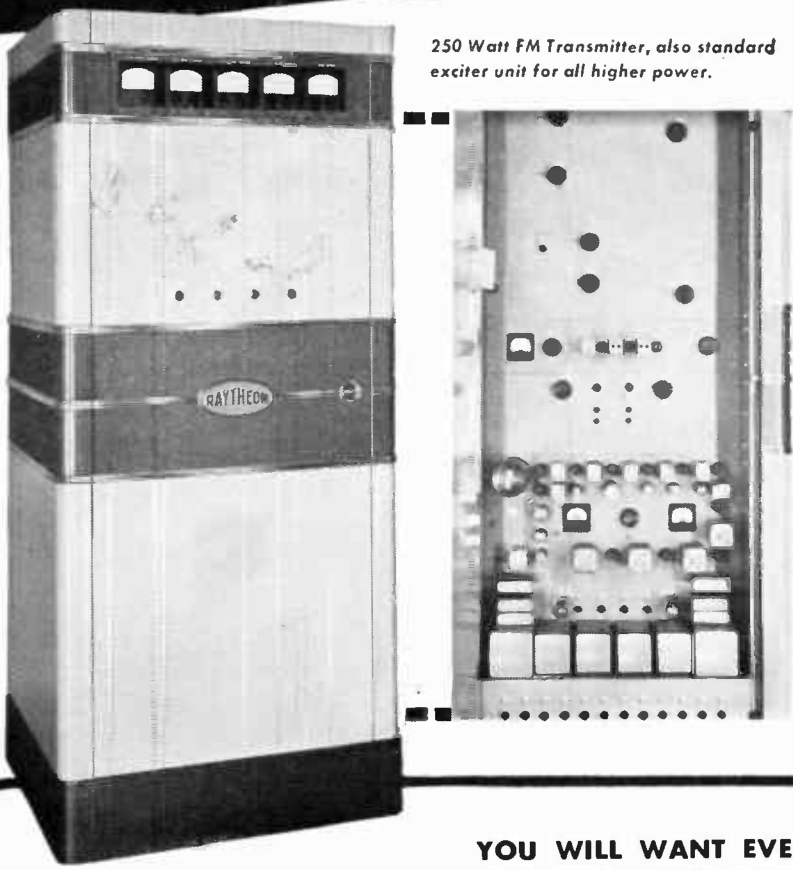
The enlarged line of chokes now offered by National includes many new sizes and types and provides units suited to specialized as well as standard applications. Many popular new chokes are illustrated above, including the R-33G which is hermetically sealed in glass. Other models cover current ratings from 33 to 800 milliamperes in a variety of mountings carefully planned for your convenience. These as well as old favorites like the R-100 are listed in the latest National Catalogue.

NATIONAL COMPANY, INC., MALDEN, MASS.

RAYTHEON'S 250 WATT FM TRANSMITTER

INCORPORATING THE NEW

Cascade PHASE SHIFT MODULATION

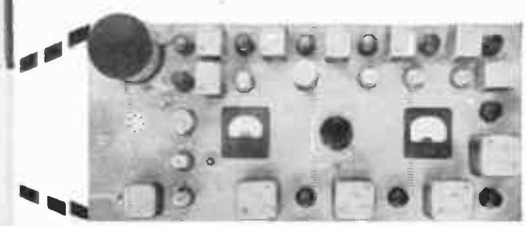


250 Watt FM Transmitter, also standard exciter unit for all higher power.

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

FM AND TELEVISION

FORMERLY: FM MAGAZINE and FM RADIO-ELECTRONICS

VOL. 6 DECEMBER, 1946 NO. 12

CONTENTS

★ ★ ★ ★ ★ ★

MILTON B. SLEEPER, *Editor and Publisher*

WILLIAM T. MOHRMAN, *Advertising Manager*

STELLA DUGGAN, *Production Manager*

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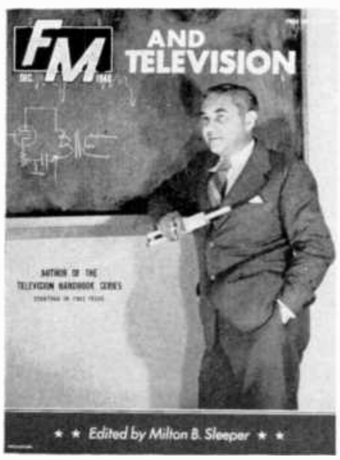


THIS MONTH'S COVER

When Madison Cawein, director of research for Farnsworth, explains a television problem in person, he looks as you see him on this month's front cover. In the capacity of instructor, he has outstanding ability, for he has such a complete command of the subject of television that he is equally at ease in discussing the mathematics of electron optics or explaining the practical aspects of circuits and their functions. You'll probably find his "Television Handbook" series, starting in this issue, the most readable and informative contribution that has been made to television literature.

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. Please Include Us Out!
2. First FMA Meeting

1. FCC Chairman Denny says that "Commission and industry engineers are busy making studies looking toward concrete proposals for revamping clear channels so as to give service to the white, unserved areas on the coverage map."

Well, it'll be just ducky if they can see somewhere on those maps an answer to the problem of buttoning down the night-time sky waves so they'll stay put, but we think that if these same engineers discarded their maps and slide-rules, and sat up nights listening to those sky waves, as ordinary citizens do, they'd soon say, "Nuts to this proposition."

Listening at Great Barrington, Massachusetts, we came to that conclusion long ago. Just to give you an idea: Trying to get election returns on November 5th, we went up and down the AM dial, searching for just one ungarbled spot. At last, we got New York's WCBS at 880, we thought. While we were puzzling over the names of the candidates who seemed strange to us, we heard a time announcement: nine o'clock. That took us off the chair, because we knew it was wrong. Then came the announcement "WHAS, Louisville." Now what did we care about election returns in Kentucky, or Eastern Central time? If we couldn't have switched to FM, we'd have switched off altogether, and waited for our election returns until next day, when we could have read the results in the newspaper!

The funny sound effects from simultaneous reception of WEAF New York at 660 kc. and WMAQ Chicago on 670 kc. may have helped us to develop a sense of humor, but what happened to Lily Pons' voice on the Chase & Sanborn program recently almost broke our heart. WMAQ's 50,000 watts fade out just often enough to give us 50% intelligibility from WEAF.

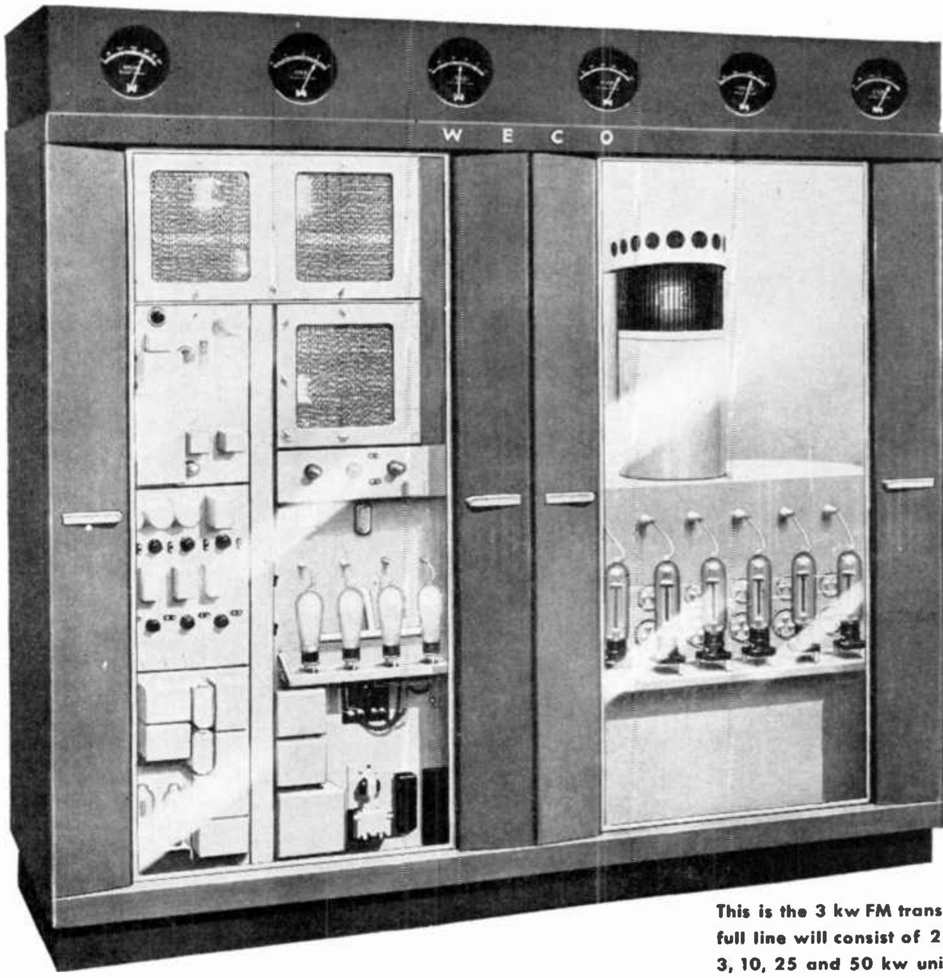
The pay-off came on Sunday evening, November 24th. We undertook to get the Suspense mystery story on WJZ at 8:30, while engaged in playing two-handed solitaire. The program started off all right, but it was the craziest plot. It was so mixed up that it didn't make sense. Toward the end, hoping to clear up the outcome, at least, we listened with undivided attention. To our amazement, we heard the voice of the Crime Doctor, and then the announcement "WBBM, Chicago." No wonder we couldn't follow the plot. WJZ New York, on 770 kc., has been slid-

(CONCLUDED ON PAGE 38)

TRANSVIEW design

. . . still another pioneering step in FM by

Western Electric



This is the 3 kw FM transmitter. The full line will consist of 250 watt, 1, 3, 10, 25 and 50 kw units.

Why you'll like it:

You'll like the full-length glass doors, which provide an unobstructed view of all tubes at all times.

You'll like the striking modern appearance—and the attractive station call letters.

You'll like the big, easy-to-read meters and the ease of access to components.

Most of all you'll like the *low* intermodulation, the *low* harmonic distortion and other features that put this new line of FM transmitters as far out in front in performance as in appearance!

Since the very beginning of broadcasting, Western Electric has been noted for pioneering new ideas in transmitter design, which have later become standard practice in the industry.

Stabilized Feedback—the High Efficiency Amplifier Circuit—mounting all electrical components on a central vertical structure, achieving maximum accessibility—Synchronized Frequency Modulation are typical Bell Laboratories-Western Electric contributions.

And today Western Electric's TRANSVIEW design FM line sets the pace for tomorrow! For technical information, talk to your local Graybar Broadcast Representative or write to Graybar Electric Company, 420 Lexington Avenue, New York 17, N. Y.

— QUALITY COUNTS —

ADVERTISERS INDEX

REL

NICE to look at, BUT...

THE NEW REL 10 KW FM TRANSMITTER

Most important to you is what makes it "tick" — 10 years of REL pioneering in FM high power — all this experience led to creation of the "Broadcasters Transmitter" tops in performance and long term dependability.

JOIN FMA NOW!

RUGGED "BATTLESHIP" TYPE CONSTRUCTION OF CABINETS WITH MASSIVE DOORS HUNG ON STURDY CONCEALED HINGES.

EXTREME EASE OF ACCESSIBILITY. ALL CHASSIS TYPE UNITS, SWING—SLIDE OR HINGE OUT FOR EFFORTLESS INSPECTION.

LOWER OVERALL POWER CONSUMPTION BY USE OF TETRODES IN PUSHPULL, HIGH EFFICIENCY CLASS "C" FINAL AMPLIFIER STAGE. CONVENTIONAL CIRCUITS.

REL TRANSMITTER COMBINATIONS

- MODEL 549DL — 250 W
- MODEL 518DL — 1 KW
- MODEL 549DL DRIVER → MODEL 519DL AMP. — 3 KW
- MODEL 518DL DRIVER → MODEL 520DL AMP. — 10 KW
- MODEL 518DL DRIVER → MODEL 520DL DRIVER → MODEL 521DL AMP. — 50 KW

RELIABLE ENGINEERING LEADERSHIP

WRITE FOR LITERATURE

RADIO ENGINEERING LABS., INC.

Long Island City, N.Y.

ENGINEERING SALES

Philco: General southern sales manager D. J. MacKillop, of Atlanta, Ga., has retired after 33 years of service with Philco.

Meck: Newly appointed jobbers are: Fulton Radio Supply Company, 707 S. Blackstone Street, Jackson, Mich.; Lifsey Distributing Company, 730 N. Saginaw Street, Flint, Mich.; Fischer Distributing Company, 222 Fulton Street, New York City; Anthony Wayne Electrical Supply Company, 2732 Broadway, Fort Wayne, Ind.

Hickok: Service and repair of Hickok instruments in the eastern area will be handled at a newly established service station, 339 W. 44th Street, New York City. District representative Kenneth E. Hughes is in charge of this work.

Collins: A. E. Bachmann has been transferred from the engineering division to the sales department. He now heads up special products sales, including the Collins railroad radio entertainment system, control devices, and applications of the Autotune mechanism.

Sams: B. V. K. French, formerly head of the field engineering department at P. R. Mallory, has joined Howard W. Sams, publishers of Photofact service folders, as director of field relations.

Farnsworth: Hector A. Castellucci, who served as Farnsworth procurement specialist during the war, is now assistant manager of the sales division.

New York City: Land-C-Air Sales, Inc. has been formed by Robert E. Sargent, Paul Nichols, and Walter C. Hustis, operating as sales representatives in the northeastern states. The three partners were, respectively, western sales manager, eastern sales manager, and director of purchases for Jefferson-Travis.

Zenith: A series of four-color, full-page advertisements have been released in leading consumer papers, despite Zenith's increasing backlog of orders. Coöperating dealers have nailed their demonstration models to the floor, so they can be used to get orders for future delivery.

Sylvania: Frank J. Prime, who joined Sylvania in 1932, has been appointed assistant to the vice-president in charge of the radio tube division.

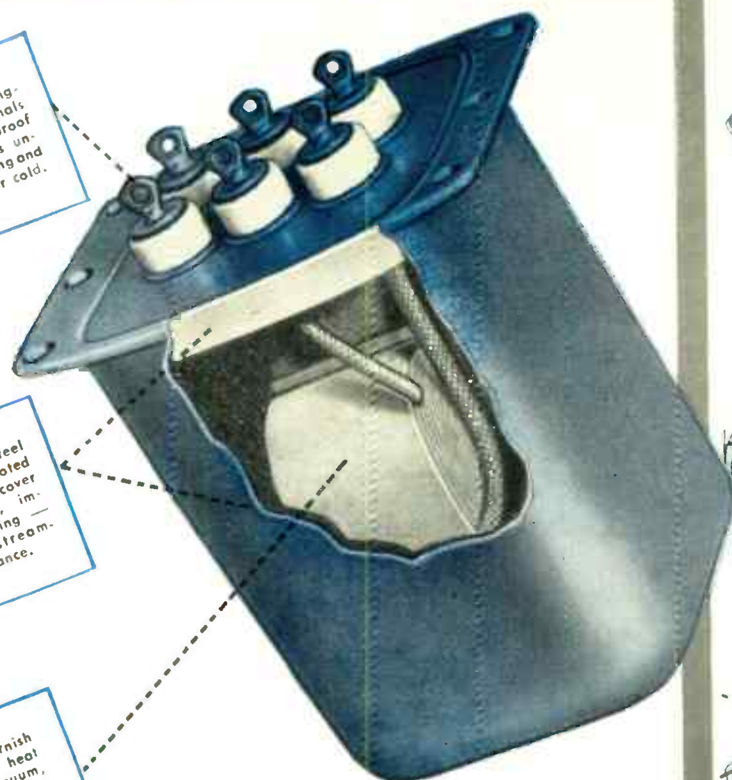
For an Extra Margin of

DEPENDABILITY

UNDER ALL OPERATING CONDITIONS

CASE TYPE

CHICAGO TRANSFORMERS *Sealed in Steel*



Exclusive C. T. bushing-gasket seal of terminals is permanently proof against moisture, is unimpaired by soldering and by climatic heat or cold.

Seamless drawn steel case and C.T.-innovated "Deep-Seal" base cover provide a strong, impenetrable housing — rust-proofed, streamlined in appearance.

Coil is wax and varnish impregnated under heat and alternating vacuum, pressure, to remove moisture, prevent its reentrance during assembly of unit.

Sealed AGAINST ATMOSPHERIC MOISTURE AND INDUSTRIAL FUMES

THUS *Sealed* AGAINST CORROSION OF COPPER COIL WINDINGS

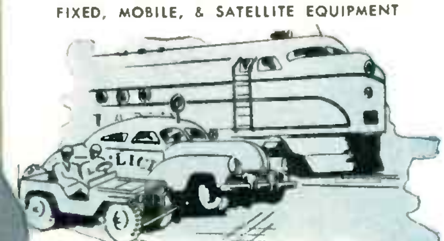
STAY *Sealed* IN EXTREMES OF HEAT AND COLD!

FITTED TO THE APPLICATIONS WHERE COMPONENT DEPENDABILITY IS ESSENTIAL TO

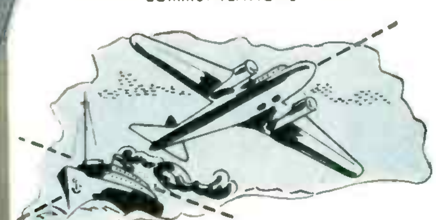
Avoid

COSTLY MAINTENANCE
LOSS OF LIFE
DISRUPTION OF A VITAL SERVICE

RADIO AND TELEVISION BROADCASTING FIXED, MOBILE, & SATELLITE EQUIPMENT



MILITARY, POLICE, AND RAILROAD COMMUNICATIONS



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INDUSTRIAL CONTROLS

★ In these and many other transformer applications, economy, as well as efficiency, is best served by Chicago Transformer's *Sealed in Steel* construction.

Let its assurance of long-lasting transformer reliability help make your electronic product free of component replacements and expensive servicing regardless of adverse operating conditions.

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TRADE MARK REG.

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DIVISION OF ESSEX WIRE CORPORATION

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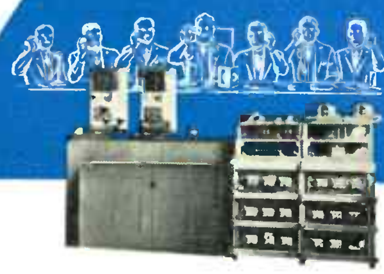
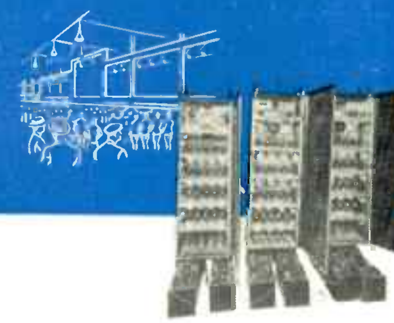
Why this team stands



1914. World's first vacuum tube repeater amplifier; designed by Bell Telephone scientists and made by Western Electric for transcontinental telephony, was the start of modern electronic communications.



1919. These Western Electric amplifiers powered the mightiest sound system of its day, used at New York's "Victory Way" Celebration after World War I. There were 113 loudspeakers in the system.

WHEN Bell Telephone scientists designed and Western Electric manufactured the first vacuum tube repeater amplifier back in 1914, they opened a vast new frontier of communications and sound distribution. Up to that time, telephone communications—both by wire and radio—could cover only limited distances and produce relatively low volumes.

For more than 30 years, this team has produced ever better amplifiers for almost every use — long distance wire and radio telephony, radio broadcasting, sound distribution systems, mobile radio, sound motion pictures, disc recording, acoustic instruments and radar.

Equipped with unexcelled tools of research, experience, skill and manufacturing facilities, the Bell Laboratories-Western Electric team will continue to design and build amplifiers outstanding in quality, efficiency and dependable performance.

— QUALITY COUNTS —

BELL TELEPHONE LABORATORIES

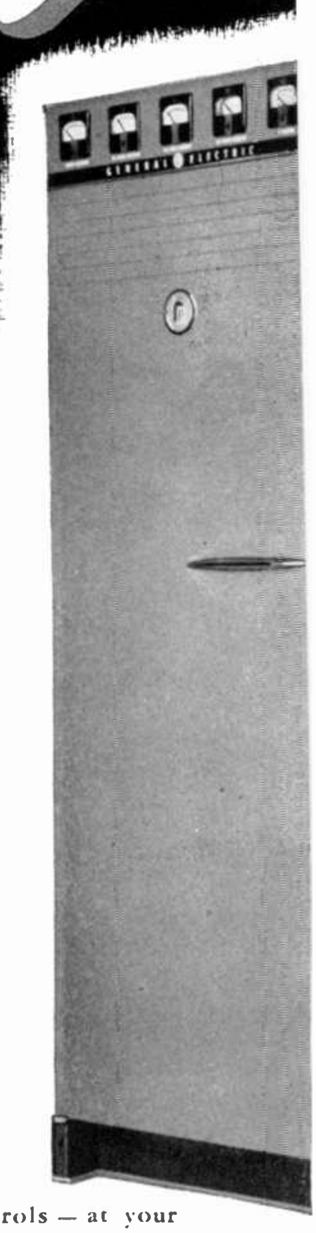
World's largest organization devoted exclusively to research and development in all phases of electrical communications.

Western Electric

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

3 KW of

NEW G-E TYPE BT-3-A ⇨



The 3-kilowatt FM broadcast transmitter with the famous Phasitron Modulator

- ✓ FEWER TUBES
- ✓ FEWER CIRCUITS
- ✓ FEWER COMPONENTS
- ✓ FEWER MAINTENANCE MINUTES
- ✓ FEWER PROGRAM OUTAGES
- ✓ FEWER INVESTED DOLLARS

BUILT for performance and economy, General Electric's new BT-3-A offers to broadcasters a *completely self-contained* 3-kw FM transmitter with every electrical and mechanical feature required by modern broadcast station owners and engineers. Designed with the revolutionary Phasitron Modulator and with fewer stages and fewer tubes than 3-kw FM transmitters of other design, here is 3000 watts of FM power that guarantees maximum audience and advertiser service—assures you lower cost per hour of operation.

For the full facts see your nearest General Electric broadcast sales engineer, or write the *Electronics Department, General Electric Company, Syracuse 1, New York.*

LOOK! ***New On-the-air reliability***

Fewer stages • Fewer tubes • Fewer components • Fewer outages • Complete fuseless overload protection with fast-acting circuit breakers • Automatic power reclosure after power failure • Longer tube and component life with air-blower system and lifetime air filters • Highest quality components used throughout • Simple, straightforward, all electronic circuits • Delta-Wye switching with instantaneous high-low power transfer for uninterrupted programming • Power amplifier tubes **quickly interchangeable.**

New Electrical Features

Push-pull tetrode power amplifier using the new ring seal GL-7D21's • No intermediate amplifier between 250-watt exciter and 3-kw amplifier • Critical neutralization eliminated • Includes the Phasitron Modulator • Block-built design for combining units to meet future power requirements • Complete metering • Power supply 208/230 volts ± 5%, 50/60 cycles, 3 phase.

New Accessibility

Completely self-contained • Full-length doors front and rear • Vertical chassis easy-to-get-at • Tubes, components, adjustments and controls — at your finger tips.

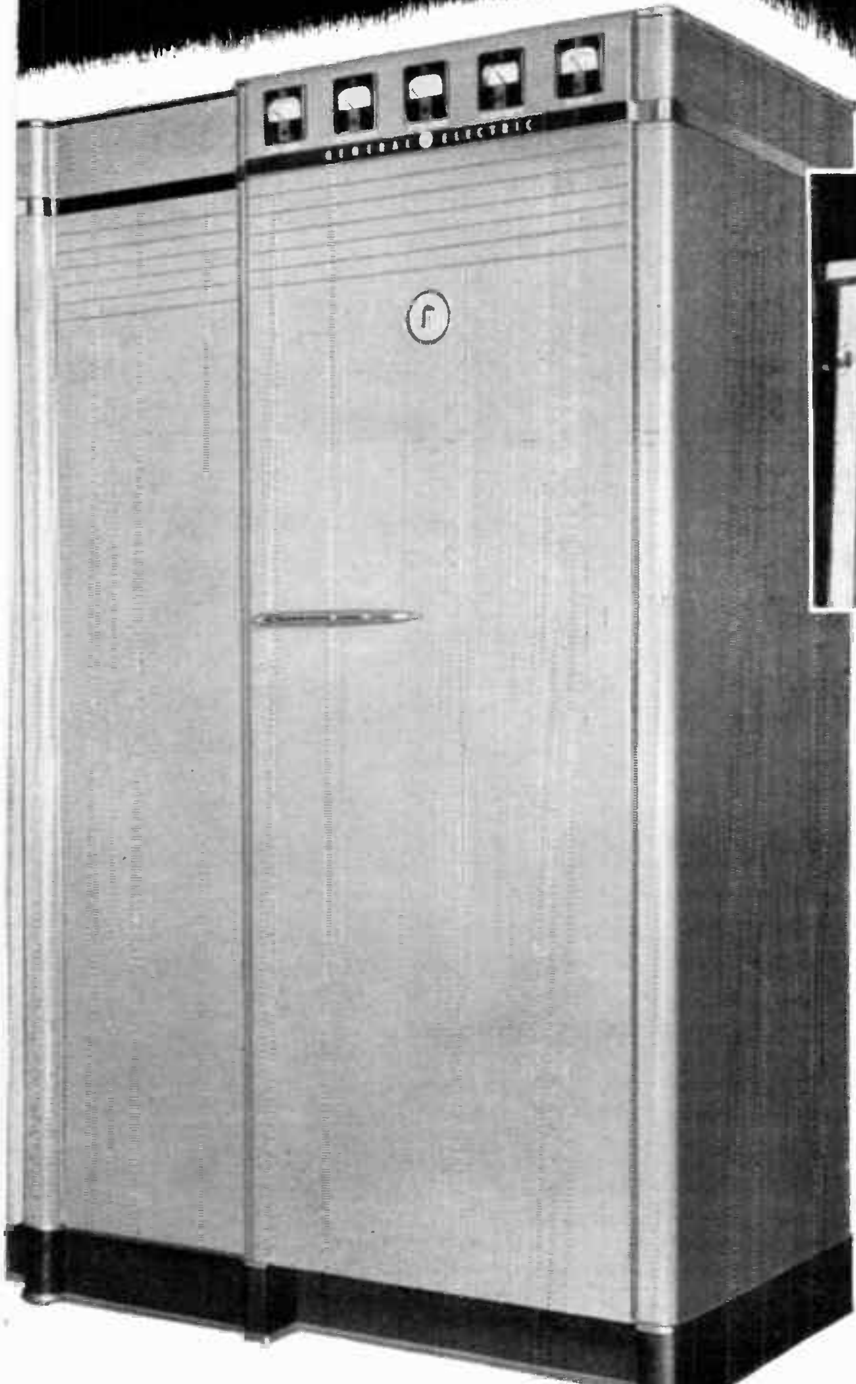
New Ease of Installation

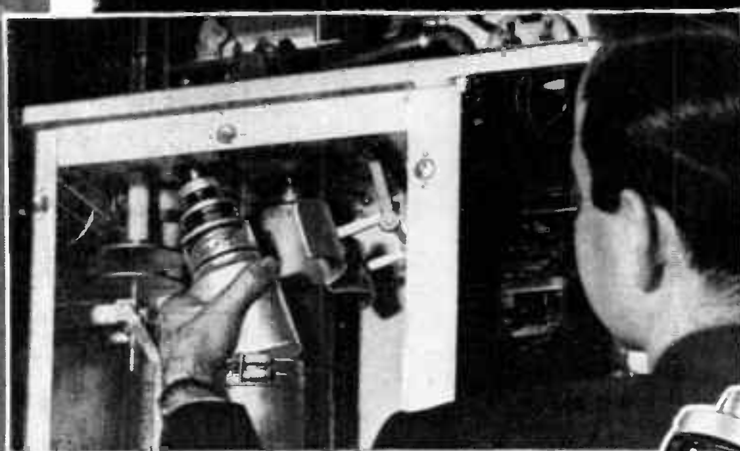
Only 75 inches high, 72 inches wide, and 25 inches deep • Two easily-joined space-saving units for convenient transportation through standard doorways and in elevators.

New Styling

Husky and handsome • Matches other G-E FM transmitter units • Stainless steel trim • Rounded corners • Baked synthetic enamel with beautiful opalescent finish • Utility and beauty contribute to station appearance.

FM PERFORMANCE! Economy!





Power Amplifier

Two plug-in, radiator-type GL-7D21's in clean-cut symmetrical push-pull circuit. Neutralization adjustment is unnecessary. Tubes are replaced easily.

New G-E 3-kw FM Transmitter, type BT-3-A

Meets all FCC standards and latest proposed RMA standards.

Air-radiator type GL-7D21

New h-f tetrodes used in the BT-3-A power amplifier. In push-pull, delivers 3 kilowatts of power with only 120 watts of driving power.

Block-Build to higher power

The BT-3-A includes a G-E 250-watt FM exciter and a 3-kw FM amplifier. If you now own a 250-watt exciter, simply add a G-E 3-kw amplifier. And if you anticipate swinging ultimately to higher power, then simply add a G-E 10-kw FM amplifier to your 3-kw G-E unit.

In combining G-E FM Transmitter units, there is no expensive equipment duplication, no equipment obsolescence, no relocation of existing units. Simplified wiring insures easy inter-unit connections. Size and appearance of all G-E units are harmonious and adaptable to future additions for higher power.

GENERAL ELECTRIC

160-E12-6914

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$10 Per Month for This Standard Space. Orders Are Accepted for 12 Insertions Only

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THE WORKSHOP ASSOCIATES
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Bigelow 3330

Since 1940, this Magazine has been the broadcasters' chief source of information on FM activities and progress.

DALE POLLACK

FREQUENCY MODULATION

development and research
transmitters, receivers
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New London, 2-4824

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1309 Kenwood Road • Santa Barbara, California

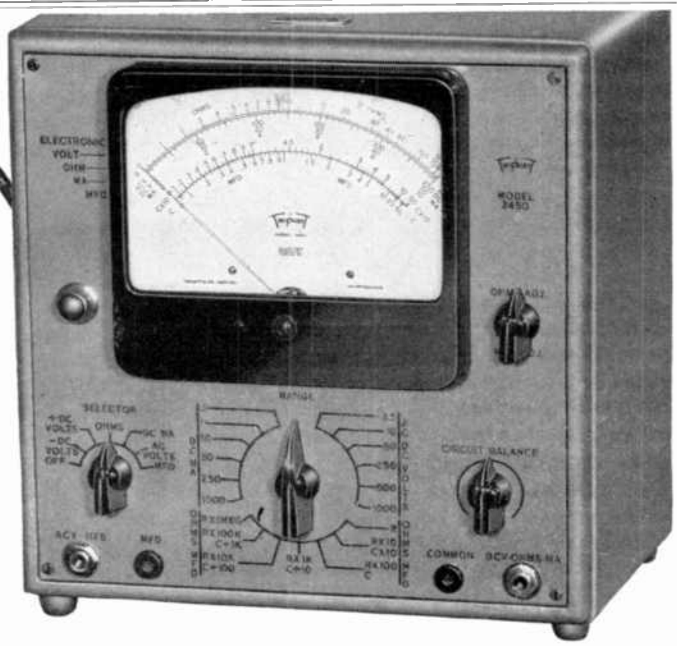
Model 2450
ELECTRONIC TESTER
★

There's never been a tester like this!

Here's a tester with dual voltage regulation of the power supply DC output (positive and negative), with line variation from 90 to 130 Volts. That means calibration that stays "on the nose"! That means *broader service* from a tester that looks as good as the vastly improved service it provides. This model includes our Hi-Precision Resistor which outmodes older types.

HIGHLIGHTS—42 ranges: DC and AC. Volts: 0-2.5-10-50-250-500-1000 • DC MILLIAMPS: 0-0.1-1.0-10-50-250-1000 • OHMS: 0-1000-10,000-100,000 • MEGOHMS: 0-1-10-100-1000 • CAPACITY IN MFD: 0-.005-.05-.5-5-50 • LOAD IMPEDANCE: 51 megohms on DC Volts • CIRCUIT LOADING: Low frequencies. Circuit loading equal to 8 megohms shunted by 35 mmfd. High frequency circuit loading equal to 8 megohms shunted by 5 mmfd.

Detailed catalog sheets on request.



Precision first ..to last

Triplett
ELECTRICAL INSTRUMENT CO. BLUFFTON, OHIO

STANDARDS ARE SET BY TRIPLETT

ALL-INDUSTRY FM ASSOCIATION LAUNCHED

After 26 Years, Broadcasters and Manufacturers Join Forces in the Interests of Radio Listeners

BY MILTON B. SLEEPER

WHILE NAB and RMA management were busy with plans for nothing more important than a National Radio Week, a real contribution to U. S. listeners was being wrapped up and readied for delivery by a group of men meeting in Washington.

It isn't clear why there should be a National Radio Week when AM listeners have nothing to celebrate except deteriorated performance from postwar sets, reduced night-time range, and more interstation interference. And we don't know why people should be asked to clutter up every room in the house with such sets, or to spend more hours listening to such programs.

But it does make sense for FM broadcasters and FM set manufacturers to plan an organization, in the service of public interest, convenience, and necessity, to coördinate the efforts of those who will put out programs of superior quality, and those who will produce the sets to receive these programs without interference.

The Purpose ★ Meeting under the temporary chairmanship of Roy Hofheinz on November 11th and 12th at Washington, the committees appointed in Chicago[1] set to work on the all-industry organization which will be called the FM Association. The purpose of FMA was summarized by chairman Hofheinz as filling the need for "a hard-hitting promotional organization to acquaint Mr. and Mrs. America with the superior quality of FM in a new era of broadcasting."

C. M. Jansky, Jr., a member of the Objectives Committee, elaborated on this by explaining: "The future of American Broadcasting depends upon the untrammeled development of FM. Active, aggressive promotion of FM by an association dedicated to the task of informing the public of the advantages of this new service will speed the day when the public will have a truly American broadcasting system, in which competition will be between programs for listeners, and not between broadcasters for facilities."

Specifically, the objectives were summarized in these five points:

1. To encourage the development of FM broadcasting.
2. To publicize the superior quality of FM as an improved broadcasting service to the public.
3. To disseminate information among the members of FMA regarding the general problems incident to FM operation.
4. To coöperate with receiver and transmitter manufacturers, and other suppliers of FM equipment and services, with the objective of establishing the widespread operation of FM stations as rapidly as possible.
5. To act as liaison between FMA members, the FCC, and other agencies and organizations on the continuing overall problems affecting FM broadcasting.

The Plan ★ FMA is being set up as a thoroughly democratic organization to represent the common interests of the broadcasters and equipment manufacturers in their efforts to raise reception standards.

Accordingly, no slate of officers is being set up in advance by the Nominations Committee. Instead, an organization meeting will be called as early in 1947 as hotel accommodations can be arranged. It is expected that the meeting will be called in New York City during January.

At that time, officers will be nominated and elected by representatives of companies who apply for membership. Then permanent committees will be appointed, and the work of the Association will begin in earnest.

With the total of FM stations on the air and projected now above the 1,000 mark, and with practically every radio manufacturer putting pressure behind FM set production for 1947, this will be one of the largest and most significant industry meetings ever held. Added import will be given this meeting because, by that time, quite a number of 10-kw. FM transmitters will have been delivered, and FM receivers will be rolling out at more than 100,000 a month.

Initial FMA membership applications may well total 500, assuring adequate funds to carry on FMA activities.

No announcement has been made concerning dues. FMBI membership cost $300 per year. NAB dues are scaled according to revenue from time sales. FM stations have little or no income now, so that system cannot be used by FMA. However, it is possible that applicant members will pay a smaller fee until their transmitters are on the air. Also, to ease the strain, FMA may adopt the NAB plan of monthly dues. In any case, it appears certain that FMA will have an income of more than $50,000, and perhaps as much as $100,000 during its first year.

Enthusiastic Support ★ Announcements that NAB will meet the threat of a separate trade association have met with cool response. The time for that was in 1945, when FMBI was taken over, and not after NAB found it couldn't kill FM by kicking it around. Whether the AM-minded NAB management likes it or not, it has forced the creation of a competitor whose strength will grow from its service to the radio audience.

FCC Chairman Denny expressed his approbation of FMA in the following letter to the Association:

"Believing as we do that the American people will be quick to avail themselves of the advantages of FM as soon as stations and receivers come into their community, provided they are properly informed, the Federal Communications Commission extends its best wishes to the FM Association for success in its plans to enlighten the public concerning this new and improved system of broadcasting.

"As I stated in my address at the recent convention of the NAB, the Commission considers FM the finest aural broadcast system attainable in the present state of the radio art, and expects that eventually the entire nation, except the most sparsely settled Western areas, will be served by FM.

"An organization such as yours, concentrating on the building of FM, can perform one of the most valuable services in the history of broadcasting. Those of us close to radio are excited over this revolutionary improvement, but to the vast majority of listeners FM is still just another alphabetical combination. It is highly gratifying to know that your group has embarked on a crusade to carry the story of FM to every radio listener in the land."

Meanwhile, Commissioner E. K. Jett, in a transcribed interview available to broadcast stations, said in part: "We, at the FCC, expect some 2,000 [FM broadcast stations] in the next few years." Pointing out that FM and AM will be available "for some time to come," he advised: "If I were buying a new radio today, I certainly would not buy one that did not include FM." Furthermore: "Despite shortages, FM sets are coming onto the market in increasing numbers. The latest estimate is that at least 5,000,000 will be produced next year [1947]."

Further Information ★ Inquiries from those who plan to join FMA should be addressed to the Acting Secretary, in care of Commerical Radio Equipment Company, International Building, Washington 4, D.C.

[1] For details of that occasion, and membership of the committees see *FM and Television*, November, 1946, page 19.

B.B.C. FIELD TRIALS OF FM

An Evaluation of FM Broadcasting Made by the British Broadcasting Company—Part 2

BY H. L. KIRKE

3. PROPAGATION, FIELD STRENGTH, AND FADING CHARACTERISTICS

Propagation ★ The propagation of ultra-short waves is not materially affected by the type of soil over which the waves pass, as is the case for medium and long waves, but ultra-short waves are more affected by ground contour. Hills cast shadows and, as many listeners live in valleys, ultra-short waves tend to be at a disadvantage. Considerable advantage can be obtained, however, by siting the transmitter on high ground and with as high an aerial as possible. In America a 500-ft. mast is commonly used for supporting the transmitting aerial, and in some cases FM transmitters have been built on tops of mountains 7,000 ft. high! In addition, it is neither difficult nor expensive to build a high-efficiency aerial system giving a field strength of more than twice that of a single dipole for the same power. The gain in field strength is roughly proportional to the height of the transmitting aerial above the surrounding country and, as the field strength is approximately inversely proportional to the square of the distance, doubling the height of the aerial above the surrounding country will normally increase the range by about 1.4 times and the service area by twice approximately.

Propagation is also affected by the condition of the atmosphere. Due to bending (refraction) in the atmosphere, the waves follow a curved path and thereby reach greater distances than would otherwise be the case. The amount of bending depends upon the condition of the atmosphere as regards the moisture content, temperature, and temperature and moisture gradients. These characteristics have been the subject of considerable study by other organizations during the war, and a great deal is known of the effects of these variations, but more particularly at the shorter wavelengths. A number of workers have calculated the field strengths obtainable on ultra-short wavelengths. The results of the calculations by Norton in America have been published in convenient form by the FCC, and those curves have been studied in relation to measurements made in this country.

The curves indicate the hypothetical field strengths which would result from propagation under idealised conditions of a smooth earth. The field strengths which would result under practical conditions may differ very considerably from the idealised values, and depend upon the type of intervening country and the situation of the receiver. The field strengths are all calculated for a receiving aerial height of 30 ft. The field strength for lower heights and for indoor aerials will be considerably less, but it is not possible to make allowances for height in many practical cases with any degree of accuracy, although normally the field strength is approximately proportional to the height of the receiving aerial.

Measurements of field strength have been made in the 40- to 50-mc. band. Before the war, measurements were made of the field strength of the Alexandra Palace television sound transmitter, and some check measurements have been made recently, as well as measurements of the field due to the Research Department's FM transmitter on 45 mc. at Alexandra Palace. A survey has also been made of the field strength from the Research Department's FM transmitter near Oxford on 45 mc. The latter measurements have been made on both horizontal and vertical polarisation. Briefly, it can be said that there is substantial agreement with the FCC curves on 45 mc., but in certain cases where screening occurs the field strength may be well below the calculated value. A factor of 5:1 is not uncommon. This effect makes it difficult to calculate service areas with any degree of accuracy, and any attempt to do so must take into account the nature of the terrain, but even when this is done only a rough estimate can be made.

Field strength measurements have been made on 90 mc. and, although these are incomplete, sufficient information is available to indicate the values of field strength which are likely to occur in practical cases. The shadows cast by hills cause more variation in the field strength on 90 mc. than on 45 mc., and the effect of ground contour, therefore, is greater. In some cases the actual field strength is equal to, or even greater than, the idealised value, while in some cases field strength as low as one-twentieth of the idealised value have been measured. Such cases are extreme, but it is not, however, unusual for field strengths of between one fifth and one-tenth of the idealised values to occur. On the whole, it is thought that if an average value of about one-half of the idealised field strength is used, and an allowance made for ground contour, it is possible to obtain a fair estimate of the service area of a transmitter. Some care has to be taken, however, in the assessment of the height of the transmitting aerial above the surrounding country. It would seem necessary to take into account the average slope and shape of slope of the ground between the transmitter and receiver, and it does not seem possible at present to lay down any hard and fast rules. Each case must be dealt with individually, and on its merits. The estimation of the height of the transmitting aerial is important, however, as it is one of the major factors affecting the field strength at a distance, particularly at the greater distances and with considerable heights.

It is to be noted that, theoretically, the field strength at 90 mc. should be about twice that at 45 mc. for the same power, aerial height, and aerial gain. If, as is suggested above, the figure of one-half be taken as the ratio of average to idealised field on 90 mc., the field strengths for 90 and 45 mc. should be approximately equal. On the other hand, in reception the pick-up of a dipole aerial on 90 mc. is only half that at 45 mc. since the aerial is one-half the length. Greater receiver sensitivity will therefore be needed at 90 mc. than at 45 mc.

There appears to be very little practical difference between horizontal and vertical polarisation as regards field strength. In some cases, behind hills, lower field strengths were obtained with horizontal than with vertical polarisation, but in others the reverse was the case. In practice there will be considerable variations of field resulting from the shadows of hills, etc., and these variations are usually much greater than any difference between horizontal and vertical polarisation. Fig. 4 shows a typical 90-mc. field-strength vs. distance curve. The transmitter was at Alexandra Palace, the aerial being approximately 600 ft. above mean sea level.

During the various tests on horizontal and vertical polarisation, the effect of signals reflected from aircraft was studied, as it had been noticeable on television before the war. An aircraft was arranged to fly on a selected course, and observations were made of the effects. This was done at 45 mc., but has not yet been repeated on 90 mc., although it is proposed to do so. The effect was much more marked in degree and was much more frequent with horizontal than with vertical polarisation. In general the effect is most noticeable when the aircraft is fairly near the receiver. The results of reflections from aircraft would not normally be noticeable within the first- or second-class service areas of a transmitter, but might be troublesome in areas of relatively weak field strength, where what can best be described as a *fluffing noise* accompanied by distortion would be heard.

While horizontal polarisation is superior to vertical from the point of view of motor-car interference, there might be a case for preferring vertical polarisation if suppressors were universally fitted to motor vehicles.

Fading ★ On ultra-short waves in normal circumstances, there is very little fading at distances below 50 miles, while considerable fading may be experienced at greater distances. Fading on long, medium and short waves, as well as transmission to great distances, is caused by the reflection of waves from the ionosphere and, due to the considerable difference in the time taken for the waves to travel along the ground and to the ionosphere and down again, the type of fading which occurs is that known as selective fading.

On ultra-short waves the amount of fading depends upon conditions in the lower atmosphere which may give rise to high field strengths at a distance. Normally, the field strength at a distance depends upon the amount of bending that takes place, and in this case it is only one ray which is received at a distance and not several, as in the case of longer waves. If more than one ray were received, due for example to different amounts of bending at different heights in the lower atmosphere, the difference in transmission time between the several rays would be so small that selective fading would not occur. With the exception of the multipath phenomena mentioned below, which may be due to reflection from mountains or buildings, fading is usually merely a variation in the field strength.

A number of fading measurements have been made during the FM experiments, but so far it has only been possible to carry out such measurements for a few days or weeks. In order to obtain complete data, it is necessary to carry out continuous field strength recordings at a large number of distances and over a very considerable period of time, and a series of long-period observations is shortly to be undertaken.

There are two main types of propagation which must be studied when considering any ultra-short wave service. The first is that which affects the service area of a transmitter up to, say, 70 miles, when the important factor is the minimum field strength received, and not the average, maximum, or quasi-maximum value. The other type is that which takes places at much longer distances, and could cause interference with another transmitter working on the same wavelength.

Transmission to the greater distances can take place by bending in the lower atmosphere, by reflection from the ionosphere and by what have been termed *bursts*. Reflections from the ionosphere may occur on frequencies up to about 40 to 50 mc. during the years of sunspot maximum, but transmission by this means falls off very rapidly as the frequency is increased, and at 90 mc. is negligible.

Transmission by bending in the lower atmosphere depends upon its temperature and humidity, and also upon the latitude and whether transmission is taking place over land or sea.

The phenomenon referred to above as bursts was observed on television transmissions in this country before the war. These bursts of signal last usually for a very short time, and occur at ranges of upwards of 100 miles. The evidence indicates that they are more prevalent during times of high meteor activity, and it is thought that the bursts are in fact reflection of signals from small ionic clouds which surround meteors. These bursts can cause interference with a distant station operating on the same wavelength, and in FM, if the bursts are strong enough, will capture the receiver for a short time, and during that time an unwanted programme may be heard instead of the wanted programme. The extent to which this is liable to occur is not known, and full reports have not yet been received from America, where this effect is at present being studied. In the experiments referred to above, it is proposed to include a watch for bursts.

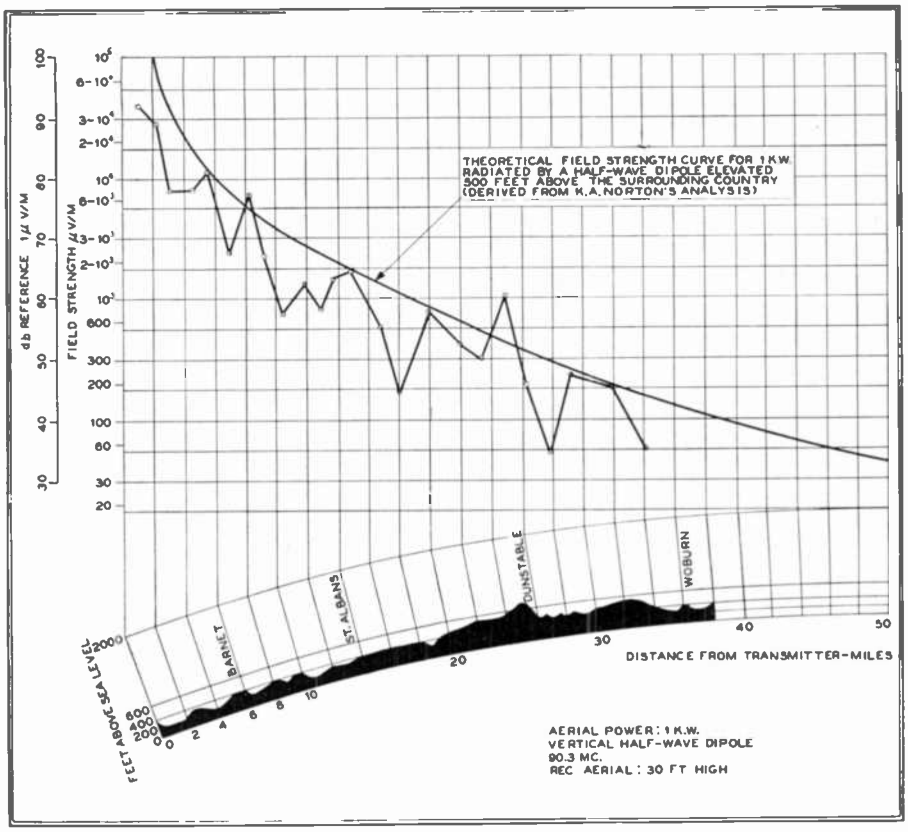


FIG. 4. TYPICAL PLOT OF FIELD-STRENGTH VS. DISTANCE ON 90-MC. TRANSMISSION

Multipath Distortion ★ This is a curious effect somewhat analogous to selective fading in medium and short waves, but with more serious results. It occurs when signals arrive at the receiver from two or more paths, such as by reflection from high buildings or mountains, but only when the strengths of the two signals are of the same order and when the difference in path length is greater than about a mile. It is likely to occur at times in mountainous country, and at least one such case has been reported in America.

In the tests on 45 mc. in this Country, two instances of multipath distortion were noted, but these were of a somewhat different type. One of these occurred in Reigate when variations of as much as 100:1 in the direct-ray field strength occurred at places distant only a few feet from one another. In places where the field strength was low, the multipath distortion was heard due, it was thought, to reflection from a gas holder a few miles distant. The distortion was completely eliminated by moving the receiving aerial a few feet. In some tests carried out from Moorside Edge in very hilly country, no evidence of multipath distortion was obtained, even in places in which it was thought likely that such effects might have been produced. Theoretically, multipath distortion tends to be more important for large deviations than for small, but a reduction in deviation would not in general result in a complete cure, although it might lessen the probability of its occurrence to some extent.

4. SERVICE AREAS

The planning of an ultra-short wave service is in some respects more difficult than for a medium or long wave service, chiefly on account of the much greater effect of ground contour, as explained in Section 3. For this reason it is not possible to calculate the field strength at any specific point with any degree of accuracy. Service areas can therefore be stated only in fairly general terms.

In considering the grades of service, the effect of motorcar interference, receiver noise, and receiver sensitivity must be taken into account. It is convenient to divide service areas into two main classes, urban and rural. In the former, the field strength must be such that a good service is provided in the presence of considerable motorcar interference. In the latter only receiver noise and receiver sensitivity are considered. Naturally, there will be intermediate grades of service. For example, in a fairly quiet suburban street, where little car interference occurs, a low field strength is adequate, while in some country towns considerable interference may be experienced, and it would not be correct to classify such places as rural areas. In any case, the position of the receiving aerial relative to traffic will considerably affect the grade of service. On 45 mc. it is suggested that the following grades of service would be acceptable for horizontal polarisation, while for vertical polarisation fields of two to three times would be required:

	Field Strength
Grade 1. 1st class urban area service, sufficient to override practically all motor-car interference:	5,000 μv/m
Grade 2. 2nd class urban area service, sufficient to override most motor-car interference:	1,000 μv/m
Grade 3. 1st class rural area service:	200 μv/m
Grade 4. 2nd class rural area service:	50 μv/m

On 90 mc., motorcar interference is considerably less than on 45 mc., and a field of about one-half to one-third of the strength is sufficient. As receiver sensitivity and aerial pickup tend to be less on 90 mc. than on 45 mc., the lower limit of field strength required for rural area service on 90 mc. should be 100 μv/m, although with a sufficiently sensitive receiver and in the absence of ignition interference, a good service would be provided at a much lower field strength. On 90 mc., any motorcar interference in rural areas will be considerably less annoying than on 45 mc., as the interference itself is less and the suggested minimum field strength for rural service greater.

The field strengths recommended for the various grades of service on 90 mc. with horizontal polarisation are as follows, while for vertical polarisation two to three times the field strength will be required:

Grade 1	2,000 μv/m
Grade 2	500 μv/m
Grade 3	200 μv/m
Grade 4	100 μv/m

Table 2 gives the distance at which the grades of service specified on 45 mc. should be obtained. As the field strength may be as low as one-fifth of these values in some cases, the figures must be considered as applicable to good conditions only. In some practical cases the range might be between one-half and two-thirds of those stated.

Table 3 shows the probable average ranges for various grades of service and different transmitter powers for 90 mc. This table has been prepared on the assumption that the actual average values of field strength will be one-half the theoretical values. It is to be noted that the maximum power has been taken as 25 kw., as this is probably the maximum realisable power at present. However, an increase in power increases the range by a relatively small amount.

A comparison of the figures is interesting. The primary service area on 90 mc. is slightly greater than that on 45 mc., even though the field strengths at the higher frequency are assumed to be only one-half of the theoretical value. This is largely due to the lower interference level on 90 mc., but takes into account the fact that a given field strength on 90 mc. produces in the receiving aerial only one-half the voltage produced on 45 mc., as the physical length of a half-wavelength dipole for 90 mc. is one-half of that on 45 mc. The secondary service areas are greater on the lower frequency, but in many cases these ranges will be reduced, due to screening.

In comparison, in the FCC's "Standards of Good Engineering Practice for FM Broadcasting," the field strength requirement for the primary service area in large cities is 5,000 μv/m, the secondary service area in towns of the order of 10,000 inhabitants 1,000 μv/m, and for rural area coverage 50 μv/m.

TABLE 2—SERVICE AREA FOR 45 MC.

Horizontal Polarisation

Hght. of Trans. Aerial above Surrounding Country Feet	No. of Aerial Stacks	Aerial Gain in Field Strength	Aerial Power Kw.	Field Strength Multiplier from 1 Kw. with Single Dipole	Radius of Service Area in Miles Rec. Dipole 30 Ft. above Ground: 5,000 μv/m 1st Class Urban	1,000 μv/m 2nd Class Urban	200 μv/m 1st Class Rural Service	50 μv/m 2nd Class Rural Service
1,000	8	2.8	50	20	35	57	78	120
500	8	2.8	50	20	26	44	66	86
500	8	2.8	10	9	19	35	55	75
200	4	2.0	5	4.5	9	18	34	52
200	4	2.0	1	2.0	6	13	25	41
100	2	1.4	0.25	0.7	2.5	6	12	30

5. RECEPTION

Experience with different types of receivers ★ A number of types of British and American receivers were used for the tests and, as might be expected, there was a considerable difference in performance between them, particularly in regard to the suppression of receiver noise, impulsive noise, and sensitivity. The degree to which this is accomplished depends, as has already been stated, to a large extent upon the design of the receiver, which may be reflected in its cost. In order to suppress noise satisfactorily, a receiver should have adequate RF and/or IF amplification, and a well-designed limiter.

FM receivers are in general more difficult to tune than AM receivers, in that there is no point of maximum signal to which to tune. In order to obtain the maximum suppression of interference and receiver noise, it is necessary to tune the receiver correctly, but the degree to which this is critical depends upon both the mechanical and electrical design of the receiver. The receiver heterodyne oscillator must have good frequency stability after a short period from switching on has

TABLE 3—SERVICE AREA FOR 90 MC. (Provisional)

Horizontal Polarisation

Hght. of Trans. Aerial above Surrounding Country Feet	No. of Aerial Stacks	Aerial Gain in Field Strength	Aerial Power Kw.	Field Strength Multiplier from 1 Kw. with single Dipole	Radius of Service Area in Miles Rec. Dipole 30 Ft. above Ground: 2,000 μv/m 1st Class Urban	500 μv/m 2nd Class Urban Service	200 μv/m 1st Class Rural Service	100 μv/m 2nd Class Rural Service
1,000	8	2.8	25	14	40	56	67	76
500	8	2.8	10	9	26	38	49	57
200	4	2	5	4.5	13	23	30	38
200	4	2	1	2.0	9	17	23	30
100	2	1.4	0.75	0.7	4	8	12	17

been allowed for steady conditions to be reached, as any detuning causes distortion, particularly on modulation peaks, as well as impairing the signals-to-noise ratio. As the correct tuning position is not easily identified, some tuning indicator, or preferably some automatic tuning or frequency-correcting device, is likely to be essential if ordinary listeners are to obtain reliable and satisfactory results.

Crystal control may appear to be uneconomical, but as so much work has been done on the mass production of crystals, it would not appear impossible to envisage the production of very cheap crystals of adequate stability, say 1 part in 10^5. The use of crystals might, in practice, enable the ganged condenser to be eliminated and, for the whole tuning to be of the press button type, crystals of appropriate frequency being provided to suit the transmitter frequencies for each district. A fault of some receivers is that the IF band width is too narrow. If this is the case, distortion will occur, particularly on weak signals, as the effective band width of an FM receiver increases as the signal strength increases.

A point of importance in receiver design is the band width of the discriminator. If this is too narrow, distortion will occur on the peaks of modulation, and if it is too wide, the suppression of ignition noise will suffer. A judicious compromise is required, therefore, and it is suggested that for a peak deviation of ±75 kc. a discriminator band width of ±100 kc. is about right.

An interesting comparison is that between FM receivers on ultra-short waves and a medium wave receiver of comparable price class. In tests carried out, the improvement of FM on ultra-short waves over AM on medium waves was substantially the same as that between FM and AM on ultra-short waves for general and set noise, but for ignition noise the improvement is less, as ignition noise is not a problem on medium and long waves.

The incorporation of an ultra-short wave band in a broadcast receiver would increase its cost, and an additional increase would be entailed if FM transmissions also are to be received. But it is thought that the increase in receiver cost for FM compared with AM is not unduly great, when considered in relation to the benefits of FM as a service. It is clearly not possible here to give any indication of actual costs, as this is a question for the manufacturers. Nevertheless, it is safe to say at this juncture that the additional cost of FM is not prohibitive, and it is not asking too much to expect that future development by receiver manufacturers and others would not only improve the performance of FM receivers but, it is hoped, reduce the cost.

General Listening Tests by Members of Staff ★ In order to provide practical data on the reception of Frequency Modulation in the home, and also to give BBC staff an opportunity of forming an opinion as to the value of FM, the Home programme was radiated on FM from Alexandra Palace from 7 P.M. to 10:30 P.M. each evening. This was done on 46.3 mc. for four months from June 11 to October 10, 1945, and on 90.3 mc. from November 20, 1945 to March 2, 1946. Simultaneously with the 46.3-mc. tests, the programme was also radiated on AM from the television sound transmitter on 41.5 mc. The power output of FM on 46.3 mc. was 800 watts, and on AM between 1.5 kw. and 2 kw., and this with a more efficient aerial. Thus the effective power of AM was considerably greater than that on FM. The power on 90.3 mc. was 500 watts.

In these transmissions, an omnidirectional vertical transmitting aerial was used. The 90-mc. tests were discontinued on March 6, 1945, but were resumed some weeks later, an aerial lower down the Alexandra Palace mast now being used. This was made directional to the southwest to avoid losses in the mast. The latter transmissions were at first radiated with horizontal polarisation, and later with vertical polarisation.

45-Mc. Tests ★ Reports were received from listeners at distances of up to 120 miles from the transmitter. All listeners who were able to make a comparison between FM and AM, thirteen out of fifteen, were unanimous that FM was an improvement over AM, despite the greater power of the AM transmitter.

Some listeners commented on the silent background of FM, and some that the background noise was less than on the normal medium-wave service. One listener asked for greater dynamic range to be used on FM, and some listeners thought that the dynamic range appeared to be greater — an impression easily obtained due to the low background noise. However, habitual listening to a good FM service tends to make listeners less tolerant of the background noise heard under average medium- and long-wave conditions. Car interference was the most serious source of irritation, and some listeners were disappointed with FM in this respect. Generally speaking, however, the tests bear out the results obtained in the laboratory.

Reception Conditions on 90 Mc. ★ Listening tests have also been carried out on 90 mc. In general, the service was satisfactory and in some cases more so than on 45 mc., despite lower transmitter power and greater attenuation (lower field strength).

In suburban areas, an ambient field strength of 700 $\mu v/m$ vertically polarised provided a very satisfactory service free from interference in most cases.

A problem which will require attention is that of the receiving aerial, particularly if a listener has an AM medium-wave receiver, a television receiver, and an FM receiver. It would simplify the problem if the polarisation of both television and FM were the same, so that they could both be received on the same aerial. An efficient combined receiving aerial system for television, FM, and medium and long waves would be the ideal arrangement.

6. TRANSMITTING EQUIPMENT

One of the advantages of FM is that the carrier can be modulated at low power. It is usual to modulate at a frequency much lower than the carrier frequency. The modulated carrier is then passed through frequency multipliers and power amplifiers until the appropriate carrier power is reached. As has been mentioned before, a further advantage is obtained, namely, that as the carrier does not vary in amplitude, power amplification can be carried out at high efficiency.

There are two principal methods of effecting frequency modulation. One of these is the original Armstrong system, in which the carrier oscillation is generated at a comparatively low frequency and at low power and is then phase-modulated and frequency-multiplied. Since phase modulation is the differential of frequency modulation, this method requires the modulation to be integrated in order to obtain frequency modulation. In a modification of Armstrong's method, developed by the Zenith Radio Corporation in the United States and later perfected by the American General Electric Company, use is made of a special type of valve called a ***phasetron***.

The second main method is more direct, the frequency of an oscillator being modulated by the use, for instance, of a reactance valve. A method of achieving direct frequency modulation has been developed in the B.B.C. Research Laboratories, and employs a circuit wherein the phase angle of a feedback chain is modulated, whereupon the frequency changes so that the phase shift reverts to zero.

In any direct method of Frequency Modulation, the frequency of oscillation itself is varied. It is, therefore, necessary to provide some means of stabilising the mean carrier frequency. There are two principal methods; one is to design all the circuits to be extremely stable in frequency, such as by the use of low temperature-coefficient components and the stabilisation of voltages, etc., and in addition it may be necessary to control the temperature of the circuits themselves. The other method is to compare the mean carrier frequency with that of a stable oscillator such as a crystal, and to feed back a voltage dependent upon the difference between the two frequencies to the frequency-modulated oscillator, so that automatic frequency control is effected. There does not seem to be any outstanding preference for one method or the other, and the method used will largely depend upon the personal choice

(CONTINUED ON PAGE 42)

SPOT NEWS NOTES

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

Charles R. Denny, Jr.: Appointed permanent Chairman of the Federal Communications Commission on December 4. Although Charles Denny has been referred to as a disciple of Paul Porter, from whom he inherited the Blue Book issue, his administration as acting chairman has been characterized by a practical regard for the needs of the industry that was not displayed by ex-chairman Porter or Fly. As an appointment made on the basis of merit, the selection of Mr. Denny has the unqualified support of this publication.

FM at San Francisco: In conjunction with the San Francisco section of the IRE, Frank Gunther put on a demonstration of FM broadcasting from November 19th to 21st. According to reports from those attending Pacific Coast broadcasters and engineers who heard FM for the first time were surprised at the improvement over AM, even in an area where natural static is relatively low. Result: the 1-kw. REL transmitter was sold on the spot!

Leslie G. Thomas: Formerly works manager of International Resistance Company, has been elected vice president in charge of manufacturing for Solar Manufacturing Corporation. He will have charge of the plants at Bayonne and North Bergen, N. J., and at Chicago.

Too Little, Too Late: Now that the organization of the all-industry FM Association is formally under way, NAB and RMA have announced plans to provide coöperation between broadcasters and manufacturers. Since it has taken them 26 years to discover the existence of mutual interests, these gestures will not lessen the need for the FM Association.

Speech Equipment: A new catalog of speech equipment, showing postwar units, has been issued by Collins Radio Company, Cedar Rapids, Ia. Information and illustrations are planned to aid broadcast engineers to select combinations of units to meet the particular needs of their stations.

Color Television: As the FCC hearing on color television nears, conflicting claims by the proponents of simultaneous and sequential transmission indicate that a considerable length of time must elapse before either side will be in a position to present convincing evidence of the superiority of one method over the other.

It Went Astray: We have wondered what happened to the 50-kw. low-band FM amplifier that G.E. built but didn't deliver to Gordon Gray's WMIT. Now we learn from Harold Essex, WMIT's managing director, that it was warehoused in Schenectady, under Government orders, until June, 1944. Then the Navy shipped it to North Africa, and set it up to jam the radio equipment on German bombers. The first story of WMIT (né W41MX) was published in *FM* Magazine, April, 1942.

Recognition: Capitol Radio Engineering Institute, Washington, D. C., has the unique honor of being the first correspondence school to be named on the list of schools accredited by the Engineers' Council for Professional Development. ECPD is an organization which operates in conjunction with the engineering societies and the National Council of State Boards of Engineering Examiners. Similar recognition has been given the CREI residence courses.

NAB Speech: The only complete version of FCC Chairman Denny's speech at the NAB Chicago Conference, when he discussed the whole range of broadcast problems, was published in the November issue of *FM* AND TELEVISION. A few copies of that issue are still available. Even *Broadcasting*, while it carried most of the text, omitted certain parts, including some of the comments on FM.

Oscillograph Manual: DuMont Laboratories, Passaic, N. J., has published a very helpful manual on the use of the oscillograph, including instructions for aligning FM and AM receivers, and for checking transmitters. It is planned for engineers and servicemen. Copies are available at 50¢.

Something New: It's hard to believe that there could be something new about so commonplace an item as a pilot light, but Technology Instrument Corporation has hit upon the bright idea of illuminating their trade mark by printing it on the back of the red bull's-eye. The appearance is very effective.

Set Production: October RMA figures show the month's production at 1,646,651 AM sets, 23,793 FM-AM sets, and 827 television sets. Thus, AM sets were up 25% over September, and FM-AM sets up 36%. However, with AM models averaging $30 retail price and FM-AM models somewhat above $300, the latter accounted for about 1½% of the units, but 15% of the dollar volume.

Threadbare Excuse: Quoted from a catalog description of a tape recorder: "The frequencies best suited for music are from 100 to 5,000 cycles, but experiments have proven that most people, unless their ears are educated to appreciate the higher ranges, prefer those at the lower end of the scale. That is why the tone control on most radios is kept turned to base." This may be as good an excuse as any for poor audio capabilities, but today it fools mostly those who hope people will believe it.

14 Kw. of FM: W1NC-FM, Winchester, Va. is now on the air from 3:00 to 9:00 P.M. with a 3-kw. Federal transmitter and a Western Electric 8-bay cloverleaf antenna, at 92.2 mc. The station is putting a solid signal into Washington, D. C., and chief engineer Phil Whitney is getting reports of reception with full limiter action up to 400 miles. The transmitter, high up in the Blue Ridge Mountains, is connected to the studio by a 4,000 mc. Raytheon beam transmitter, using a Magnetron oscillator.

Ceramic Design Data: A 28-page bulletin from Centralab, 900 E. Keefe Avenue, Milwaukee, contains very complete data on design standards and criteria, and characteristics of ceramic materials, including Steatite, Cordierite, and Zirconite. Purpose of the bulletin is to guide designers so that they can avoid expensive impractical details and specifications. Also included are dimensions drawings of standard shapes and parts.

Index of Articles: In our issue of April, 1945, we published a cross-reference index of articles appearing in *FM* AND TELEVISION from November, 1940 to December, 1944. The index of articles published in 1945 appeared in the December, 1945 issue. A few copies of April and December, 1945 are still available at 25¢ each. The index of articles published in 1946 appears on pages 49 and 50 of this issue.

Gerson Lewis: Wartime engineer at Eastern Amplifier, has been appointed general manager in charge of production and purchasing for Telomatic Products, Inc., 304 Clifton Avenue, Clifton, N. J.

Hats Off Department: We always believed that some day, someone would write a book about radio that would make interesting reading. Well, Donald McNicol has done it! His new book "Radio's Conquest of Space" is an account of the men who built the science of radio, and of their experiences. Written by an author who knows and remembers radio progress from the early work of Marconi and Tesla, on through the time when the plate of a vacuum tube was called a wing, and up to the days when G.E.'s 3-tube set at $250 was the ultimate in broadcast receivers, this book is a delight to old-timers, and an inspiration to new-comers. For four dollars you can get a copy at your local book store, or from the publisher, Murray Hill Books, Inc., New York City.

Hempstead, N. Y. will soon have an FM station. Construction has started on the

(CONTINUED ON PAGE 53)

NEWS PICTURE

THE accompanying illustration reproduces one of a series of advertisements which FM station WCFC, at Beckley, West Virginia, is running in their local newspapers. It was sent to us by E. J. Hodel, manager of the station. Concerning the activities of WCFC, Mr. Hodel wrote:

"Thinking that your readers might be interested in some of our local developments, I am sending you tearsheets from the local papers which tell the story, at least in part.

"In connection with our promotion campaign in the Beckley area, we are now concentrating on the radio dealers. Our newspaper and radio advertising has been continuing without letup — the former starting last April, and the latter when we went on the air last August 15th.

"On Wednesday, November 20th, we gave a banquet for radio dealers in this area. There were 76 firms represented at the FM dinner. Part of the proceedings were broadcast over WCFC. Those attending were shown the General Electric film *The Story of FM*, and they were given an on-the-air demonstration from our studios. The demonstration included an address by our program director, W. S. Jackson, followed by sound effects and music.

"The group was also addressed by the architect of our new $100,000 studio-transmitter building; our chief engineer, George W. Yazell; Charles Hodel, president of Beckley Newspapers Corporation; and yours truly. An exhibit of promotional material was shown in the banquet hall. This material is available to the dealers, without charge, from WCFC. It includes window streamers, FM pamphlets, and placards.

"Also shown was a new FM receiver which picked up WCFC's signals from inside the underground hall in Beckley with no static or interference, despite numerous blower fans, neon signs, and other static-producing devices which cut out the local AM stations almost completely.

"Our audience is fast increasing — in direct proportion to the increasing shipments of FM receivers. There appears to be such a demand that all the FM sets sent into the WCFC service area will be snapped up rapidly by an eager, FM-conscious public.

"WCFC expects to establish a rate-card and go commercial by not later than the second quarter of 1947, after we get into the new building which is now nearing completion.

"Our next film showing and demonstration will be held for the Beckley Civitan Club. Then others will be staged for the Kiwanis, Lions, and Rotary Clubs, and the Junior Chamber of Commerce."

"FM Needs Only To Be Known In Order To Be Welcomed . . . ."

FCC Chairman Charles R. Denny, Jr:, had this to say to Beckley area radio dealers at WCFC's FM Banquet - - -

THE COMPANY WILL APPRECIATE SUGGESTIONS FROM ITS PATRONS CONCERNING ITS SERVICE

CLASS OF SERVICE — This is a full-rate Telegram or Cablegram unless its deferred character is indicated by a suitable sign above or preceding the address.

WESTERN UNION

R. B. WHITE PRESIDENT — NEWCOMB CARLTON CHAIRMAN OF THE BOARD — J. C. WILLEVER FIRST VICE-PRESIDENT

SIGNS: DL = Day Letter; NM = Night Message; NL = Night Letter; LC = Deferred Cable; NLT = Cable Night Letter; Ship Radiogram

The filing time as shown in the date line on full-rate telegrams and day letters, and the time of receipt at destination as shown on all messages, is STANDARD TIME.

E J HODEL MANAGER
RADIO STATION WCFC
BECKLEY WVIR

CONGRATULATIONS TO WCFC ON ITS PREPARATIONS TO USHER IN A NEW ERA OF RADIO ENJOYMENT IN THE BECKLEY AREA WITH THE INAUGURATION OF FM SERVICE. LISTENERS IN YOUR COMMUNITY ARE FORTUNATE TO BE AMONG THE FIRST IN THIS POST-WAR PERIOD TO BENEFIT BY THIS GREAT IMPROVEMENT IN RADIO BROADCASTING.

THE COMMISSION IS FIRMLY CONVINCED THAT FM NEEDS ONLY TO BE KNOWN IN ORDER TO BE WELCOMED BY EVERY RADIO LISTENER. THE RADIO DEALERS OF YOUR COMMUNITY CAN RENDER A VALUABLE PUBLIC SERVICE BY EXPLAINING ITS SUPERIOR QUALITIES; NAMELY, FREEDOM FROM STATIC AND INTERFERENCE FROM OTHER STATIONS, FREEDOM FROM FADING AND LIFELIKE TRANSMISSION WITH FULL TONAL RANGE. THEY SHOULD ALSO EMPHASIZE THAT FM MAKES MORE STATIONS POSSIBLE, MEANING GREATER CHOICE OF PROGRAMS.

THE QUICKER YOU UNFOLD THE STORY OF FM THE QUICKER YOUR COMMUNITY WILL ENJOY ITS FULL BENEFITS. ONE HUNDRED FM STATIONS ARE ALREADY IN OPERATION. FIVE HUNDRED AND FIFTY MORE ARE UNDER CONSTRUCTION AND THREE HUNDRED AND FIFTY APPLICATIONS ARE PENDING.

BEST WISHES TO YOU AND YOUR RADIO DEALERS IN YOUR EFFORTS TO BRING THIS BETTER SYSTEM OF BROADCASTING TO YOUR AREA.

CHARLES R DENNY ACTING CHAIRMAN
FEDERAL COMMUNICATIONS COMMISSION

BE SURE YOUR NEW RADIO HAS FM BEFORE YOU BUY! ASK YOUR RADIO DEALER ABOUT FM!

First With FM In West Virginia — **WCFC** — *101.1 Megacycles On Your FM Dial*

305 Reservoir Road - Telephone 5778

TELEVISION HANDBOOK

CHAPTER 1—Part 1: Standards Which Form the Basis of the Study of Television

BY MADISON CAWEIN*

INTRODUCTION

IN THIS year One Thousand Nine Hundred and Forty Six, after a quarter of a century of heroic development, electronic television has arrived at a threshold. This threshold is the beginning of commercialized television in the United States.

Other countries, such as Germany, England, and France, attempted to commercialize television before World War II. These attempts must be considered as unsuccessful on any basis of comparison relative to what is considered as commercialization in the United States. No industry has a commercial status in this country unless its products, are available in quantities comparable to the potential demand. Before any real commercialization in the sense implied here can become important, it will be necessary to build up factory, sales, and service organizations capable of producing, selling, and installing many different types of television receivers in many millions of homes.

The purpose of this series of articles is to acquaint men in all branches of the radio industry with the theory and facts of television. This will not be a mathematical presentation. Instead, the basic principles of television equipment and circuits will be described in words and diagrams easily understood by the average man who has an elementary knowledge of electricity and radio circuits. By this means, all those whom we call "radio men" may be brought to familiarity with television, and thus participate in the growth of this new public service.

No attempt will be made to confuse the reader with the kinds of arguments in which engineers frequently find themselves involved, such as for instance those arguments which are presented from time to time before the FCC. Television will be treated as a straight-forward science, the fundamentals of which are well known, and the practice of which is a commercial possibility as of today.

In spite of the non-mathematical treatment which will be followed in general, some attempt will be made to give pertinent formulae in terms or symbols which will be defined according to usual practice. To anyone having a fair knowledge of the radio art these formulae should prove useful for interpreting various phases of the subject. They may stimulate the more inquiring minds to a further study of the fundamentals. This applies particularly to radio engineers whose work has not yet touched this new field.

TABLE OF CONTENTS

Following is the list of chapters which will comprise the TELEVISION HANDBOOK series, to be published from month to month. Subsequently, this series will appear in book form as the STANDARD TELEVISION HANDBOOK.

Also, it is hoped that radio servicemen may acquire from this series of articles a sufficient knowledge of the television art to prepare them with an understanding approach to the installation and maintenance work, since this will become a source of substantial, additional income. Already, in areas where we have television broadcasting, there is a crying need for well-qualified television servicemen. The problems are by no means so difficult as to avoid understanding by men of average technical qualifications and intelligence. It is no more necessary to understand the intricacies of the complex theories of electron optics, in order to have a working knowledge of television than it is to spend years of study in theoretical mechanics in order to be engaged in the production, sale, or service of automobiles.

With this brief introduction, a series of articles will be presented in these pages to give a comprehensive picture of the theoretical background for television as it is today, in such everyday words as may be understood easily. The subject matter has been divided into six chapters, each of which contains several parts subdivided into a number of sections. It is expected that the series will be completed within the coming 12 months.

1. Definitions ★ The word television describes a process which is pretty well understood by everyone. It can be defined as the art of transmitting visual information by electro-optical means from one point of space to another, for reception at locations usually inaccessible by means of direct vision. It is probable that more classical definitions of television have been given by other authors, but this one will suffice for practical purposes.

At this writing, it is a rather difficult thing to set down a complete list of television terms, together with their definitions. Radio handbooks published to date have avoided the presentation of television information as a coördinated subject, due principally to a lack of authentic and complete material from the industry itself, which is relatively young in relation to its complexity. However, an attempt will be made here to define only the more commonly accepted terms as used today, in order to clarify the use of terms in the subsequent text. It should be noted that words are only defined in their relation to television practice.

Definitions of ordinary and special terms as applied to television:

amplifier: a conventional vacuum tube amplifier or a secondary-emissive type, broad-band or narrow-band.

amplitude excursion: power-levels of carrier occupied by amplitude-modulation components. In Fig. 1 is shown the RMA

*Director of Research, Farnsworth Television & Radio Corporation, Fort Wayne, Ind.

standard television signal wave-form, in which amplitude excursion is illustrated. For example, the synchronizing signals are modulations occupying the maximum power-levels S of the carrier, peak carrier occurring at tips of sync peaks T. In the British system, the BBC standard television signal wave-form is reversed as to amplitude excursion, as shown in Fig. 2, where tip of sync peak T represents zero carrier level.

amplitude separation: separation of signal components by virtue of their various amplitude excursions, usually accomplished by use of a clipper.

angular velocity: the time rate of change of phase of an alternating wave. It is equal to 2π times the frequency of the wave.

anoptric: without optics, as applied to a direct-view television receiver in which the picture appears directly on the cathode-ray tube screen, without use of lens or mirror.

band-pass filter: an electrical network designed to transmit a band of frequencies and to reject all other frequencies.

beam: refers to a stream of electrons, all moving in directions relatively parallel to one another.

beam current: the electrical current conveyed by an electron beam by virtue of its charge and velocity.

beam relaxor: a type of sawtooth-current generator consisting of a single beam-power oscillator which generates magnetic deflection-currents on the L/R principle.

black-level control: adjustment for setting the amplitude excursion of that part of the video signal corresponding to black in the picture.

blacker-than-black: the region of amplitude excursion of the video signal which corresponds to levels lower than black in the picture. These are not seen on the picture tube when the background is correct. This region is occupied by sync signals.

direct a beam upon a fluorescent screen. Scanning of the beam produces light at all points in the scanned raster.

catadioptric: this refers to an optical system for the projection of images by means of combinations of mirrors and lenses.

catoptric: this refers to an optical system for projection of images by means of mirrors alone, without lenses.

centering: the process of moving the center of the received image to coincide with the center of the cabinet opening which frames the picture.

centering control: an adjustment for moving the raster electrically in either a horizontal or vertical direction for framing the image.

channel: a region of frequency space assigned for the transmission of television images and the accompanying sound. Commercial channel assignments are as follows:

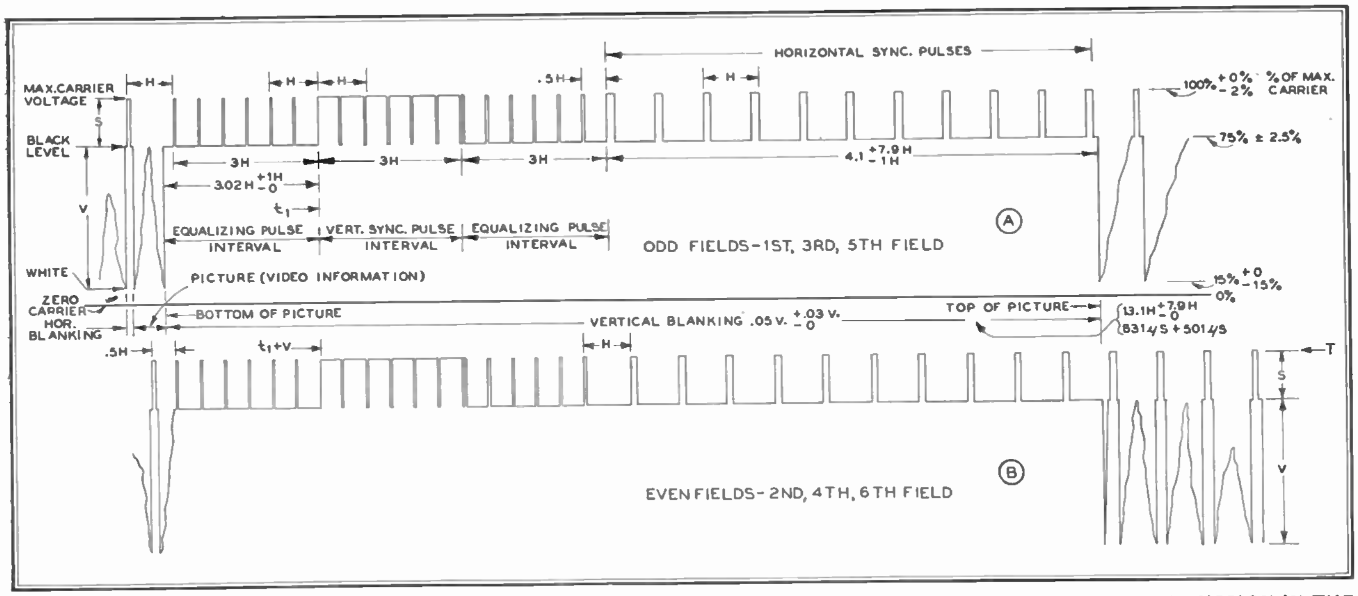


FIG. 1. ODD AND EVEN FIELDS, ACCORDING TO RMA STANDARDS USED FOR BLACK-AND-WHITE TELEVISION TRANSMISSION IN THE U.S.A. DETAILS OF THIS STANDARD SIGNAL WAVE-FORM WILL BE DISCUSSED AND EXPLAINED IN SUCCEEDING CHAPTERS

antinode: a point along a standing wave which has maximum amplitude. The opposite of "node," which is a point of zero amplitude in a standing wave.

aperture: a small opening; usually refers to size of spot, or electrical window, through which an electrical image is viewed or reproduced. The size of aperture limits the resolution obtainable in a television picture, by reducing the amplitude of the high-frequency components.

aperture compensation: amplification of those high-frequency components which have been reduced in amplitude by the aperture, up to the first elided frequency, or zero frequency.

aperture distortion: reduction in amplitude of high-frequency components of a television receiver due to finite spot-size of camera tube and picture tube.

array: a geometric arrangement.

aspect-ratio: ratio of width of image to height of image.

automatic background control: a device for controlling automatically the background illumination of the reproduced image.

background: average illumination of a scene.

band: a group of continuous frequencies occupying "room" in frequency space.

blanking: signals for setting the black-level at the end of each line and each frame, in order to extinguish the beam during retrace. May refer to any signal used to suppress part of a signal wave.

blooming: the defocussing of regions of the picture where the brightness is at an excessive level, due to enlargement of spot-size and halation of the fluorescent screen of the cathode-ray tube.

brilliance: intensity of illumination of points in an image field.

broad-band amplifier: an amplifier for a wide band of frequencies, usually greater than 1 mc. wide.

caesium-antimony: a photo-surface responsive mostly to blue light.

caesium-oxide-silver: a photo-surface which can be controlled during formation for peak-response at almost any color of visible light, or for infrared light.

cathode input: use of cathode as control grid, for applications where low input-impedance is required.

cathode-follower: use of cathode load instead of anode load, for applications where low output-impedance is required.

cathode-ray tube: a vacuum tube assembly containing an electron gun arranged to

Group A

Channel No.	1	44–50 mc.
	2	54–60
	3	60–66
	4	66–72
	5	76–82
	6	82–88

Group B

Channel No.	7	174–180 mc.
	8	180–186
	9	186–192
	10	192–198
	11	198–204
	12	204–210
	13	210–216

The relative location of the video and audio carriers within the channel is shown in Fig. 3. Audio carrier is 4.5 mc. *above* video.

clipper: a vacuum tube arranged in circuit to operate under non-linear or overloaded conditions as regards a portion of the amplitude excursion of the input signal, in order to produce an output signal-wave in which this portion has been removed.

clipping-level: the level of amplitude excursion at which it is desired to clip, or remove part of, the signal impressed upon a clipper.

critical viewing-distance: the ratio of distance at which the line structure of an image just disappears, to the height of the picture (about 4 or 5 to 1 in practice).

co-ax: a cable, consisting of an inner conductor, an outer, surrounding conductor, and insulation between, which, when properly terminated, acts as a pure resistance equal to its surge impedance.

color amplifier: a multi-channel amplifier, each channel of which amplifies a separate color-field, and which has arrangements to blank out in regular time-sequence all ward, or to "crawl" on the image-field.

cut-off frequency: a frequency beyond which no signals of other frequency are transmitted or utilized. It may refer to an upper limit, or a lower limit, or both.

DC transmission: this refers to the background component of a television picture.

deflection: a process whereby an electron beam is deviated from its straight-line path by means of an electrostatic or electromagnetic field.

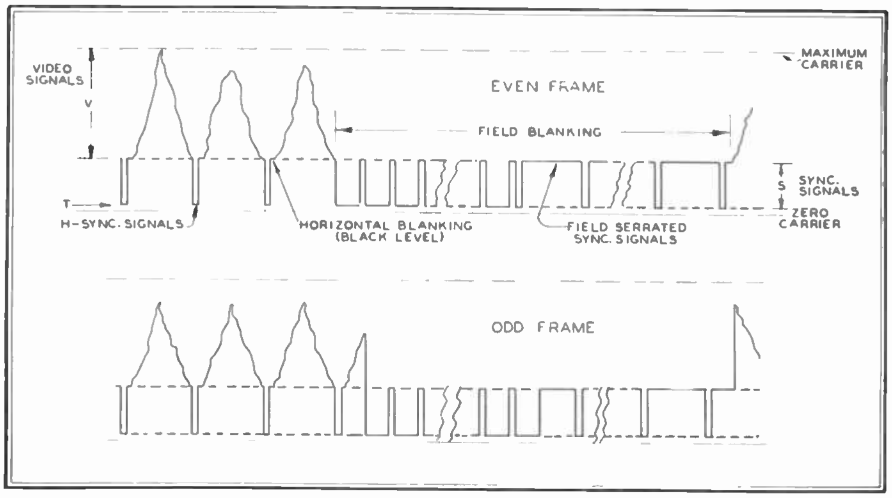


FIG. 2. B.B.C. STANDARD TELEVISION SIGNAL WAVE-FORM USED IN ENGLAND

color fields except the one being transmitted.

color-field: the time of transmission for one complete field, in which all the picture elements are of the same color.

color-frame: the time of transmission of the complete information for any single color in an image field.

color sequence: the order in which color-fields follow one another in a sequential, color-television system. In the CBS system this order is red, green, blue.

compensation: a term which refers usually to the correction of non-uniform amplification or response with frequency, in order to obtain uniform amplification or response at all required frequencies.

composite-signal: a television signal whose wave form is composed of both video and synchronizing signals, each having different amplitude excursions. It is standard practice for the amplitude excursion of sync signals to lie in the blacker-than-black region outside the video signals. See Fig. 1.

composite-sync: a signal composed of horizontal sync-signals, vertical sync-signals, and equalizing pulses when these are needed.

continuous-motion projector: a motion-picture projector in which the image moves continuously, without shutter action, and the projected image is stationary without any dark interval.

contrast: the range of light and dark values in an image. Contrast between picture elements constitutes information and requires both time and frequency-band for its transmission.

crawl: this is a psychological effect produced in sequential interlace systems due to the fact that the eye has a tendency to follow the direction of presentation of lines in each following field. Thus, the sets of lines appear to move downward or up-

demodulation: the derivation of a waveform having substantially the same form in time as the amplitude or frequency modulation of a carrier.

demodulation-distortion: a change in the amplitude excursion or relative time-occurrence of demodulation components relative to the carrier modulation.

detail: the perceptible structure of an image in regard to the number of separate areas or picture elements which can be seen and recognized as different from one another.

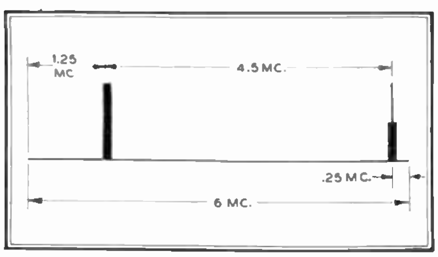


FIG. 3. LOCATION OF TELEVISION CARRIER

Detail requires contrast for its recognition and, like contrast, it constitutes information which requires both time and frequency-space for its transmission.

diathermy: a high-frequency signal with strong hum-modulation, operating usually in a television IF or RF channel. It is usually synchronous with the television field-frequency, or drifts very slowly relative thereto, and is recognizable as a series of fine-structure lines having a semi-parabolic form.

differentiating-circuit: a circuit arranged to derive an output potential which is proportional to the time-rate-of-change of the input current.

dioptric: a projection system which employs refractive lenses.

dipole: a linear conductor whose length is approximately one-half the optimum wave-length of resonance, generally used as a television antenna. It is usually divided in the middle into two arms, where the impedance is lowest (72 ohms theoretically) for connection to a transmission-line lead-in.

director: a dipole placed in front of a dipole antenna, toward the transmitter, to narrow down the angle of reception in order to obtain greater directivity. No connection is made to a director.

dissector: a photo-pick-up tube containing a continuous, uniform photo-sensitive cathode arranged opposite to an aperture in the anode which admits electrons to an electron multiplier, and with a window for projection of an optical image onto the cathode surface to create an extended, electron image arranged to be scanned across the aperture to produce therethrough an electrical signal in time-sequence with the scanning.

distortion: the departure, during transmission or amplification, of a reproduced waveform relative to the original form.

distortion components: frequency components, introduced into a waveform during transmission, which were not present in the original signal.

discharge tube: an electronic tube arranged to be non-conductive normally, but to supply high conductivity when properly excited, usually for the purpose of discharging a condenser.

distribution: vertical linearity, or spacing of the lines along the vertical dimension of a television picture.

diversity system: a television system with two or more identical components, such as two antennas set up in different locations to feed the same receiver, or three television picture tubes having the same picture on each and arranged to project these pictures in registry on a viewing screen. In the latter case color filters may be inserted between each tube and screen, and the pictures on the tubes may be of the same image-field but with different color content, as in one type of color-television system.

double-sideband transmission: the transmission of a modulated carrier-wave accompanied by waves whose frequency values are represented by the sum and difference of the modulation and carrier frequencies.

double-sided mosaic: an array of photo-sensitive elements insulated one from the other and arranged for projection of a light image, through optical means, upon one side and, for scanning, by electronic means, upon the other side.

double-tuned-circuits: circuits resonant to two frequencies, usually closely adjacent, and coupled in such manner as to show two values of peak response, approximately equal, with a dip-response between.

duration: the process of lasting for a finite time.

dynatron: a vacuum tube operating on a secondary-emission characteristic of the anode.

dynode: a stage in an electron multiplier.

echo: usually a pulse signal of lower amplitude than the parent, primary pulse from which it originates by reflection, and occurring at a later time than the primary pulse. An echo pulse usually exhibits some phase-distortion.

electric field: either an electrostatic or a magnetic field of force.

electric focus: sharpening the definition of an electrical image by squeezing the diameter of electron beams creating the image to the smallest possible value.

electrical image: an array of electrical charges, either stationary or moving, in which the density of charge is proportional to the light values in an optical image to be reproduced. An exact electrical image would be arranged with charges in a geometrical array corresponding identically to light values in the image arranged in the same geometrical array, undistorted.

electrical width: the width of a pulse in electrical degrees, or angle of phase in reference to an entire cycle (360 electrical degrees) of the waveform in which the pulse is reproduced periodically.

electrical window: a small hole in space which is practically totally transparent to the flow of electrons. An aperture is an electrical window. It may have any shape, and it constitutes a device with which to view or "paint" an electrical image through the use of electron beams.

electron: an elementary charge (very small) which constitutes one of the entities of our physical universe. The value of its charge is 1.6×10^{-19} coulombs, and its mass is 9.11×10^{-28} grams.

electron beam: a beam of electrons (see definition of beam).

electron gun: an arrangement of electrodes inside of a vacuum tube which will direct electrons from many directions, falling upon one end of it, into a beam emerging from the other end. The speed of the emerging beam may differ from that of the entering electrons.

electron image: an electrical image in motion through space, usually inside of a vacuum tube, as a dissector.

electron multiplier: a device arranged to receive electrons at an input and to deliver a greater number of electrons to an output. The increase in number is due to multiplication by secondary emission in one or more stages.

electron optics: the treatment of electric fields as lenses for electron beams, similar to treatment of ordinary lenses in ordinary optics in regard to ordinary light beams.

electron path: the path which an electron follows when moving through an electric field, or through space.

electronic scanning: the deflection of electrons from a straight-line path by means of electric fields

electronic television: the art of television without recourse to mechanical means, in the sense of mechanically moving parts, as wheels or discs, or waves in fluids.

electrostatic field: a twisting of space which exerts a force on any stationary or moving electric charge within its region of influence.

electrostatic scanning: the deflection of electrons from a straight-line path by means of an electrostatic field of force, which depends upon the force-at-a-distance between electric charges.

equalizing pulses: H-sync pulses occurring at twice line frequency and of half normal duration.

extended image: an electron image moving through space, as in an image dissector.

fidelity: the faithfulness of reproduction with which a reproduced waveform simulates the original. It may refer, therefore, to the band width of a video amplifier, usually expressed in megacycles, which is required to give good reproduction of waveform.

field: the time of presentation of a part of the information in an image, consisting of a complete arrangement of picture elements relatively uniformly spread over the field-of-view, such as in the form of a series of parallel strips, uniformly spaced.

field frequency: the number of fields transmitted per second.

field-of-force: a region in space in which force is exerted on electric charges or currents, due to the presence of other charges, either stationary or moving.

field-of-view: the area covered by an image: an image-field.

field period: the time required to transmit a field, equal to the reciprocal of field frequency.

field repetition-rate: the number of fields transmitted per second.

flat response: uniform amplification of a band of frequencies.

flicker: a psychological phenomenon in which the intensity of illumination of a field-of-view seems to pulsate at a slow or fast rate. It is irritating to the nerves.

fly-back: return of the electron beam from one side of the raster to the other. A British term for retrace.

flying spot: this refers to a system of television in which a simple photocell replaces a more complex pick-up tube at the camera, and in which a moving spot of light either by mechanical or electrical means is caused to scan the image field which is being transmitted. Reflected light from the moving spot across the image field is picked up by the photocell to generate the video signal.

flywheel-sync: a synchronizing device which responds to the average timing of the sync signals, and is not instantly responsive to each sync pulse received.

fluorescent screen: a screen area covered with a phosphor which emits visible light when impacted by an electron beam.

focal length: a distance, in optics or electron optics, between the center of a lens or an electric field and the plane of focus.

focus: the act of obtaining maximum detail in an image; or of increasing resolution to its maximum value.

folded dipole: a dipole antenna in which the outer ends of the two arms are connected together by a linear conductor, located at a small distance, 1 in. or so, away. Surge impedance is 300 ohms.

frame: the time of projection of the complete information, or total number of picture elements, contained in an image-field, or field-of-view. In the double-interlace system of commercial television, a frame consists of two fields and requires twice the time of one field for transmission.

frequency band: a region of frequencies, extending between limits, each frequency being adjacent to another, without gaps.

frequency components: waves of pure sinusoidal shape and of various phase and amplitude which combine or add up to form a waveform of greater complexity than the sine wave, as a sawtooth or impulse wave.

frequency-space: an intangible concept which refers to the "room" available for transmission of separate, radiated signals, each of different frequency. In our physical universe there is available approximately 2×10^{17} megacycles of frequency space to accommodate electromagnetic radiations in different channels.

fundamental frequency: the lowest frequency component of a periodic wave.

gamma: the relation of the contrast in any form of an image during transmittal or processing to the contrast of the original.

gas-focusing: the focusing of an electron beam due to its passage through the residual gas in a cathode-ray tube.

ghost: a misplaced, weaker image produced by reflections which are delayed in time relative to the direct wave from the transmitter, and which occur, therefore, out of place relative to the primary image which is in time with the direct wave from the transmitter. Ghosts are synchronous and are always misplaced to the right and downward because of the direction in which the picture is scanned.

halation: the glowing of a phosphor on the fluorescent screen, in a region immediately surrounding the scanning spot.

height: the amplitude of a picture in the vertical direction.

high voltage: a potential, usually above 500 volts, utilized usually in television equipment for accelerating or speeding up an electron beam. High voltage can be dangerous to life.

high-impedance circuit: a circuit across which a relatively high value of potential (or voltage) is required to produce a nominal value of electric current therein.

high-light brilliance: the maximum brilliance of a picture which occurs in regions of highest illumination.

hold control: a synchronizing control, either horizontal or vertical.

horizontal: pertaining to the line structure of a picture in a direction parallel to the ground, normally; it refers to the dimension of width, and is sometimes abbreviated as H.

horizontal blanking: the blanking signal at the end of each line.

horizontal period: the time of one line.

horizontal repetition rate: the number of horizontal lines per second; the H-frequency.

horizontal resolution: the number of picture elements which can be distinguished in each line of the picture.

horizontal retrace: the return of the beam across the width of the image after the scanning of one line.

hum-bar: a dark area extending horizontally across a television picture due to the presence of unfiltered electrical signals originating at the power line and synchronous therewith.

iconoscope: a television pick-up tube consisting of a mosaic of photo-sensitive elements upon which an optical image may be projected through a window, and arranged to be scanned by an electron beam which releases the stored charges in the latent image on the mosaic and produces an electrical signal in time-sequence with the scanning, at an output electrode.

image dissector: (see dissector) a device for dissecting an electron image, picture element by picture element, to derive therefrom an electrical signal arranged in a time-sequence.

image field: a geometrical area of points, having greater or less illumination, arranged in the pattern of a visual image on a plane surface, called the field-of-view.

image orthicon: a television pick-up tube which embodies the combination of dissector and orthicon principles to produce a very high value of light sensitivity.

impulse: an electrical wave having a high peak value of short duration, and having substantially zero value elsewhere than at peak. See Fig. 4.

information: an intangible concept which is related to that of physical action, and which requires, therefore, the expenditure of both time and energy for its transfer from one point of space to another. Hartley of Bell Laboratories was the first man to define the nature of information, which he showed to be proportional to the product of time and frequency-band.

infrared: radiations of dark light (invisible to the eye), of wave-length slightly longer than visible light.

ion: a charged atom (usually an atom of residual gas in a vacuum tube).

ion spot: a dark spot on a fluorescent surface or a photo-surface, produced by insensitivity of the surface due to bombardment by ions under the accelerating force of the electric field.

ion trap: an arrangement of magnetic fields and apertures which will allow an electron beam to pass through but will obstruct the passage of ions.

jittery: a tendency toward lack of synchronization in a television picture, and may refer either to jumpiness of individual picture elements, of the whole field of view, or of individual lines in the picture.

kickback: the voltage occurring across an inductance due to the collapse of current flowing therethrough.

kinescope: an RCA trademark name for a cathode-ray picture-tube used to reproduce television pictures.

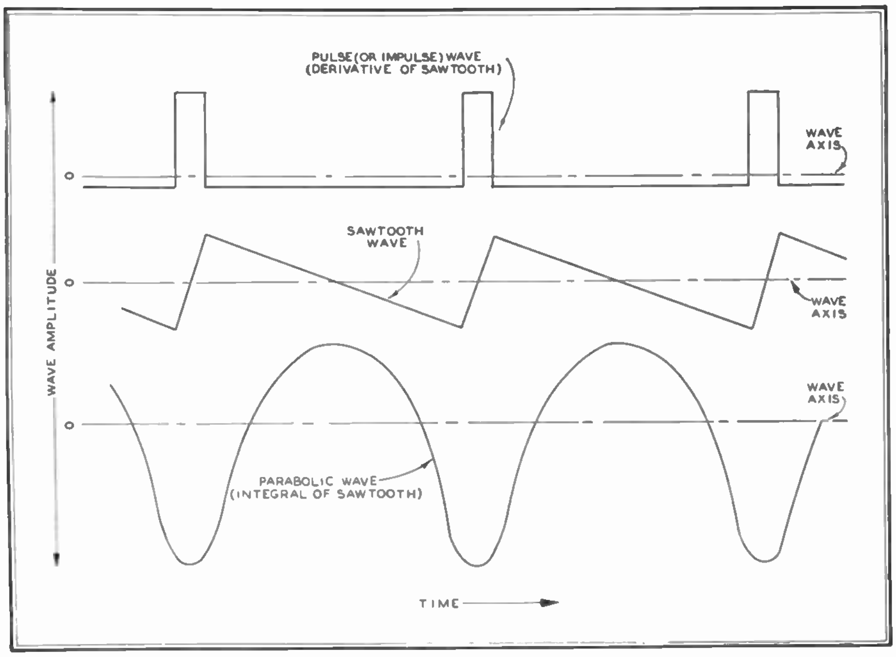


FIG. 4. TOP TO BOTTOM: PULSE OR IMPULSE WAVE, SAW-TOOTH WAVE, AND PARABOLIC WAVE-FORM. THESE TYPES ARE EMPLOYED IN TELEVISION CIRCUITS

impedance match: the process of selecting electrical components to terminate a line or a vacuum tube output circuit, so that the average impedance is substantially equal to the surge impedance of the line or the plate impedance of the tube.

integrating circuit: a circuit arranged to derive an output potential which is proportional to the stored-up value of the input current over each cycle.

interlace: the process of projecting an image in several successive fields, each of which contains only a part of the total picture information, the parts being arranged to fit together so that the information in successive fields fills in the missing parts of preceding fields. The fraction of total information in each field is inversely proportional to the number of fields required to produce a complete frame of the picture. For example, in the standard double-interlace system of television there are two fields per frame, and each field consists of 267½ lines equally spaced, arranged so that the lines projected in one field fall exactly between those projected in the alternate field to form a continuous image with 525-line structure.

Kipp oscillator: a type of relaxation oscillator used particularly in European television circuits.

keystone: a geometrical shape in the form of a symmetrical trapezoid. A picture with keystone distortion has one side shorter than the other, the distortion being the same as obtained by perspective projection.

L/R circuit: a time-determining circuit in which the time-constant depends on the ratio of inductance to resistance.

latent image: a stored image, as of charges on a mosaic of small capacitors spread uniformly over an area, in television applications. The optical image is stored as an array of charges on the photo-sensitive islands in a mosaic-type storage tube, such as the iconoscope, or as a bound electron image on the glass plate of an image-orthicon.

line: one of the strips which makes up a television image. The scanning path across the width of a television raster.

linearity: the distribution of picture elements over the image field. In a linear picture the elements are uniformly distributed, and of uniform size. H-linearity refers to distribution along a line in the horizontal direction, and V-linearity refers to the distribution of lines in the vertical direction. The word "distribution" is sometimes used in reference to this, instead of the word "linearity."

light flux: the radiant power of visible light. The term is sometimes used in reference to invisible radiations, such as infrared. Flux is measured in watts and in lumens, usually.

line-doubling: the technique of inserting line-sync pulses at double frequency during the preparatory interval that precedes the field-sync signal. The pulse width of the doubled pulses is cut in half so that integrating circuits will not store up too much energy in this period.

line-sync: sync pulses at horizontal frequency.

low-impedance circuit: a circuit through which a considerable amount of current can flow without producing an appreciable potential across it.

lumen: a unit of light flux which is equal to 1.6 milliwatts of power. A lumen should be measured, by definition, for green light with wavelength at 550 millimicrons. Actually, a lumen is usually measured through viscor filter which transmits portions of the entire, visible spectrum. The amount of power which is present in a lumen is the important fact to remember.

magnetic field: a twisting of space and time, which exerts a force only upon a moving electric charge, or upon an electric current, which moves within its region of influence.

magnetic focus: the technique of causing an electron beam to converge toward a small spot by virtue of applying a parallel or a radial magnetic field.

microsecond: one millionth of a second.

mixing amplifier: an amplifier with multiple inputs to which different signals are applied, and with a common output from which a composite signal is derived.

moiré: a pattern produced by confusion in an image, usually exemplified by false, curved lines in a region of the picture where converging lines from a resolution pattern are nearly parallel to the line structure of the image.

monitor: in television, this refers to a cathode-ray tube and its associated circuits, arranged to view a television picture, usually by wire-line.

monoscope: a pattern signal-generating tube which produces in the proper circuit a time-sequence of pulses equivalent to a fixed television signal. The pattern usually contains a resolution chart.

mosaic: an arrangement of photo-sensitive islands on an insulating surface adjacent to, but not in contact with, a collector plate. These islands charge up when photo-electrons leave them under the influence of light. Each island forms a small condenser in conjunction with the collector plate.

multiplier: short name for an electron multiplier.

multiple-interlace: a method of presenting image fields, where more than one field is presented for each frame. In triple-interlace systems, for example, three fields are presented during one frame, each field containing only one-third the total picture information; in this case a geometrical pattern of only every third line is transmitted in each field, the lines being separated by spaces equal to twice the line width, and the timing of the lines being such that the lines in the second field fall in the spaces left between lines in the first and third fields to form an interleaved pattern of continuous lines.

narrow-band: a band of frequencies, usually less than 500,000 cycles in extent.

negative: a video signal in the wrong polarity for producing a positive picture on a cathode-ray tube.

negative transmission: the polarity of modulation of the television carrier wave. Negative transmission means that the sync pulses and signals corresponding to the blackest parts of the picture drive the carrier amplitude toward maximum; while signals corresponding to white drive the carrier toward zero.

node: see antinode.

noise: the word "noise" has carried over from audio practice. It refers to random signals which produce a salt-and-pepper pattern over a picture which is called "noisy."

non-linearity: the crowding of picture elements from side to side, or the crowding of lines at either top or bottom of the picture, or in the middle.

NTSC: the abbreviation for National Television System Committee.

odd-line interlace: this refers to a double-interlace system in which there is an odd number of lines in each frame, and in which also, therefore, each field contains a half line extra.

open-wire transmission-line: two parallel wires of uniform diameter spaced at the proper distance to give a desired value of surge impedance which acts as a pure resistance when properly terminated.

orbit: the path followed by a particle (in television usually an electron or ion) in a field of force.

orthicon: a television pick-up tube somewhat similar in structure to an iconoscope but with a translucent mosaic, a collector-ring instead of a backing plate for deriving output signals, and operated on different principles whereby the scanning beam is at low velocity and always at right angles to the plane of the mosaic, which practice avoids shading signals usually generated in the iconoscope.

over-coupled circuits: usually two resonant circuits tuned to the same frequency but coupled so closely as to exhibit two response peaks with a slight valley between, in order to obtain broad-band response with substantially uniform impedance.

pairing: a partial failure of interlace in which the lines of alternate fields do not fall exactly between one another but tend to fall nearly on top of one another. The cause is usually improper timing of the field-deflection oscillator but is sometimes due to pick-up or stray fields, and the result is a raster consisting of separated pairs of lines rather than with a continuous line-structure.

panning: the process of moving a camera across a field of view, usually horizontally.

parabolic wave: the shape of this wave is similar to that of an overloaded sine wave which has one peak wider than the opposite peak. (See Fig. 4.) This wave is representative of the shape of the potential across a condenser when a sawtooth current flows through the condenser, which acts as an integrating circuit.

pass band: a band of frequencies which is transmitted freely without intentional attenuation, or reduction in amplitude of signals.

peaking coil: a small inductance placed in circuit to resonate with the distributed capacitance at a frequency where it is required to develop peak response, as in a video amplifier near cut-off frequency.

peak response: this refers usually to the maximum amplitude, or amplitudes, of gain, output, photo-sensitivity, brilliance, or other magnitude in reference to television systems.

pedestal: a blanking signal, usually of impulsive form as shown in Fig. 4.

periodic: having a repetition rate; recurrent in time.

persistence of vision: this refers to a characteristic of the eye whereby the impression of an image lingers after the scene has vanished. The eye will remember a scene for about 1/8 second.

phase: the ratio of the time-of-an-occurrence to the time-of-its-recurrence referring to cyclical phenomena, usually, such as alternating waves or periodic happenings in time. Phase is a pure number and is expressed as a fraction of a total cycle, usually as so many degrees out of 360° which represents the total cycle.

phase-delay: phase-delay refers to time-delay, since phase is always in reference to timing in a cycle. When the peak of a wave occurs at some particular point of a cycle, this means that it occurs at a particular time, in a given position on a television screen, for instance. The phase-delay of signal components in television pictures will cause certain light values to occur at the wrong time, and hence at the wrong place since the received picture is synchronized in time with the transmitter: this may result in the occurrence of shadows or ghosts in the picture.

phase-distortion: this refers to phase delays at different frequencies being of different magnitudes, which distorts peak values of the signal and spoils picture contrast and/or resolution.

phosphor: a chemical compound which fluoresces or emits light after being excited by an external source of energy, such as the impact of an electron beam.

photo-cathode: a photo-emissive cathode.

photocell: usually a vacuum tube with a photo-emissive cathode and an anode to collect the photo-electrons.

photo-electric: the ejection of electrons by the absorption of light, one electron being ejected for each photon absorbed. Einstein first expressed this effect in concrete terms, stating that the energy of the ejected electron was equal to the energy of the absorbed photon minus the threshold energy. If the threshold energy is greater than that of the photon, there is no absorption. The threshold energy is equal to that of the longest wavelength photon which the photo-electric substance will absorb, about 1,200 millimicrons in the present state of research.

photo-electron: an electron ejected by absorption of light.

photo-emissive: this refers to the property of certain substances (such as selenium, caesium, sodium, antimony surfaces) to absorb light and eject electrons.

photon: a quantum, or packet, of light-energy, which moves with the speed of light as a discreet physical entity, characterized by having mass and wavelength.

photo-sensitive: a substance or surface with photo-emissive properties.

photo-surface: a surface composed of photo-emissive substances.

pick-up tube: a camera tube used in television practice to generate a video signal from a televized scene.

picture element: an elementary area of an image field which represents one detail, and is relatively uniform in illumination. The shape of a picture element in television is considered to be square, even though the aperture or scanning spot is round, because the lines are uniform and rectilinear. The ratio of the area of an image field to the area of a picture element is representative of the *detail* of a television image. For a 525-line television picture the maximum detail which can be transmitted (with equal horizontal and vertical resolution, or square picture elements) is about 330,000 picture elements.

picture tube: any tube which will reproduce a television image, usually a conventional cathode-ray tube. (In the old mechanical system of television a neon tube served as picture tube.)

polarity: the direction, plus or minus, of a potential peak at the grid of a vacuum tube. Positive polarity of a video wave at the grid of a cathode-ray tube means that the potentials are in the right direction to give a positive, or normal, picture. In this case the pedestals, or blanking signals, have their peaks in the negative direction to cut off the beam current during the occurrence of black. Thus, in a positive picture, black is negative. This point should be kept in mind to avoid confusion.

polarization: the direction of vibration of the electric field of force in a radiated wave. The magnetic field of force is perpendicular to the electric, and so it also is defined.

positive transmission: a type of transmission used by the British in which the peak amplitude of the carrier corresponds to *white* in the picture.

pre-amplifier: a preparatory amplifier, usually located at the source to be amplified, in order to avoid extraneous pick-ups.

pre-emphasis: the technique of amplifying the high-frequency components of a signal to a greater extent than the low-frequency components.

preparatory interval: the interval in which the line-doubling signals are inserted just prior to the occurrence of the serrated, field sync-pulse.

presentation of a field: the act of building up a picture which contains only a fraction of the total information in the field of view, in some prearranged pattern such as a number of parallel strips, or lines, with spaces in between.

progressive interlace: in a multiple-interlace system, the technique of arranging successive fields to follow one another in order, so that the series of lines transmitted in each field lies directly under those of the preceding field, line for line.

Next installment of this series will appear in the January issue

CASCADE PHASE-SHIFT MODULATOR

Discussing the Relationship between Phase and Frequency Modulation, and the Theory and Operation of Raytheon's New FM Transmitter — Part 1

BY M. MARKS*

SOME very interesting work has been done by the broadcast equipment division of Raytheon Manufacturing Company in the development of FM transmitter circuits designed to provide a simple and relatively low-cost direct crystal control of the center frequency.

The result of this effort, involving an exhaustive theoretical and experimental investigation of phase-shift modulators, is a transmitter employing a relatively low order of frequency multiplication, attained by adding the phase shift of a number of stages operating at the crystal frequency.

The basic circuits, identified as the Cascade Phase-Shift Modulator, operate with a minimum of inherent amplitude modulation. Fig. 1 presents a block diagram of the complete system.

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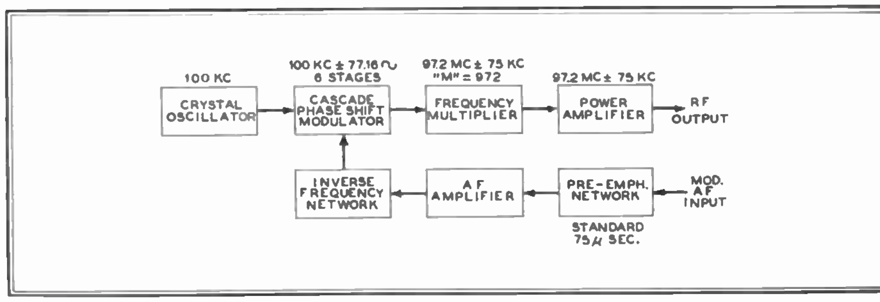
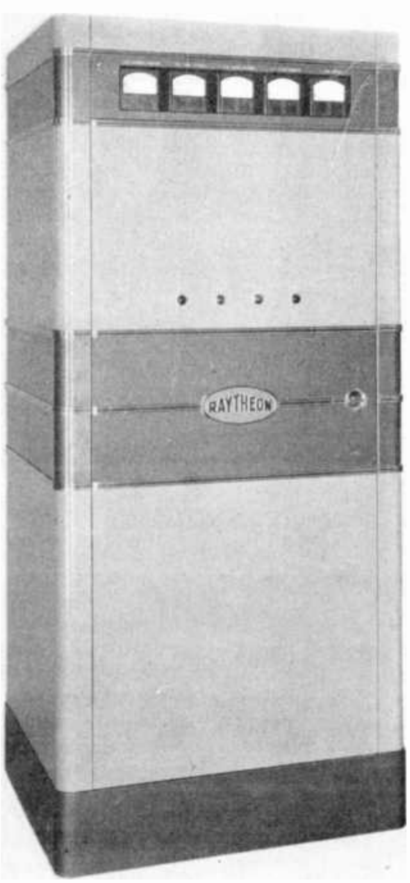


FIG. 1. BASIC CIRCUIT OF RAYTHEON'S CASCADE PHASE-SHIFT MODULATOR, DESIGNED TO EMPLOY A RELATIVELY LOW ORDER OF FREQUENCY MULTIPLICATION

This paper will give a brief general review of phase-shift modulators, showing the relationship between phase and frequency modulation. It will then develop the theory of the new modulator.

250-WATT RAYTHEON FM TRANSMITTER CAN BE USED ALSO AS A DRIVER UNIT



Characteristics of Phase-Shift Modulators ★ When the phase of a carrier wave of constant frequency is advanced or retarded, the instantaneous frequency of the carrier also changes, and the frequency deviation is proportional to the rate of change of phase.[1] The operation of all phase modulators depends on this important relationship which can be visualized clearly by considering a sinusoidal voltage of constant frequency. If the phase of this wave is advanced say by 90°, through the insertion of a suitable phase shifting device, it can be seen that during the time taken for the phase to change to the new advanced value, the wave actually moved faster than it would have moved if no change had taken place. Therefore, while the *phase* is changing, the *effect* is the same as if the frequency were higher. In a like manner, delaying the phase results in a lower frequency while the change is taking place. As soon as the shift in phase is stopped, the wave continues at the original frequency.

From this, it follows that the more rapidly the phase is shifted, the greater will be the resulting frequency deviation. If the phase of an RF signal is shifted plus and minus 90° at a sinusoidal audio frequency rate of 100 cycles, the frequency will deviate (in accord with a cosine function) 157 cycles above and below the original frequency; if the audio frequency rate of phase shift is now increased tenfold to 1,000 cycles, the frequency deviation will likewise be increased 10 times to give 1,570 cycles deviation. The frequency deviation in cycles, therefore, can be seen to equal the product of the audio frequency in cycles and the phase shift in degrees, divided by a constant (the number of degrees per radian).

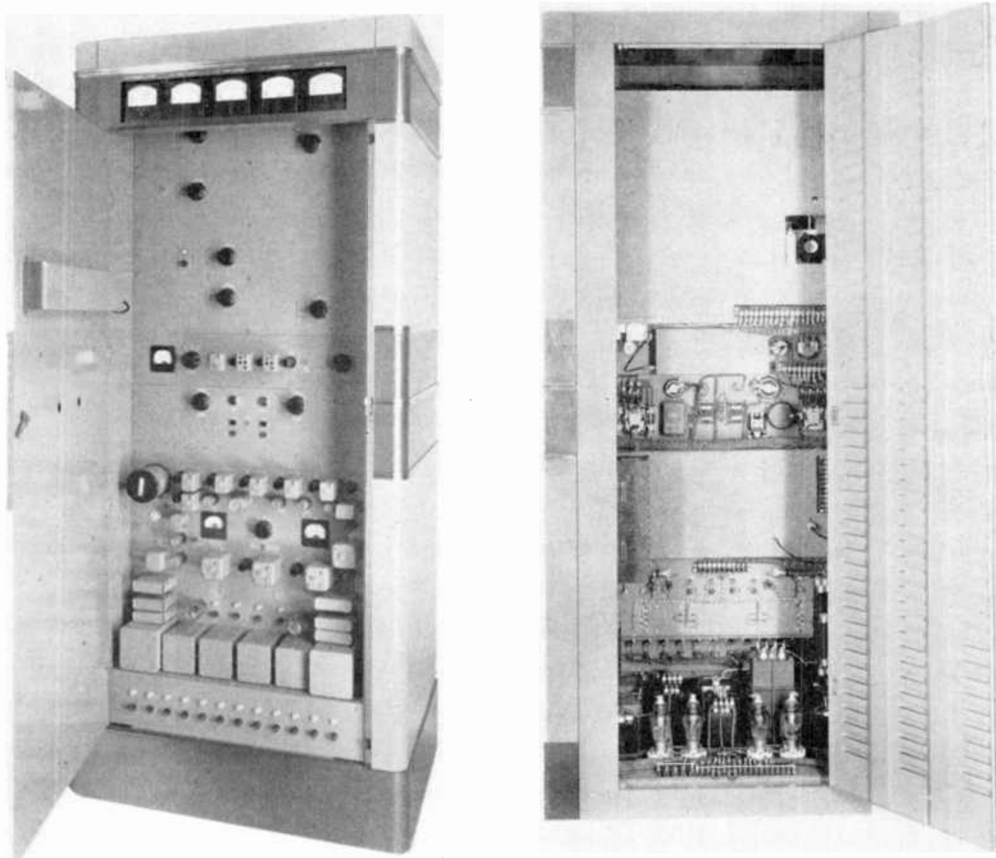
Inasmuch as the frequency deviation must be held constant at ± 75.000 cycles for 100% modulation, regardless of the modulating frequency, the number of degrees phase shift must be varied inversely with the modulating audio frequency. For example, a typical phase modulator may require 10 volts at its control element for a 30-cycle modulating signal to produce 100% modulation; for a 15,000 cycle signal and the same modulation level, only 0.02 volts would be required. This example is illustrated in the curve of Fig. 2, which gives the modulation signal voltage required for 75,000 cycles frequency deviation as a function of the applied audio frequency. Such action is readily accomplished by the use of an integrating circuit (also known as an inverse frequency or $1/f$ network), consisting of a series resistance and a shunt capacitance, usually placed between the source of modulating signal and the phase modulator. The higher modulation frequencies are thus attenuated in precisely the desired manner for true frequency modulation.

The phase shift obtainable with low distortion from conventional phase modulator circuits rarely exceeds 25°. With the aid of the equation given above, the resulting frequency deviation for a 30 cycle modulating signal may be readily calculated to be equal to 13.1 cycles. Since this small deviation falls far short of the required 75,000 cycles, it becomes necessary to multiply the original frequency deviation by a factor M, approximately

[1] "High Frequency Measurements" by August Hund, 1933, pp. 368–369.

equal to 6,000 in order to attain the required final frequency deviation. The well known fact that multiplication of modulating frequency produces a like multiplication of frequency deviation is used for this purpose to good advantage in practically all phase modulators.

There is a good practical reason, however, for the use of a frequency multiplication factor M of not much over 1,000. Assuming the lowest usable crystal frequency as 75 kc., 5 times the highest audio frequency, and an operating frequency of 100 mc., a factor M equal to 1,333 is obtained. To attain higher multiplication factors than this, it is necessary to resort to the use of heterodyne frequency converters. In general, frequency converters are undesirable because the spurious beat frequencies present in their output circuits must be carefully discriminated against by means of tuned circuits and adequate shielding. In addition, there is the possible production of additional spurious beats caused by voltages from the low frequency stages entering one or more of the broad pass-bands of the stages following the converter. Hence, if M can be reduced to approximately 1,300 or less, the above difficulties will not materialize. Large values of M are a direct consequence of the limited phase shift of which conventional modulators are capable. It is possible, however, to increase the useful phase shift of a modulator substantially by adding the individual phase shift of two or more stages connected in cascade. The block diagram Fig. 3 illustrates the manner of connecting the phase shift stages in cascade for the transfer of RF energy, but in parallel as far as the AF signal is concerned. The progressive increase of frequency deviation from stage to stage is also given for N, the number of cascaded stages, equal to 6, and for a maximum phase shift per stage of 23.9°, required for a 30-cycle AF signal at full deviation. It should be noted that if only the first stage were used ($N = 1$), the conventional modulator would result, for which the multiplication factor M must



FRONT AND REAR VIEWS OF THE TRANSMITTER. DETAILS ARE SHOWN ON PAGES FOLLOWING

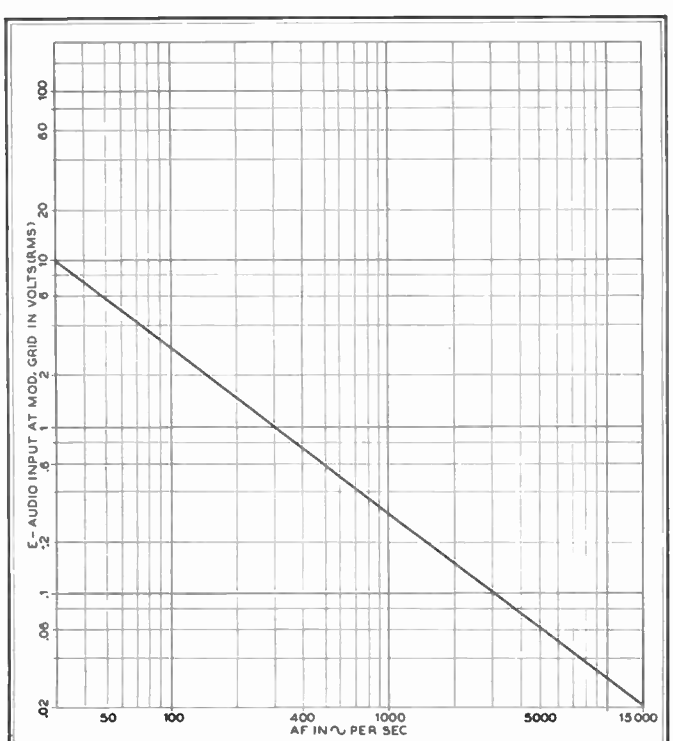


FIG. 2. MODULATION SIGNAL VOLTAGE REQUIRED FOR 75,000 CYCLES DEVIATION AS A FUNCTION OF THE APPLIED AF

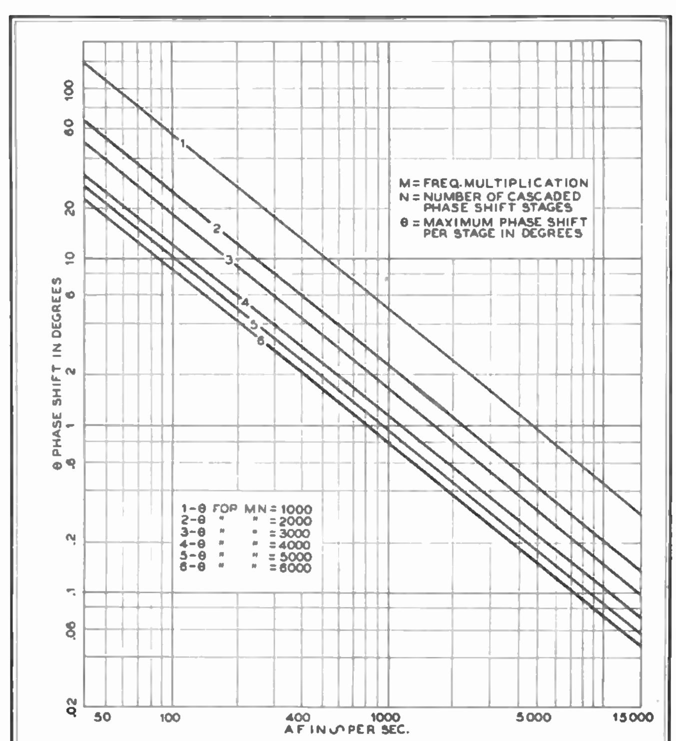
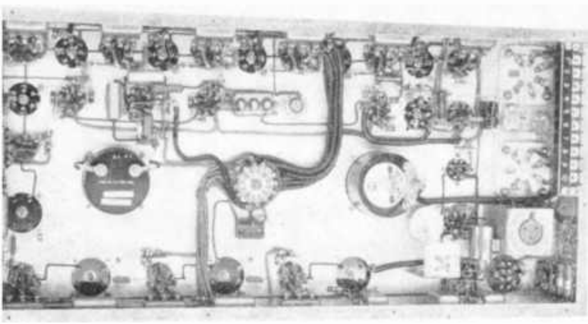


FIG. 4. PHASE SHIFT AS A FUNCTION OF AUDIO FREQUENCY, AND MN VALUES FOR DEVIATION EQUAL TO PLUS-MINUS 75,000 CYCLES

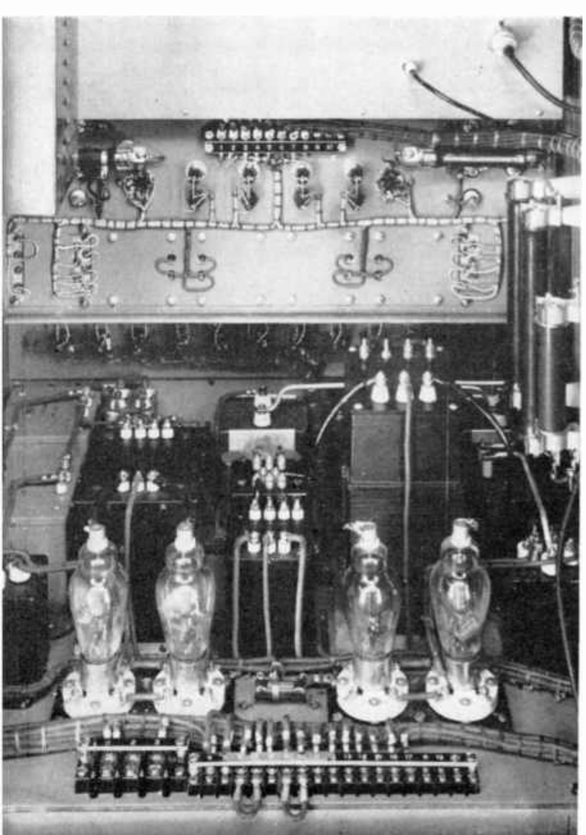


NEXT SECTION ABOVE, WITH COVER PLATE REMOVED

be 6,000 (75,000 cycles/12.5 cycles), while if all six stages are used (N = 6), M is reduced to 1,000 (75,000 cycles/75 cycles). The latter condition obviates the need for a frequency converter.

From the preceding discussion, it follows that the factor N may be considered as effective as the factor M in producing the final frequency deviation. This relationship can be stated as follows: The frequency deviation at the operating frequency in cycles is equal to the product of the audio frequency in cycles, the phase shift per modulator stage in degrees, the factor M, and the factor N, divided by the number of degrees per radian (57.3). This equation was used in curves 1 through 6 of Fig. 4 to show the phase excursion as a function of the applied audio frequency and the product M times N for a constant frequency deviation of 75,000 cycles. Curve 6 of this illustration represents the conditions set up in the block diagram of Fig. 3.

BOTTOM SECTION CONTAINS RECTIFIER AND POWER SUPPLY CIRCUITS



There is yet another advantage which comes from keeping the factor M relatively low. When an unmodulated RF signal is passed through a vacuum tube amplifier, it becomes modulated by the random noise voltages which are ever-present; one portion produces amplitude modulation of the RF signal, and the other produces irregular fluctuations in its phase.

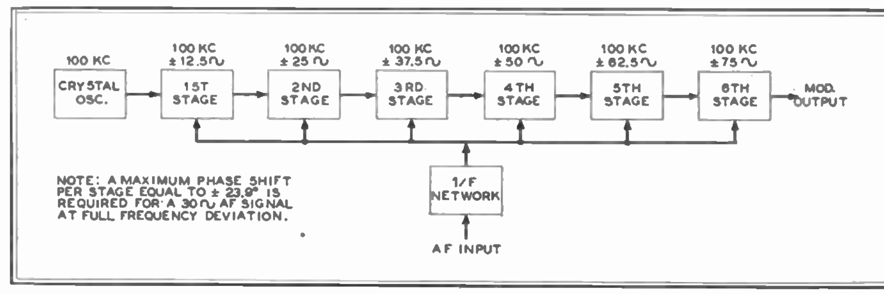


FIG. 3. BLOCK DIAGRAM OF THE CASCADE PHASE-SHIFT MODULATOR, SHOWING 6 STAGES

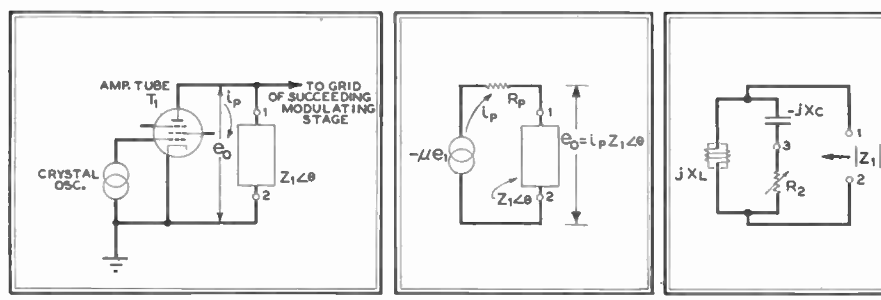


FIG. 5, LEFT) ELEMENTARY DIAGRAM OF THE BASIC PHASE-SHIFT STAGE FIG. 6, CENTER) EQUIVALENT OF CIRCUIT IN FIG. 5. FIG. 7, RIGHT) CONSTANT IMPEDANCE NETWORK

The amplitude modulation is readily removed by the limiting action of subsequent multiplier stages, but the irregular fluctuations in the phase of the signal represent a noise modulation. The frequency deviation corresponding to these fluctuations increases for the higher audio frequencies because there is no inverse frequency network to attenuate them. The magnitude of the resulting phase shift of the RF wave due to the noise can be shown to be approximately equal to 57.3 times the ratio of noise voltage divided by the signal voltage.[2] Hence, assuming a noise of 10 microvolts and a signal of 10 volts, the phase shift would be approximately 0.0000573°. From curve 6 of Fig. 4 for N = 1 and M = 6,000, approximately 0.05° phase shift is required at 15,000 cycles to produce 100% modulation. The ratio, then, of the phase shift for 100% modulation to the noise phase shift, expressed in db, should give the FM noise level at the output frequency. For the above case (M = 6,000) the noise level is 58.8 db below 100% modulation. Now performing the same calculation for M = 1,000 and N = 1 (see curve 1, Fig. 4) the phase shift required is 0.3° and the noise level for this source of noise becomes 74.4 db below 100% modulation.

The foregoing calculations considered the case of an unmodulated RF signal for N = 1. The effect on the noise level of adding N modulator stages in cascade will now be taken up. As previously explained, the phase shift appearing at the modulator output terminals is equal to the sum of the phase shift produced in the individual stages. But the random nature of fluctuation noise produced in each modulator stage makes it necessary to take the RMS sum of these voltages in order to find the resultant noise voltage at the modulator output terminals. Therefore, N modulator stages will add $\sqrt{N}$ times the noise of one stage. Thus, if 4 stages are cascaded, there will be a four-fold increase in phase shift, but only a two-fold increase in the noise of the system. In actual practice, noise is also produced in other parts of the transmitter, so that the relative contribution of the modulator section to the total noise is even smaller proportionately.

In order to minimize harmonic distortion under certain conditions of modulation, it is desirable to use a modulator circuit in which the percentage of amplitude modulation produced concurrently with phase modulation is very small. This distortion becomes a maximum when the percentage of phase modulation is such as to produce only the first pair of sidebands.[3] The effect in this case consists of a change in the relative magnitudes of the sideband, and any subsequent limiting action which may remove the amplitude

[2] "Frequency Modulation" by August Hund, 1942, pp. 104–107.

[3] "Frequency Modulation" by August Hund, 1942, p. 59.

variation will still be powerless to restore the relationship between the carrier and sidebands necessary for low distortion. Therefore, a further requirement for the design of the modulator is that any amplitude modulation produced along with the desired phase modulation be kept at a minimum.

Theory of the Cascade Phase-Shift Modulator ★

From the circuit[4] shown in Fig. 5, the basic phase-shift stage may be seen to be composed of an amplifier tube T_1 and its plate load impedance, the two terminal network Z_1 connected across terminals 1 and 2. T_1 serves both as an amplifier which isolates the cascaded phase-shift stages from one another, and as a source of constant current for Z_1. From the equivalent circuit for this tube shown in Fig. 6, it follows that the phase of the output voltage e_o must vary as the phase angle of Z_1. This is so because the load impedance is very much smaller than the plate resistance R_p, and therefore can have practically no part in determining the tain a substantially constant impedance while phase modulation is taking place. To demonstrate this, the general expression for the impedance of this network has been derived in Appendix I and is given below:

$$|Z_1| = X_L \sqrt{\frac{1+\left(\frac{1}{b}\right)^2}{1+\left(\frac{1}{b}\right)^2\left(\frac{1}{a}-1\right)^2}} \quad (1)$$

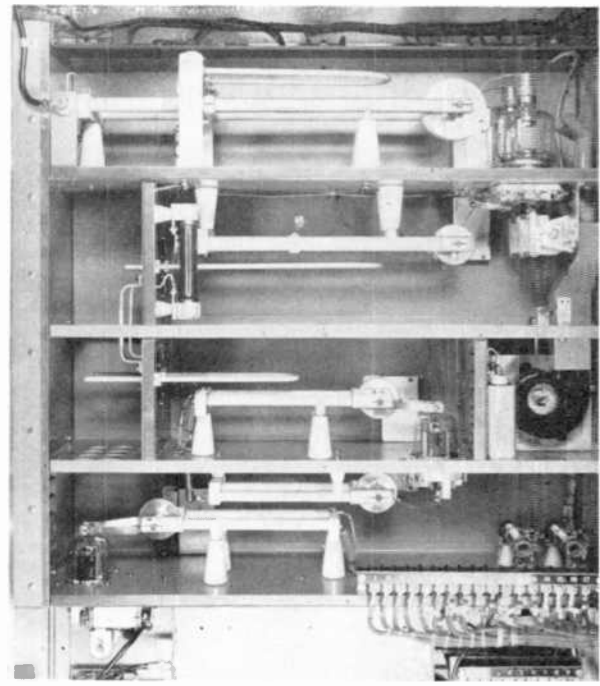
where

$$a = X_C/X_I \quad (2)$$

$$b = R_2/X_C \quad (3)$$

A study of equation (1) will show that when the quantity $\left(\frac{1}{a}-1\right)$ is set equal to unity, the quantity under the radical sign will also be equal to unity and therefore $|Z_1|$ will remain constant and equal to X regardless of any variation of b. This condition occurs when a is set equal to 0.5. Substituting this solution in equation (2), it follows that $|Z_1|$ will be constant when

$$X_L = 2X_C \quad (4)$$



OUTPUT CIRCUIT OF THE 250-W. UNIT

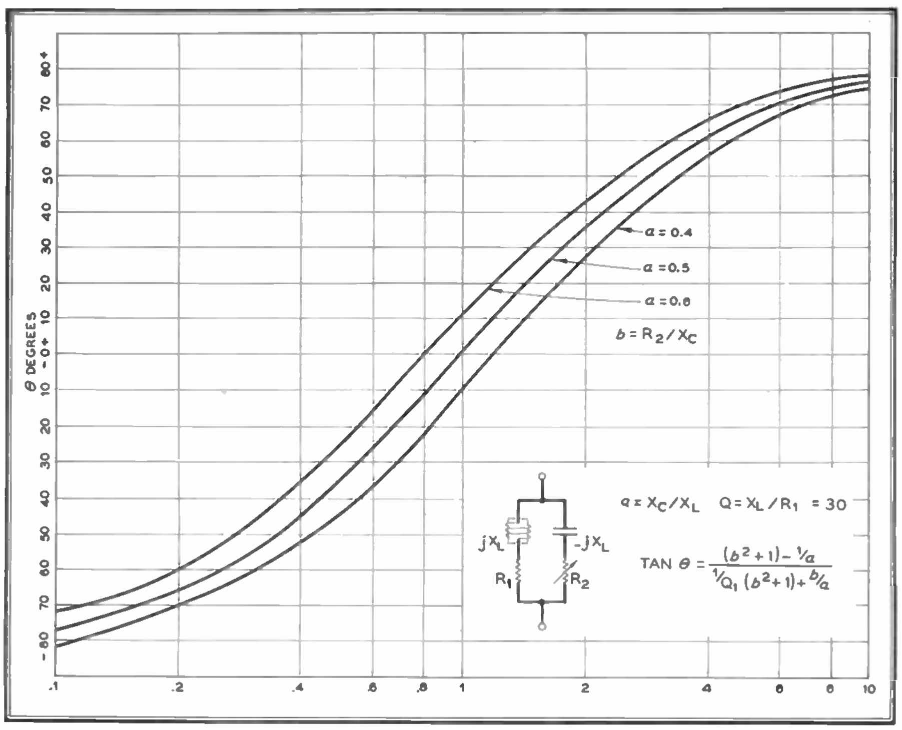


FIG. 8. PHASE CHARACTERISTIC OF A CONSTANT IMPEDANCE NETWORK

plate current i_p, and since the product of the plate current and the vector impedance $Z_1 \angle\Theta$ is equal to the output voltage, any change in phase of this impedance must therefore result in phase modulation of the output voltage. It also follows that any change in the magnitude of Z_1 will result in amplitude modulation of the output voltage.

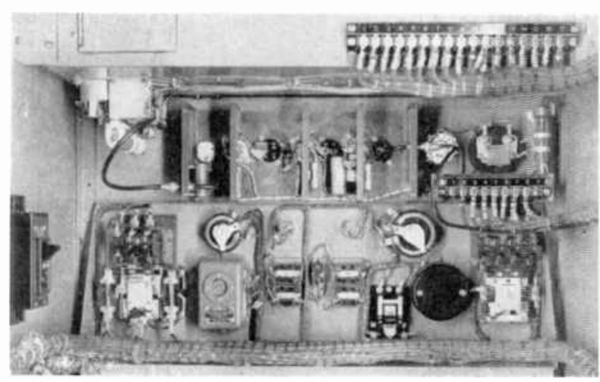
However, the two terminal network shown in Fig. 7 can be designed to main-

This network is used as the plate load of a vacuum tube whose plate resistance is over 100 times greater than $|Z_1|$, and since the parallel resistance of a coil with a Q of about 50 is also of the same high order of resistance, the effect of these two quantities on the magnitude of Z_1 can be neglected. These two quantities, however, do play a minor part in determining the phase angle of the network. Therefore, they are included in the derivation of the general relation between the phase angle of the network and the ratio of R_2 to X_C; this derivation appears in Appendix II. A plot of phase angle Θ against b (the ratio R_2/X_C) is shown in Fig. 8. Curves are drawn for a equal to 0.4, 0.5 (the constant impedance solution), and 0.6.

A mental picture of the phase-shift action to which the output voltage in this circuit is subjected can be obtained by considering the two extremes of resistance, bearing in mind that the inductive reactance is equal to twice the capacitive reactance (equation 4). For R_2 open-circuited, the current through terminals 1 and 2 of Fig. 7 must be inductive. Therefore, the output voltage will lead the plate current by approximately 90°. When R_2 is short-circuited, the current taken by the capacitive branch will be twice as great as that taken by the inductive branch, making the net current into terminals 1 and 2 capacitive. The output voltage, therefore, will lag behind the plate current by approximately 90° for this other extreme. Intermediate values of R_2 will cause the locus of the output voltage vector to follow the semicircle depicted in Fig. 9.

Concluding Part 2 will appear in our January issue

DETAILED VIEW OF NEXT LOWER SECTION, WITH COVERS REMOVED FROM SHIELDED UNITS



[4] A variation of this circuit is described by Seeley, S. W., Kimball, C. N., and Barco, A. A., "Generation and Detection of Frequency-Modulated Waves," RCA Review, Vol. 6, No. 3, January 1942, p. 276.

FM AND TELEVISION PROGRESS REPORT

Construction Permits Issued by the FCC in October 1946

TELEVISION STATIONS

INDIANA

INDIANAPOLIS: William H. Block Co.
Commercial No. 3 60–66 mc. 14.44 kw. Video 331 ft.

FM BROADCAST STATIONS

ALABAMA

BIRMINGHAM: Birmingham Bcstg. Co., Inc. (WBRC)
Class B No. 230 93.9 mc. 30 kw. 645 ft.

BIRMINGHAM: Voice of Alabama (WAPI)
Class B No. 232 94.3 mc. 13.7 kw. 640 ft.

MOBILE: Pope Bcstg. Co. (WALA)
Class B No. 271 102.1 mc. 32.5 kw. 510 ft.

ARKANSAS

FORT SMITH: D. W. Reynolds (AM Grantee)
Class B No. 267 101.3 mc. 180 kw. 802 ft.

CALIFORNIA

FRESNO: The George Harm Station (KARM)
Class B No. 270 101.9 mc. 24.5 kw. 360 ft.

MARYSVILLE: Marysville-Yuba City Bcstrs. (KMYC)
Class B No. 224 92.7 mc. 4.7 kw. 395 ft.

OAKLAND: Tribune Building Co. (KLX)
Class B No. 251 98.1 mc. 6.4 kw. 223 ft.

SAN JOSE: Santa Clara Bcstg. Co. (KSJO)
Class A No. 288 105.5 mc. 1 kw. 610 ft.

STOCKTON: E. F. Peffer (KGDM)
Class B No. 267 101.3 mc. 39 kw. 310 ft.

DELAWARE

WILMINGTON: Delaware Bcstg. Co. (WILM)
Class B No. 266 101.1 mc. 20 kw. 500 ft.

FLORIDA

CORAL GABLES: Southern Media Corp.
Class A No. 282 104.3 mc. 270 w. 208 ft.

ST. PETERSBURG: Pinnelas Bcstg. Co. (WTSP)
Class B No. 221 92.1 mc. 37 kw. 430 ft.

GEORGIA

COLUMBUS: Radio Columbus, Inc.
Class B No. 246 97.1 mc. 10.4 kw. 545 ft.

IDAHO

TWIN FALLS: Radio Bcstg. Corp. (KTFL)
Class B No. 241 96.1 mc. 3 kw. 270 ft.

ILLINOIS

DECATUR: Commodore Bcstg. (WSOY)
Class B No. 254 98.7 mc. 31.2 kw. 460 ft.

ELMWOOD PARK: Elmwood Park Bcstg. Corp.
Class A No. 238 103.5 mc. 320 w. 240 ft.

HARRISBURG: Harrisburg Bcstg. Co. (WEBQ)
Class B No. 255 98.9 mc. 32.7 kw. 350 ft.

QUINCY: Lee Bcstg., Inc. (WTAD)
Class B No. 251 98.1 mc. 53 kw. 880 ft.

ROCK ISLAND: Rock Island Bcstg. Co. (WHBF)
Class B No. 264 100.7 mc. 36.6 kw. 385 ft.

INDIANA

COLUMBUS: Syndicate Theatres, Inc.
Class B No. 237 95.3 mc. 31 kw. 270 ft.

CONNERSVILLE: News Examiner Co.
Class B No. 273 102.5 mc. 6.5 kw. 200 ft.

EVANSVILLE: Tri-State Bcstg. Corp.
Class B No. 230 93.9 mc. 20 kw. 330 ft.

KOKOMO: Kokomo Bcstg. Corp. (WKMO)
Class B No. 268 101.5 mc. 34 kw. 400 ft.

TERRE HAUTE: Banks of the Wabash, Inc. (WTHI)
Class B No. 244 96.7 mc. 20 kw. 200 ft.

TERRE HAUTE: Wabash Valley Bcstg. Corp. (KTHI)
Class B No. 242 96.3 mc. 20 kw. 305 ft.

KENTUCKY

WINCHESTER: Winchester Sun Co.
Class A No. 282 104.3 mc. 975 w. 250 ft.

MARYLAND

BALTIMORE: Belvedere Bcstg. Corp.
Class B No. 255 98.9 mc. 20 kw. 390 ft.

MICHIGAN

DEARBORN: Herman Radner
Class A No. 282 104.3 mc. 480 w. 350 ft.

GRAND RAPIDS: Grand Rapids Bcstg. Corp.
Class B No. 226 93.1 mc. 10.5 kw. 390 ft.

LANSING: WJIM, Inc. (WJIM)
Class B No. 258 99.5 mc. 53 kw. 360 ft.

MINNESOTA

ROCHESTER: Southern Minn. Bcstg. Co. (KROC)
Class B No. 234 94.7 mc. 20 kw. 500 ft.

MISSOURI

ST. JOSEPH: KFEQ, Inc. (KFEQ)
Class B No. 234 94.7 mc. 63 kw. 550 ft.

NEBRASKA

LINCOLN: Cornbelt Bcstg. Corp. (KFOR)
Class B No. 247 97.3 mc. 25 kw. 820 ft.

NEW JERSEY

ASBURY PARK: Radio Industries Bcstg. Co. (WCAP)
Class A No. 296 107.1 mc. 260 w. 250 ft.

NEW YORK

NEW YORK: Fordham University
Educat'n'l No. 211 90.1 mc. 3.5 kw. 200 ft.

POUGHKEEPSIE: Poughkeepsie Newspapers (WKJP)
Class B No. 278 103.3 mc. 33.2 kw. 395 ft.

SYRACUSE: Syracuse Bcstg. Corp.
Class B No. 224 92.7 mc. 8.5 kw. 690 ft.

TROY: Troy Bcstg. Co., Inc. (WTRY)
Class B No. 272 102.3 mc. 2.4 kw. 1,090 ft.

NORTH CAROLINA

AHOSKIE: Parker Bros., Inc.
Class A No. 282 104.3 mc. 665 w. 300 ft.

ASHEVILLE: Radio Station WISE, Inc. (WISE)
Class B No. 234 94.7 mc. 9.6 kw. 670 ft.

GASTONIA: F. C. Todd (WGNC)
Class B No. 271 102.1 mc. 11.1 kw. 890 ft.

GOLDSBORO: Eastern Carolina Bcstg. Co. (WGBR)
Class B No. 259 99.7 mc. 35 kw. 500 ft.

HICKORY: Catawba Valley Bcstg. Co. (WHKY)
Class B No. 258 99.5 mc. 180 kw. 965 ft.

WILSON: Penn T. Watson (WGTM)
Class B No. 245 96.9 mc. 20 kw. 500 ft.

OHIO

CANTON: Ohio Bcstg. Co. (WHBC)
Class B No. 246 97.1 mc. 9 kw. 410 ft.

CINCINNATI: Cincinnati Times Star Co. (WKRC)
Class B No. 245 96.9 mc. 12.6 kw. 600 ft.

FINDLAY: Findlay Radio Co. (WFIN)
Class B No. 269 101.7 mc. 8.2 kw. 245 ft.

FOSTORIA: L. E. Kinn
Class B No. 274 102.7 mc. 8.5 kw. 420 ft.

MARION: Marion Bcstg. Co. (WMRN)
Class B No. 272 102.3 mc. 2.3 kw. 325 ft.

PORTSMOUTH: Sciota Bcstg. Co. (WPAY)
Class B No. 280 103.9 mc. 4 kw. 525 ft.

WOOSTER: Wooster Republican Printing Co.
Class B No. 250 97.9 mc. 9.6 kw. 300 ft.

YOUNGSTOWN: WFMJ Bcstg. Co. (WJFM)
Class B No. 253 98.5 mc. 50 kw. 330 ft.

OKLAHOMA

MUSKOGEE: Muskogee Bcstg. Co.
Class B No. 221 92.1 mc. 6.5 kw. 320 ft.

SHAWNEE: KGFF Bcstg. Co. (KGFF)
Class B No. 242 96.3 mc. 7.2 kw. 390 ft.

OREGON

ASHLAND: Siskiyou Bcstg. Co.
Class A No. 284 104.7 mc. 270 w. 1,470 ft.

EUGENE: Valley Bcstg. Co. (KUGN)
Class B No. 259 99.7 mc. 8 kw. 250 ft.

PENNSYLVANIA

ALLENTOWN: Penn-Allen Bcstg. Co.
Class A No. 286 105.1 mc. 1 kw. 180 ft.

HARRISBURG: Patriot Co.
Class B No. 245 96.9 mc. 6.3 kw. 770 ft.

PITTSBURGH: WCAE, Inc. (WCAE)
No. 223 92.5 mc. 20 kw. 500 ft.

SCRANTON: Union Bcstg. Co. (WARM)
Class B No. 263 100.5 mc. 6 kw. 780 ft.

SHARON: Sharon Herald Bcstg. Co.
Class B No. 275 102.9 mc. 26 kw. 455 ft.

WILLIAMSPORT: WRAK, Inc. (WRAK)
Class B No. 223 92.5 mc. 3.2 kw. 1,270 ft.

PORTO RICO

SAN JUAN: Radio Americas Corp.
Class A No. 286 105.1 mc. 330 w. 270 ft.

SOUTH CAROLINA

ANDERSON: Wilton E. Hall (WAIM)
Class B No. 278 103.5 mc. 33.2 kw. 395 ft.

TENNESSEE

CHATTANOOGA: WAPO Bcstg. Service (WAPO)
Class A No. 233 94.5 mc. 37.2 kw. 840 ft.

TEXAS

AMARILLO: Plains Bcstg. Co. (KGNC)
Class B No. 269 101.7 mc. 50.4 kw. 390 ft.

VIRGINIA

DANVILLE: Piedmont Bcstg. Corp. (WBTM)
Class B No. 221 92.1 mc. 31 kw. 615 ft.

HARRISONBURG: Shenandoah Valley Bcstg. Co. (WSVA)
Class B No. 232 94.3 mc. 37.2 kw. 1,845 ft.

NORFOLK: WTAR Radio Corp. (WTAR)
Class B No. 226 93.1 mc. 33 kw. 345 ft.

RICHMOND: T. G. Tinsley, Jr. (WLEE)
Class B No. 250 97.9 mc. 21 kw. 290 ft.

WEST VIRGINIA

HUNTINGTON: Mayflower Bcstg. Co.
Class A No. 282 104.3 mc. 275 w. 150 ft.

WISCONSIN

BELOIT: Daily News Pub. Co.
Class B No. 230 93.9 mc. 3.8 kw. 330 ft.

RICE LAKE: WJMC, Inc. (WJMC)
Class B No. 259 99.7 mc. 4.4 kw. 360 ft.

WAUSAU: Northern Bcstg. Co. (WSAU)
Class B No. 235 94.9 mc. 19.5 kw. 500 ft.

WYOMING

CHEYENNE: Frontier Bcstg. Co. (KFBC)
Class B No. 239 95.7 mc. 9.5 kw. 750 ft.

WHY WORRY ABOUT FACSIMILE PROGRAMS NOW?

To Avoid Making a False Start, Facsimile Should Be Introduced to the Public As a Program Service, Not As a Scientific Curiosity

BY MILTON ALDEN*

LAST month the writer discussed some of the elements to be considered in formulating plans[1] for home facsimile broadcasting and reception, pointing out that facsimile can be the one advertising medium to guarantee 100% readership attention.

It was further developed in the article that the size and format of facsimile program were favored by the choice of a 4.1-in. useful scanning or recording line, with a linear paper feed of approximately 3 ins. a minute.

Reading directly across the paper makes for both easy reading and scanning of programs received in the absence of the set owner.

A paper feed of 3 ins. per minute, 4 ins. wide insures twice as many words a minute as the ordinary radio announcer speaks, and is a speed as fast as anyone can read readily.

Text of this width insures that any advertisement placed at the side of a single column of reading matter will get complete attention. This is equally true in placing advertisements at the end of any article or illustration. Where advertising appears parallel to a column, the number of words are still equivalent to those that would be heard at normal speech rate (125 a minute) with time enough to give attention to the commercial. This would seem to make facsimile advertisements unobtrusive, yet positively effective.

Progress Toward Standards ★ Since the first part of this discussion appeared in the November issue, there have been developments which insure that equipment going on the air will have both useful scanning widths of 4.1 ins. and 8.2 ins., and that field tests can be conducted for the purpose of determining the consumers' preference.

The immediacy of field tests is only in part the answer the question to "why worry about facsimile programs now?"

Facsimile broadcasters are not only confronted with the need of choosing the most favorable standard of width, paper feed and format, but of doing now the necessary things that will lead to setting a sufficiently high standard of program content for facsimile to succeed from the start.

Television Gives A Cue ★ As a prelude to discussing the content of facsimile programs, let's take a look at a few scrambled notes on television to see if they are not a cue to the probabilities in facsimile.

Note 1. Television sets were shown at the World's Fair held at New York in 1939 and 1940. We are told that some of the same sets used there still work well and at the present time are shown in the NBC radio broadcasting tour at Radio City, New York.

Note 2. Trained market reporters who watching television sets shown at the World's Fair and at night clubs noted that practically no one asked: "How much are they?" or, "How quickly can I get one?" A possible observation or conclusion that can now be made from this is that *technically* television has been reasonably acceptable for some time, but early showings did not have *programs* which viewers felt they didn't want to miss.

Note 3. More recent studies show that now, with better programs but with no tremendous improvement in reproduction, youths rush home from school to huddle around television sets and watch programs devised for them, women do not want to miss the plays they like, and men are enthusiastic over viewing wrestling, boxing, and football games. They nearly all become television addicts, and seek invitations to the homes that are television-equipped when the programs of their tastes are scheduled.

True, it hasn't been program difficulties alone that have delayed television.

Now Comes Facsimile ★ Facsimile does not need to have as long a transition period as television. Facsimile is ready to go and grow with the new Frequency Modulation stations. It can be the means of making these stations pay quickly and soon — but the mistake of sending out poor programs should be avoided.

Program trial and error had best be in the laboratory or with a limited number of fascimile receivers. With the kind of programs that people feel they cannot miss, tremendous pressure will be developed quickly to solve all the remaining problems, whether they be with the set manufacturer, the broadcasters, or F.C.C.

Therefore, those who wish to get aboard the bandwagon should not delay, because this new industry can click fast. It is needed to serve the interests of everyone connected with radio. AM is dying on its feet. AM set manufacturing, after the first of the year, will be a competitive cat-and-dog fight. Television is coming, but it needs a little time. FM stations need something to make them pay quickly, that they may not blight on the vine.

Facsimile Can Do The Work ★ Now, it may sound very contradictory, but facsimile can appear so simple and, in principle, it is, but as soon as you start working with it, you find the problems become interrelated with many factors about which those who are going to work with it and be responsible for it need first-hand information and experience.

Printing is very simple in principle. I have before me three magazines and one newspaper. These are *Woman's Day*, *World Report*, *Business Week*, and *Wall Street Journal*. All very successful, not because they are primarily good printing jobs, but because of the content and their presentation.

You or I could buy the equivalent equipment, presses, and the paper that these different publications have, but we could not turn them over to the office boy, or even to the best of our staff, and produce equal publications that would show an operating profit.

Yet we are inclined to think that if we can buy facsimile equipment and put it on the air, we shall either know what is wanted, or we can quickly assemble a group who will know all the answers. But can we?

I'm looking at *Woman's Day*, representing the combined efforts of a skilled staff with excellent direction, published once a month, yet you and I are thinking in terms of a daily program. It's a magazine built for women, particularly A & P customers. I do not know the editor or the publisher, but there is obvious evidence of:

Skill in choosing a timely, attractive cover and, throughout the book, knowledge of photography, sketching, and illustrating, planned with an understanding of plates, inks, paper, and presses. As to the contents, there are such timely topics as Make It Without Fat or Oil — Found Money — Outgrown Clothes Make Brief, Trim Styles — How To Be A Girl — The In-between Stage — Needlepoint Stitches — Keep the White Removable — Spare the Sugar — Meat for Two — The Hollywood Picture — From the New Books — plus short stories — all put together

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

[1] "Elements of Home Facsimile Standards" by Milton Alden, *FM* AND TELEVISION, Nov. 1946.

with wonderful use of small-space illustrations. To the woman of the type it is intended to reach, it is irresistable.

In short the attention-compelling factor is not accidental, or the work of amateurs.

My interest in examining this publication is that, contents-wise, it is an excellent guide as to what will probably be liked by a substantial part of the probable facsimile audience. This audience will be mainly women, from whom facsimile advertisers will get their best returns.

Now there are many veteran editors of magazines and feature sections of newspapers whose skills are going to be most admirably adapted to facsimile programming, but there are few, if any, *who know the why's and wherefore's of facsimile reproduction from the choice of copy to the final reproduction*.

It would be boring to trace all of the variables of facsimile from the scanned line to the recording. Photography can be learned in part from books, word of mouth, and trial and error. The same thing is true of facsimile. But much more than an academic knowledge of the mechanics is required to make pictures or programs of commercial value.

The Army Air Corps and the Signal Corps had their intensive, specialized courses for facsimile operators. The OWI facsimile department had to train their personnel as did all the other war services; yet with selected people, full-time intensive courses, and the most advance methods of presenting and teaching the subject, they found difficulty in training operators to be on their own.

Nearly every new facsimile purchaser is first thrilled because the recorder works. People see it and its novelty appeals. But the engineer who operates the equipment realizes that perhaps he is not getting as good reproduction as samples that he has seen. Eventually all programs can be pretested as to the optimum scanner settings. But initially he will find certain photographs reproduce better than others, different wedge settings do this and do that, and only with some practice and some natural aptitude will the operator obtain the best results.

Here is something of what takes place at the transmitter: A photo-electric cell scans a line through a microscope. This response has some color discrimination. The scanning, in some instances, has to straddle a fine line, and a 50–50 straddle in theory would be gray or half the total impulse of black, although the line being scanned is full black.

This is cited to illustrate that there are variables from true response in every step from scanning to recording. Now the photo-cell impulse is amplified and becomes a part of the modulated signal. This again is amplified and transmitted over radio or wires. Here noise, attenuation, and other things introduce variables. At the receiving end, the signal is detected, amplified, rectified, and passed through the paper. In many of the steps the response or change is not in direct proportion to the impulse. True, equipment design has taken nearly all these factors into consideration and compensated in part; but all design, in the last analysis, has some factor of compromise.

Thus, experience and knowledge of the technical factors are as essential in producing quality facsimile programs as the knowledge of printing, paper, and illustration are to the publishing business.

I know of a small newspaper in the deep South that is occasionally sent us. Although it is printed, and is called a newspaper, it is far from the usual conception of a newspaper. Its spelling, typography, and contents are so substandard and weird as to be laughable. Some initial facsimile programs are apt to be rated about the same for interest and quality as this paper, if facsimile programming is considered only a matter of getting copy on the air.

What Facsimile Can Be ★ Facsimile will have a low standard unless artists are selected and trained to know the most effective kind of sketches and illustrations. Editors and make-up experts must experiment with format, easy-reading text type, and headings that will tell what is coming when the facsimile reader is giving the recording only his partial attention. These and a thousand and one other details must be tested carefully before conclusions can be drawn.

We are told *Readers Digest* had to lighten their copy with anecdotes. The *Saturday Evening Post* uses cartoons liberally; one of New York's well-known conservative papers at last has funnies. But the funnies and all the techniques are the result of analysis, study, and proving by test.

Many of the publishers' techniques can be borrowed or adapted, but perhaps the facsimile funnies need to have different standards than the daily press. Who knows?

Time To Act Now ★ All this leads to the conclusion that it is *none too soon* to put prototype equipment into operation, to gain experience in all the phases of giving customers what they like and will read, plus encouraging adventures and research that will concentrate on producing, at reasonable cost, sufficient and varied programs. Then facsimile will not bog down from being unprepared for the practical phases from which the revenue, so necessary, must finally come.

WHAT'S NEW THIS MONTH

(CONTINUED FROM PAGE 4)

ing in and out alternately with WBBM on 780 kc.!

Don't ask us who sponsored those programs. If we heard, we were too annoyed to remember. As far as we're concerned, if Mr. Denny finds that Great Barrington is in a white spot on the AM coverage map, he needn't worry about us. Even our phlegmatic disposition can't take any more of those fancy AM nighttime sky waves.

And if any sponsor wants us to eat Munchy-Krunchies or brush our teeth with Kolodent powder, he'll have to tell us so via FM.

Surely the FCC and the broadcasters, if they stopped looking and did a little listening, wouldn't make plans for the further extension of that kind of service. We've got too much of it already!

2. What may well prove to be the most important event in the history of radio broadcasting will take place on January 10th. On that date, the organization meeting of the FM Assocation will be held at Hotel Statler, Washington, D. C.

Some 2,500 broadcasters, transmitter and receiver manufacturers, and transcription and news services have been invited to attend, and to take part in formulating plans for the expansion of FM broadcasting as an improved service to the radio listeners.

At this meeting, officers and directors will be elected, and a proposed plan of FM promotion, aimed at both the public and the radio dealers, will be submitted for discussion, modification, and final approval by the members.

Those attending will be invited to join the Association. Annual dues have been set at $100. According to Leonard Marks, acting treasurer, a considerable number of checks for this amount have been received already from those who wanted to help meet the initial expenses.

There has been an immediate and favorable reaction to the announcement of this meeting which, fortuitously, followed directly after the appointment of Charles R. Denny, an avowed FM enthusiast, as permanent Chairman of the FCC.

In fact, both network and independent AM station officials who, through NAB, fought against the idea of an FM association, have apparently reached the conclusion that, since they could not vanquish the enemy, they will join him. Or, to put it differently, perhaps those who have so consistently opposed FM now feel that, since the support behind the FM Association was strong enough to overcome all opposition, they must join in self defence.

The steering committee of the FM Association has been very conservative in its estimate of attendance at this meeting. They say that the event will be a signal success if it totals 300 to 400. In that case, ample funds are assured for the aggressive plan of promotion which has been formulated. However, recalling the unexpectedly high registration at the last FMBI conference three years ago, it seems more likely that the attendance will exceed 1,500.

MAGNETRON: GENERATOR OF CENTIMETER WAVES

The Theory of the Magnetron, and Its Development as a Practical Means for Generating Centimeter Waves—3rd Installment

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

6. Resonator Systems ★ 6.1 *Two Coupled Resonators:* The resonator system of the magnetron oscillator consists of a number of individual resonators of distributed parameters, machined into the anode block. As the simplest case of a system of coupled resonators, consider that having two resonators which are coupled only by the mutual linkage of magnetic lines and which resonate at the same frequency ω_0 when uncoupled.

When such a coupled system is shock excited it is observed that the oscillation amplitude in either of the circuits is modulated at a so-called beat frequency ω_B. A fraction or all of the energy in the system, depending on the initial conditions, surges back and forth at this frequency between the circuits similar to the manner in which the energy of motion is exchanged between two coupled pendulums. The total energy in the system is constant, the beats differing in phase by $\pi/2$ radians between the circuits.

The observation of beats is a manifestation of the fact that the two coupled resonators form a complex system oscillating simultaneously in its two modes for which the frequencies are $(\omega_0 + \omega_B)$ and $(\omega_0 - \omega_B)$. The oscillation in either circuit results from the superposition of the two component oscillations in this manner:

$$A \cos (\omega_0 + \omega_B)\, t + B \cos [(\omega_0 - \omega_B)\, t + \delta] =$$

$$(A - B) \cos (\omega_0 + \omega_B)\, t + 2B \cos \left(\omega_B t - \frac{\delta}{2}\right) \cos \left(\omega_0 t + \frac{\delta}{2}\right), \qquad (27)$$

with a similar expression for the case when $A < B$. The oscillation may be predominantly of one frequency, that is, almost entirely in one mode if, for example, $A \gg B$. In general, the oscillation is a superposition of a steady oscillation in the predominant mode $[(\omega_0 + \omega_B)$ if $A > B]$ and an oscillation whose amplitude varies with the beat frequency, ω_B. In the special case, when the component oscillations are of equal intensity, $A = B$, the amplitude of the resultant oscillation in either circuit goes to *zero* periodically at the frequency ω_B. This represents the case for which all the energy present in the system is transferred back and forth between the circuits.

The frequency separation of the two modes arises from the coupled effect of the oscillation in each of the circuits on the oscillation in the other. Thus, in the mode of lower frequency $(\omega_0 - \omega_B)$ the two circuits oscillate in phase and the self induction effect in each circuit is aided by the mutual induction, each circuit behaving as though it were oscillating freely with a greater value of self inductance and hence at lower frequency, equation (17). For the mode of higher frequency $(\omega_0 + \omega_B)$ the reverse is true. Here the two circuits oscillate out of phase by π radians, the mutual induction opposing the self induction and the circuits oscillating as though uncoupled with a smaller value of self inductance and hence at higher frequency.

If, instead of shock-exciting the system of two coupled resonators, it is forced to oscillate by applying to it a sinusoidal voltage of variable frequency, the admittance if the system is found to pass through minima at the mode frequencies $(\omega_0 + \omega_B)$ and $(\omega_0 - \omega_B)$. Thus it is possible to drive the system and store energy in either of the two modes. For each mode of the coupled circuit system, as for the simple single frequency resonator, Q parameters and a characteristic admittance can be defined which specify sharpness of resonance and energy storage capacity, respectively.

6.2 *The Multicavity Anode Structure:* As an introduction to the discussion of the multicavity resonator system of the magnetron oscillator having cylindrical symmetry, consider the system of a series of resonators machined side by side in a linear block as shown in Fig. 22. One may consider such a linear array either to be infinite in extent or to be terminated in some manner at the ends of a string of N identical resonators.

The oscillation in each resonator of the array of coupled resonators is specified by a differential equation in terms of a variable, such as current or voltage, the constants of the circuit itself, and the mutual interaction between the circuit and its neighbors. Each solution of the set of simultaneous differential equations for all the resonators involved corresponds to a definite phase shift between adjacent resonators. The allowed values of this phase shift depend upon the boundary conditions imposed on the string of resonators. If the block is infinitely long, all values of phase shift are allowed. In terms of the electromagnetic field pattern formed on the front surface of the block by the fringing fields of the individual resonators, this means that traveling wave solutions representing waves of any velocity, traveling over the surface of the block in directions normal to the slots, are possible. If the block is terminated, on the other hand, the boundary conditions restrict the phase shift between resonators to a set of specific values. These correspond to the traveling waves which on reflection at the terminations constructively interfere.

The cylindrical magnetron anode structure is a series of N resonators connected in a ring. It may be thought to be a section of a linear array of resonators rolled into a cylinder. The boundary condition imposed is that of connecting together the resonators at the ends of the string. Under these circumstances, only those modes of oscillation are possible for which the total phase shift around the ring is $2\omega n$ radians, n being any integer including zero. The oscillations in adjacent cavities then differ in phase by $2\pi n/N$ radians. Again, this means that only those waves traveling around the anode block which constructively interfere are possible solutions. These are waves which, after leaving an assumed starting point and traversing the anode once, arrive back in phase with the wave then leaving in the same direction. The anode potential waves and the RF interaction fields in the interaction space to which they correspond have already been discussed in connection with equations (12) and (13). In these electromagnetic field patterns, the electric and magnetic field components are displaced both in space and time phase by $\pi/2$ radians relative to one another, similar to the manner in which voltage and current on a terminated transmission line are related.

6.3 *The Modes of the Resonator System:* It has been seen that the modes of oscillation of a magnetron resonator system are characterized by definite values of the phase shift between adjacent resonators specified by $2\pi n/N$, in which the parameter n may assume only integral values including zero. Each such mode of oscillation has a frequency different from the frequency of any other mode and from the frequency of one of the N resonators oscillating freely and uncoupled from its neighbors. In the general case of N coupled resonators, as in the case of two coupled resonators previously discussed, the modes of oscillation have different frequencies because of the effect of the mutual coupling between the resonators. For $N = 2$, the oscillations in the two resonators are either in phase or π radians out of phase, the induction in one circuit by the other either directly adding to or subtracting from the self induction. In the case of the multiresonator system, the mutual induction effect may bear phase relations to the self-induction other than 0 and π radians. Thus not only the magnitude of the coupling but also this phase relationship determine the magnitude of the effect of the mutual induction, and hence the amount of deviation of the mode frequency from that of a single uncoupled resonator. If the coupling between resonators were in some way gradually reduced, all mode frequencies would converge to the value for a single uncoupled resonator.

The complete anode potential wave for a mode specified by the parameter n has been given in equation (12). Each of its traveling components is represented by a fundamental of periodicity n and a series of so-called Hartree harmonics of periodicities $k = n + pN, p = 0, \pm 1, \pm 2, \cdots$. Any sinusoidal component for which the number of complete cycles around the anode is greater than $N/2$ is thus a harmonic of the complete field pattern for one of the modes whose fundamental is of periodicity $n = 1, 2, \cdots, N/2$. Physically distinguishable modes of oscillation exist only for the values of n less than or equal to $N/2$, including zero. However, this accounts for only $N/2 + 1$ of the N modes of oscillation which one expects a system of N resonators to possess. The reason for this is that in general the frequency of a mode specified by the parameter n (except for the values 0 and $N/2$) is a double root for a perfectly symmetrical anode structure. The mode is thus a doublet and is said to be degenerate. One would expect this on mathematical grounds from the fact that the general solution of expression (12) has four arbitrary constants, whereas a singlet solution of the system of second order differential equations specifying the oscillations should have no more than two.

The nature of the degeneracy of the modes of the resonator system is perhaps most clearly seen by investigating what happens when the symmetry of the system is destroyed by the presence of a disturbance or perturbation at one point, a coupling loop in one of the cavities for example. Such a disturbance provides the additional boundary condition needed to remove the degeneracy.

Consider the effect of the perturbation on the nth mode. It represents an admittance shunted across the otherwise uniform closed ring of resonators. This shunt admittance may be represented by ϵY_0, ϵ being a complex number, taken to be small for simplicity, and Y_0 the characteristic admittance of the closed resonator system. In such a system, a potential wave incident upon the disturbance ϵY_0, having an amplitude a at the disturbance, breaks up into a reflected wave and a transmitted wave which, if ϵ is small, have the amplitudes $-\frac{\epsilon}{2}a$ and $\left(1 - \frac{\epsilon}{2}\right)a$, respectively. See equation (30) for the reflection coefficient on a transmission line. In passing across the disturbance, a wave undergoes a small phase shift $\delta\phi(\omega)$. Since the total phase shift around the entire system must remain $2\pi n$, one may write: $\phi(\omega) + \delta\phi(\omega) = 2\pi n$, in which $\phi(\omega)$ is the phase shift around the system not including the disturbance. If there is no disturbance, $\omega = \omega_n$ (ω_n is used here for the ω_0 of the nth mode), $\delta\phi(\omega) = 0$, and $\phi(\omega_n) = 2\pi n$. For waves incident upon ϵY_0 from either direction, the respective amplitudes a and b at ϵY_0 must satisfy the equations:

$$a = \left[-\frac{\epsilon}{2}b + \left(1 - \frac{\epsilon}{2}\right)a\right]e^{j\phi(\omega)}$$

$$b = \left[-\frac{\epsilon}{2}a + \left(1 - \frac{\epsilon}{2}\right)b\right]e^{j\phi(\omega)}.$$

Writing $2\pi n - \left|\frac{\partial\phi}{\partial\omega}\right|_{\omega_n} \cdot (\omega - \omega_n)$ for $\phi(\omega) = 2\pi n - \delta\phi(\omega)$ in these equations and keeping only first order terms, one obtains the following pair of homogeneous linear equations for a and b:

$$\left[j\left|\frac{\partial\phi}{\partial\omega}\right|_{\omega_n} \cdot (\omega - \omega_n) - \frac{\epsilon}{2}\right]a - \frac{\epsilon}{2}b = 0$$

$$-\frac{\epsilon}{2}a + \left[j\left|\frac{\partial\phi}{\partial\omega}\right|_{\omega_n} \cdot (\omega - \omega_n) - \frac{\epsilon}{2}\right]b = 0.$$

These equations have a solution if and only if the determinant of the coefficients vanishes, that is, if:

$$j\left|\frac{\partial\phi}{\partial\omega}\right|_{\omega_n} \cdot (\omega - \omega_n)\left[j\left|\frac{\partial\phi}{\partial\omega}\right|_{\omega_n} \cdot (\omega - \omega_n) - \epsilon\right] = 0.$$

The two solutions are thus: $\omega = \omega_n$, for which $a = -b$, and $\omega = \omega_n - \frac{j\epsilon}{\left|\frac{\partial\phi}{\partial\omega}\right|_{\omega_n}}$ for which $a = b$.

From these facts concerning the amplitudes, namely, that at the disturbance ϵY_0 the amplitudes of the two oppositely traveling waves must either be equal or equal and opposite in sign for all time, one can conclude that the waves are of equal amplitude and that the standing waves resulting for each frequency must have a node at the disturbance for the $\omega = \omega_n$ solution and an antinode there for the $\omega = \omega_n - \frac{j\epsilon}{\left|\frac{\partial\phi}{\partial\omega}\right|_{\omega_n}}$ solution.

What this means in terms of the general solution for the degenerate mode of periodicity n of equation (13) can now be seen. Expression (13) can be rewritten in terms of θ measured from the disturbance ϵY_0 in this way:

$$V_{RF} = \sum_k (A_k - B_k)\cos(\omega t - k\theta + \gamma)$$
$$+ \sum_k 2B_k \cos\left(\frac{\gamma - \delta}{2}\right)\cos\left[\omega t + \left(\frac{\gamma + \delta}{2}\right)\right]\cos k\theta \qquad (28)$$
$$+ \sum_k 2B_k \sin\left(\frac{\gamma - \delta}{2}\right)\cos\left[\omega t + \left(\frac{\gamma + \delta}{2}\right)\right]\sin k\theta.$$

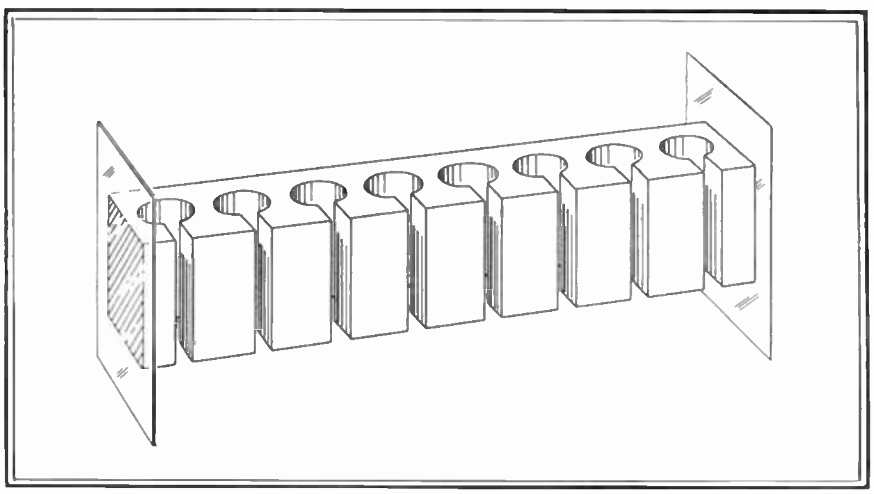


FIG. 22. A linear array of resonators terminated at both ends by generalized terminations represented by planes. The figure is meant also to indicate the nature of the infinite array of resonators referred to in the text.

When the degeneracy is removed, the first summation representing the traveling wave vanishes since the amplitudes A_k and B_k are equal for the reasons indicated. Furthermore, the second term involving cos $k\theta$ terms is then the component of the doublet whose frequency changes, and the third term involving sin $k\theta$ terms is the component of undeviated frequency. For the latter component the disturbance appears at a node and hence has no effect. The reverse holds for the cos $k\theta$ solution. For it, the frequency deviation depends on the magnitude of the disturbance through the quantity ϵ. The disturbance caused by the coupling loop in an actual magnetron resonator system is sometimes sufficient to split the components into distinguishable resonances.

Thus an unsymmetrical multicavity resonator system in general has two modes of different frequency for each value of n. With respect to the asymmetry as origin, one of these modes has a cosine-like field pattern, the other a sine-like field pattern. This is true for $n = 1, 2, \cdots, N/2 - 1$, contributing $N - 2$ modes. The remaining two modes of the resonator system, for which $n = 0$ and $N/2$, are single modes even in the symmetrical anode. This can be seen from the analysis demonstrating the splitting of the nth mode into two components. For the $n = 0$ mode, since the anode potential wave is independent of azimuthal angle, the solution $\omega = \omega_n$ for which $a = -b$ represents the trivial case of zero amplitude at all points. Similarly, for the $n = N/2$ mode (the π mode) the $\omega = \omega_n - \dfrac{j\epsilon}{\left.\dfrac{\partial\phi}{\partial\omega}\right|_{\omega_n}}$ solution for which $a = b$ yields a cosine-like pattern giving zero potentials at each anode segment, an equally trivial case. Thus each of the N modes of the multicavity resonator system have been accounted for.

As an example, plots of the field configurations for the modes of a magnetron having eight resonators are shown in Fig. 23. For clarity, only the electric field lines of the fundamental component ($p = 0$) of each mode are shown in the interaction space. Only the magnetic field lines are shown in the resonators. Below these is plotted the distribution in potential for each of the fundamentals, sin $n\theta$ and cos $n\theta$, $n = 0, 1, 2, 3$, and 4. For the $n = 0$ mode the magnetic flux threads through all the resonators in the same direction and returns through the interaction space. That all the segments are in phase and the interaction space field is independent of angle may be seen. That there is but one π mode is also seen from the fact that the cos 4θ term corresponds to zero potential on all the anode segments. The first Hartree harmonic for the $n = 1$ mode, namely that for which $p = 1$, having seven repeats ($k = 7$) or a total phase shift of 14π radians around the anode, is also plotted in Fig. 23 in addition to the fundamental. The fact that it yields the same variation of anode segment potential around the anode as the fundamental is apparent.

If the system of N resonators were shock excited it would oscillate in all of its modes simultaneously, producing beats in a manner analogous to but considerably more complicated than that for the system of two resonators already discussed. Furthermore, if the system were forced to oscillate by an external drive whose frequency can be varied, the ad-

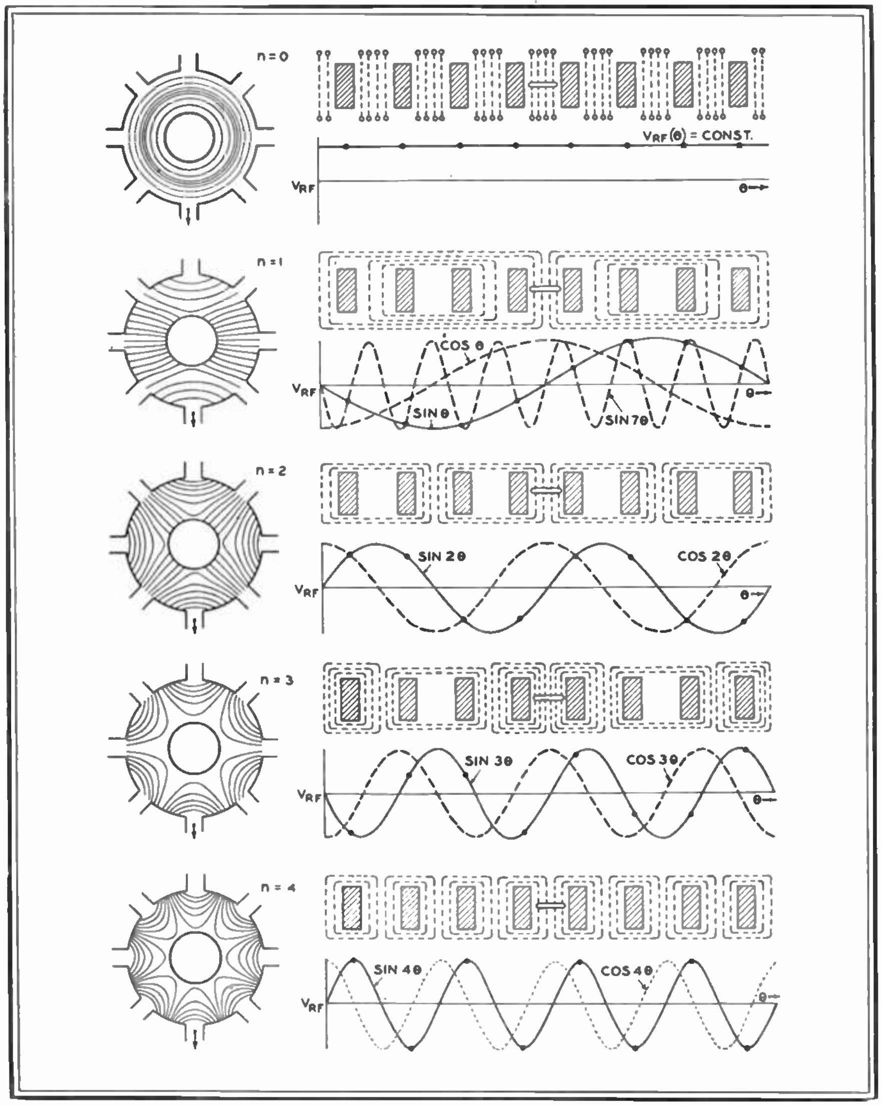


FIG. 23. Configurations of electric fields, magnetic fields, and anode potentials for the $n = 0, 1, 2, 3$, and 4 modes of a resonator system having eight resonators. For each field pattern of periodicity n, the configuration of the electric lines force in the magnetron interaction space is shown at the left, the configuration of the magnetic lines threading the resonators is shown at the upper right, and anode potential waves are shown at the lower right. The interaction field plots represent only the fundamental components in each case. The higher harmonics would affect the fields as plotted most radically near the slots in the anode surface. The arrow shown in one of the slots in each case indicates the resonator which is coupled to the output circuit. The field lines in each plot are spaced correctly relative to one another but not relative to those in any other plot. In the plot of magnetic field lines in the resonator system (shown as dashed lines), the anode is developed from the cylindrical case, the anode segments being represented by the shaded rectangles. At the center is a representation of the output loop. The magnetic lines for the $n = 0$ mode thread through each resonator in the same direction and back through the interaction space in the opposite direction as indicated by the open circles at the ends of the lines. For each mode the magnetic lines are shown for the instant when RF current flow is maximum and all anode segments are at zero potential. In the plots of anode potential, the full lines represent the potential variations with azimuthal angle θ of the fundamental components in $k\theta$, $k = n$. θ is measured from the position of the output coupling loop. The full circles on these curves indicate the potentials of the anode segments. The dashed lines represent the cos $k\theta$, $k = n$, modes. It should be noted that the cos 4θ configuration is trivial as it yields zero potential on each anode segment at all times. The cosine curves may also be taken to represent the azimuthal variation of magnetic field intensity which is in time quadrature with respect to the corresponding sine curves of potential. Similarly, the sine curves may represent magnetic field intensity corresponding to the cosine curves of potential. For the $n = 1$ mode the potential variation for the second Hartree harmonic ($n = 1$, $p = -1$) is also plotted (actually sin 7θ is plotted instead of sin -7θ for comparison with sin θ). It is to be noted that it corresponds to the same anode segment potentials as its fundamental.

mittance of the system would go through a minimum at each of the mode frequencies. With each such resonance there are associated values of the Q's, characteristic admittances, energy storage capacities, and the like.

The loading of the two modes of the same value of n by the output circuit of the magnetron depends on the position of the output loop relative to the respective standing wave patterns. If the output coupling loop forms the asymmetry discussed above, one of the modes is strongly coupled and the other weakly coupled. The strongly coupled mode is that for which the anode potential wave is sine-like with respect to the cavity containing the output coupling loop as origin. In this mode the current and hence the magnetic flux in the output cavity is maximum. The fact that one of the modes of periodicity n is weakly coupled may be of significance in magnetron operation. As will be discussed later, oscillation in a loosely coupled mode, having a high Q by virtue of its being damped only by losses in the resonator system itself, may build up more rapidly under electron drive than that of the π mode. Then it is possible for the magnetron to oscillate either steadily under certain conditions, or intermittenly, in an unwanted mode. For this reason it is usually necessary to provide a second asymmetry in the anode structure so as to shift the standing wave patterns of the two modes of same n most likely to offend and in this way to equalize their coupling to the output.

6.4 *Higher Order Modes:* To this point in the discussion the RF circuit of the magnetron has been assumed to behave like a string of N lumped circuits coupled together in a ring, each circuit having only one natural frequency of resonance. This structure, as has been seen, has N modes of oscillation. Actually the multicavity resonator, since its constants are distributed, has an infinite number of modes of oscillation. They are to be distinguished by the nature of the variation of the RF field along the axis of the resonator system and radially in the individual resonators. Thus there may be nodal planes passing through the resonator system normal to its axis, or nodal cylinders, concentric with the axis of the system, passing through the resonators. The modes may be classified as symmetric or antisymmetric depending on whether the two ends of the system are in phase or π radians out of phase. The variation of RF voltage along the anode length is a circular sine or cosine function if the mode frequency is greater than the resonant frequency of the unstrapped resonator system and is a hyperbolic sine or cosine function if the mode frequency is less. The fundamental multiplet of N modes discussed above are symmetric modes corresponding either to no variation or to a hyperbolic cosine variation of RF voltage along the length. In these modes of the resonator system the cavities, considered as radial shorted transmission lines, resonate in their fundamental modes. Generally the frequencies of the higher order modes of the resonator system are quite far removed from those of the fundamental multiplet and only rarely need be considered.

6.5 *Other Types of Resonators:* As alluded to earlier, other types of magnetron resonators have been devised which can supply the proper alternate π mode potentials to the segments of a multisection anode. Two of these which have received some consideration by magnetron designers but which have not come into general use will be mentioned in passing. One, the so-called *serpentine* anode structure, consists of a single slot, cut into the anode body, which winds up and down the anode length and around the interaction space. It is essentially a *half-section* wave guide, closed on itself, oscillating in its fundamental at the cut-off wavelength. As one passes along the resonator, the field for this mode is uniform, but, by virtue of the geometrical arrangement, the field it supplies to the interaction space is π radians out of phase from gap to gap. Other modes correspond to integral numbers of wavelengths along the length of the serpentine resonator. The separation in frequency between the fundamental and the next highest harmonic generally is not as great as is desirable.

The other magnetron resonator system to be mentioned involves the use of a single toroidal cavity of rectangular cross section whose inner cylindrical surface has been removed. Across this opening are placed the anode segments, adjacent ones being connected to opposite sides. The fundamental of this cavity corresponds to the cut-off wavelength as in the serpentine structure. This cavity has been mentioned in the literature[20] and has received some attention during the war. It is most useful in low voltage CW magnetrons where the small interaction space makes possible a resonator with sufficiently great mode separation between the fundamental and first harmonic.

[20] This resonator is the so-called "turbator" discussed by F. Lüdi, Bull-Schweitz. Elektrotechn. Verein, Vol. 33, No. 23 (1942).

4th installment will appear next month

B.B.C. FIELD TRIALS OF FM

(CONTINUED FROM PAGE 23)

of the designer. For high-power transmitters, any difference in cost in the two methods would seem to be unimportant, although for low-power transmitters the cost may be a factor of importance.

Lack of space forbids discussing these FM transmission systems in any greater detail.

To obtain the maximum range, a high transmitting aerial is needed and a mast sited on a hill will usually be adopted. About 500 feet seems the optimum mast height to carry arrays having some gain over a dipole.

Wide-Band AM with Limiter ★ This system has been proposed as an alternative to FM from the point of view of the suppression of impulsive interference. In this system a wide-band receiver is used with a special form of amplitude limiter. The wide-band receiver is necessary in order that any impulse of short duration may conserve its shape in the receiver itself, where it can then be suppressed by a special form of limiter which is sensitive to short-duration impulses, but is insensitive to modulation. In any such arrangement, however, unless the duration of the impulse and the time constant of the limiter are much less than the time for one cycle at the highest audio frequency, AF distortion of the high frequency components will result. Tests which have been carried out with this system indicate that for the suppression of impulsive interference it is about as good as FM, if it is suitably adjusted. Whether the arrangement would remain in satisfactory adjustment in the hands of the public is not known. The cost of a receiver incorporating a limiter might be somewhat less than the cost of an FM receiver. The disadvantage of this arrangement is that no suppression of random noise takes place. It would suffer from the same disadvantage as AM in this respect, and the service area would therefore be considerably reduced. Generally speaking, it is thought that if ultra-short wave broadcasting is used, FM is the better system.

Pulse Modulation ★ This system was proposed many years ago, and has been developed considerably and used during the war. In this system, pulses of comparatively short duration, and having a repetition frequency considerably higher than the highest audio frequency, are modulated in duration, phase, or repetition frequency. As the amplitude of the pulses does not vary with modulation, a limiter can be employed in the receiver, and interference and noise may be reduced. Pulse-duration modulation can be received on an AM receiver without any modification, although if this is done no advantage can be obtained by the use of a limiter. Pulse-phase and pulse-frequency modulation require a special type of receiver. In general it can be said that, as in Frequency Modulation, the advantage from the point of view of signal-to-noise ratio increases as the band width is increased, but for the same band width as is normally used for FM the advantage over AM is small, and FM is the better system. Therefore if single-channel systems are compared, there is no doubt that FM has the advantage.

(CONCLUDED ON PAGE 54)

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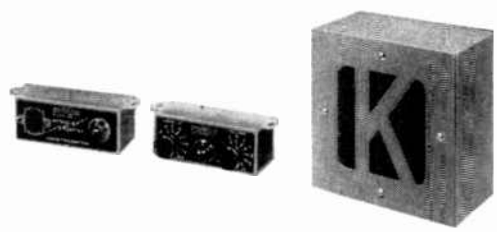

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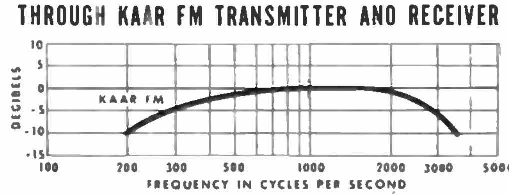

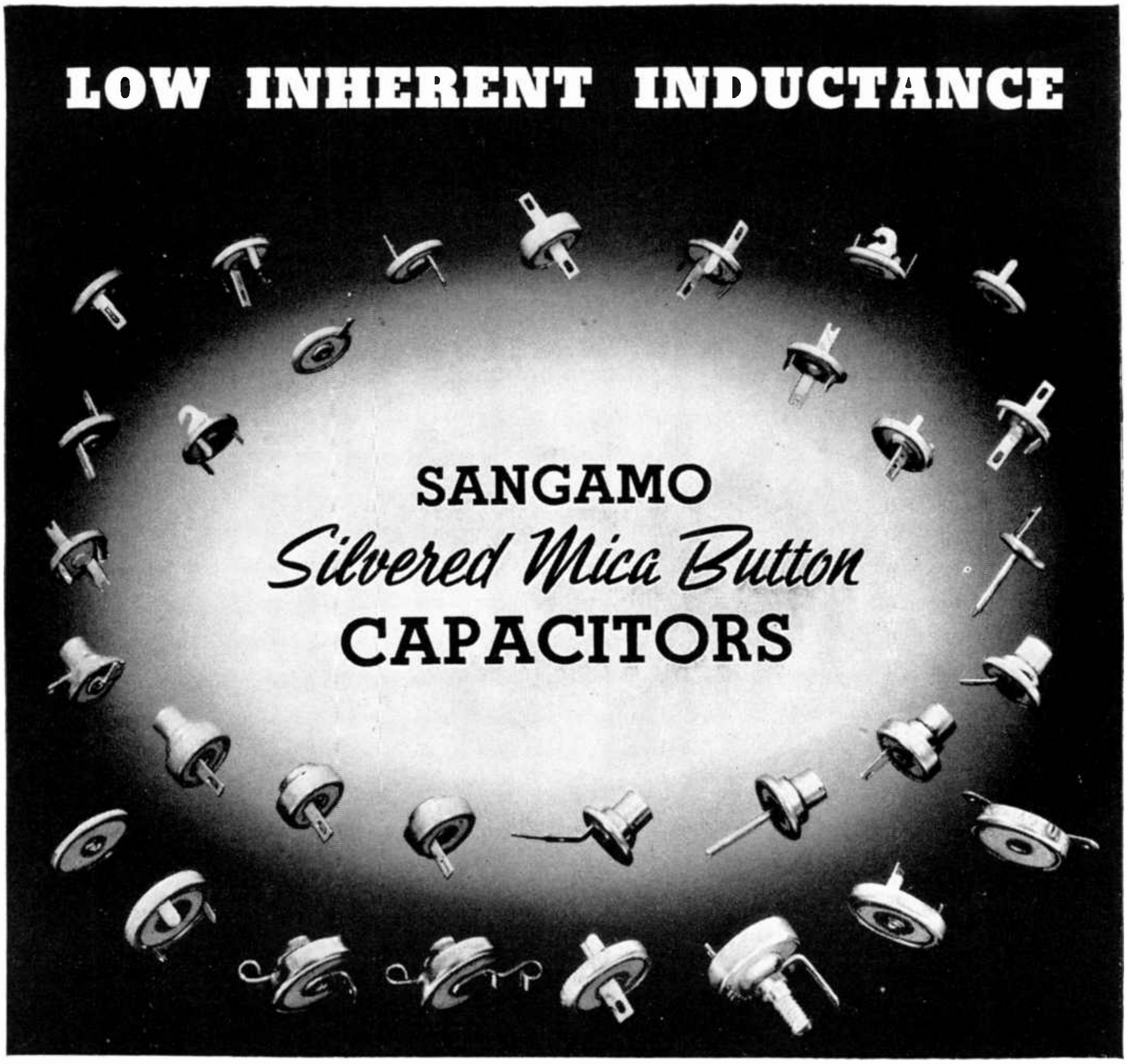

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SPOT NEWS NOTES

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buildings and antenna. Transmitter will be a 1-kw. Federal installation, with a 240-ft. Blaw-Knox tower, carrying two square loops. RCA and Collins are supplying the associated equipment. Frank Kear is the consultant, and Fred A. Semens is handling the studio design.

Ben Adler: Former chief facilities engineer of American Broadcasting Company has been appointed vice president in charge of engineering for Transmitter Equipment Manufacturing Company, Inc., New York City.

Receiving Antennas: Kings Electronics Company, 372 Classon Avenue, Brooklyn 5, has set up a new department for the design and manufacture of FM and television antennas. J. H. Robinson will handle the planning of special types engineered to set manufacturers' specifications.

FM Demonstrations: WTMJ-FM recently staged an educational program for over 300 science teachers who attended the Wisconsin State Teachers Convention. Phil Laeser and Edward Cordes explained the technical advantages of FM over AM, as an introduction to a 1-hour demonstration of sound effects and live talent broadcasting.

Television Receivers: Among the television receiver models now being readied for production are two which G.E. will produce at their Bridgeport, Conn., plant. One is a direct-viewing console, giving a picture 10 ins. wide, while the other is of the projection type, with the picture 21 ins. wide. Both cover the 13 television channels.

Scott Radio Laboratories, Chicago, has a video receiver planned to operate in conjunction with their regular sound broadcast receivers. That is, the television unit, using a 12-in. direct-viewing tube, plugs into the radio receiver for sound.

Recorders and Turntables: An interesting and well-illustrated catalog of studio and portable types of recorders and turntables has just been issued by Fairchild Camera & Instrument Corporation, Jamaica 1, N. Y. Detailed performance characteristics are given for each model.

FM Rates: New York station WGHF, operated by Capt. W. G. H. Finch, has issued a rate card for FM time. Rate after 6:00 P.M. is $100 for 1 hour, $60 for 30 minutes, and $40 for 15 minutes. Price for 1 minute spot announcement is $10. Before 6:00

(CONTINUED ON PAGE 52)

Answers to your Questions about the SHURE "556" *Super-Cardioid Broadcast Dynamic*

Q. *What is meant by Super-Cardioid?*

Answer: Super-Cardioid is an improvement on the cardioid (heart-shaped) pickup pattern, which makes it even more unidirectional. "Super-Cardioid" reduces pickup of random noises by 73% as compared to 67% for the Cardioid, and yet has a wide pickup angle across the front.

Q. *To accomplish this, is it necessary to have two Microphones in a single case?*

Answer: No. The Shure "556" is designed according to the "Uniphase" principle, a patented Shure development which makes it possible to obtain the "Super-Cardioid" pattern in a single compact, rugged unit.

Q. *Over what range does the Shure "556" give quality reproduction?*

Answer: The Shure "556" provides a high degree of directivity, both horizontally and vertically over a wide frequency range from 40 to 10,000 cycles.

Q. *Does the Shure "556" reduce feedback?*

Answer: Yes! Reflected sounds and "spill-over" from loud speakers entering from the rear are cancelled out within the Microphone.

Q. *Can the Shure "556" be used outdoors?*

Answer: Yes. It is insensitive to wind and will withstand heat and humidity. The low impedance models may be used at practically unlimited distances from the amplifier.

Q. *Can the Shure "556" be used for Studio Broadcasting?*

Answer: More than 750 Radio Broadcast Stations in the United States and Canada use the Shure "556" in their studios. Because it can be placed with its back to the wall without picking up reflected sounds or echoes, it facilitates Microphone placement.

Model 556A for 35-50 Ohm circuits—
LIST PRICE $82

Model 556B for 200-600 Ohm circuits—
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SHURE BROTHERS, Inc.

Microphones and Acoustic Devices

225 West Huron Street, Chicago 10, Illinois

CABLE ADDRESS: SHUREMICRO

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SPOT NEWS NOTES

(CONTINUED FROM PAGE 50)

P.M., rates are one-half those given here. Regular agency commission is allowed, with discounts for time contracts. It is interesting to note that commercials are limited to 6 minutes during 1 hour, 3 minutes in ½ hour, and 2 minutes in ¼ hour.

December Shipments: Sudden end of the coal strike was welcomed by radio manufacturers and dealers, because threatened freight and express embargo would have cut the month's billings and retail sales by a considerable amount. This was particularly fortunate for FM set production, now rolling at last, because most models are big and heavy.

Temporary FM Antennas: An inexpensive FM broadcast antenna which can be carried on a temporary support is available from Andrew Company, 363 E. 75th Street, Chicago 19. Called the "Folding Quadruple", it is intended for low-power, interim operation, so that FM stations can get on the air in the period specified by the FCC Construction Permits. Shipment is promised within 7 days after receipt of order.

Transmitter Shipments: According to word from Norman Wunderlich, Federal Telephone & Radio is averaging to ship 3 FM transmitters of 3 and 10 kw. output each week. At least 25 of these are scheduled to be on the air by January 1st.

Fremont, Ohio: First station to put FM on the air in northwestern Ohio is WFRO, owned by an independent group of veterans. The station has started operation with 300 watts on 104.7 mc. Power will be upped to 1 kw. early in 1947. A substantial amount of time was sold before the station was completed, according to president Robert F. Wolfe. The station is on the air 8 hours each day.

Mike Light: We've often wondered why microphones aren't fitted with signal lights to show when they are cut in. To be sure, it would mean a change in the standard microphone cable and connectors, and in the console wiring, perhaps. On the other hand, it would eliminate that psychological hazard from the feeling of uncertainty engendered by a microphone which looks just the same whether it's dead or alive. Also, it would discourage some of those post-program remarks that all-too-frequently get on the air by mistake!

Television Stations: The FCC has issued CP's to Crosley Broadcasting Corporation for transmitters to be operated at Cincinnati and at Columbus, Ohio. The former, WLWT, will have 34 kw. of video power on channel 4, 66 to 72 mc., while the latter, WLWC, will have 48 kw. of video power on channel 3, 60 to 66 mc.

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NOTE: No. 1, *November 1940 to April 1941 is out of print*

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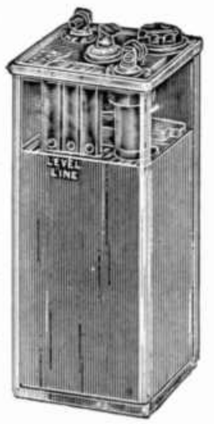

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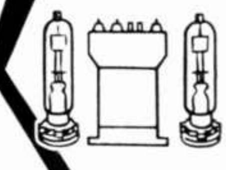

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B.B.C. FIELD TRIALS OF FM

(CONTINUED FROM PAGE 42)

Pulse modulation permits multi-channel operation in a fairly simple manner by the time selection of pulses. For example, in a four-channel system, the 1st, 5th, 9th pulses, etc., would be used for one channel, the 2nd, 6th, 10th for the next, and so on. The pulse repetition frequency would have to be increased in proportion to the number of channels, and the band width similarly increased. Such an arrangement offers possibilities for broadcasting, where it is desired to transmit a number of programmes simultaneously from the same site. But while a considerable amount of development work has been done during the war for military purposes, very little, if any, has been done from the point of view of a broadcast service.

An advantage of any pulse modulation system, and in particular of a very wide band system such as that necessary for multi-channel working, is that frequency constancy is of less importance, and therefore oscillator drift in the receiver is also less important. Another advantage is that the limiter is placed after the final detector and it may therefore be possible to achieve the overall receiver gain more economically.

7. CONCLUSIONS

1. The use of ultra-short waves for broadcasting would relieve the present congestion in the medium- and long-wave bands as soon as a sufficient number of suitable receivers were in the hands of the public.

2. The use of Frequency Modulation on ultra-short waves would immediately and considerably extend the area of noise-free, high-quality reception.

3. A reasonable number of frequency-modulated ultra-short wave transmitting stations could be arranged to provide a service throughout the United Kingdom.

4. The increased cost of a broadcast receiver incorporating an ultra-short wave FM band is unlikely to be excessive. It seems probable that with suitable development the performance of FM receivers could be improved and the cost reduced.

5. It is thought that Frequency Modulation would be superior to pulse modulation for providing a high-quality broadcasting service in this country, even taking into account the possibility of using a multi-channel system, because pulse modulation requires a wider band width than Frequency Modulation to realise a given improvement in noise suppression over Amplitude Modulation.

6. For an ultra-short wave FM service in this country, the following characteristics are thought to be optimum:

maximum deviation: 75 kc.
pre-emphasis: 50 microseconds
carrier channel spacing: 200 kc. (400 kc. between transmitters serving the same geographical area)

1000 Watts of FM Broadcast Satisfaction

Collins FM transmitters are fully engineered in every detail. They reflect many years of successful experience in designing and manufacturing broadcast transmitters unexcelled in performance and reliability. Persons who attended the NAB convention in Chicago were noticeably impressed with the 732A on exhibition there.

The Collins 732A Ikw FM Transmitter

What they saw:

RELIABILITY: They saw thorough design in every part of the equipment — Oversized components in all circuits—Personnel protection by means of electrical and mechanical interlocks—Overload protection—Proper ventilation. This transmitter is as substantial as it looks. Our engineers have the experience and know-how to design long and trouble-free life into radio equipment.

STYLE: The modern yet conservative exterior, with its three-tone gray finish, is attractive today and will be ten years from now. The beauty of Collins FM transmitters extends throughout the equipment. Chassis layout is symmetrical, roomy, and functional. Vertical construction and hinged chassis design provide utmost accessibility.

What they didn't see:

PERFORMANCE: They couldn't see the performance characteristics as measured in actual operation. Measurements show a carrier stability within ±200 cps. Distortion is less than 1.0%. The frequency response is within 1.0 db total variation from 50 to 15000 cps. The noise level is at least 65 db below 100% modulation.

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FIGURE the cost of a BROWNING Universal FM-AM Tuner and power supply, plus the kind of speaker and amplifier you prefer to use. Then compare that total with the price of a cabinet-type radio of equivalent performance.

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But the BROWNING Tuner offers more than a saving in cost. It assures the true quality of FM reception which only the genuine Armstrong circuit can deliver, plus the exact tone you want from a power amplifier and speaker of your own choosing! In addition, it provides AM reception with a stage of tuned RF, and connections for a record-player if you want one.

Such flexibility makes the BROWNING Tuner ideal for home installations, public auditoriums, skating rinks, and dance halls and with the rack mounting, for broadcast station monitor systems.

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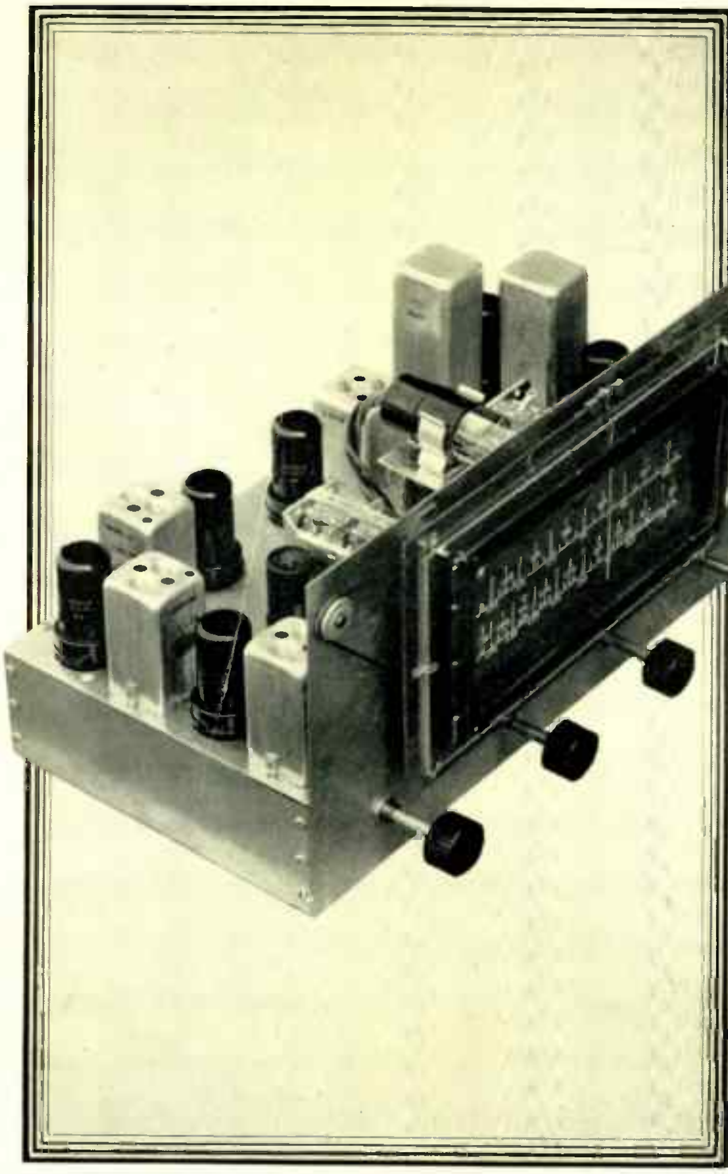

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SPECIFICATIONS ON THE RJ-12 TUNER

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 FCC.

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 furnishes AVC voltage and AF output to the 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 in the FM section assure high 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.