PRICE FIFTY CENTS

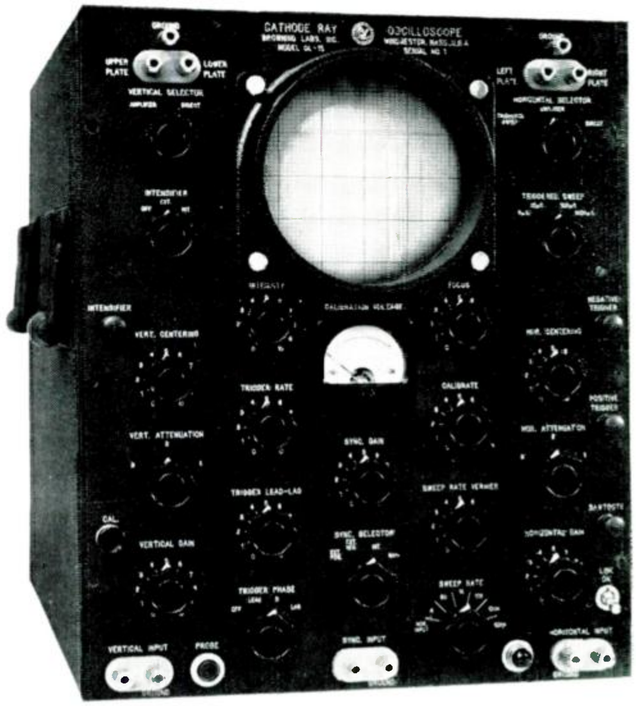
FM AND TELEVISION

MAR. 1947

DESIGNS WHICH ELIMINATE "RADIO FURNITURE"

(SEE PAGES 3 AND 31)

★ ★ Edited by Milton B. Sleeper ★ ★



MODEL OL-15

Developed to Meet the New Requirements of Peacetime Research. Price $1275.

The Improved BROWNING Oscilloscope

A Superior Design, Engineered for Engineers

The BROWNING model OL-15 oscilloscope is equipped with a 5-in. tube operated with an accelerating voltage of 3,000 to give increased intensity and definition of images. Among the operational features of the associated circuits are:

1. Sawtooth sweep for frequencies of 5 cycles to 500 kc.

2. Single sweep-triggered time base for transient phenomena of varying rate of repetition.

3. Internal trigger generator and built-in phasing circuit for single-sweep time base.

4. Vertical amplifier flat to ±10% of average value from 20 cycles to 4 mc. Input deflection sensitivity .05 RMS volts per inch.

5. Horizontal amplifier flat to ±10% of average value from 20 cycles to 1 mc. Deflection sensitivity .1 RMS volts per inch.

Other advantages are described in detail in the descriptive folder which will be sent on request.

THE BROWNING model OL-15 oscilloscope affords advantages over other laboratory types in two essential respects. First, the range of flat frequency response has been extended. Second, measurements and observations can be made with this instrument, because of added facilities, that are impossible with other oscilloscopes.

To these operational advantages BROWNING LABORATORIES have added another reason for choosing this instrument: It costs no more than oscilloscopes of relatively limited capabilities.

For measurements on AM and FM broadcast and communications equipment, or television, radar, and facsimile apparatus, we suggest that you give careful consideration to advantages of the BROWNING model OL-15 when you purchase a new oscilloscope.

Another Product of the

BROWNING LABORATORIES, INC.

WINCHESTER • MASSACHUSETTS

Canadian Representative: Measurement Engineering, 61 Duke St., Toronto

FM AND TELEVISION

FORMERLY, FM MAGAZINE and FM RADIO-ELECTRONICS

VOL. 7 MARCH, 1947 NO. 3

CONTENTS

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THIS MONTH'S COVER

How can we provide full FM performance without making sets cost so much as to limit the market? That is the No. 1 problem of the industry today, for it is certain that there is a limit to the number of FM-AM receivers that can be sold at prices which start at $500.

Walter Buehr, artist, industrial designer, and FM enthusiast says: "You can't take it out of the radio without cutting the performance. So the thing to do is to take the radio out of the furniture." This argument, as he presents it on page 31, may revolutionize postwar set designs. This month's cover shows Walter Buehr in his New York studio on East 35th Street.

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MEMBER, AUDIT BUREAU OF CIRCULATIONS

WHAT'S NEW THIS MONTH

1. Tele-Strategy

2. What is Standard?

1. It seemed as if FM took a terrible beating at the time of the FCC hearings which were concluded in 1945, but that was nothing to the job that is being done on color television.

The sequential vs. simultaneous color transmission has degenerated into an out-and-out slugging match, with CBS-sequentials standing toe-to-toe with NBC-RCA-Dumont-Philco-simultaneous exponents swapping haymakers.

CBS-Goldmark claims that "it is grossly inaccurate to call the sequential system a mechanical one" because it can be just as electronic as the simultaneous system. Furthermore, he insists that he saw at RCA's Princeton demonstration none of the fundamental qualities such as high color-fidelity and resolution apparent in the CBS sequential system, and at Princeton, "for the first time in my experience with color television, I was conscious of eyestrain."

Back came Philco-Bingley with a kidney punch assertion that the CBS mechanical equipment is so deficient at the present time that, "In 7 out of 8 test locations within 25 miles of the transmitter in New York, a color picture could not be seen even when elaborate antenna installations, far too costly for the average home owner, were resorted to . . . perhaps the most surprising of all is the fact that proponents of this mechanical system of color have asked the FCC to accept their standards as commercially acceptable when practically no field tests under actual home conditions had been made until last week."

(CBS claims to have assembled more field-test and propagation data than anyone else.)

RCA-Engstrom let loose a hook to the jaw with the claim that the all-electronic, simultaneous system is superior because of its freedom from flicker, greater brightness, absence of color fringe and breakup, greater possibilities as to color fidelity and picture brightness for pictures of comparable size, less band width, more flexibility for network operation, and its compatability with present black-and-white equipment.

And so it went, round after round, until both sides were talked out. The FCC will render a technical decision, since neither side was able to score a knock-out.

(CONTINUED ON PAGE 70)

FM

. . . a challenge to the radio industry

Frequency Modulation radio is out of the theory and experimental stage. FM is now a commercial reality, ready to provide the public with radio communication far superior to anything known in the past. *In fact, FM has obsoleted old-fashioned AM radio.*

This simple fact presents the radio industry — including the manufacturers, the dealers and the broadcasters — with the biggest single challenge in radio history — and with the biggest single opportunity.

The opportunity lies in the greater service made possible by FM's superior quality of radio transmission, and its vastly improved coverage through greater numbers of non-interfering stations. The opportunity is equally apparent in the enormous new markets which such advance opens for the radio industry.

The challenge lies in the *manner* in which these opportunities are acted upon. They can be *developed* to the great and mutual advantage of the public and the radio industry. Or they can be *exploited* for the short run gain of a few and permanent harm for the many.

The opportunity will best be realized and the challenge squarely met:

— If manufacturers see to it that the true advantages and quality of genuine Frequency Modulation are built into every piece of FM broadcasting and receiving equipment.

— If dealers are careful to demonstrate the true performance and educate the public on the selection, use and enjoyment of bona fide FM receivers.

— If broadcasters are quick to bring new FM stations to high power levels of efficient signal transmission and coverage.

— In short, if all the components of the radio industry will work together to give the public the full advantage of Frequency Modulation *from the outset.*

FM has been pioneered, proven and is now in mass production. We have entered a new era of radio. The public is entitled to the best from FM from the beginning.

Edwin H. Armstrong

ADVERTISERS INDEX

ENGINEERING SALES

Los Angeles: W. S. Harmon Co., manufacturer's agents covering California and Arizona, has moved to permanent quarters in a new building at 830 W. Venice Boulevard, Los Angeles. W. S. Harmon was formerly vice president and chief engineer of Hoffman Radio.

Collins: Russell B. Rennaker, W9CRC, has joined Collins Radio as broadcast sales manager. Prior to war service in the OSS, he was with Federal at Newark and Chicago, and with CBS as engineering supervisor. Robert H. Hollister, who joined Collins in 1945, has been named assistant.

Heintz & Kaufman: Have appointed E. V. Roberts & Associates, 6516 Selma Avenue, Hollywood, as representatives in southern California and Arizona.

Jensen: Grant Shaffer, formerly sales manager of Stancor's distributor division, will represent Jensen Manufacturing Company in Michigan. He will make his headquarters at 6432 Cass Avenue, Detroit.

Emerson: Charles O'Neil Weisser has been appointed sales manager for Emerson Radio and Phonograph Corporation. For the past 10 years, he was Emerson's western divisional manager.

Hallicrafters: Jack F. McKinney, of Dallas, is now southwestern regional representative for Hallicrafters. Previously, he represented only the Echophone division.

General Instrument: Has opened a regional sales office in the White Memorial Building, Syracuse, New York. Raymond D. Griffiths will be in charge as district manager.

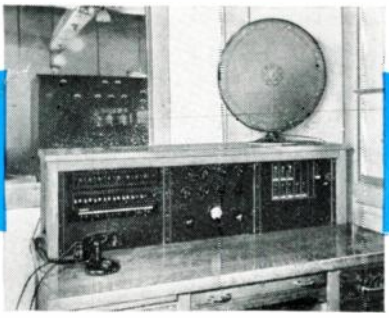
RCA: Dealer meetings were staged in Los Angeles on February 26–27 by Leo J. Mayberg Company, RCA Victor distributor, to mark the launching of television set sales in that area. Four models were shown: two table types, a direct-viewing console with FM-AM radio and phonograph, and a projection-screen console with FM-AM broadcast and short-wave reception.

Raytheon: Headquarters for Raytheon's receiver tube sales division have been established at 445 Lake Shore Drive, Chicago. All sales and promotion activities of this division will be directed by sales manager Ernest Kohler, Jr.

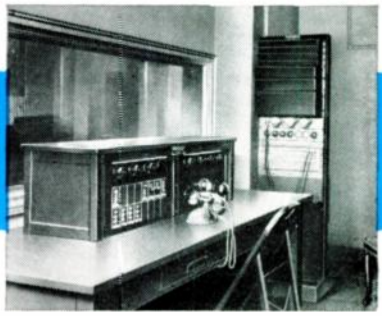
(CONCLUDED ON PAGE 69)

Why this team is out

1922. *One of the earliest audio systems,* shown here at WWJ, Detroit, used a Western Electric 8-type amplifier, with keys, jacks and plugs provided for line selection and output switching.

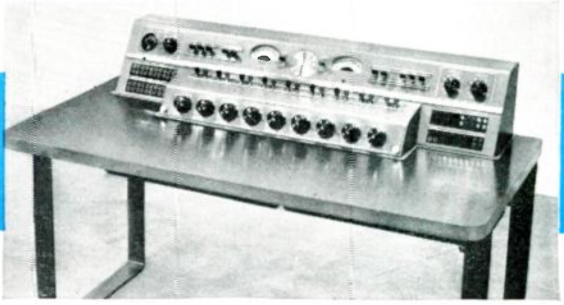


1926. *The first coordinated speech input system* was this Western Electric 7A, with all controls in a wooden console mounted on a desk. First to use rectified a-c for plate supply.



1929. Studio control equipment installed in the first New York studio of the Columbia Broadcasting System. *This was one of the first custom-built audio systems.*

1939. This custom-built audio console for WOR was the *first commercial type meeting all requirements for FM use.* It provided circuits and equipment to meet specific operating conditions. The tailored metal desks mounted amplifiers, control and switching equipment and turntable units—all within easy reach of the operator.



1946. The 25B console is an improved, enlarged version of the 25A, introduced in 1942. For either FM or AM use, the 25B provides two channels and controls two FM or AM programs simultaneously. This new equipment is compact, rugged and modern in appearance. Ease of control, instant accessibility, plug-in cable connections and a frequency response of ±1 db, 50 to 15,000 cycles are some outstanding features.

—QUALITY COUNTS—

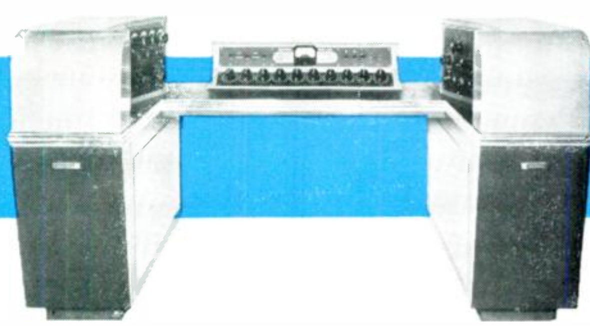
Distributed by Graybar
OFFICES IN 95 PRINCIPAL CITIES

front in Broadcast Audio Systems

1931. This smartly styled 9A audio equipment was the *first all a-c system.* All controls in a single panel; frequency response stepped up to 10,000 cycles.

1933. The factory-assembled 700 series was *the earliest to use recessed panel construction,* interchangeable for rack or cabinet mounting. For multiple channel operation, several panels were combined.

1936. The all a-c, console type, self-contained 23A studio control equipment introduced a brand new style for standardized studio units. *First studio system to use stabilized feedback.* The current 23C, with frequency response to 15,000 cycles, is widely used in AM and FM broadcasting.



1947. Typical of the custom-made broadcast audio systems being produced by the Bell Laboratories-Western Electric team is this up-to-the-minute custom console designed for KHJ, Hollywood. Custom-built equipment such as this is engineered to meet completely requirements of any station and provides the most flexible, versatile method of program control.

Ever since the Laboratories' scientists designed and Western Electric produced the first high power commercial broadcast transmitter and provided the audio facilities to go with it, this same team has pioneered in broadcast audio systems. Years of experience in the production of telephone amplifiers and switching equipment have given Bell Laboratories and Western Electric a head start in the broadcast audio facilities field—and constant research has kept them ahead.

When you need speech input equipment—for studio or portable use, standard console or tailor-made, AM or FM or both—look to Western Electric.

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.

for proved performance in FM

Specify These Federal Air Cooled Triodes

3,000 and 10,000 Watts per pair at 88 to 108 Megacycles

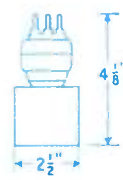
LEADING FM STATIONS all over the country report that these Federal triodes are not only living up to—but *far exceeding*—their exacting specifications, in day-after-day performance on the job.

To us at Federal, such service records are no surprise. Because long before these tubes were announced, they were subjected to the most rigorous and exhaustive development tests at the factory—for dependability, permanence of characteristics, overload capacity and long life. And in production, every tube is checked and double checked all along the line, from raw materials to finished product, to assure the utmost perfection of every detail. For complete information, write today to Dept. K520.

DATA—TYPE 7C26

Frequency, 88-108 Megacycles
(Max. Output up to 150 Mc)

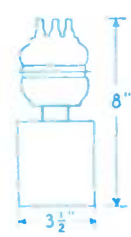
Maximum plate dissipation	1000 watts
Filament voltage	9.0 volts
Filament current	28.0 amp
Amplification factor	22
Mutual conductance	20,000 Umhos
Cooling air requirements at maximum dissipation	75 cfm



DATA—TYPE 7C27

Frequency, 88-108 Megacycles
(Max. Output up to 110 Mc)

Maximum plate dissipation	3000 watts
Filament voltage	16.0 volts
Filament current	29.0 amp
Amplification factor	27
Mutual conductance	20,000 Umhos
Cooling air requirements at maximum dissipation	175 cfm



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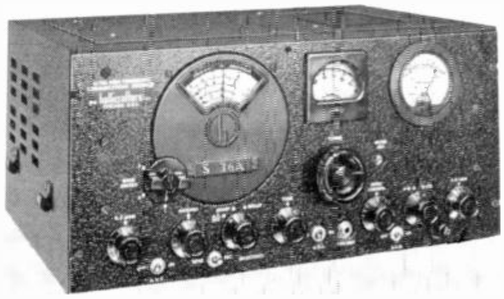
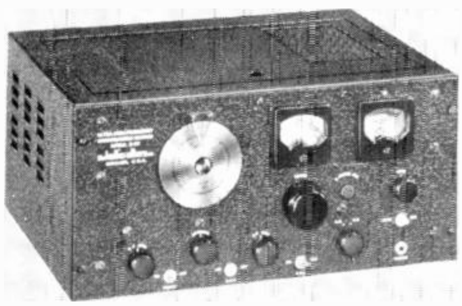


Model S-36A

The Model S-36A is probably the most versatile VHF receiver ever designed. Covering a frequency range of 27.8 to 143 Mc it performs equally well on AM, FM or as a communications receiver for CW telegraphy. Equipment like this was introduced by Hallicrafters more than 5 years ago, clearly anticipating the present trend toward improved service on the higher frequencies.

FIRST . . .



Model S-37

Model S-37 FM-AM receiver is an outstanding example of Hallicrafters pioneering work in the upper regions of the spectrum. Covering the frequencies between 130 and 210 Mc, the S-37 provides superior VHF performance. An indispensable instrument for all engaged in FM experimentation.

Model SX-42

With the introduction of the new Model SX-42 Hallicrafters further strengthens its foremost position in FM. The SX-42 offers the greatest continuous frequency coverage of any communications receiver . . . from 540 kc to 110 Mc. Tremendous frequency range made possible by new "split-stator" tuning system and the use of dual intermediate frequency transformers.

FOREMOST

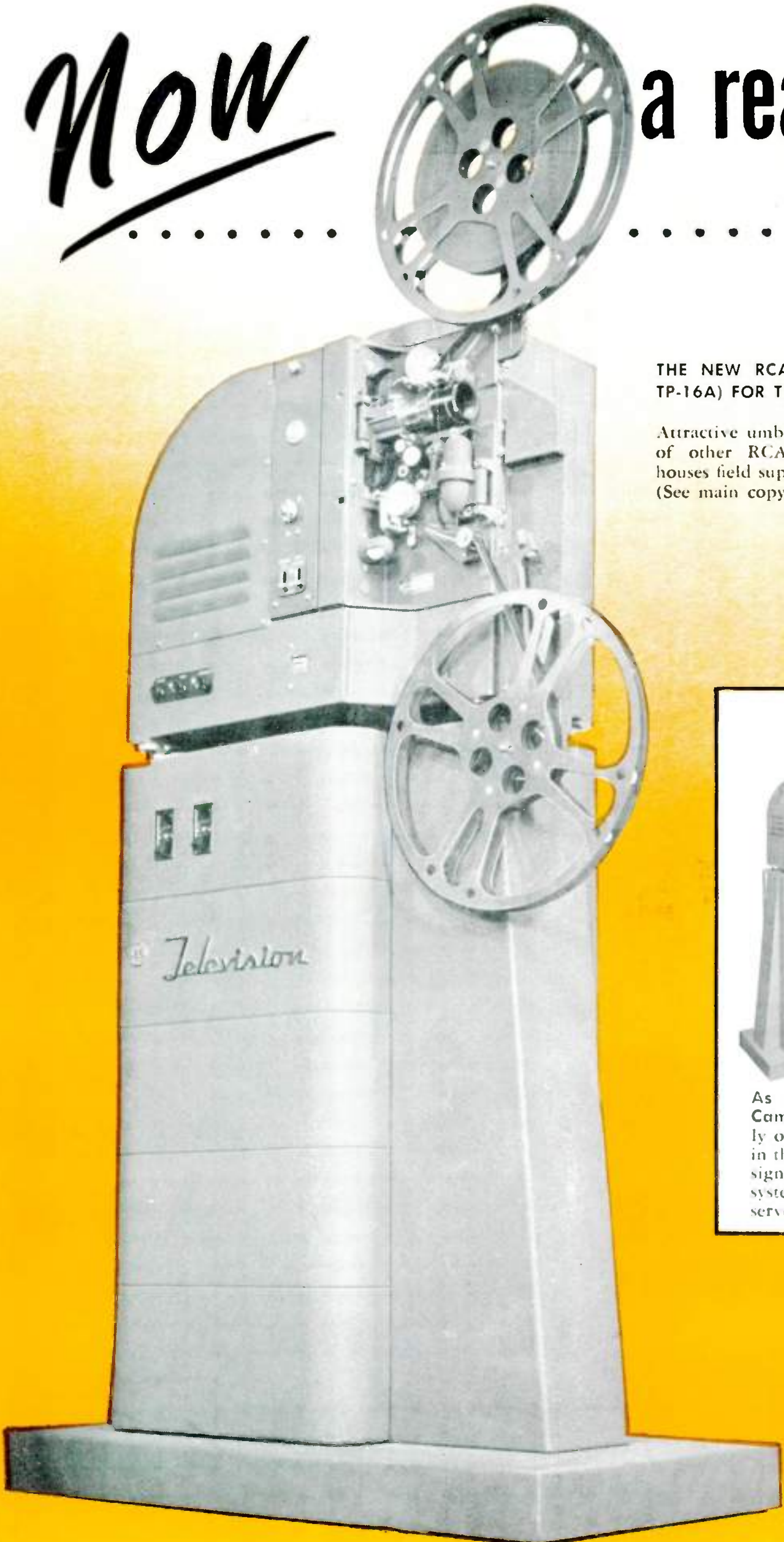
IN FM RECEIVERS

By experience and accomplishment Hallicrafters is a factor to be reckoned with in FM. This brief summary shows how models like the S-36A and the S-37 were developed more than 5 years ago—five years in advance of other commercially developed receivers. The new Model SX-42 and other FM receivers now in development will continue to maintain Hallicrafters foremost position in the highly specialized FM field. Hallicrafters will have high quality FM equipment available in every price bracket.

hallicrafters RADIO

THE HALLICRAFTERS CO., MANUFACTURERS OF RADIO AND ELECTRONIC EQUIPMENT, CHICAGO 16, U. S. A.

Now a really simple,



THE NEW RCA TELEVISION PROJECTOR (TYPE TP-16A) FOR TELECASTING 16mm SOUND FILMS

Attractive umber-gray, crackle-finish matches that of other RCA television equipments. Pedestal houses field supply and control circuits for motor. (See main copy).

As Used With RCA's TK-20A Film Camera. Pictures are projected directly on the mosaic of the pick-up tube in the film camera to obtain the video signal. By means of a mirror switching system, one camera can be used to serve a pair of projectors.

NOW that the "Sunday Supplement" era of Facsimile publicity has had its run . . . *nearly everyone wants to get down to cases*

WITH ALDEN EQUIPMENT THIS IS EASY

No Strings Attached* • *No Long Delay

FOR INSTANCE: YOU CAN ORDER A SINGLE RECORDER WITH AMPLIFIER . . . and operate it from whatever FM set you choose to use getting any experimental facsimile program that is on the air in your vicinity or operate it by wire from a scanner if there are no stations.

IF YOU ARE A BROADCAST STATION, EMERGENCY SERVICE, OR, DEALER . . . who wants to be first, and, perhaps only transmit to his window or showroom . . . you can ORDER NOW, for prompt delivery, an ALDEN UNIVERSAL SCANNER and RECORDER.

IF YOU ARE A DEALER OR EXPERIMENTER . . . and want only the mechanical part of the scanner we will supply that, you building your own amplifier. YOU DO NOT HAVE TO BUY THE COMPLETE SCANNER and cabinet that anticipates every need of the broadcaster.

IF YOU ARE AN EMERGENCY SERVICE . . . you will want our *DISPATCH SCANNER. This will not be available until later in the year. In the meantime you can prove out the value of facsimile using our UNIVERSAL SCANNER and RECORDERS, which are so simple, rugged, and compact in construction as to be entirely suitable for use by the non-technical operator.

*The ALDEN DISPATCH SCANNER—at the press of a Key picks up copy of any length, automatically; produces a signal which automatically starts the recorder on the receiving end, transmits the copy, ejects it when finished. Then it resets ready for the next message. It takes up little room.

What Can Be Ordered Now

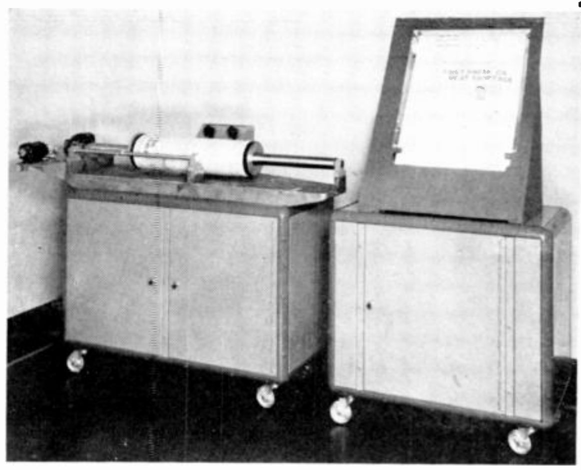
MERCHANDISERS AND PROMOTION MEN ARE GOING WILD OVER POSSIBILITIES OF THE LARGE MASTER SCANNERS AND MASTER RECORDERS

(as pictured below)

Paper — 18 inches wide.

Life size pictures appear at 3 inches a minute. A full newspaper page can be reproduced in 8 minutes.

A large size bulletin, copy enlarged to 3 times that of the original (to be visible at a distance) appears at 9 inches a minute. It's an attention-getter of the first order.



You may order now

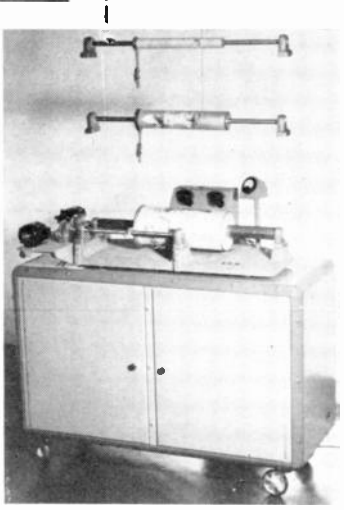
CHAIRSIDE RECORDERS—recording either 4.1 or 8.2 inches wide—With its special amplifier, it will operate from any FM set you choose. Your FM set being placed in the best position for audio-reception and the Recorder where most convenient to view.

You may order now

RECORDERS alone, either size, without cabinet or without special amplifier.

You may order now

The **ALDEN UNIVERSAL SCANNER**, with its quality signal capable of transmitting to all widths of recorders and standards of definition. Complete with cabinet, quick interlocking electronic units, or, the Scanner itself alone, or, with whatever units you may select.



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Hop a plane, or train, and talk it over with us, personally. It's a wise plan, in fact almost essential, TO FIRST PHONE FOR AN APPOINTMENT. Then we'll be sure to be ready to receive you.

WARNING Our literature is not as yet complete and comprehensive enough to tell all the story and we do not have enough trained representatives to call on you, but we want to work with you—so either come to the factory, or write us. At least get on our mailing list, to keep posted. Please tell us frankly whether your interest is **casual** or **specific**.

Alden PRODUCTS CO. 117 NORTH MAIN STREET BROCKTON 64, MASSACHUSETTS

New Audio Facilities

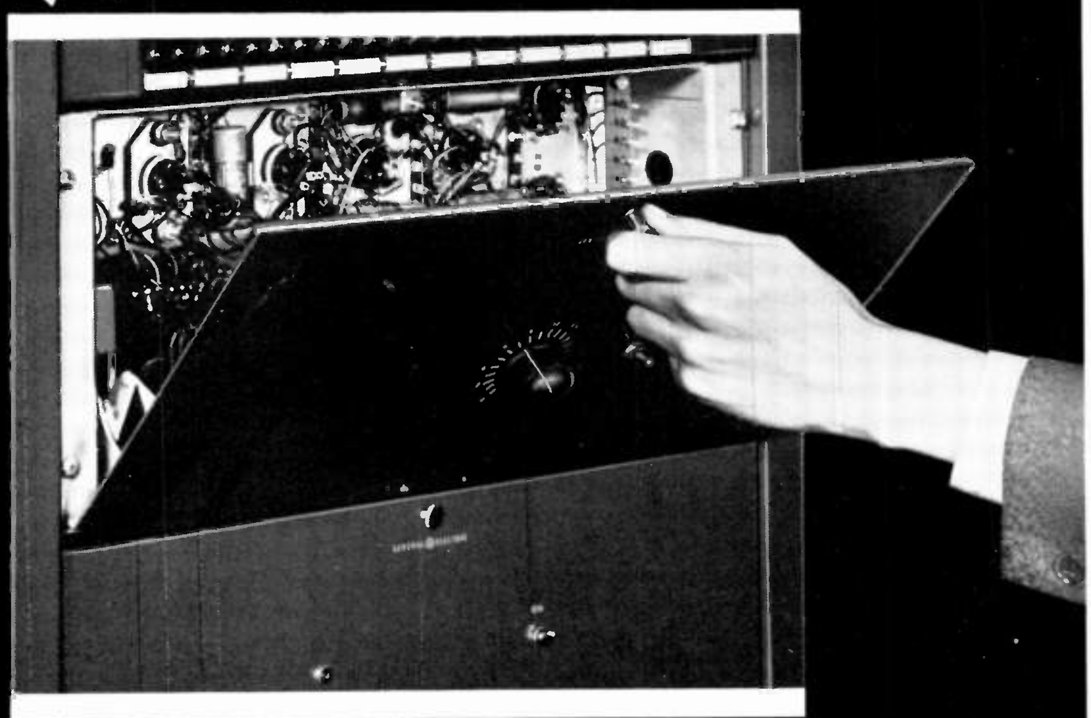

Illustration shows ease of access to Audio rack unit

COMPLETE ACCESSIBILITY

All components instantly accessible without removal of any chassis. Operating controls—switches, lights, meters, gain controls located on front panel. Tubes and plug-in electrolytic capacitors readily accessible from rear of cabinet. Permanently attached, hinged front panels serve as shelves when open, thus providing still greater convenience.

EXCELLENT PERFORMANCE

Extended frequency response, lower noise and distortion levels meet every requirement in FM, AM and TV service. More than satisfies all FCC regulations and latest RMA proposals. Any combination of input and output impedances may be used, with provisions for present 30 and 250 ohm or proposed 150 and 600 ohm microphones.

NEWLY STYLED . . . Attractively finished, mechanically clean—these handsome blue-gray audio racks are a complement to any modern studio. Recessed panel mounting and General Electric amplifier construction eliminate the need for accessory trim.

HIGHLY ADAPTABLE . . . New wiring duct affords maximum ease of installation and flexibility to meet the widest possible variety of station requirements. Full length duct covers and closely spaced wiring ports contribute to neatness of installation.

Audio Equipment Data Book FREE

Free to you for the asking is General Electric's new 44-page technical specification book that describes the new a-f amplifiers, accessories, and loudspeakers. Ask your General Electric broadcast sales engineer for a copy, or write to the *Electronics Department, General Electric Company, Syracuse 1, New York.*

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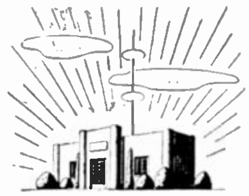

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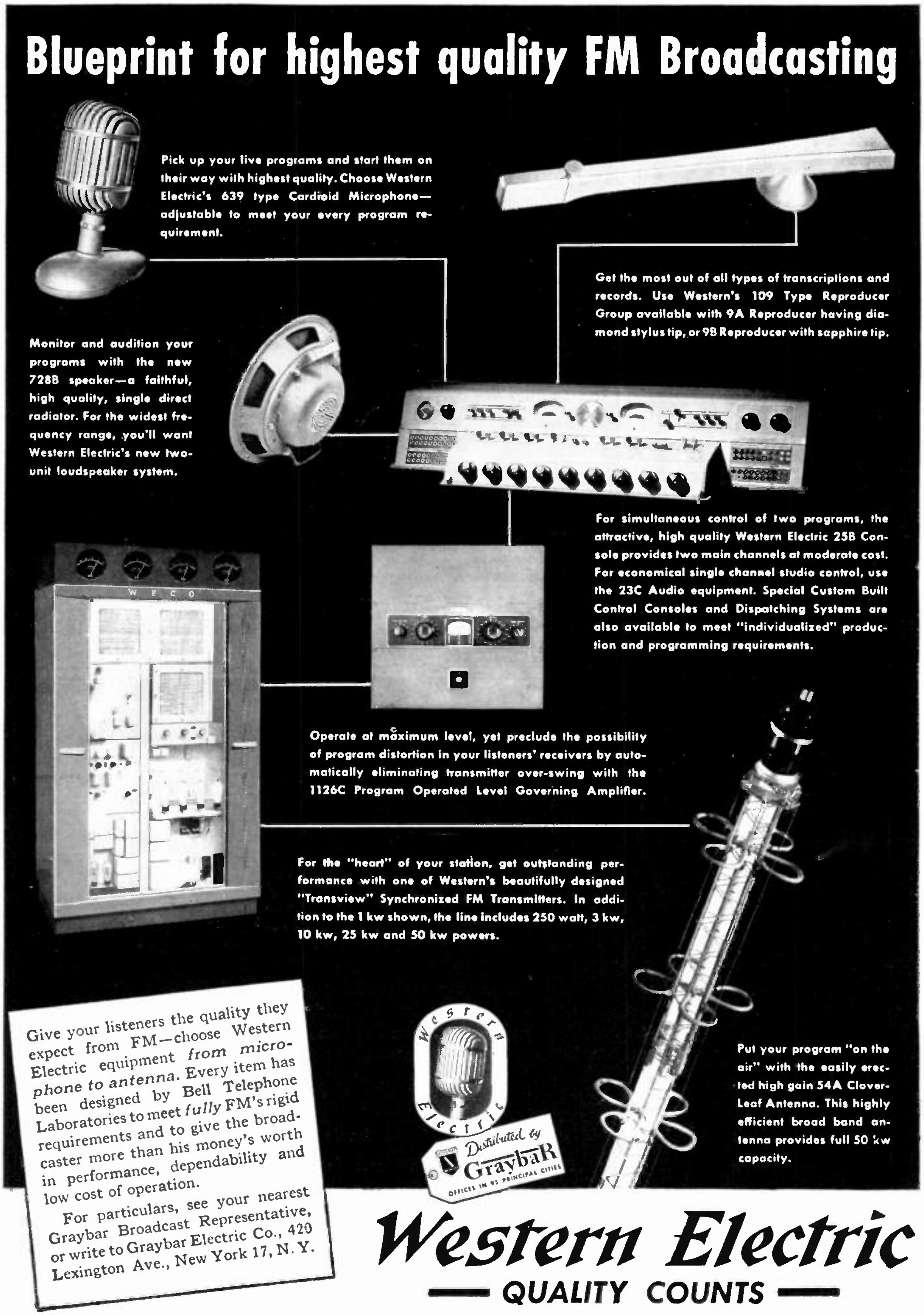
Professional Service Directory



Blueprint for highest quality FM Broadcasting
Pick up your live programs and start them on their way with highest quality. Choose Western Electric's 639 type Cardioid Microphone—adjustable to meet your every program requirement.
Get the most out of all types of transcriptions and records. Use Western's 109 Type Reproducer Group available with 9A Reproducer having diamond stylus tip, or 9B Reproducer with sapphire tip.
Monitor and audition your programs with the new 728B speaker—a faithful, high quality, single direct radiator. For the widest frequency range, you'll want Western Electric's new two-unit loudspeaker system.
For simultaneous control of two programs, the attractive, high quality Western Electric 25B Console provides two main channels at moderate cost. For economical single channel studio control, use the 23C Audio equipment. Special Custom Built Control Consoles and Dispatching Systems are also available to meet "individualized" production and programming requirements.
W E C O
Operate at maximum level, yet preclude the possibility of program distortion in your listeners' receivers by automatically eliminating transmitter over-swing with the 1126C Program Operated Level Governing Amplifier.
For the "heart" of your station, get outstanding performance with one of Western's beautifully designed "Transview" Synchronized FM Transmitters. In addition to the 1 kw shown, the line includes 250 watt, 3 kw, 10 kw, 25 kw and 50 kw powers.
Give your listeners the quality they expect from FM—choose Western Electric equipment *from microphone to antenna*. Every item has been designed by Bell Telephone Laboratories to meet *fully* FM's rigid requirements and to give the broadcaster more than his money's worth in performance, dependability and low cost of operation.
For particulars, see your nearest Graybar Broadcast Representative, or write to Graybar Electric Co., 420 Lexington Ave., New York 17, N. Y.
Western Electric
Distributed by Graybar
OFFICES IN 95 PRINCIPAL CITIES
Put your program "on the air" with the easily erected high gain 54A Clover-Leaf Antenna. This highly efficient broad band antenna provides full 50 kw capacity.
Western Electric
— QUALITY COUNTS —

THE REL CLINIC BROUGHT ENGINEERS FROM ALL OVER THE U.S., AND SENT THEM BACK WITH A NEW CONCEPT OF FM PERFORMANCE

FM CLINIC FOR BROADCAST ENGINEERS

REL Presents FM as the Standard of Broadcast Performance at 4-Day Lecture-Demonstration Course

BY MILTON B. SLEEPER

THE FM broadcast engineering clinic at the REL plant in Long Island City, held on January 20-23, marked another milestone in the progress of the radio art. On this occasion, more than 100 broadcast station engineers were shown, by a series of on-the-air demonstrations, that FM offers a new standard of performance, namely, reproduction in which nothing is added to or omitted from the original speech and music.

The REL clinic, indeed, opened a startling vista of what broadcasting can accomplish now, and what must soon become universal practice. One of the engineers who attended the 4-day meeting expressed it in this way: "After what I heard and saw, I feel that all the limitations of broadcasting I had come to accept during years of AM experience have been swept away!"

That is an accurate way to express the extent of the radical changes which FM has brought to broadcasting. But to understand the full significance of this change, it is necessary to look back to the early days of the art when Marconi and his contemporaries were seeking to perfect long-distance transmission of code messages, without the use of wires.

In that effort, over a period of years, they were eminently successful. As the early spark transmitter was succeeded by the arc, the alternator, and the vacuum tube, message transmission by continuous-wave telegraph was expanded into a world-wide service.

The perfection of continuous-wave telegraphy challenged the engineers to find a way to modulate the amplitude of the transmitter output not merely in dot-dash intervals, but in accordance with the volume and frequency of the human voice. In the end, this was accomplished, and today we have at our command the facilities of a world-wide wireless telephone system.

The success of Amplitude Modulation for speech transmission opened up another kind of public service — the broadcasting of entertainment by radio. Here, indeed, was a service that all could enjoy, and the demand for receiving sets and for stations to originate programs outran the vision of the engineers who pioneered this branch of the radio art.

More than ten years ago, it was clear that broadcast service rendered by the old system of wireless telegraphy, however skillfully modified for speech and music transmission, was deteriorating at a rate determined by the expansion of its use!

The inadequacy of Amplitude Modulation for broadcast service had become a limiting factor when Major Armstrong first announced the invention of Frequency Modulation, not as another modification of the wireless telegraphy, but a completely new system of telephone communication and broadcasting, planned to do what could not be done by applying voice modulation to continuous-wave transmission.

Purpose of the REL Clinic ★ The purpose of the REL Clinic was 1) to demonstrate to broadcast engineers that FM actually accomplishes its intended purpose of duplicating at the receiver the speech and music fed into the studio microphone, and 2) to acquaint them with transmitting equipment designed to accomplish this specific result.

Actually the difference between the type of AM receiver now in general use and an adequately-designed FM set is comparable to the difference between the first electric washing machines and the sleek automatic washers of today. Do you remember those machines? A zinc-lined, wooden tub, supported on spindly legs, carried a motor on one end, and a clattering chain drive that turned a set of wooden paddles. On the side of the tub was a maple-framed wringer, equipped with a crank and cast-iron gears that turned rubber-faced rollers.

After 25 years or so, someone got the idea of discarding a rig that merely substituted an electric motor for human back muscles, and designed a handsome machine which, at the turn of a switch, automatically performed the functions involved in washing and drying clothes!

Similarly, FM discards all previous concepts of broadcasting by means of modulated, continuous-wave transmission. Thus it is not a new variation of an old method, but a totally new system from microphone output to speaker input devised, to meet the functional requirements of broadcasting. The degree of improvement is such that any doubts in the minds of those who attended the clinic were dispelled for all time before the session ended!

Proof of Performance ★ The outstanding feature of the REL clinic was the daily demonstrations of live-talent FM broadcasting, and high-fidelity reception. For this purpose, Major Armstrong and C. R.

SETUP FOR SOUND EFFECTS AT W2AG

Runyon, Jr., set up the same arrangement they used in the original demonstrations [1] in 1935, notably for the November IRE Meeting. That is, the music and speech were originated at Mr. Runyon's home in Yonkers, N. Y., beamed with a 10-watt, 156-mc. transmitter to Alpine, where the signals were detected, fed into the modulator of W1XEA, and rebroadcast on 92.1 mc. The receiver was an REL model, working into an Altec-Lansing speaker.

As for the results — well, it's no use trying to describe them. If there were words to use, they would still be ineffective because that kind of reception must be experienced to be appreciated. Besides, it would encourage some people to make such remarks as: "That's just the way WCBS sounds since I rigged up my new amplifier." But I'm sure that CBS engineer H. A. Brown, who attended the REL clinic, would be the first to say that WCBS or any other AM station *couldn't* sound that way, even on a studio monitor!

There's a Reason ★ There's a reason for that difference between AM and FM reception of live talent, which many still do not understand. It is simply that FCC Standards of Good Engineering Practice for FM broadcast installations specify 15,000 cycles response, and limit the distortion and noise to a point where, for practical purposes, they are eliminated entirely. Thus we can say that an FM broadcast transmitter, installed and maintained in accordance with FCC standards, puts out a *perfect* signal.

AM installations could be designed to the same performance standards, but there would be no purpose because, since AM channels are only 10,000 cycles wide, AM receivers must be designed to limit response above 5,000 cycles, in order to prevent adjacent-channel interference.

In England, for example, AM audio quality is even more limited. As H. L. Kirke, of the BBC, pointed out recently [2]: "With AM on medium [broadcast] waves, wide audio-band reception would be possible were it not for the close spacing (9 kc.) of adjacent channels, and the consequent interference from distant stations at night. The majority of receivers are designed for a bandwidth of $4\frac{1}{2}$ kc., or less, in order to eliminate this interference."

Our American AM broadcast system cannot be revised to provide wide channels because the present number of channels is already inadequate, and the AM band cannot be widened.

Even if that were possible, there would be no improvement in the quality of AM reception. Static and background noise response on AM receivers is increasingly objectionable at the higher end of the limited audio spectrum now in use, with the result that listeners habitually turn down their tone controls to reduce that interference.

Accordingly, the first step toward improving audio reproduction is to eliminate the noise component of the signals fed into the loudspeaker. That, of course, is accomplished by FM transmitters which meet FCC standards, and by the use of correctly designed FM receivers.

You Can't Fool FM Listeners ★ When watches and clocks were first made, people didn't complain if their time-pieces gained or lost a few minutes a week. As long as there was no universal time standard available, who could say that his watch was not accurate?

How different it is today, when we have Western Union clocks in offices and public buildings, chronometers displayed in jewelers' windows, electric clocks in our homes, and radio time signals from every broadcast station! Today, we know whether watch or clock keeps accurate time or not, and there's no room for any difference of opinion about it.

FM has done for broadcasting what standard time has done for watchmaking. It provides *perfect* reception as a standard of performance. The human ear may be an imperfect organ in some respects, but the ear and brain are keen to detect any departure from normal sounds — as for example, the difference between voices, music, and activities heard directly, and through the medium of an electrical system that introduces distortion or interference.

Thus, properly designed FM equipment affords a true standard of broadcast reception, not at some particular degree of distortion, but with all distortion eliminated.

For example: On the first day of the REL clinic, Major Armstrong, after a brief address, announced that there would be a demonstration duplicating the original Yonkers-to-Alpine setup of 1935. Thereupon, he picked up a telephone and asked the REL operator to get Mr. Runyon at Yonkers, so he could tell him to go on the air.

While Major Armstrong was waiting for the call to be put through, we heard a telephone ring somewhere outside the lecture room, and the rattle of the instrument as it was picked up. Then a loud and cheery voice said: "Hello, Major! Are you ready to start the demonstration?"

Every engineer in the room looked up, as if to say: "What's going on here?"

Actually, Major Armstrong had played a trick on us. The relay at Yonkers, the broadcast transmitter at Alpine, and the receiver at the front of the lecture room had been turned on all the time. We didn't know it, though, because there was not the slightest background noise in the speaker.

The telephone at Yonkers was near the microphone, and when the bell rang, it came through so perfectly by FM that not a man in the audience knew he was hearing it from a loudspeaker! The setup at Yonkers is shown in the accompanying illustrations.

Such distortion-free performance does, indeed, afford a standard of broadcast reception quality for all practical, comparative listening purposes.

Significance of This New Standard ★ There is no radio subject about which there is as much discussion as *tone quality*. The only aspect of this matter about which complete agreement exists is the original speech and music. No one finds fault with that. No one has ever asked the broadcasters to modify the output of the microphone with filters or expanders in the studio controls.

But when it comes to reproduction from AM receivers, the fight begins! The line of battle starts at arguments over tone controls and fancy speaker designs, and extends all the way to listening tests and

[1] See *FM Handbook*, Chapter 1, Background of Frequency Modulation.

[2] "BBC Field Trials of FM" by H. L. Kirke, *FM and Television*, Nov. and Dec., 1946.

measurements of the tone-deafness characteristics of people's hearing equipment.

Why? Because if, at the loudspeaker output, anything is added or substracted from the original input to the microphone, the result is distortion. And when self-styled tone experts talk about one degree or kind of distortion as being superior to another degree or kind, there *can* be no agreement.

The only reproduction that is universally acceptable is that in which *no* distortion is present. Now, that is a most convenient standard, because anyone, without having to be an expert, can readily detect distortion in one loudspeaker if he can compare it with undistorted reproduction from another speaker!

FM listeners are coming to understand this. Specifically, they are coming to realize, by comparing FM and AM reception, that the only function a treble or bass tone control can perform is to introduce distortion. That is the first stage in the development of public demand for distortionless reception. The next step in the progress of critical listening will be the demand for distortionless transmission!

Today, most FM program quality, however superior it may be to AM, is still very poor because so much of it originates from inferior phonograph records. Some, from live talent or good transcriptions, is not bad at all. And there are a few beautiful programs that provide the full audio capabilities of FM.

The difference in programs is plain to hear even on small FM receivers. The most enjoyable reception of fine programs is from sets providing undistorted reception. Thus, broadcasters, receiver manufacturers, and radio listeners are being shifted by FM to a new and basic standard of performance.

Broadcasters' Problem ★ The lectures given during the REL clinic, each by a specialist in his particular subject, added up to the conclusion that FM has introduced a new factor to the competition between stations for listeners' attention. This factor is the quality of FM transmission, as determined by studio facilities, audio equipment, and transmitter performance, plus the skill of the program department and operating staff.

No longer will listeners write: "I enjoyed your program, even though the static was bad, and your station was sometimes blanketed by another in Mexico." Instead, they will complain: "What's the matter with your transmitter? There was a lot of noise during the concert last night, the percussion instruments had no depth, and the strings were very weak."

Make no mistake about it: AM broadcasting made us a nation of radio listeners. Now, FM will make us a nation of critical listeners. With FM to give us undistorted reception as a standard, we shall become increasingly unwilling to accept less than perfect transmission and reproduction.

AT W2AG, C. R. RUNYON, JR. ACTING AS PROGRAM DIRECTOR FOR THE DEMONSTRATIONS

That was the real lesson the engineers attending the clinic took back to their respective stations. Each one, after hearing live-talent FM, must have said to himself: "People aren't going to listen to AM when they can get FM reception like that." And those from FM stations must have thought: "If some FM broadcaster comes on the air with live-talent programs, people aren't going to listen to the second-rate recordings we've been putting out."

And they were right, too, in both cases. As a nation, we aren't satisfied with what we have after something better becomes available!

Attendance at the Clinic ★ The engineers who came to the 4-day series of demonstrations and lectures present a cross-section of broadcasting activity in the United States. In addition, engineers from Australia, Canada, England, and Liberia came to take part. Following is the complete roster:

Albee, Wilbur — Chief Eng., WCSC Charleston, S. C.
Amidon, W. — Chief Eng., WWHG Hornell, N. Y.
Armstrong, E. H. — W2XMN Alpine, N. J.
Arnow, B. G. — Engineer, Unity Bcstg. Co., N. Y.
Avery, Joyce M. — Engineer, WABF New York
Bailey, Fred — Chief Eng., WJBC Bloomington, Ill.
Barnes, B. B. — Chief Eng., WAPO Chattanooga, Tenn.
Barrett, A. E. — Rep., British Bcstg. Co.
Battison, John — Engineer, KMBC Kansas City, Mo.
Behr, Joseph — Engineer, REL, L. I. City
Beville, R. — Chief Eng., WWDC Washington, D. C.
Bivins, John F. — Agent, High Point, N. C.
Bose, John — Chief Eng., Armstrong Lab., N. Y.

(CONCLUDED ON PAGE 49)

NOW BACK FROM THE AAF, C. R. RUNYON 3RD TOOK UP HIS OLD POST AS CONTROL OPERATOR

SPOT NEWS NOTES

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

KAKC-FM: First FM station in Tulsa, Okla., went on the air February 23rd, using 94.9 mc. with 250 watts. Authorized power is 3 kw. KAKC has 1 kw. on 1,570 kc. Complete installation, including studio facilities, is of Collins design and manufacture. Sam E. Avey, president, and general manager Glenn Condon have launched a vigorous campaign of co-operation with set manufacturers and local dealers to promote the sale of FM receivers.

Slug-Tuned Inductors: Midget types, only 7/8 in. high, are being produced by Cambridge Thermionic Corp., Cambridge, Mass., for filters, wave-traps, and oscillators. Designed for single-hole mounting, with spring-lock adjustment, they are admirably suited for use where space is limited.

IRE Annual Conference: At Grand Central Palace, New York, March 3–6, proved to be a success far beyond management expectations. Attendance not only exceeded the 1946 record of 7,000, but reached the spectacular figure of 15,000 this year! Special credit is due leg-man Will Copp, who carried the load of organizing the most interesting display of technical exhibits ever assembled.

Double Triodes for UHF: Have been announced by Sylvania. Providing single-ended operation for cascade amplifiers at frequencies up to 400 mc., they are designed with independent elements except for the heaters. Applications include grounded-grid, cathode follower, and push-pull amplifiers and converters in FM and television circuits. Type 7F8 uses 6.3 volts, .300 ampere on the heater, while the 14F8 uses 12.6 volts and .150 ampere, with 250 volts on the plates. Lock-in base is RMA type 8BW-L-O.

KWLK-FM: At Longview was the first FM station to go on the air in Washington. Since January 25th it has been operating with 250 watts on 104.3 mc. from noon to 3:00 p.m., and from 6:00 to 9:00 p.m. This is a G.E. transmitter, operating with an antenna designed by Harold Singleton, of Portland. Manager is C. O. Chatterton.

Questions and Answers: If you want to know how much you know — and don't — about operating a radio station, get a copy of the newly-revised "Radio Operating" by Arthur R. Nilson and J. L. Hornung. This book of 433 pages, written in question-and-answer form, is intended particularly for those planning to take radio license examinations. However, it makes interesting reading as a challenge to anyone's knowledge of the practical aspects of radio equipment and circuits, and the Communications Act of 1934. Publisher is McGraw-Hill Book Company, 330 W. 42nd Street, New York 18. Price is $3.50.

New York City: Newly organized manufacturer of communications equipment is Supreme Transmitter Corporation, 280 Ninth Avenue. Samuel L. Sack, formerly of Temco, is president and chief engineer, and Leon Adelman, formerly of Cornell-Dubilier, is vice president and sales manager.

Charles R. Denny: FCC Chairman, addressing the radio engineers at the annual IRE President's Dinner: "If radio is not to impose a ceiling on the expanding communications and commerce of the world, we must find a way of using microwaves between continents. I know this suggestion is a big assignment, but I doubt if there is a man in this room tonight who would venture to say that it cannot be done."

The high respect in which Chairman Denny is held by the industry was expressed when his speech was greeted by applause such as has never been accorded any other speaker on similar, previous occasions.

Heavy-Duty Twin Line: Capable of handling 2 kw. with proper matching and standing-wave voltage ratio of less than 2 to 1, has been brought out by Amphenol. Impedance is 72 to 75 ohms. Conductors, each of 7 strands of No. 21 copper wire, are spaced in polyethylene.

AC-DC Patent: Under out-of-court settlement, RCA has been licensed under Cisin patent 2,186,256. This ends a decade of litigation. License extends to RCA licensees, also.

Television Tower: Contract has been let by Bamberger Broadcasting Service for the erection of a Lehigh tower, 300 ft. high, at 40th and Brandywine Streets, Washington, D. C. This will carry the television antenna for station WWBR.

Radio Wages: RCA's annual report shows average take-home pay for hourly workers in December, 1946 was $47.41. This was up 27.7% over December, 1945 average of $37.13, and 87% above January, 1941 average of $25.35. Average hourly rate in December, 1946 was $1.08, exclusive of overtime.

FM Association: New telephone number at the Washington headquarters is Republic 8532.

FM Network: Independent Ohio FM stations WFOB Fostoria and WFRO Fremont are exchanging live-talent shows. They will be joined soon by a new station at Tiffin. With the stations separated about 23 miles, this is the first postwar effort to operate an FM net.

FCC Expenses: Congress has been asked by the FCC for an appropriation of $7,300,000 for the 1947–48 fiscal year. This includes salaries for: Engineering Department, 727 employees; Accounting, 163; Legal, 111; Administration, 344. Of the 1,345 total, 853 are in Washington, 492 in the field.

WMIN: First full-time independent FM station in St. Paul went on the air February 13th. Five studios of suspended, sound-insulated type, occupy 6,000 sq. ft. in the Hamm Building. Main studio has polycylindrical walls, designed for full FM program quality. Construction will start soon on a 445-ft. tower suitable for both FM and AM transmission. Antenna output will be stepped up to 120 kw. authorized for FM. Owner and general manager is Edward Hoffman, and Frank M. Devaney is assistant general manager.

Exonerated: Blame for interference between FM broadcasting and instrument landing equipment on planes coming in at La Guardia field has been fixed on the use of surplus Army receivers, not intended for civilian service. This has been confirmed by Gordon O'Reilly of Aeronautical Radio. Wall Street Journal built up the incident in a silly and unfounded story about Government consideration of reassigning FM frequencies. Fact is that if fields and airlines discarded all their inadequate and obsolete radio equipment, they wouldn't have much left.

Fast Start: WEAW, first FM station in Evanston, Ill., went on the air last month with 25 sponsors signed up. News and speech departments of Northwestern University will help furnish program material and talent. Owner is ex-Marine Edward Wheeler, Harry L. Hale, Jr. is Chief Engineer.

Antennas: TBA has gone to bat on the apartment house television problem. Landlords in New York refuse to permit erection of individual antennas, thus eliminating a considerable market for sets among well-to-do prospects. Solution calls for an adequate multiple-outlet system.

Sir Noel Ashbridge: Deputy Director of BBC: "I believe that FM will be of greater importance in our country (England) than it is in the United States — because our present wavelengths have to be shared between a great number of countries." According to Sir Noel, a 25-kw. station is under construction in London, and 40 more will be erected to cover all Britain.

NEWS PICTURE

ON the hour, every hour, daytime AM station WJMR, New Orleans, puts on a 1-minute plug for its sister-station WRCM. Then, during the last 15 minutes before sundown, WJMR carries a discussion of FM questions of special interest to radio listeners, concluding with the suggestion that sets be switched over for the evening programs transmitted from WRCM on 95.3 mc.

This FM installation is the first in the New Orleans area. It is atop the Jung Hotel, as the accompanying photograph shows, on Canal Street in the heart of the city's business section.

The 260-ft. tower, 466 ft. above ground at the top, is used as an AM radiator. The upper section is a Wincharger mast, carrying a 3-bay REL antenna for FM.

Although WRCM is still on interim power, excellent coverage is being obtained. Later, a more powerful REL transmitter and a permanent radiator will provide FM service over a still larger area.

48-CHANNEL FM PHONE TRANSMITTER

Equipment Used between Philips Factories in Eindhoven and Tilburg, Holland, for an Automatic Telephone System

BY A. van WEEL*

A TRANSMITTER working with Frequency Modulation has been developed for an experimental ultra-shortwave radiotelephone link between the Philips factories at Eindhoven and those at Tilburg, Holland, on a wavelength of 90.5 cm. for one direction and 99 cm. for the other. Modulation with frequencies from 12 kc. to 204 kc., for 48 telephone calls at once, takes place on a carrier wave with a frequency equal to 1/9 of the desired transmitter frequency, with a maximum frequency swing of 67 kc.

This article points out the advantage of this method, and describes how the frequencies have been chosen and the transmitting stages arranged. A brief description is also given of the construction of the transmitter, attention being drawn in particular to the distribution of the circuiting over two separate panels and the simplification of the wiring, both of which have been made possible by the application of a new method of coupling between successive stages, further explained in this article.

AN EXPERIMENTAL radiotelephone link between the Philips factories in Eindhoven and those at Tilburg[1] has existed for several years. This has been working lately on a wavelength of 90.5 cm. for one direction and 99 cm. for the other. The link is so arranged that the radio installation can function as an entirely automatically acting link in the telephone network. Neither the person phoning nor the operators of the telephone exchange through which the connection passes need to be aware of the fact that the calls are transmitted by wireless instead of by cable.

Since the installation was first set up there have been important developments both in the field of telephony and in shortwave transmitting technique. In telephony there is an increasing tendency to use a single pair of conductors in a cable for the transmission of a large number of calls at the same time by means of a carrier telephone system.[2] The frequency band of about 3,000 cycles width necessary for transmitting a call is modulated on specific carrier, the carriers or channels for the different calls lying 4,000 cycles apart. Only one side band is used, for instance at 32 kc., 36 kc., 40 kc., etc. It was found desirable to have the radiotelephone link referred to above equipped for such a carrier telephone system, namely for 48 channels, in connection with the available carrier telephone apparatus. The 48 channels, which cover the frequency region from 12 kc. to 204 kc., have to be modulated as a whole on the radio wave, which in this case serves as a *pair of conductors* in the link. The transmitter and receiver had therefore to be made suitable for this very wide range of modulation frequencies, up to 200 kc.

At that time, there was an important development in the field of ultra-short waves, < 10 m. *viz* the gradual superseding of the old method of Amplitude Modulation by Frequency Modulation. The advantages of this method led us also to rebuild our ultra-shortwave link for the new method.

All these facts led to a complete reconstruction of the transmitter and receiver of this experimental communication not only as regards electrical connections but also in the actual construction. Of the old installation only the Yagi directional aerials for transmitter and receiver could be retained unaltered.

Method of Modulation ★ The advantages of Frequency Modulation over amplitude modulation are twofold: 1) In Amplitude Modulation of ultra-shortwaves it is almost inevitable that an undesired frequency modulation also occurs; the difficulties created by such a mixed modulation are avoided by employing pure Frequency Modulation. 2) Frequency Modulation, compared with Amplitude Modulation, gives an appreciable improvement in the ratio between the intensity of the signal and that of the fluctuation noise.

In order to make full use of the second advantage, *i.e.*, in order to reduce noise to the lowest possible level, it is necessary that the maximum frequency swing, or the largest deviation occurring from the average frequency, should be about 10 times as large as the highest modulation frequency to be transmitted. In our case, this was not less than 0.2 mc., so that the maximum frequency swing had to amount to 2 mc. Since, for the undistorted transmission of a frequency-modulated oscillation, a side band of at least $1\frac{1}{2}$ times the frequency swing on both sides of the carrier frequency has to be transmitted, the transmitter and receiver would have to be adapted for a frequency band with a total width of 6 mc. Because of the difficulties that would have been involved in getting such a great band width, we confined ourselves to a frequency swing of the emitted signal to about three times the highest modulation frequency. In this way one arrives at a band width of 2 mc., which is well possible in practice, while the ratio between intensity of the signal and that of the noise is still 14 db greater than it would be with Amplitude Modulation.

With frequency-modulated transmitters, it is customary to apply the actual modulation process to oscillator connections which oscillate at a low frequency. By frequency multiplication, where the average oscillator frequency and the frequency swing are increased in the same proportions, the desired transmitting frequency is then obtained. This method, which we also employed, has the advantage that it is easier to obtain the required proportionality between frequency swing and intensity of the modulated signal. This can be explained as follows:

Modulation is effected by detuning the oscillator circuit with the help of a so-called reactance valve. This is a normal multigrid valve, between the cathode and anode of which the circuit to be detuned is connected, while part of the circuit voltage is applied to one of the grids with 90° in phase displacement. The AC anode current is then shifted 90° in phase with respect to the AC anode voltage. In other words, the valve acts as a reactance, either capacitative or inductive, according as grid AC voltage is shifted + 90° or − 90° in phase.

To take a specific case, let us assume that the tube acts as a capacity, C_1. The reactance $1/\omega C_1$ is equal to the ratio of the amplitudes of the AC anode voltage and AC anode current, while the frequency ω at which the circuit connected oscillates is determined by C_1 together with the remaining circuit capacity C_0. C_1 is now varied by applying the modulating signal voltage to a second grid of the valve, whereby the slope, and with it the amplitude of the AC anode current, is changed in the rhythm of that voltage. The detuning, $\Delta\omega$ of the circuit obtained with respect to the frequency ω_0, with $C_1 = 0$, is given by

* Research Laboratory, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland.

[1] C. G. von Lindern and G. de Vries: An ultra shortwave telephone link between Eindhoven and Tilburg, *Philips Technical Review* 2, 171, 1937.

[2] See, for example, the articles published about carrier telephony: *Philips Technical Review* 4, 20, 1939; 6, 325, 1941; 7, 83, 104, 184, 1942.

$$\Delta\omega = \frac{\omega C_1}{2C_0}$$

We will now consider the influence of the oscillator frequency to be chosen, ω_0.

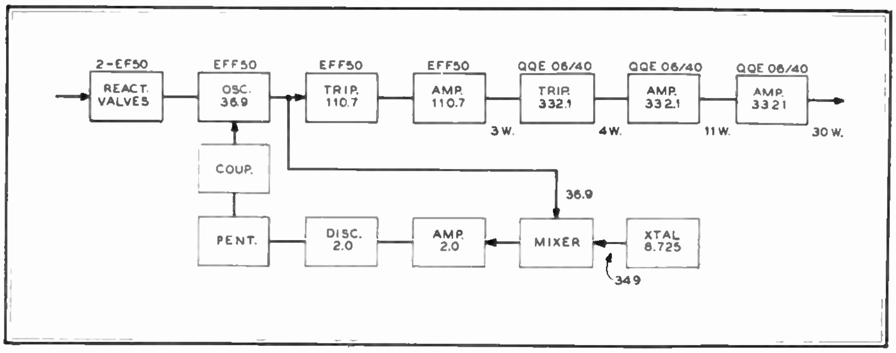


FIG. 1. DIAGRAM OF THE TRANSMITTER, CIRCUIT FREQUENCY IS SHOWN IN EACH BLOCK

In connection with the linearity of the modulation, only a certain change in slope of the reactance valve is permissible, namely such that there is no deviation from that section of the valve characteristic where the slope is by sufficient approximation proportional to the grid voltage. Corresponding to the permissible maximum slope, which depends only on the properties of the valve and not on the oscillator frequency ω_0, is a certain maximum AC anode current. Thus, because the AC anode voltage is fixed, there is a certain maximum value of the reactance $1/\omega_0 C_1$, likewise independent of ω_0. The maximum detuning to be obtained $\Delta\omega$, which according to the formula is proportional to the greatest value of $\omega_0 C_1$, is therefore independent of the frequency ω_0, because C_0 can be considered as a constant also. In order to make the detuning by the reactance valve as great as possible, C_0 will be kept as small as possible, and thus will be limited to the unavoidable capacities of valve and wiring. The choice of ω_0 is then realized with the self-induction of the circuit.

Since, therefore, the same absolute frequency sweep can be obtained with a low oscillator frequency as with a high one, if in the manner described one begins with a low oscillator frequency and a correspondingly small frequency sweep, it will actually be easier to ensure the necessary linearity of the modulation. We shall revert later to the exact choice of oscillator frequency.

The Connections ★ The connections are in push-pull arrangement for various reasons: variations in the feeding voltage are much less manifest as undesired modulation, since they act on the two halves of the modulator in the same phase instead of in counterphase. Furthermore, one avoids the strong high-frequency currents which otherwise flow in the earth connections and also through the chassis, causing all kinds of undesired couplings, since all points to be earthed cannot be connected to the same point on the chassis. Finally, by using push-pull amplifier valves, several difficulties occurring at very high voltages are diminished, because, among other reasons, the influence of the self-induction of the cathode feeding connections is much smaller. In Fig. 1 a block diagram is given of the transmitter connections. We shall first consider only that part drawn in the upper row. The low-

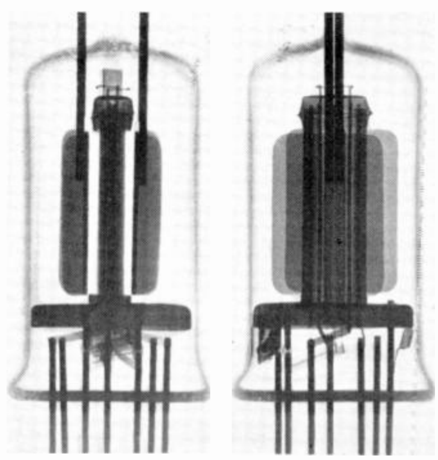


FIG. 2. X-RAY VIEWS OF QQE 06/40 TUBE

frequency signal from the telephone exchange (the term *low-frequency* is here used in a relative sense, the frequencies of this signal being as high as about 200 kc.) is led to two reactance valves which influence the frequency of the push-pull oscillator. The signal obtained from the oscillator, *i.e.* the frequency-modulated oscillator voltage, is led to a push-pull valve, connected as a frequency triplicator. Then the signal is amplified and conducted to another frequency triplicator. The signal here reaches its final frequency, after which it is further amplified in two end stages and sent to the aerial.

Choice of Oscillator Frequency ★ The reason for the multiplication of the frequency in stages by a factor of 3 lies in the nature of the connections. In push-pull connections, the output voltage can contain, in principle, only the odd harmonics of the frequency of the grid AC voltage applied so that, by filtering out the harmonics in question, a frequency multiplication by a factor 3, 5 or 7, etc. can be obtained. For the sake of efficient output, the lowest factor has been chosen. Since the transmitting frequency, if we confine ourselves for the moment to one single call direction, was fixed at 332.1 mc. (90.5 cm. wavelength), the possible choices of oscillator frequency were 332.1, 110.7, 36.9, 12.3, 4.1 mc., etc. We have explained above that the oscillator frequency must be chosen as low as possible. From the frequency values indicated in Fig. 1 in the different stages, it can be seen that the choice fell upon 36.9 mc. This still seems relatively high, but it must be taken into account that the receiver for the same connection is situated close to the transmitter. The receiver works on the superheterodyne principle with an intermediate frequency of 18 mc. In order to prevent interference in the reception, it is necessary that neither the oscillator frequency of the transmitter nor any harmonics of it shall fall in the intermediate-frequency band of the receiver, which band, according to the above figures, must extend from 17 to 19 mc. An oscillator frequency of 12.3 or 4.1 mc. would, it is true, also answer this condition, but the transmitting apparatus in question had to be so designed that later on, if necessary, the connections built up with the same stages could also be used for telephone links on other wavelengths between about 1.5 and 0.9 meter simply by changing the oscillator frequency slightly. In order to avoid once for all the danger

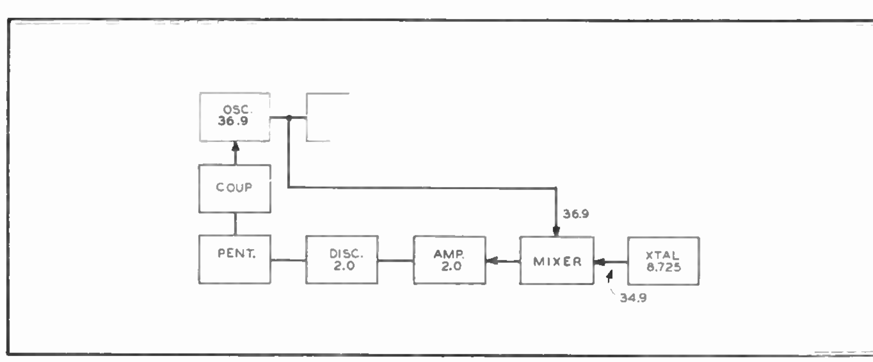


FIG. 3. DIAGRAM OF CIRCUIT TO KEEP THE AVERAGE OSCILLATOR FREQUENCY CONSTANT

of interference in the receiver, it was therefore decided to fix the oscillator frequency above the intermediate frequency band of the receiver.

It is perhaps advisable to stress the point that, for a favorable ratio between signal and noise, the frequency sweep must be several times as large as the highest modulation frequency occurring, but this is only applicable for the signal emitted by the aerial. In our case, as a consequence of the frequency multiplication, the maximum frequency swing in the oscillator stage amounts to only 1/6 of the final value. If a modulating signal with the frequency of 200 kc. and with the largest permissible amplitude is applied to the oscillator, the oscillator delivers an oscillation with a frequency fluctuating 200,000 times per second between 36.833 and 36.967 mc. In the case of the frequency multiplication here employed, the rhythm of the fluctuation, *i.e.*, the modulation frequency, naturally remains unaltered. The following stage delivers an oscillation with a frequency fluctuating 200,000 times per second between 110.5 and 110.9 mc., etc.

This, however, is impossible, because if that were done, very high AC voltages, of the order of 500 volts, would have to be applied to the grid of the last valve. In order to function as a frequency multiplier, the valve must work in class C, with very high negative grid bias. It has been found in practice that with the very small distance between grid and cathode in these shortwave tubes, the high voltages mentioned lead to disturbances, breakdown may occur, or the insulation between grid and cathode may be damaged, especially at very high frequencies.

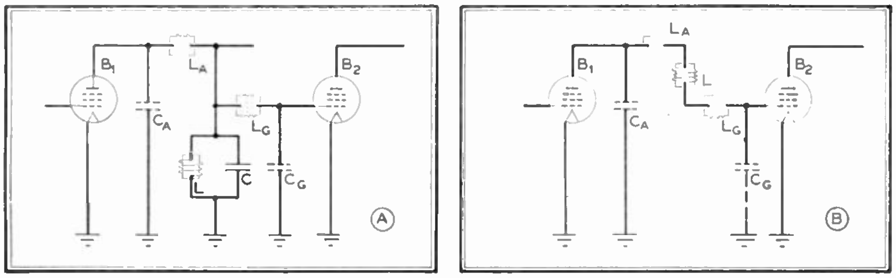


FIG. 4. THE USUAL AND THE NEW METHODS OF COUPLING TWO AMPLIFIER TUBES B_1 AND B_2

The Valves Used ★ The valves used are indicated over the blocks in the diagram of Fig. 1. Except for those in the three last stages, they are all normal receiving valves with only a low energy dissipation so that a compact assembly is possible. The last stages must, of course, have transmitting valves in order to produce the power required for transmission.

Nevertheless, the energy amplification in the last two stages is only slight, as may be seen from the wattage figures given in Fig. 1. This is due to the high frequency at which these amplifier stages have to function. It would seem obvious to ask why the once-amplified signal of 110.7 mc. is not first amplified further to the desired final level and then given the necessary frequency amplification in the last stage.

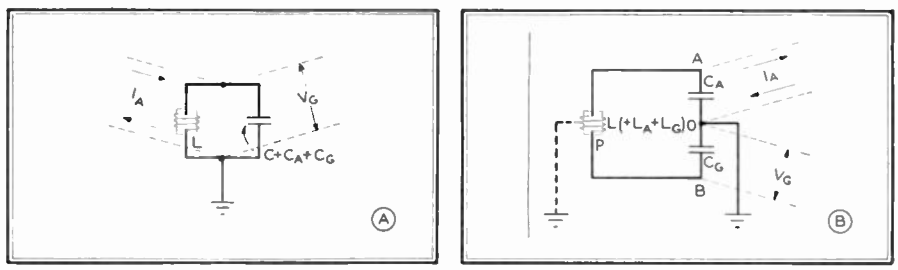


FIG. 5. MORE DETAILED DIAGRAMS SHOWING THE TWO TYPES OF AMPLIFIER COUPLINGS

Fig. 2 is a reproduction of two X-ray photographs of the type of short-wave transmitting valve used, the QQE 06/40. It is a double tetrode in which the two balanced systems have a common screen grid. The power on 3 meters is 40 watts; at 1 meter about 30 watts.

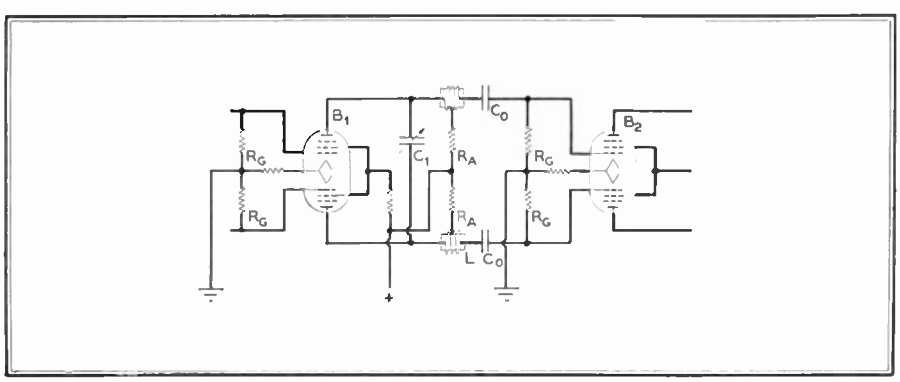


FIG. 6. A PUSH-PULL AMPLIFIER STAGE EMPLOYING THE NEW TYPE OF COUPLING CIRCUIT

Maintaining Constant Oscillator Frequency ★ The part of the diagram in Fig. 1 which is in the lower blocks serves to keep the average oscillator frequency constant; it is given again separately in Fig. 3.

The usual method of synchronizing the oscillator vibration directly with the characteristic oscillation of a quartz crystal or a harmonic of the crystal could not be employed in our case, since the oscillator vibration is already frequency-modulated upon its formation and, consequently, when keeping the oscillator frequency constant a certain margin has to be left for the frequency swing. For that reason the following method was chosen:

A small part of the output voltage of the oscillator stage, or which the average frequency f_0 must amount nominally to 36.9 mc., is tapped off and in a mixing valve is mixed with an AC voltage of the very constant frequency of 34.9 mc. from a vibrating crystal. The output voltage of this mixing stage has an average frequency $f_1 = f_0 - 34.9$ mc. If f_0 is exactly 36.9 mc., $f_1 = 2$ mc. If f_0 differs slightly from 36.9 mc., f_1 exhibits the same absolute difference from 2 mc. Furthermore, the intermediate frequency f_1 is, of course, frequency-modulated with the telephone frequencies in the same way as the high frequency f_0 applied.

This output voltage of the mixing stage is now amplified to a discriminator connection. This produces a DC voltage proportional to the difference between the average frequency f_1 of the applied voltage and the fixed frequency $f_d = 2$ mc. at which the discriminator is set. An AC voltage is superposed on the DC voltage, namely the original modulation voltage which, however, is suppressed by a low-pass filter. The DC voltage is now applied to the grid of a pentode. The anode current of this valve, which is thus proportional to the absolute deviation of the average oscillator frequency from the prescribed value of 36.9 mc., flows through a coil wound around a core of ferromagnetic material [3] magnetically coupled with the self-induction coil of the oscillator circuit. Owing to the fact that the anode current changes the premagnetization and thus the permeability of the coil core it affects the self-induction of the oscillator coil in the sense that the change in the average oscillator frequency, to which the anode current is proportional, is opposed. In this way it proved possible to reduce the drift by a factor 30.

The fixed frequency f_d at which the discriminator is set is, of course, not actually fixed either, but subject to some

(CONTINUED ON PAGE 54)

[3] It is necessary to use a ferromagnetic material the losses of which are sufficiently small, even at high frequencies.

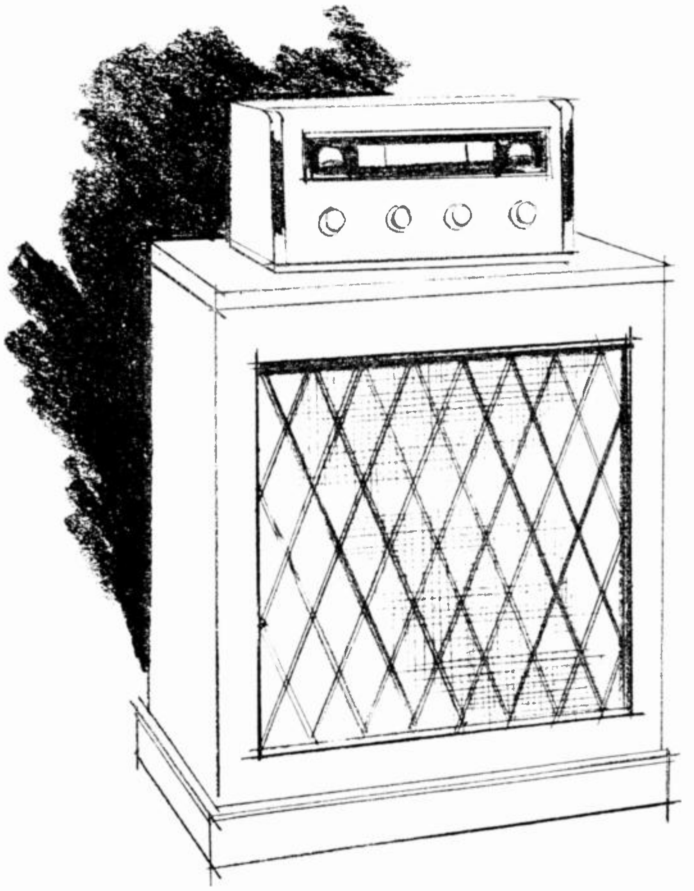


FIG. 1. BASIC DESIGN PROPOSED FOR LOW-COST, HIGH-QUALITY FM RECEIVERS

HIGH-FIDELITY FM DESIGNS AT MASS-MARKET PRICES

Shifting Design Emphasis from Furniture to Performance Will Benefit Manufacturers, Dealers, and Consumers

BY WALTER BUEHR*

As an artist who designs furniture and interiors of homes and offices, I am drawn repeatedly into discussions of radio cabinets and the failure of the manufacturers to make them either beautiful in appearance, or functional in form.

Invariably, after I have held forth on the anomalies of what I hear called "radio furniture", and how I think radio sets should be designed, someone asks me what kind of a radio set I have. Well, I have done what is the easiest thing for me, yet the most unsatisfactory from the point of view of good radio reception: I use a very small table model, so inconspicuous that its appearance is of no consequence. Not, however from choice, but because I can't buy what I want in any store, and because, like the shoemaker, I don't do for myself the things I do for others!

* 137 E. 35th Street, New York, N. Y.

I'm sure that thousands and thousands of other people are getting along with poor reception — not because they aren't willing to pay the price for what they'd like to have, but because they don't want conventional borax cabinets, and because they don't want to spend $750 or more for an expensive cabinet to camouflage a relatively inexpensive piece of radio equipment. Besides, until FM came along, there was no real justification in improved performance for spending more than the cost of a cheap table set.

The foregoing statement covers a lot of territory, so let's break it down:

Fundamental Considerations ★ Call a radio set a machine or a musical instrument, as you please, in neither case is it a piece of furniture, any more than a violin, kettledrum, or clarinet can be considered furniture. Those instruments can no more be disguised as furniture than a vacuum cleaner, a washing machine, or an ice box.

We could try, of course, but at a loss of efficient and satisfactory operation, and at considerable extra cost. But the end result would not be pleasing or in good taste, and every one would be unhappy about the whole affair.

Yet that's exactly what set manufacturers have tried to do ever since the advent of the loudspeaker made radio a source of family enjoyment. That's why, as American taste in home furnishings and decoration has improved, and it has improved greatly in the past 25 years, radio cabinet design has come to be considered more and more an anomaly. This, by definition, is something irregular or abnormal, and out of keeping with accepted notions of fitness or order, which is a pretty good explanation of what I mean.

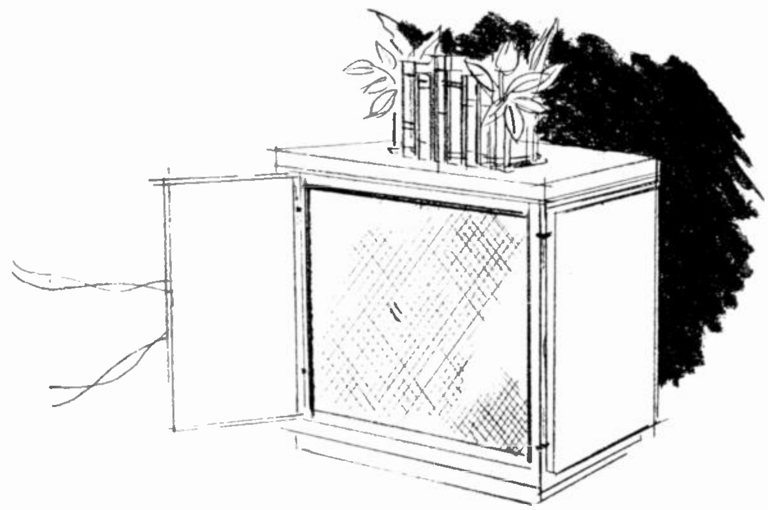
Why People Don't Listen ★ Let's look at another angle. Mrs. Smith goes out to buy a radio set. If she took her husband or son along, she might be called upon to give some consideration to the fundamental purpose of radio reception, which is to provide entertainment. But when she walks into the radio store, she is only thinking, "I wonder if they'll have anything that will be suitable for the north living-room wall," or, "I'll have to find a mahogany cabinet that will fit on the table by the windows." At the same time, Mrs. Jones may be out looking for one of those perfectly darling little tiny sets she saw advertised in a four-color picture of a glamorous model, holding one up and saying, in large type: "Cathedral tone from an 18-ounce radio!"

The net result is that Mrs. Smith gets something that she probably doesn't like, although it's the best she can find, and Mrs. Jones gets a set that can be mailed first-class for 54 cents. But neither one has a radio that will give them the full measure of enjoyment that broadcasting can provide. So, after the novelty has worn off Mrs. Smith's acquisition, it will stand mostly silent, except for news periods or presidential speeches and possibly Fibber McGee and Molly. As for Mrs Jones's darling little radio, when the batteries run down it will be put away on a shelf and soon forgotten.

Multiply this by any figure you choose, and you can make your own guess as to the number of program-hours per listener that are being lost today to the AM stations.

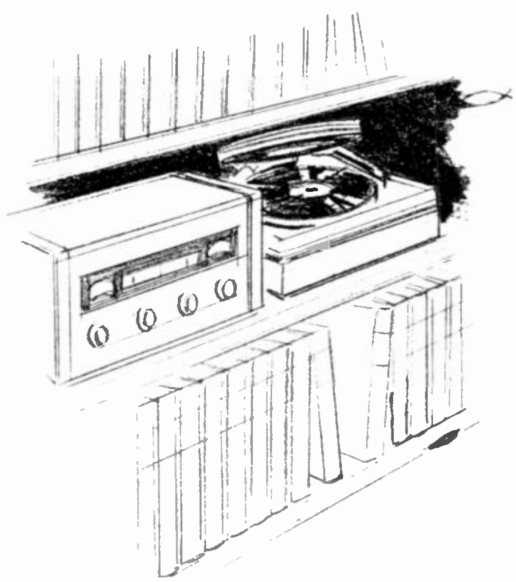
FM Calls for a Change ★ Because this situation has developed over a period of years, it can very easily be carried over into the coming era of FM broadcasting. If it does, most of the advantages of FM will be lost, for FM is not some totally new service, but a tremendous improvement in an old one.

FIG. 2. APPLICATIONS OF THE BASIC DESIGN. A CHASSIS SUCH AS IS USED IN PRESENT $1,000 CONSOLES CAN BE ENCLOSED IN A SIMPLE, METAL CASE, SMALL ENOUGH TO HIDE IT AWAY ON A BOOK SHELF. THE SPACE REQUIRED IS NO MORE THAN IS OCCUPIED BY A CHEAP AM MODEL

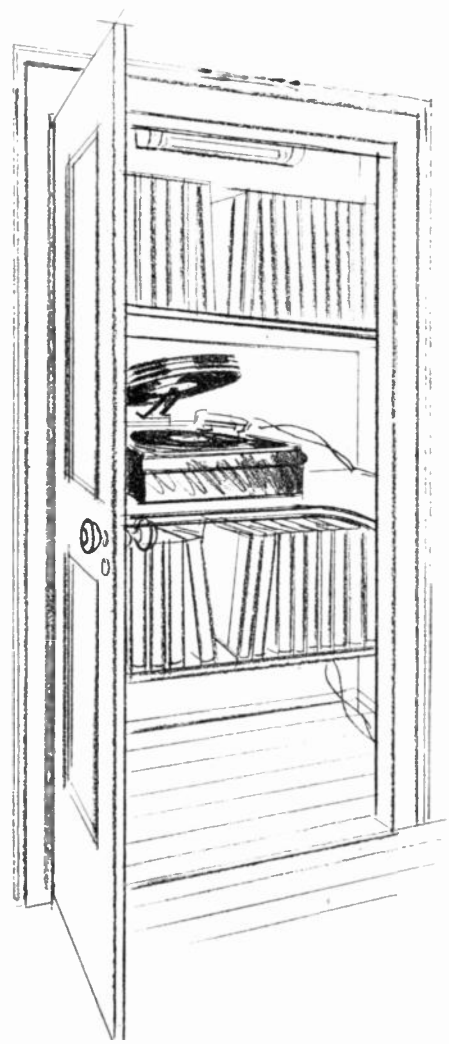


RIGHT) A PLAIN, INEXPENSIVE CABINET, WITH OR WITHOUT DOORS, FITTED WITH A FINE LOUD-SPEAKER, WILL GIVE THE SAME TONE QUALITY AS IS PROVIDED BY ONE OF THOSE ULTRA-ULTRA FURNITURE-PIECE MODELS WHICH FEW CAN AFFORD AND FEWER CAN ACCOMMODATE IN THEIR HOMES

BELOW) HERE IS THE IDEAL KIND OF INSTALLATION FOR THOSE WHO TAKE THEIR RECORDS SERIOUSLY. THE RECORD-PLAYER IN THE CLOSET CAN BE CONNECTED WITH THE SET AND SPEAKER ABOVE, OR ON THE OPPOSITE PAGE. PERFORMANCE WILL BE TOPS



LEFT) THIS ARRANGEMENT USES A BOOK CASE FOR THE RADIO SET AND AUTOMATIC RECORD-CHANGER. ADJACENT SHELVES PROVIDE A HANDY PLACE TO STORE RECORDS AND ALBUMS. NO GREATER CONVENIENCE CAN BE PROVIDED BY MOUNTING THESE UNITS IN A PIECE OF FURNITURE COSTING $500 EXTRA



That, in itself, would not necessarily be a reason for set manufacturers and dealers to reorient their thinking about cabinets. However, this time of fundamental, technical change is opportune for considering other revisions, too.

The great, and immediate manufacturing problem is to increase net profit. Obviously, this cannot be done by making sets cheaper since, quantitatively, the consumption of sets has already reached its peak. It can only be accomplished qualitatively, by increasing the unit of sale.

Radio circuits that give genuine FM performance call for more, and more expensive components, increased power output, better and larger speakers, and housings for such speakers that will be adequate acoustically.

Thus, added to the increased cost of the chassis and speaker is the cost of a relatively large and well-constructed cabinet. There's where the rub comes: in the cabinet work. It's a two-way rub, for suitable lumber is exceedingly scarce right now, and good cabinets, like any furniture pieces, are very expensive. That is confirmed by the scarcity and the high prices of good FM sets today.

No wonder, then, that manufacturers are worried over making the choice between building cheap FM sets that will be

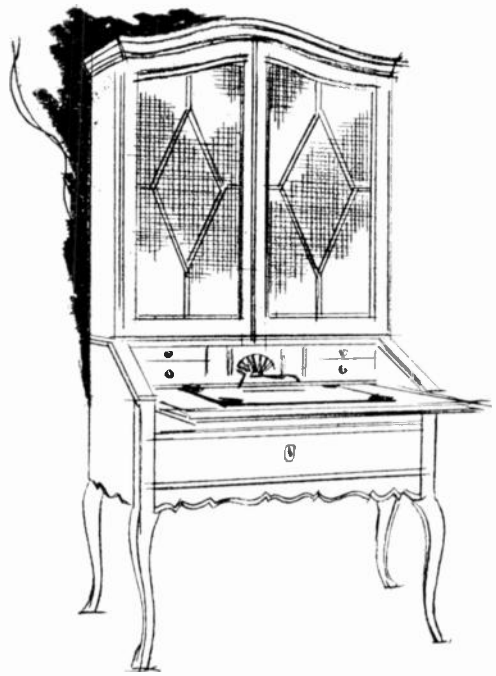


FIG. 3. EXISTING FURNISHINGS IN THE FINEST HOME NEED NOT BE DISTURBED BY THE ADDITION OF HIGH-QUALITY FM RECEPTION. LEFT) BY TAKING OUT THE GLASS FROM THE DOORS OF A DESK OR CABINET AND SUBSTITUTING GRILLE CLOTH, A SPEAKER AND BAFFLE CAN BE CONCEALED EASILY

RIGHT) HERE IS ANOTHER EXAMPLE OF WHAT CAN BE DONE TO HIDE A LOUDSPEAKER, WITHOUT INTRODUCING SOME NEW AND UNSUITABLE PIECE OF RADIO FURNITURE. PEOPLE OF MEANS ARE GLAD TO PAY EXTRA FOR SUCH INSTALLATION WORK, RATHER THAN ALTER EXISTING DECORATIONS

LEFT) RADIO ENGINEERS WILL SURPRISE THEMSELVES WHEN THEY UNDERTAKE TO DESIGN CHASSIS THAT CAN BE FITTED INTO INCONSPICUOUS, PLAIN METAL CASES OF PURELY FUNCTIONAL APPEARANCE. IF THE POWER SUPPLY AND AMPLIFIER ARE PUT IN THE SPEAKER CABINET, FURTHER ECONOMY OF CUBIC CONTENTS CAN BE ACHIEVED READILY

no better than AM models, or building genuine FM receivers to sell at such high prices as to limit the market.

Let's Junk the Furniture ★ From where I sit, it seems that the logical out in this situation is to eliminate that radio furniture! I may be wrong. I'm a designer and an artist, so perhaps I shouldn't presume to offer an opinion to manufacturers. On the other hand, I've often thought that the men who run the industry are so close to the woods that they don't see the trees, and it has been my observation, as an outsider looking in, that many of the best minds are too busy watching competitors to take time out for independent, constructive thinking.

At the same time, my suggestion cannot be altogether unsound. Consider, for a moment, the automobile industry. Surely, you'll agree that some smart thinking is done by this group to coördinate factors of style, service, and performance at price levels which strike the correct balance between unit price and maximum annual dollar volume.

In the beginning, you'll recall they took the shafts off conventional horsedrawn buggies, strengthened the springs so that they could tack on an engine, and added a steering bar. They called the result a "horseless carriage." Can you imagine anything screwier-looking to the people of that day than a buggy rolling down the street without benefit of a horse? There was an anomaly indeed!

If it seemed reasonable to continue the practice of styling automobiles after carriages, it was only because most of the early producers were originally carriage makers. They thought in terms of carriage designs and materials, and their factories

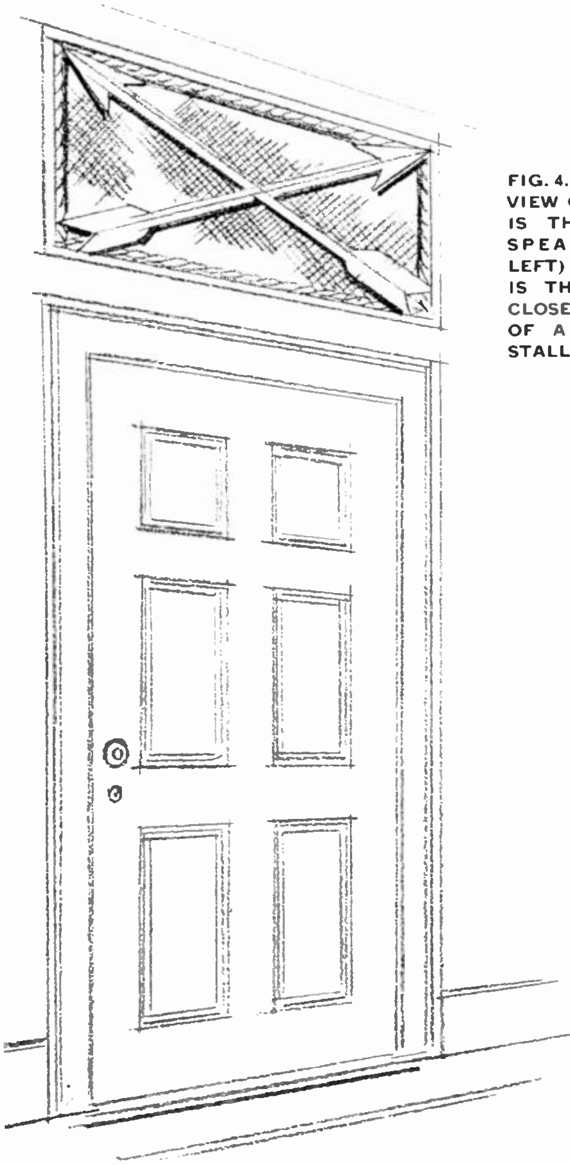
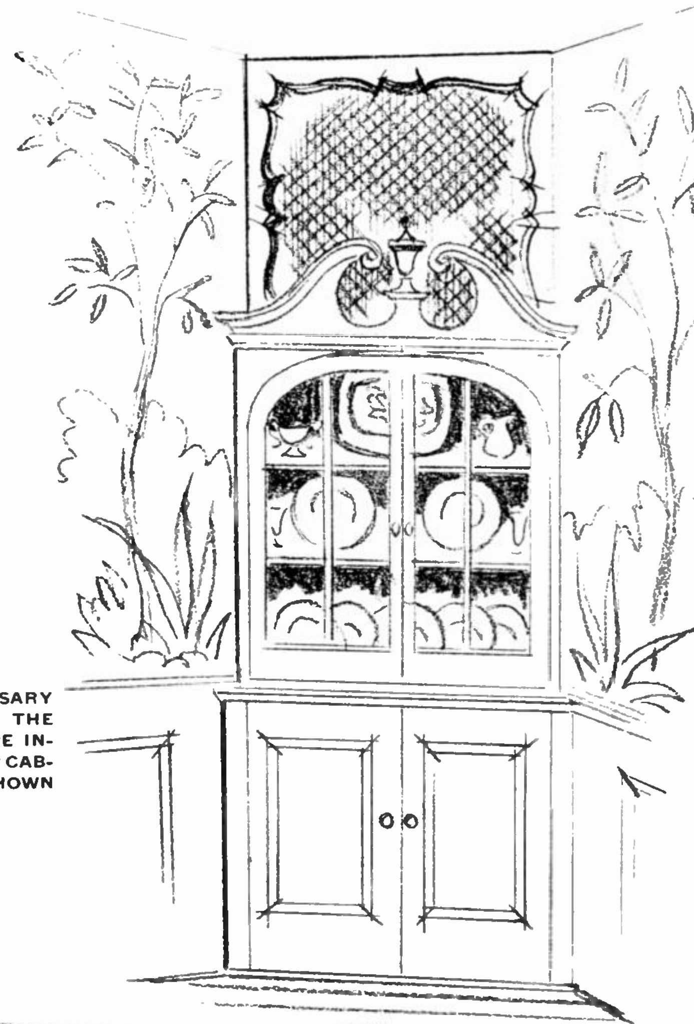
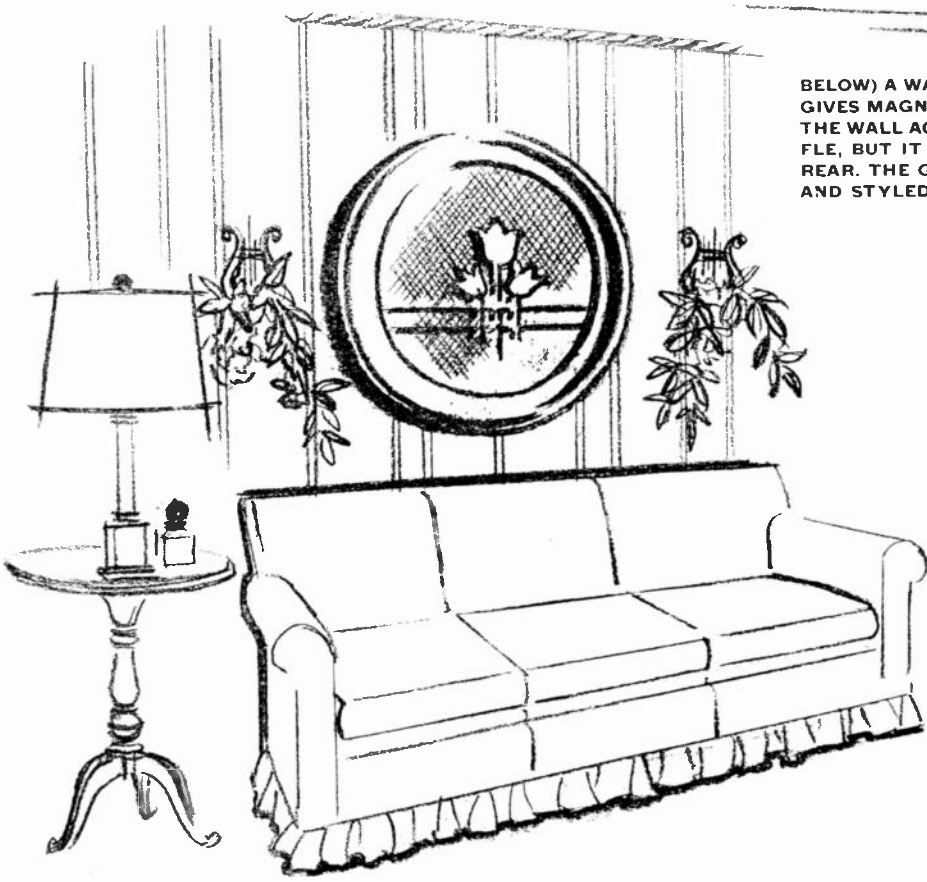


FIG. 4. FROM THE POINT OF VIEW OF ACOUSTICS, THIS IS THE BEST TYPE OF SPEAKER MOUNTING. LEFT) AN IDEAL LOCATION IS THE SPACE ABOVE A CLOSET DOOR. THIS KIND OF A LOUDSPEAKER INSTALLATION IS EASY TO MAKE, TOO



RIGHT) IT IS NOT NECESSARY TO CUT THE WALL WHEN THE SPEAKER AND BAFFLE ARE INSTALLED ABOVE A CORNER CABINET, IN THE MANNER SHOWN



BELOW) A WALL-MOUNTED SPEAKER GIVES MAGNIFICENT TONE BECAUSE THE WALL ACTS AS AN INFINITE BAFFLE, BUT IT MUST BE OPEN AT THE REAR. THE GRILLE CAN BE FRAMED AND STYLED IN COUNTLESS VARIATIONS were equipped accordingly. Remember when wheels were laboriously and expensively fabricated of wood? And all the arguments against the use of steel stampings?

To see how the thinking of the automo-

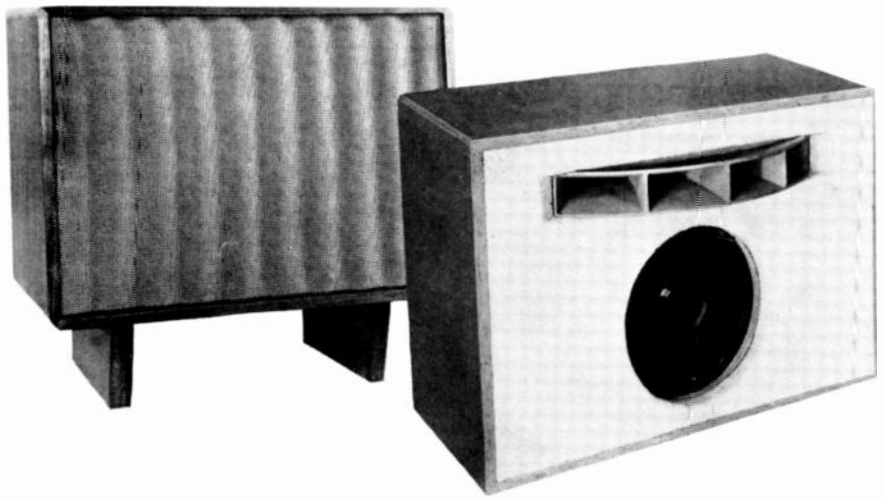


FIG. 5. A VERY SIMPLE AND ATTRACTIVE CABINET FOR THE NEW 60- TO 15,000-CYCLE WESTERN ELECTRIC SPEAKER

bile industry has changed, next time you are out in the country, if you see a buggy hitched in front of the village feed store, stop your car, get out, and compare the two vehicles, side by side. Well, if cars can change that much, why not radios?

There's Much to Gain ★ There's no more reason for putting a radio chassis in a modification of a furniture piece than for fastening a motor under a carriage dismantled to the extent of removing the horse, shafts, and harness.

A radio receiver is essentially a chassis and a loudspeaker mounted in an acoustic chamber. Why not stop there? The chassis needs protection against dust and prying fingers. Fine! Put it in an inconspicuously-finished metal box. You have a small, functional unit that you can put on a table, or bookshelf, or anywhere else that's convenient. The box needn't be any larger than a cheap AM set, yet it can contain all the circuits for AM and genuine FM reception.

The set must have a good speaker. All right, put the speaker in a plain wood case of sturdy construction. The case requires no factory finish. The purchaser will want to stain or paint it according to his tastes.

To keep the radio chassis small in size, the power amplifier and perhaps the power supply should be located in the case with the speaker. The appearance will be something like Fig. 1.

Add a small cable from the chassis to the speaker, and you'll have a radio capable of giving such performance on FM as to make any AM table model sound as if it's got the pip, by comparison.

How much? The difference in price will be no more than is obviously justified by the improvement in performance over AM sets, and it will be low enough to permit the development of a mass market.

Let's examine some of the advantages of this type of set design, and it's effect on the public, the dealers, and the manufacturers:

1. Price Reduction ★ The first result will be much greater *real* value to the purchaser. Since most radio cabinets are bought from cabinet plants, by the time the radio manufacturer adds his profit, and the trade discount, a cabinet originally sold at $50 costs the consumer $150 to $200. And that would be one of the less expensive designs. Added to that is the cost of storing, uncrating, and handling the cabinet, mounting the chassis and speaker in it, retesting, repairing, refinishing, and repacking, plus the cost of an expensive shook, plus extra shipping cost because of the added weight of the cabinet.

Thus, a conventional FM-AM model of high-quality performance that now retails for $650 could be reduced to at least $350 by eliminating the cabinet and putting up in such form as indicated in Fig. 1.

The chassis can be tucked away in a bookshelf by itself, or in combination with a record player. In the latter case, the shelves would accommodate record albums.

This provides the maximum of convenience, service, and radio performance, eliminates all the problems of cabinet design in the house, involves no extra installation expense, and costs 25 to 50% less than an awkward piece of radio furniture, which is not furniture at all, that will give the same quality of entertainment.

Fig. 3 carries the idea a little farther for those who want fine radio performance, but are unwilling to have the loudspeaker in evidence.

The radio chassis must, of course, be located where it is convenient to operate it, but if the lines are kept clean and functional, it will not be out of place in any scheme of decoration.

People who take their records seriously will welcome the suggestion that the automatic record changer be put away in a closet where record books can be kept conveniently at hand. This puts the machinery out of sight, where the sounds of changing records cannot be heard, and removes any sense of mechanics from the realism of the music.

Either of the speaker mountings shown in Figs. 1 and 2 could be used, or the speaker could be set into a conventional furniture piece. Two examples are suggested in Fig. 3. In the case of the desk, it would be necessary, of course, to replace the glass with grilled cloth. In either case, great care would be required to reinforce the interior to provide an adequate baffle, and to prevent rattles.

Fig. 4 offers suggestions for those particular people who are unwilling to have the speaker in evidence at all, or to use their furniture pieces as a disguise.

Easiest to install is the arrangement over a corner cabinet. If it is beyond the skill and experience of the dealer, a local cabinet maker or carpenter can be called upon for assistance. The wooden frame, grille cloth, and speaker baffle must be assembled as a unit, and then secured to a mounting fastened permanently to the wall. Then the speaker can be removed if service is required.

Similarly a set selling at $149.50 could be reduced to $99.50. And that $99.50

(CONTINUED ON PAGE 52)

FIG. 6. FRANK GUNTHER WITH REL'S FM RECEIVER AND ALTEC SPEAKER

Farnsworth RAILROAD RADIO

A MILESTONE IN RAILROAD RADIO!

"Modern railroad transportation systems cannot function to their maximum efficiencies without the use of modern communications networks. That is why the Santa Fe System maintains complete telephone and teletype, as well as telegraph systems along its entire thirteen-thousand-mile right-of-way. It is also the reason for Santa Fe's immediate and careful exploration of all new communications techniques, such as railroad radio, and accounts for the many 'firsts' contributed by the Santa Fe to the railroad communications art."

President
Atchison, Topeka and Santa Fe Railway

"RAILROADS . . . LIKE A GIANT CONVEYOR BELT"

"The war has emphasized the importance of American railroads. Like a giant conveyor belt, they link up the industrial, agricultural and mining areas of this country with the many thousands of markets that dot our land. With reconversion a fact, far-sighted railroad management is carefully exploring many technical war developments, and, in particular, radio, with the expectation that radio will help keep American railroads the safe, efficient and modern network of transportation which has so ably served the Nation during the war."

S. P. [signature]

"THIS PIONEERING EFFORT . . ."

"The Chicago and North Western Railroad, always interested in technological developments which promise improvement in the efficiency and safety of railway operations, participated in the first regular use of very high frequency railway radio. This installation went into operation in our Proviso Yards in September, 1940, and continued for over a year thereafter.

"We are happy that the technical and operating information secured from the pioneering effort was subsequently useful to the Army Ordnance Department and to the operators of the large Army Ordnance Plants in making their decision to use railroad radio in connection with the war effort.

"The case histories provided by the use of radio at Proviso and in the large ordnance plants were later to become an important part of the railroad testimony in the Federal Communications Commission hearing which brought about the present allocation of frequencies for railway use."

PRESIDENT
Chicago and North Western
Railway System

Farnsworth radiotelephone systems, now ready to serve the Nation's railroads, provide:

(1) RELIABLE RADIOTELEPHONE CIRCUITS
Farnsworth guarantees its railroad radiotelephone systems for a period of one year—the same kind of comprehensive guarantee furnished with U. S. Government war-time radio equipment on which battles and lives depended.

(2) IMPROVED OPERATING SERVICES AND FACILITIES
Radiotelephone circuits between train crews and supervisory personnel permit industrial customer requirements to be fulfilled more rapidly; provide reliable and instantaneous communications even during adverse visibility conditions; enable the quick reporting of equipment failures and the more rapid and efficient dispatching of relief; permit crews instantly to report unscheduled stops to near-approaching trains.

(3) SAVINGS IN OPERATIONS
Railroads using modern radiotelephone circuits have reported through official Association of American Railroads documents convincing proof of the important money-saving, as well as safety-contributing abilities of radiotelephone circuits.

(4) LOW-COST INVESTMENT AND MAINTENANCE
Farnsworth equipment incorporates such important operating and maintenance features as standardized chassis with unitized construction, low-clearance antennas, automatically engaging plug-in type connectors, and special test circuits. The combination of these features, *found only in Farnsworth equipment,* guarantees maximum availability, flexibility, and usefulness with simplified low-cost maintenance. Yet, Farnsworth railroad radio equipment is priced competitively with other quality systems, many of which lack these special features.

For detailed particulars of Farnsworth Mobile Communications Systems, write Farnsworth Television & Radio Corporation, Dept. FM-3, Fort Wayne 1, Indiana.

"TO ATTAIN STILL HIGHER STANDARDS OF SERVICE . . ."

"An asset in which the Nickel Plate Road takes great pride is the high standard of service which it renders to the shipping public. With its record for outstanding performance during the war years back of it, the Nickel Plate is looking forward to the utilization of new technological developments, such as radio and teletype, in order to attain still higher standards of service and usefulness."

J. W. Davin
President,
The New York, Chicago & St. Louis R. R. Co.

"Train Radio to Aid in Operation of Pere Marquette's New Streamlined Trains"

"By virtue of their efficient and effective performance during the war, the nation's Railroads have won the respect and goodwill of the American people. It is essential that this public esteem be maintained. That is why progressive railroad managements are planning the use of many technical developments capable of making additional contributions to the safety and comfort of rail passenger service and why the new, streamlined passenger trains which Pere Marquette soon will put into operation are to be equipped with train radio communication systems."

President
Pere Marquette Railway Company

FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON 25, D. C.

IS READY TO SERVE THE NATION

ADDRESS ALL ... TO THE

November 27, 1946

Mr. John Curtis, Manager
Mobile Communications Division
Farnsworth Television & Radio Corp.
Fort Wayne 1, Indiana

Dear Mr. Curtis:

I wish to thank you for your letter outlining the excellent progress which the Farnsworth Television and Radio Corporation has made in developing and producing various types of equipment for railroad radio communication. I was especially pleased to read that section of your report which quotes various railroad presidents who recognize that radio will enhance safety and efficiency in railway operations.

As you know, the Commission has been convinced for some time that a properly engineered railroad radio system will contribute to safety of life and property, both in preventing accidents and in reducing the seriousness of injury and damage after accidents. While safety is of paramount importance we also recognize and encourage the use of radio as a means of improving the overall efficiency of the railroads.

Sincerely yours,

E. K. Jett,
Commissioner

Commissioner Ewell K. Jett has been a motivating factor in the development of radio communications since the pioneering days of the early 20th Century. From 1911-1929 he participated in the development of the Navy's use of what was then a new communications art. Since 1929, Mr. Jett has been associated with the Federal Communications Commission and its predecessor, the Federal Radio Commission, first as Assistant Chief Engineer; then, since February 1, 1938, as Chief Engineer. On February 15, 1944, Mr. Jett was appointed Commissioner.

Throughout his career with the Navy and the Commission, Mr. Jett has been alert to the ever-increasing usefulness of radio in mobile operations. More recently, with the development of radio equipment for railway and highway services and Mr. Jett's origination of the Citizens' Radio Communication Service, his activities wth the Commission have taken on even more significance to American economy and well-being.

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TELEVISION HANDBOOK

CHAPTER 1—Part 2: Characteristics of Images—1. Nature of Information, 2. Detail and Focus

BY MADISON CAWEIN

1. The Nature of Information ★ It is the purpose of this section to examine both the theoretical requirements of frequency spectra in the transmission of visual information, and the practical implications thereof. Some of the basic material has been discussed by others. It is hoped that this form of presentation, however, will be found useful. An attempt has been made to correlate and clarify available material necessary to an understanding of the subject.

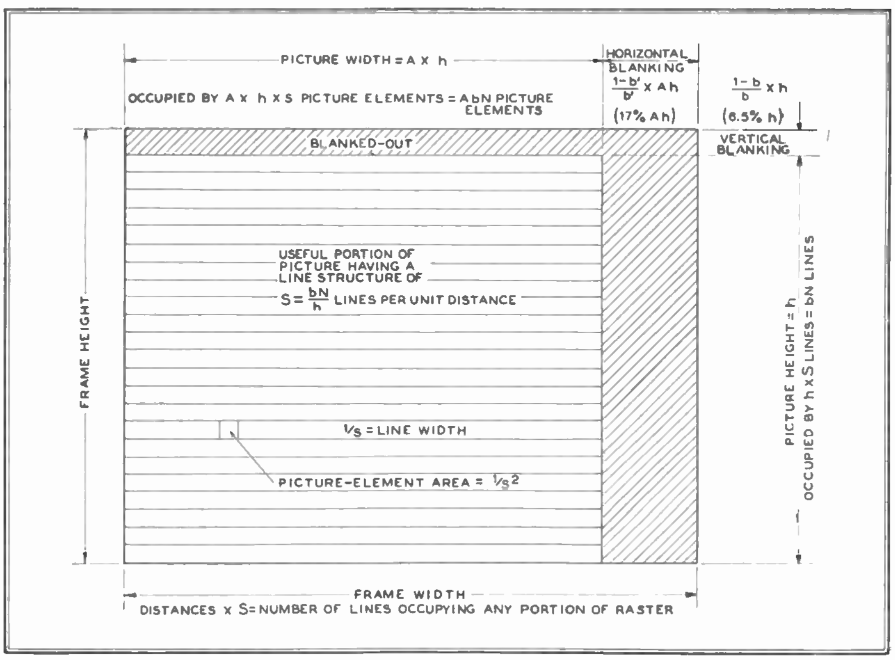


FIG. 7A. DIAGRAM SHOWING THE USEFUL PORTION OF THE TELEVISION RASTER, AND THE PORTIONS WASTED BY THE HORIZONTAL AND VERTICAL BLANKING

1. Detail in an Image: According to *Webster's New International Standard Dictionary*, an image is "the geometrical figure made up of the foci corresponding to the points of the object." The images which will be dealt with here can be considered to be constructed of points of light in a plane, some having different intensities relative to one another, and some having equal intensities.

Since a true mathematical point has no reality, no shape, and no dimensions, it is best to define the shape and dimensions of the points of light and thus avoid a philosophical impasse. The shape of a point will be defined as *square*. The dimensions of the square will be defined as the smallest that can be resolved at close range by the average, unaided human eye.

These concepts are in keeping with the uses to which television is put. The eye cannot distinguish shape in the smallest resolvable points, nor can it distinguish change in intensity over the area of the point. Thus, an image constructed of white and gray dots, the dots being .003 in. square, on a black background, will simulate perfection to the eye, in all except color.

A clue to the necessary minuteness of the dots is given by available data on the smallest angle which the eye can resolve. Points which subtend an angle of 1 minute of arc at the eye are at the limit of normal resolution. The word *normal* is used because resolving power is to some extent dependent upon brilliance of the point: very bright points which subtend much less than one minute of arc at the eye are resolvable because of *spill-over* to rods in the retina which are stimulated by proximity to the excited areas.

The question arises as to what is the optimum viewing distance: i.e., at what distance is the eye satisfied that the resolution of the image is a maximum? The answer to this question will constitute a statement of the dimensions of the smallest resolvable image element. The optimum viewing distance is 10 ins. for the normal eye, so that the width of minimum picture element which can be distinguished is $1 \times 10 \div 60 \times 57 = .003$ in., approximately. This is the finest detail which can be resolved by the average eye. The height of the minimum picture element would be the same.

The foregoing discussion would indicate that *detail* has the dimensions of area. It is assumed that this is a true statement of fact. The following analysis evaluates the performance of a television system on the basis of a ratio of areas: i.e., the ratio of the area of the image-field to that of a resolvable picture element, or of the image detail.

2. Factors Which Affect Video Frequency-Band Computation: The video frequency band necessary to produce a television picture extends from a lower limit of zero, or DC, to an upper limit which is determined by the scanning standards and the desired detail within the line. The necessary detail within the line for a satisfactory picture depends upon the experience of the human eye. This experience has shown that the horizontal resolution should be approximately equal to the vertical resolution.

It is the purpose of this section to deal with the factors involved in computing the frequency band required to transmit a television image. This frequency band depends upon the amount of information which is to be transmitted.

The transmission of information itself consists in the transfer of energy from one point of space to another. It always requires time to transfer energy through space. The rate at which energy is transferred is called *power*. The product of the total energy transferred, and the time required to transfer it, is called *action*. Power and action are physical concepts. Information is a mental concept, which is, despite this abstract quality, closely associated with the physical concepts of energy and time. It is the opinion of the author that information has actually the physical dimensions of *action* as represented by the product of energy and time, and that the amount of information which may be transmitted depends only upon the product of the energy and the time involved.

However this may be, it is a fact of considerable importance that the product of frequency band-width and time is required to transfer information. This principle was first proposed by R. V. L. Hartley[1] in 1928, and most men are convinced that it is at least as fundamental as that of the conservation of energy. The essence of this principle is that the more information which is transmitted in a given time, the greater the band-width required. The proportionality is direct, so that if 10 times the time is available for sending a message, or transmitting information, only 1/10 of the band-width will be required.

A television image is a form of information, and constitutes a message. A telegram can be sent visually as well as aurally. Or a message can be conveyed by means of a picture as well as by conversation. In what follows, reference is made to Fig. 7A.

1. Time Element Involved: Only a fraction, bb′, of the frame cycle is useful because, in the reproduction of the picture, (1-b)N lines are blocked out during each field scansion, and (1-b′) of each line is blocked out, to allow for scanning retraces. Into this interval of time, bb′/F, must be crowded all the detail of a picture.

2. Perfect Reproduction: The original image may be considered as divided into contiguous strips of width 1/S, each strip being made up of square elements, for purposes of reproduction by rectilinear scanning methods. In the following analysis it is assumed that the scanning lines do not overlap, in which case the picture will be reproduced essentially by means of rectangular elements.

3. Area of Each Detail: The smallest dimension (1/S) which can be seen in the original image will depend upon the viewing distance. The square of this dimension represents the area of the smallest square picture element which is discernible at a particular viewing distance. The ratio of the area of the element to the area of the picture is a measure of the frequency band required to reproduce the picture electrically. The extent of this frequency band for perfect reproduction can be computed.

4. Time-of-Transmission for a Single Picture Element: Assume a perfect (pick-up) transmitting device and a perfect (reproducing) receiving device. These devices include a means of rectilinear scanning with apertures much smaller than any picture element, or detail, to be transmitted. The scanning at the transmitter will, by electro-optical means, spread the image out into a continuous signal wave having a fundamental periodicity equal to that of the image repetition frequency. All the detail in the wave will appear as harmonic frequencies of this fundamental. The scanning at the receiver, also by electro-optical means, will reconvert the periodic signal-wave into an image which can be perceived by the eye. This image will have the same dimensions as the original, and the eye, in viewing both the original and the reproduction *at the same distance*, will see substantially the same detail in each because it will be unable to resolve the dark spaces between the lines of light.

Assume that the original image is being converted to an electrical signal-wave at a rate of F (30) frames per second. The harmonic frequencies which compose the electrical pulses, corresponding to the picture elements in the original image, depend upon the ratio of the time of transmission of a single element to the time of transmission of the entire image.

Since .003 in. is the smallest dimension which can be seen by the unaided eye (See Subsection 1 above), a 6- by 8-in. picture (h = 6) would require 6/0.003 = 2000 active, horizontal lines for *perfect* reproduction. The number of picture elements along each line would be 8/0.003 = 2666, so that the total number of visible picture elements required is 2000 × 2666 = 5,332,000. From Subsection 1 it is seen, however, that this represents only bb′ = 93.5% × 83% = 77.6% (by RMA standards) of the total (active and blanked-out) picture elements which must be transmitted in a perfect reproducing system. Thus, the actual, total number of picture elements, including those blanked out during retrace of the cathode-ray tube beam, is 5,332,000/0.776 = 6,870,000 (approximately seven million). The time of transmission of a single element, then, is approximately 1/7,000,000th of that for an entire frame of the image, or 1/210,000,000th of a second (30 frames per second).

The computation above was calculated for so-called *perfect* reproduction, with a line structure of S = 333 lines per inch, which is impractical with present-day techniques. Fortunately, the value of S under RMA standards, in a 6- by 8-in. picture, is only (93.5% × 525)/6 = 82 lines per inch, or ¼ of the ideal.

Time-of-transmission, Te, of a single picture-element depends upon line structure, S, and the aspect ratio, A. It can be computed, as indicated in the example above, by dividing the time, Tu, required to transmit the useful (unblanked) portion of a frame by the number of active picture elements, which is (h × S) × (A × h × S) as indicated in Fig. 7A. Since Tu is equal to $\frac{bb'}{F}$. Te can be represented by $\frac{bb'}{FAh^2S^2}$, or by

$$\frac{b'}{b} \times \frac{1}{AN^2F} = \frac{.83}{.935} \times \frac{1}{AN^2F} = \frac{0.9}{AN^2F},$$

approximately. Thus, Te depends upon the inverse of the square-of-number-of-lines, and is inversely proportional to the square of the line structure.

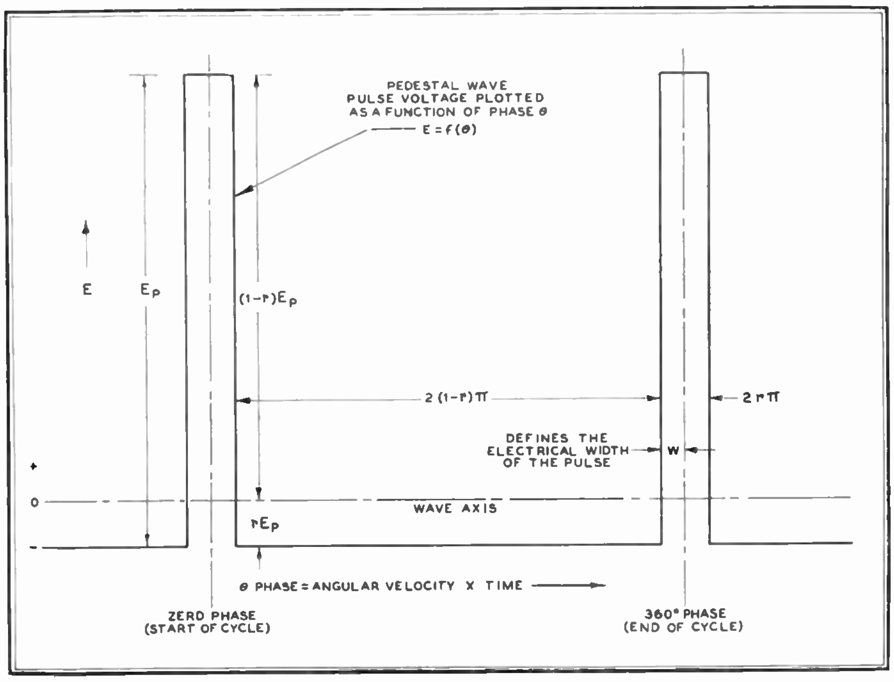


FIG. 8. SQUARE ELECTRICAL PULSE, OR PEDESTAL, HAS THE DISTINGUISHING CHARACTERISTICS OF AMPLITUDE, DURATION, AND FREQUENCY OF REPETITION

5. Harmonic Composition of a Pulse: The ideal shape of an electrical signal used to recreate a horizontal element is that of a square pulse. The Fourier analysis of a finite, square pulse shows that it is made up of an infinite number of cosine waves, harmonically related to one another and all in phase with one another.

A_r = Relative Amplitude of Harmonics =

$$\frac{\sin mr\pi}{mr\pi} \qquad (1.0)$$

Where m is the order of harmonic, and r is the fraction of the frame cycle during which the picture element, or light pulse, occurs. The cycle under consideration is that of a complete frame of the picture, so that if only one detail occurs in the picture, the fundamental frequency of the electrical pulse which reproduces it will be at the same frequency as that of the

[1] R. V. L. Hartley, "Transmission of Information," *Bell Tech. Jour.*, 7 (3), p. 535, July 1928.

frame cycle. This pulse is very narrow. It requires a great number of harmonics of the frame frequency to reproduce it. The amplitude of these harmonics, as given in equation (1.0) above, depends not only upon the order of the harmonic, but also upon the r-index of the wave, where r refers to the fraction of the cycle for which the pulse endures. Each pulse of light will have as its electrical counterpart a pulse of potential across some element of the electric circuits connecting transmitter and receiver.

A square electrical pulse, Fig. 8, is referred to sometimes as a pedestal. Pedestals have three distinguishing characteristics: amplitude, duration, and frequency of repetition. The latter two of these characteristics contribute to the frequency spectrum, which depends solely upon the ratio of the duration of the pulse to the period of the image projection. The frequency spectrum can be computed quite easily by means of a Fourier analysis of a narrow, finite pulse, created electrically at the transmitter by the scanning of a single illuminated point in the image. This analysis shows that the pulse can be considered as a series of harmonics of the frame projection-frequency, with relative amplitudes as indicated in equation (1.0), and plotted in Fig. 9.

6. Electrical Width of a Pulse: Of the three distinguishing characteristics of a pedestal, that of duration is of primary importance in television analysis. Duration is very closely related to electrical width, as shown in Fig. 8. Electrical width refers to one-half of the portion of the cycle (in electrical degrees or radians, there being 360° or 2π radians in a complete cycle) for which the pulse peak endures. According to the definition of the symbol r given in the second paragraph above, this value is $r \times \pi$ in radians (π radians in a half-cycle). Expressed as an equation, the electrical width w is therefore

$$w = r\pi \qquad (1.1)$$

By the use of equation (1.1) the relative amplitude of harmonics expressed in equation (1.0) can now be written

$$A_r = \frac{\sin mr\pi}{mr\pi} = \frac{\sin mw}{mw} \qquad (1.2)$$

where A_r is relative amplitude of harmonics, and mw indicates the order of the harmonic, that is, whether 1st harmonic, 2nd harmonic, et cetera, according to the value of m. Now, let the product of m and w be represented by ϕ = mw. Then:

$$A = \frac{\sin mw}{mw} = \frac{\sin \phi}{\phi} \qquad (1.3)$$

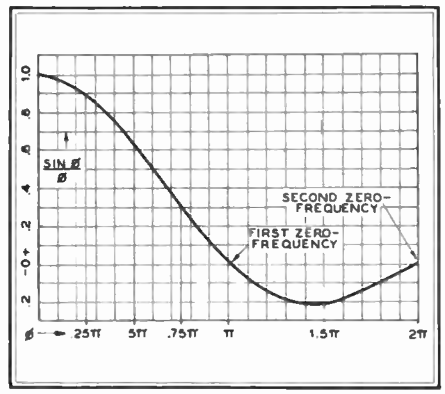


FIG. 9. RELATIVE AMPLITUDE OF HARMONIC COMPONENTS OF PEDESTAL

In equation (1.3) the symbol m is always an integer (a whole number, such as one, two, etc.) which refers to the number, or order, of the harmonic. For example, m = 1 refers to the fundamental frequency, also called the first harmonic. The symbol w is usually a small quantity, because the values of r, on which w depends, is usually small as applied to television. The value of r for the RMA-standard field-pedestal is about 0.065. Thus the value of w calculated from (1.1) is $.065\pi$, or 0.204 radians, or 11.7 degrees.

7. Reconstruction of a Pulse from its Harmonics: A reference to Fig. 9 will show the relative amplitudes of the harmonic components composing a field pedestal of this width, as expressed by the relative values of $\sin \phi / \phi$. There are 15 additive (or plus-valued) harmonic components which compose this pedestal wave up to the first, zero frequency which occurs at $\phi = \pi$, at which frequency the harmonic amplitude passes through zero. There are only fifteen, because $15 \times 0.065\pi = 0.975\pi$, while $16 \times 0.065\pi = 1.04\pi$. Thus, the 15th harmonic is the last plus-valued harmonic, and the 16th harmonic is negative and will subtract from the peak value of the pulse. An approximate peak value of the pulse can be obtained by adding up the first 15 positive harmonics at the start of the cycle, where the peak occurs. The relative values of the first 15 harmonic amplitudes can be found from Fig. 9, by assigning values to m from 1 to 15 (corresponding values of ϕ are from 0.065π to 0.975π, as computed from equation (1.3)), and by reading the values of $\sin \phi/\phi$ from the curve, for these values of m. These values are:

TABLE I

m	$\sin \phi/\phi$
1	.99
2	.97
3	.94
4	.90
5	.84
6	.79
7	.71
8	.62
9	.54
10	.45
11	.36
12	.27
13	.18
14	.10
15	.03
sum	8.79

The sum of the values of $\sin \phi/\phi$ for the first 15 harmonics is 8.79. This sum was obtained by actually adding up the 15 harmonics in Table I, at the point where the peak occurs. It can be shown that the peak value for any large number of harmonics, M, is represented by:

$$E_M = 2rE_p \sum_{m=1}^{m=M} \frac{\sin \phi}{\phi} \qquad (1.4)$$

where E_p is the peak-to-peak amplitude of the rectangular pulse, or pedestal wave, shown in Figs. 8 and 10, and the $\sum$ sign signifies that values of $\frac{\sin \phi}{\phi}$ as taken from the curve of Fig. 9, for each value of ϕ = mw, are all added together for values of m from 1 to M.

Applying formula (1.4) to the data of Table I, the peak value of the first 15

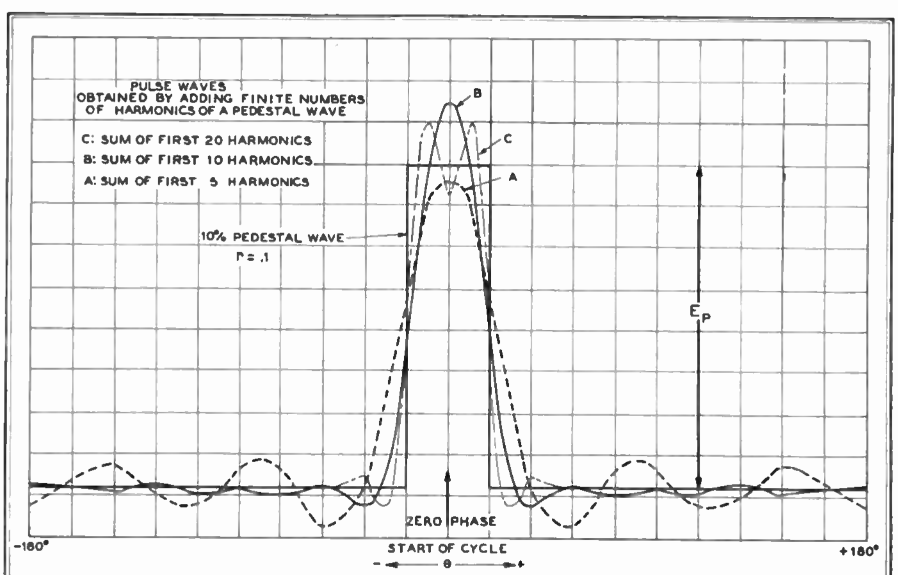


FIG. 10. PULSE WAVES OBTAINED BY ADDING FINITE NUMBERS OF HARMONICS OF A PEDESTAL WAVE

harmonics of the RMA standard field pedestal can be calculated as $E_{15} = 2 \times .065E_p \times 8.79 = 1.14E_p$. Thus, the sum of the harmonics up to the first zero-frequency yields a pulse with a peak amplitude a few per cent (14% here) greater than the pedestal height itself.

In Fig. 10 there is plotted one cycle of a pedestal wave similar to that shown in Fig. 8, but for a finite value of r, chosen to simplify calculations: that is, for $r = 0.1$, which defines a pedestal whose width is 10% of the cycle ($w = 18°$, or $w = \pi/10$ radians). Plotted in Fig. 10, also, are waves A, B, and C which would be obtained in simulation of the pedestal wave if only 5 harmonics, 10 harmonics, or 20 harmonics were used to simulate the infinite number of harmonics required to produce the pure, rectangular pedestal.

It will be noticed that the peak amplitudes at zero phase, or the start of the cycle, for waves A, B, and C are either greater than or less than that of the pedestal itself. This phenomenon is known as *overshooting*. Overshooting occurs whenever a finite number of harmonics is used to simulate a steep wave front, or sharp corner (such as in the pedestal wave) which requires actually an infinite number of harmonics for perfect simulation.

By means of methods beyond the scope of this discussion, it can be proved that a pedestal wave having a value of r smaller than 10% can be simulated by adding up the harmonics to the first zero-frequency, and that the simulated pulse obtained in this manner will be substantially the same as shown for curve B in Fig. 10. What this means, actually, is that any pedestal-type of impulse wave which has a very short duration can be simulated accurately enough for most practical purposes by M harmonics, where $M = 1/r$. The number of necessary harmonics is proportional to the inverse of the pulse width. In Fig. 11 there is shown a graph of a pedestal wave having a narrow width w. There is shown also the pulse wave which would be obtained by adding all the harmonic components of this pedestal to a value $M = 1/r = \pi/w$. The graph of Fig. 11 is universal. That is, it holds approximately for all pedestals of short duration and of narrow width, whether the value of w is .1 of a radian or .000001 of a radian.

The practical implications of this fact are as follows: if a periodic electrical wave having the form of a short, rectangular pulse (or pedestal) of width w is applied to an electrical network with a finite frequency band (of band-width Mf, where $M = \pi/w$ and f is the frequency of repetition of the pulse), then the output pulse will have the shape shown in curve B of Fig. 11, relative to the shape of the original pedestal wave shown in curve A. This fact is very useful in estimating the performance of an electrical system in regard to its transmission of rectangular pulses, and is also useful in the computation of the frequency band necessary in a television system in order to transmit a picture which has any predetermined value of resolution, or line structure, which determines the time of transmission of a single picture element.

It can be shown, also, that if higher numbers of harmonics than those existing up to the first zero-frequency (for example, if the harmonics up to the second zero-frequency were plotted) then the shape of the reproduced pulse would be universal for all narrow widths of pedestals, and would be of the form shown in curve C of Fig. 10. Each time the frequency band of the electrical system is extended by a multiple of the first zero-frequency,

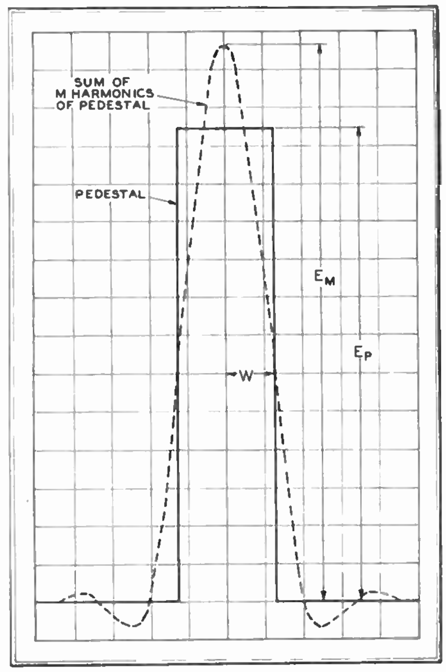


FIG. 11. SUM OF M HARMONICS OF A PEDESTAL, UP TO FIRST ZERO FREQUENCY

a new peak is added to the simulated reproduction of the rectangular pulse peak. That is, if harmonics of the pedestal up to the fifth zero-frequency were plotted, the peak of the pedestal would have five oscillations on top of it, similar to the two oscillations shown in curve C of Fig. 10, which was plotted for harmonics up to the second zero-frequency.

This fact is mentioned as a matter of general interest, and is not too important to elementary television analysis. Nevertheless, the facts related to pedestals in regard to their harmonic composition up to the vanishing point at the first zero-frequency are quite important to a comprehensive grasp of television theory. It is for this reason that considerable space has been devoted here to the subject.

It is sufficient here to consider harmonics only up to the first zero-frequency. In this case the distortion of the reproduction of a rectangular pedestal is approximately as shown in Fig. 10, where there is a positive overshoot in the peak direction having a magnitude of approximately 17% as shown by a comparison of curves A and B, and there is also a negative overshoot of approximately 6%, as shown. The actual width of the reproduced pulse, however, is almost identical to the width of the original pedestal. For mathematical reasons, also beyond the scope of this article, the effective, or average, width of a pulse is taken to be represented by the area of the pulse divided by its amplitude. A reference to Fig. 11 will show that the areas of the pulses of curves A and B, divided by their peak amplitudes, are approximately the same and are equal to one another, so that the values of w are the same for each.

2. Detail and Focus ★ From the discussion in Section 1, it should be evident that sufficient information has been presented to allow the formulation of the dependence of the required frequency bandwidth on the visible detail in the image. This formulation is quite important to the proper understanding of the problems of television. These problems may be said to be related to the required bandwidth, for the most part, and to the methods of presenting the information contained in this bandwidth within the time allowed for transmission of a television image. This information is presented at the receiving end on the illuminated area known as the scanning raster of a cathode-ray tube. A photograph of a blank scanning raster is shown in Fig. 12. Fig. 13 shows the presentation of detail within this raster in the form of a test chart.

In the 4th paragraph of Item 1, Subsection 2 in Section 1, it has been shown that the line structure of an RMA 525-line standard picture is about ¼ that of the so-called *perfect* or ideal television picture of 6 by 8 ins. The ratio of time-of-transmission of a single element to that for the entire image is therefore 16 times more favorable under RMA standards than for perfect reproduction, and the time-of-transmission for one element is 16 times longer, or about 1/13,000,000th of a second.

It will be shown here that the frequency band required for transmission of a television image is inversely proportional to the time-of-transmission of a single element, and thus depends directly on the square of the number of lines.

1. Number of Harmonics of the Frame Frequency Required ★ It has been shown in Section 1, Subsection 4, Item 4 that the time-of-transmission of a single picture element depends upon the scanning standards: i.e., upon the frame frequency F, and upon the number of lines N. The signal from this single picture element takes the form, in an electrical circuit, of a very narrow pulse occurring at the frame repetition rate of 30 per second, when a stationary image is being transmitted under RMA standards. It was shown, furthermore, in Item 7 that this pulse could be reproduced very well, for all practical purposes, if only those harmonics up to the first zero-frequency were transmitted.

The number of harmonics required is M, which is the number that exists up to the first vanishing harmonic which occurs when $\phi = \pi$, or $\sin \phi/\phi = (\sin \pi/\pi) = 0$. The number of harmonics of a pulse in the interval up to $\phi = \pi$ is determined by the electrical width w of the pulse as presented in the example for w — 0.065 in Item 7, where 15 harmonics were required. This number M is determined by setting $Mw = \pi$ and solving for M. Thus:

$$M = \frac{\pi}{w} = \frac{\pi}{r\pi} = \frac{1}{r} \qquad (1.5)$$

2. Video Frequency Band Required for High Fidelity: Since M defines the number of harmonics of the frame frequency required to reproduce the width of a picture-element pulse, the frequency bandwidth required is given by the equation

$$f_c = MF \qquad (1.6)$$

It must be remembered that r, which determines M from equation (1.5), represents the fraction of the cycle for which the pulse endures. Thus, r is the ratio of the time-of-transmission of a picture-element pulse to the time-of-transmission of a complete frame, or picture cycle, which is the same thing as the ratio of the area of a picture element to the area of the unblanked raster shown in Fig. 7A. The ratio r, therefore, can be represented in mathematical symbols by dividing Te Paragraph 4 by Tu, which is 1/F.

$$r = Te/Tu = \frac{0.9}{AN^2F} \div \frac{1}{F} = \frac{0.9}{AN^2} \qquad (1.7)$$

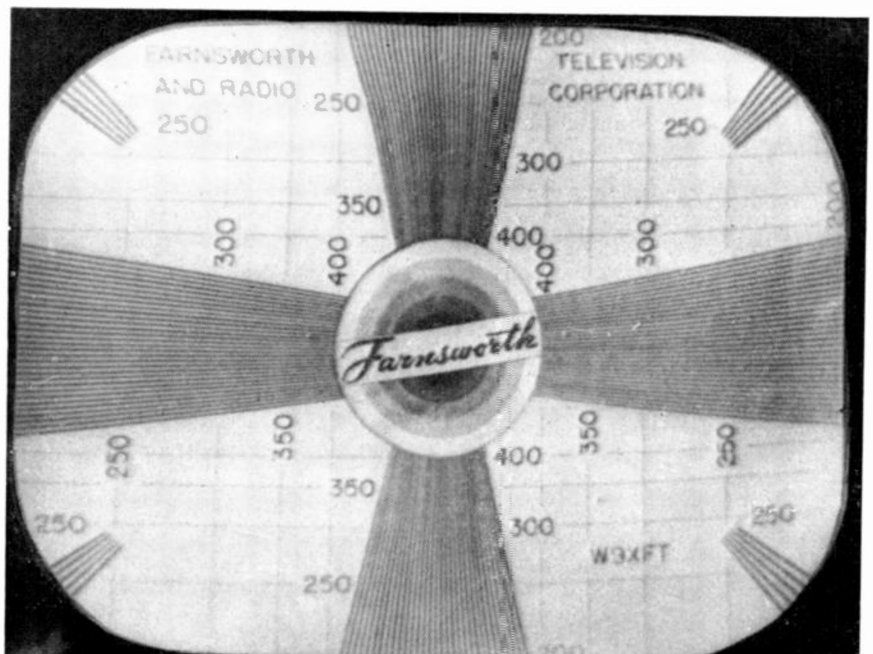


PHOTO SHOWING PRESENTATION OF DETAIL, IN THE FORM OF A FIXED TEST CHART

Substitute from equation (1.7) into equation (1.5):

$$M = 1/r = 1.11AN^2 \qquad (1.8)$$

Now substitute from (1.8) into (1.6) to obtain the value of f_c, which is the bandwidth required to transmit the image:

$$f_c = MF = 1.11AN^2F = 1.47N^2F \qquad (1.9)$$

The bandwidth expressed in equation (1.9) will reproduce the wave form of a picture-element pulse with only slight variations in brightness, within the limits of observation by the human eye, as shown in Fig. 11. It is, therefore, sufficient for the perfect transmission of the detail necessary to produce a television image constructed of N lines per frame and at a rate of F frames per second, under RMA standards and with equal values of line resolution in the horizontal and vertical directions.

Under RMA standards, this means that a bandwidth of $f_c = 1.11 \times 1.33 \times 525^2 \times 30 = 12,237,000$, or approximately 12 mc. is required to reproduce a perfect picture, *within the capabilities* of a 525-line, 30 frame television system having equal horizontal and vertical resolution.

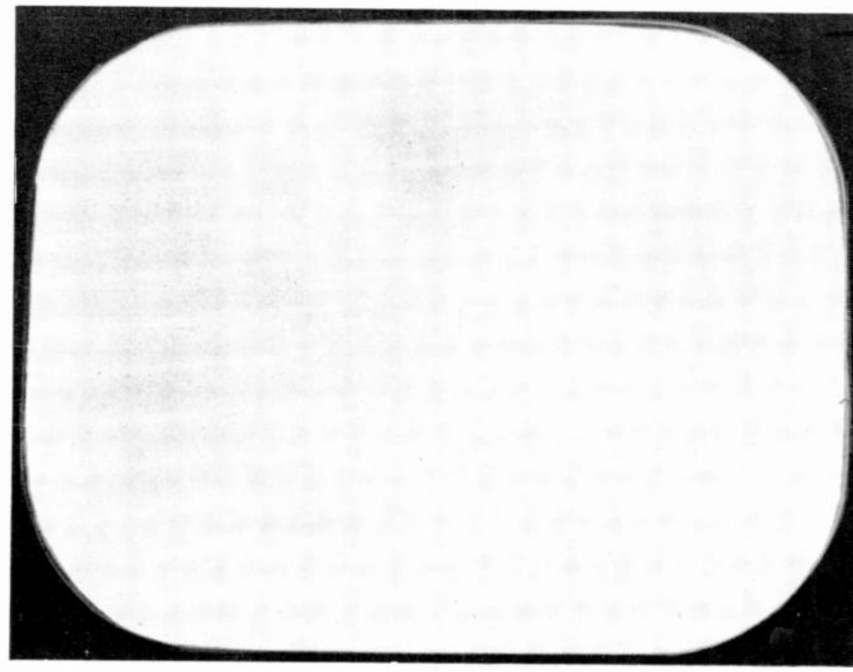


FIG. 12. PHOTOGRAPH OF A BLANK SCANNING RASTER, SHOWING RETRACE LINES

3. Empirical Bandwidth Formula: This does not mean that 525 lines can be resolved in both the horizontal and vertical dimensions of the picture when using a 12-mc. pass-band. The actual resolution will depend upon the sharpness of focus of the electron beam used to create the image, upon the stability of synchronization, upon the blurring effect of motion in the image, and upon an empirical factor which concerns resolution [2] and which depends partly upon the change in reg s-try of scanning lines with respect to the image being resolved, and partly upon the psychology of the observer. Probably the best value of this latter factor has been determined experimentally as K = 0.7, as it affects the number of lines in the vertical direction which can be resolved.

Some of the details of the picture are lost in the blanked-out portions of the raster. The useful area in Fig. 7A is only 77.6% of the total; and since the total number of *square* picture elements in the entire raster of this figure is $(A \times N) \times N = 4/3 \times 525 \times 525 = 367,500$, there are actually only 285,180 visible picture elements in a near-perfect television image under RMA standards. Only 93.5% of the lines are useful, at best, in the vertical direction, so that 491 lines would be the maximum number which ever could be resolved vertically in this system, although the picture is referred to as a 525-line picture by general usage.

The eye does not need to perceive the

[2] "A Determination of Optimum Number of Lines in a Television System," R. D. Kell, A. V. Bedford, and G. L. Fredendall, *RCA Review*, July 1940.

change from black-to-white as sharply as indicated by the pulse waveforms of Fig. 11: any form of change will be perceived as a difference of shading between adjacent picture elements and can be distinguished by the eye. This is true even though absolute black and absolute white are not obtained in the reproduced image relative to that in the original image being transmitted.

For this reason an empirical formula for frequency band, based on just perceptible resolution between adjacent picture elements is usually used. This formula for the bandwidth required to show N-line resolution is:

$$f_c = 0.35AN^2F \qquad (2.0)$$

It is interesting to compare this with equation (1.9). It is based on actual tests[2] with observers as to their ability to see transmitted detail in a black-and-white resolution chart. Using RMA standards, equation (2.0) states that the necessary bandwidth for transmitting 525-line images is $f_c = 0.35 \times 1.33 \times 525^2 \times 30 = 4{,}183{,}000$, or approximately 4 megacycles. The standard RMA bandwidth is 4.5 mc. between video and audio carriers, which allows a guard band for audio rejection circuits.

4. Aperture Distortion and Its Effect Upon Detail. The act of scanning an image-field by means of a finite aperture will modify the amount of detail which can be observed in the reproduced picture. In the following discussion it is assumed that the aperture is square, and of dimensions 1/S by 1/S, as shown in Fig. 7A. The aperture under immediate discussion, however, refers to the spot size at the transmitter and not to that at the receiver.

The finite size of the transmitter aperture occurs in all kinds of pick-up tubes. In the Farnsworth image dissector the aperture is an actual square, or rectangular hole, or sometimes a circular hole, which is placed in the shield surrounding the multiplier and collector for the purpose of admitting only a small portion of the electrons arriving from the cathode, so that the electron image can be viewed bit by bit during the scanning processes. In the iconoscope and other types of electron-beam pick-up tubes, the aperture is established by the cross-sectional area of the electron beam itself. The ideal pick-up tube should contain an aperture of very minute dimensions compared to the smallest picture element to be scanned in the image field. Unfortunately, however, it is quite difficult to utilize small apertures in pick-up tubes, partly because of mechanical difficulties, partly because of electron-optical difficulties, and partly because of reduction in sensitivity in some tubes, as in the dissector. This matter will be discussed in a later section.

The finite size of the aperture has the practical effect of attenuating the higher-frequency electrical components in the electrical signal from the image, due to ellision of harmonics in the electrical pulse from any given picture element in the image field. This ellision, or removal, of higher-order harmonics, due to finite aperture size, is quite similar to the reduction in amplitude of the harmonics of a pedestal due to the finite electrical width w of the pedestal. Actually the effect of the finite size of the aperture is to integrate the variations in light intensities along the

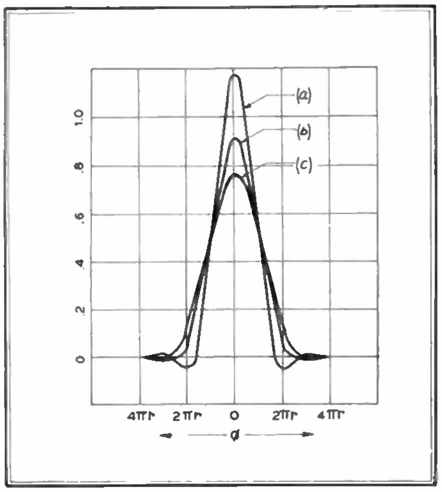


FIG. 15. MODIFICATION OF A PULSE BY SCANNING WITH FINITE APERTURES

line scanned by the aperture, as shown in Fig. 14.

Because apertures obey the law of conservation of energy, the total energy delivered to the collector, or scanned off by the electron beam during the process of scanning, is conserved, regardless of the dimensions of the aperture. This is true

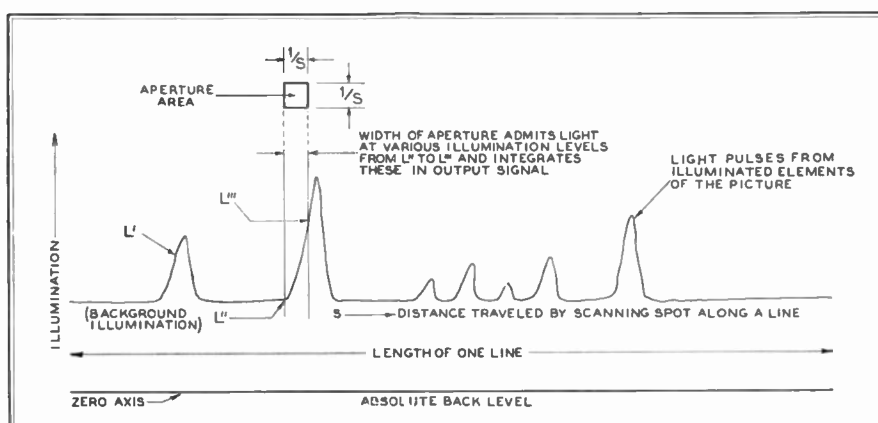


FIG. 14. SCANNING OF LIGHT PULSES ALONG AN ILLUMINATED LINE BY A FINITE APERTURE

only providing the overall light flux from the optical image or the magnitude of aperture current is scaled down in inverse proportion to the area of the aperture, in order to maintain the signal output constant as the aperture size increases. The physics of this is that the light flux delivered through the aperture has the dimensions of power, which is energy per unit time, and the wider apertures admit more flux for a longer period of time at a given scanning velocity. If the total flux is reduced proportionally to the increase in aperture area, the net product of power flowing through the aperture, and time, will be a constant, having the dimensions of energy.

In Fig. 14 the intensity of illumination, L', in an image field, or the corresponding density of current in an extended electron image, is shown for a single line of the scanned raster at the transmitter as a function of the distances traveled along the line. Assume that L'' is reduced proportionally as $\frac{1}{S^2}$ (aperture area) is increased. Then the effect of the traversal, by the aperture having an area of $\frac{1}{S^2}$, across this luminous field is to integrate the light values of adjacent regions of the picture over the aperture width in such a manner that the peak intensity of the light pulsing through the aperture is reduced as a function of the aperture width; while the length of time, or time-of-transmission, during which the light flows through the aperture is increased.

It can be shown that the effect of any aperture upon the peak value of the signal entering it, or upon the harmonic content of the electrical pulse derived from the aperture as it crosses a luminous point, is mathematically the same [3] as the effect of finite, electrical width on the harmonic content of a narrow electrical pulse, as shown in Fig. 11. This means that another factor of the same form as that of $\sin \phi/\phi$ is introduced into the equation (1.4) each time an aperture is introduced into the transmission system. This factor modifies the peak value of a rectangular pulse, and the effective width of pulse, for any number of harmonics.

Equation (1.4) is modified as follows, if n apertures (the value of n would be at least 2 in present-day television systems, where an aperture exists both at the transmitter pick-up tube and at the receiver cathode-ray tube) are introduced into the transmission system between the image field to be transmitted and the reproduced picture:

(CONCLUDED ON PAGE 46)

[3] Mertz & Gray, "A Theory of Scanning," *Bell Sys. Tech. Jour.*, p. 464, July, 1934.

WTCN-FM SOLVES UNUSUAL ANTENNA PROBLEM

Assembled in Elevator Shaft, Tower Was Raised through Top of Foshay Building

JOHN M. SHERMAN, technical director of station WTCN, overcame seemingly insuperable obstacles in the erection of the 80-ft. FM antenna which now dominates the skyline of Minneapolis, and delivers FM programs far beyond the calculated range of the 3-kw. interim transmitter now in use. The unusual method employed to erect the antenna and its supporting structure is illustrated in the accompanying photographs.

The Foshay Building, site of the WTCN-FM transmitter, offered an ideal location. However, it first appeared that this building, of steel and stone construction, with smooth sides rising to a height 447 ft. from the street, posed difficulties that would more than offset the advantages to be obtained from putting the antenna atop this dominating height. Chief obstacle was that materials and equipment could not be hoisted outside the building and assembled on the top. The situation was further complicated by the fact that the work could not be completed before cold weather set in unless the start was postponed until spring. (WTCN-FM actually started regular transmission on December 27th.)

In the end, John Sherman assembled a construction team made up of the original architects and builders of the Foshay Building, together with engineers from the WTCN staff and from Federal Telephone and Radio Corporation, suppliers of the antenna and FM transmitting equipment.

They evolved the plan of clearing an unfinished elevator shaft from the basement to the 30th floor, a height of 400 ft. The strategy was to raise materials to the 30th floor, assemble the tower and the square loops in the shaft at that point, working from the top down, and then to raise the antenna step by step through a hole cut in the roof.

At the top of the page opposite are pictures of the elevator shaft and the opening in the roof. The lower photos show how the tower and loops were put together at the 30th floor, and then raised by a system of steel cables attached to hand-operated winches.

Under this procedure, the top section, surmounted by the 300-mm. aircraft warning beacon, appeared first to the sidewalk superintendents watching below. This is shown by the left hand picture on this page. As the process of building from the bottom was continued, all eight sections and their associated loops and coaxial transmission lines were put together until the complete assembly was finished and anchored permanently. The foundation for the tower and the offset section of the transmission line can be seen at the bottom center of the page opposite.

Other views show the transmitter room in course of completion with the troughs laid out for power lines, and the final installation of the 3-kw. Federal FM transmitter. There are also detailed views of the antenna phasing equipment, showing how the two lines, each running to 4 antenna bays, are joined to the single feeder from the transmitter.

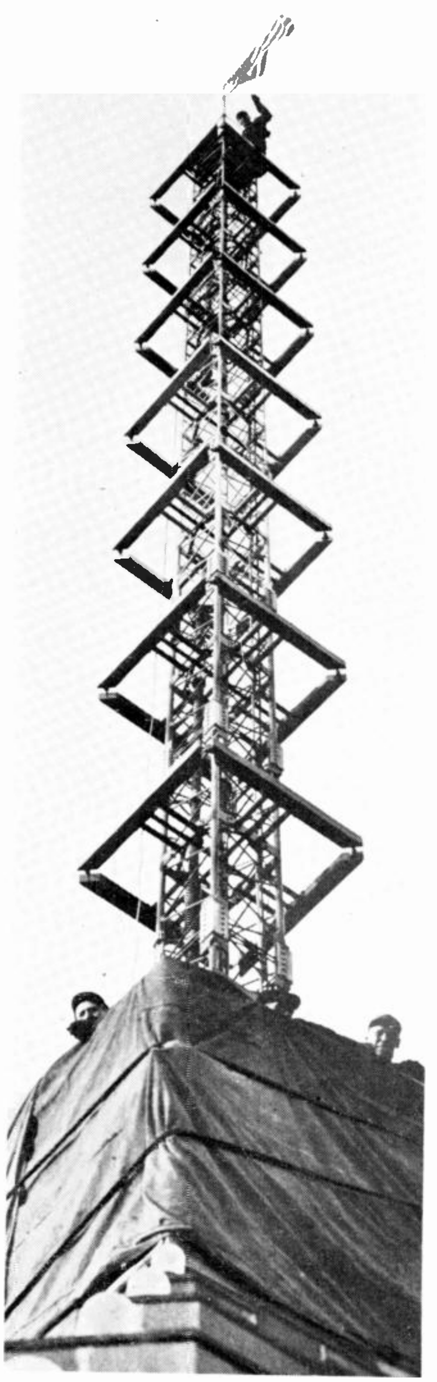
With an antenna gain of 8, the present effective radiated power is approximately 25 kw. transmitted on a frequency of 97.1 mc. Subsequently, a 50-kw. amplifier will up the rating to 400 kw., making WTCN-FM one of the most powerful FM stations authorized by the FCC up to this time.

Meanwhile, on low power, the station is being reported consistently at St. Cloud, a distance of 60 miles; Rochester, 78 miles; Little Falls, 80 miles; and Duluth, 130 miles. This is very significant, particularly in view of the fact that AM station operators have predicted freely that FM coverage would not show up advantageously, in comparison to AM, in the flat sections of the Country.

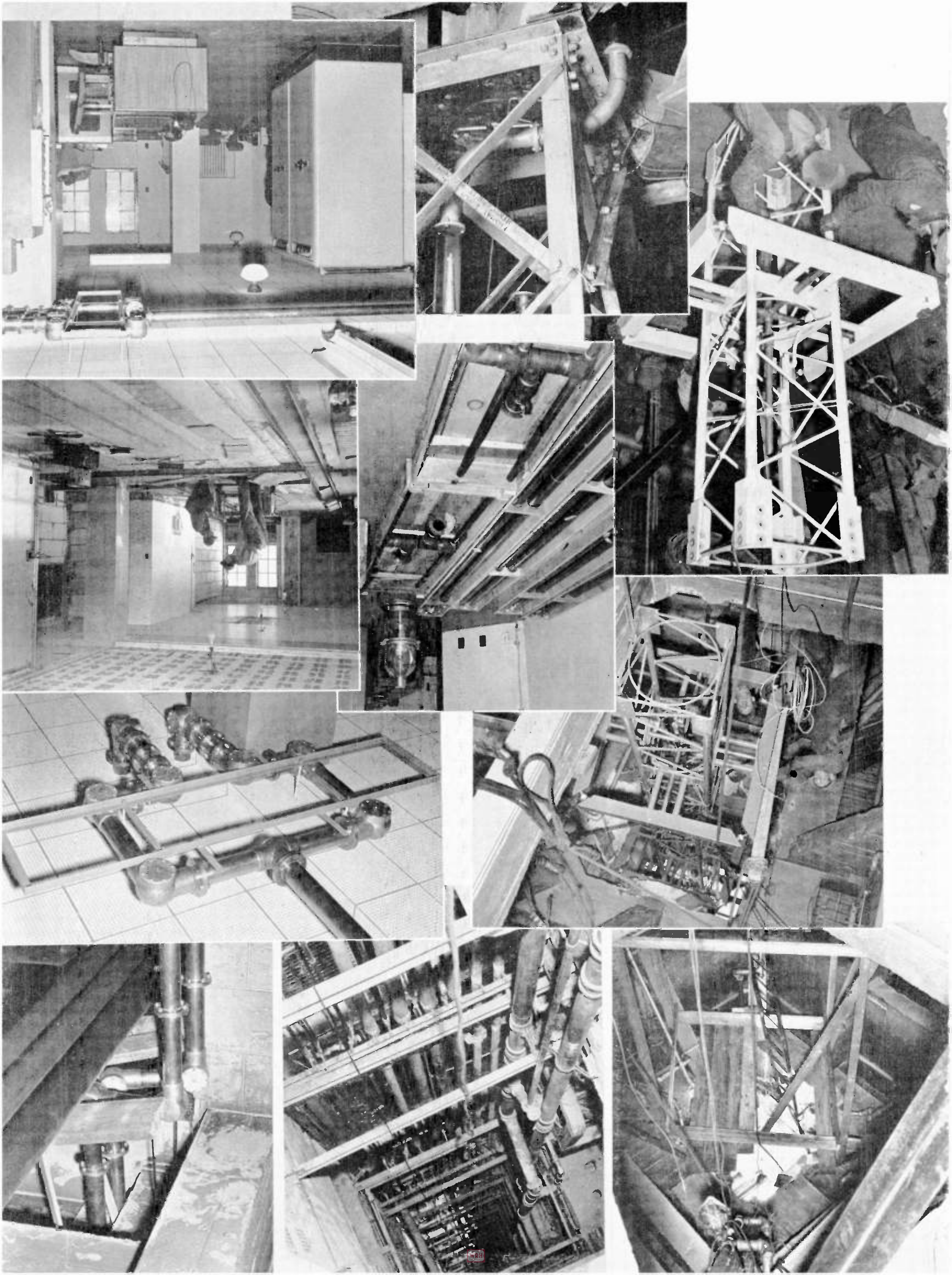
On the basis of performance from this station, it appears that when the power is upped to 400 kw. from the antenna, it will afford solid coverage over a considerably larger area than the primary service areas of the largest midwestern AM stations.

Starting off with a live-talent broadcast of the Minneapolis Symphony Orchestra, WTCN-FM is doing an exceptional job of featuring fine programs, and in less than two months, 3,000 FM sets have been sold in the Minneapolis area.

ASSEMBLED IN THE ELEVATOR SHAFT, TOP OF ANTENNA APPEARED FIRST



COMPLETED FEDERAL SQUARE-LOOP ANTENNA AT WTCN-FM MINNEAPOLIS



MAGNETRON: GENERATOR OF CENTIMETER WAVES

The Theory of the Magnetron, and Its Development as a Practical Means for Generating Centimeter Waves—6th Installment

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

9.4 *Pulling Figure:* The Rieke diagram completely specifies the dependence upon load of the magnetron output power and frequency of operation. Nevertheless, it is convenient to be able to specify by a single parameter the dependence of operating frequency on load changes. The preceding discussion has shown that the changes in load conductance reflected into the resonant circuit of the magnetron, that is, specified at either the primary or secondary terminals of the ideal transformer of Fig. 31 (b), vary output power only. Further, if G_e and B_e are unrelated, load susceptance changes specified at the same points vary frequency only. Since G_e and B_e are in fact related, constant frequency contours on the $G'_L - B'_L$ plane, as has been seen, are inclined to constant B'_L lines at the angle α. Thus changes in B'_L are more effective by the factor $1/\cos\alpha$ in affecting frequency than equation (37) would indicate. The quantity calculated for $\Delta\omega/\Delta B'_L$ from equation (37), multiplied by the factor $1/\cos\alpha$, is a parameter which specifies the dependence of frequency on load. It may be specified at any value of load admittance Y'_L, that is, for any position on the $\bar{r}$ plane. Generally, however, one considers the rate of change of frequency with susceptance at matched load, for which Y'_L is equal to the characteristic admittance Y'_0 of the output line at the point in question. Using the parentheses $(\ )_0$ to indicate that the quantity enclosed is measured at the match point and incorporating the factor $1/\cos\alpha$, from (37):

$$\left(\frac{\Delta\omega}{\Delta B'_L}\right)_0 = \frac{1}{2}\left(\frac{M}{L}\right)^2 \frac{\omega_0}{Y_{0c}} \frac{1}{\cos\alpha}. \qquad (42)$$

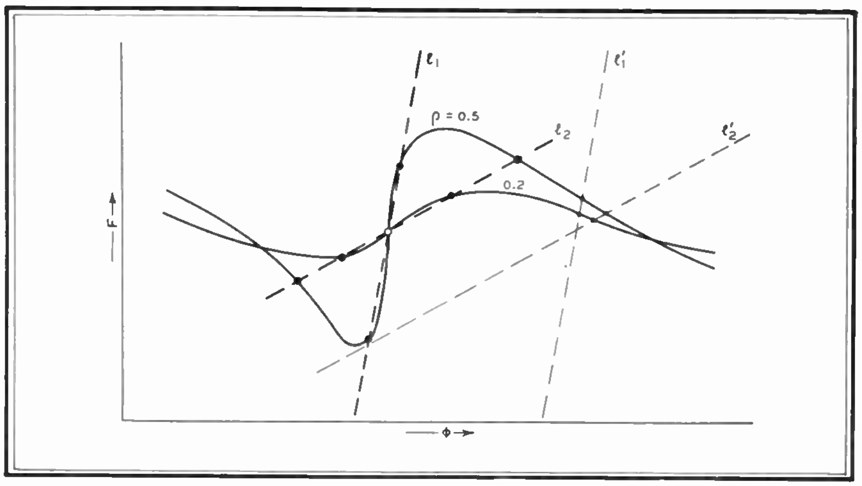


FIG. 35. Plots of the frequency characteristics of a magnetron and a frequency-sensitive load for two magnitudes of reflection coefficient ρ and two line lengths ℓ. The ordinates are fequency and the abscissas are phase angle of the reflection coefficient in the fundamental period 0 to π radians. Stable oscillation occurs at the intersections indicated by filled circles. The open circle indicates a point of unstable operation for the three conditions $\rho = 0.5$ and $\ell = \ell_1$, $\rho = 0.5$ and $\ell = \ell_2$, and $\rho = 0.2$ and $\ell = \ell_2$. In addition, it indicates a point of stable operation for $\rho = 0.2$ and $\ell = \ell_2$. These four points are coalesced on the figure for simplicity. The lines ℓ_1' and ℓ_2' indicate how stable operation at both $\rho = 0.2$ and 0.5 can be attained by an increase of line length of approximately a quarter wavelength.

The $(\Delta\omega/\Delta B'_L)_0$ as it stands is not a convenient one to measure. For this reason it is customary to specify the total excursion of frequency, $\Delta f = \Delta\omega/2\pi$, resulting from a standard variation in $\Delta B'_L$, namely, that obtained by the total possible phase variation of a standing wave of 1.5 voltage ratio in the line at the point in question. This is equivalent to traversing the $\rho = 0.2$ circle on the reflection coefficient plane, shown on Fig. 33. It can be shown that such a variation of load admittance results in a variation of susceptance of $\pm$ 0.41 times the characteristic admittance of the line Y'_0, corresponding to a total susceptance variation of 0.82 Y'_0. When determined in this way, the total frequency excursion is called the pulling figure, *PF*. Hence by equation (42)

$$PF = \Delta f = \frac{\Delta\omega}{2\pi} = \frac{1}{2}\frac{2\pi f_0}{2\pi}\left(\frac{M}{L}\right)^2 \frac{.82 Y'_0}{Y_{0c}} \frac{1}{\cos\alpha}$$

$$= 0.41\, f_0 \frac{\left(\frac{M}{L}\right)^2 Y'_0}{Y_{0c}} \frac{1}{\cos\alpha}. \qquad (43)$$

Since $Y'_0 = ((G'_L)_0$, the quantity $(M/L)^2$ Y'_0 in this expression is recognized as $((G''_L)_0$, the load admittance at the primary terminals of the ideal transformer when the line is matched at the point in question, namely, the secondary terminals. Using this fact and equation (23), the pulling figure is seen to be:

$$PF = 0.41\, f_0 \frac{(G''_L)_0}{Y_{0c}} \frac{1}{\cos\alpha} =$$

$$\frac{0.41\, f_0}{(Q_{ext})_0} \frac{1}{\cos\alpha}. \qquad (44)$$

Although this equation was derived for a specific point in the equivalent circuit, it is of general validity at any point in the output circuit or load line of the magnetron, provided the quantity $(Q_{ext})_0$ is properly interpreted as the external Q measured at match in the line at the same point.

10. Special Topics ★ 10.1 *Frequency Stabilization:* The degree of stability of the operating frequency of the magnetron to load changes is specified by the external Q, as equation (44) indicates. The external Q, by equation (23), can be increased either by decreasing the load conductance G''_L, or by increasing the circuit characteristic admittance Y_{0c}. The first alternative can be accomplished by reduction of the coupling between the load and magnetron resonator system. Although this results in greater frequency stability, it entails a reduction in output power. Increase of the characteristic admittance of the magnetron resonator system, on the other hand, increases the energy storage capacity as indicated by equation (20) without appreciably changing the output power. Frequency stability can be increased in this way either by redesign of the magnetron resonator system or by coupling to it a tuned cavity of high unloaded Q. In the latter case, the degree of stabilization, defined as the ratio of energy stored in the combination of magnetron resonator system and stabilizing cavity to the energy stored in the magnetron resonator system alone, is the factor by which the external Q is increased and the pulling figure decreased. In actual practice, the stabilizing cavity can be coupled into one of the magnetron resonator cavities or built into the output circuit.

10.2 *Frequency-Sensitive Loads:* In the preceding sections it has been seen how the load admittance, among other parameters, determines the frequency at which the magnetron oscillates. If this load admittance is itself a function of frequency, it may be possible for the condition of oscillation to be satisfied at more than one frequency. This fact makes for an uncertainty of operation, which is to be avoided. Should the load fluctuate, for example, as it does in many applications, the oscillation may jump discontinuously from one frequency to another. If the magnetron is pulsed, it may in certain circumstances oscillate at different frequencies on successive pulses. A tunable magnetron operating into a frequency sensitive load exhibits periodic gaps in its tuning characteristic in which the magnetron cannot be made to operate.

The discussion here will be limited to the specific type of frequency-sensitive load consisting of a long line terminated in an admittance, assumed to be frequency insensitive, which differs from the characteristic admittance of the line. The input admittance of such a line is represented by a reflection coefficient of amplitude, ρ, depending only on the termination [see equation (30)] and of phase ϕ, depending only on the frequency f and the line length ℓ. Thus:

$$\phi = \frac{2\pi\ell}{\lambda/2} = \frac{4\pi\ell f}{c},$$

from which

$$f = \frac{c\phi}{4\pi\ell}. \qquad (45)$$

This equation expresses the linear relation between frequency and phase for the load, specified by the reflection coefficient, into which the magnetron operates. The heavy dashed lines in Fig. 35 represent this relation for two particular line lengths, ℓ_1 and ℓ_2, with ℓ_2 very much longer than ℓ_1. The difference in line length $\ell_2 - \ell_1$ corresponds to an input phase difference of many times π radians. For the case in Fig. 35, however, this is chosen as an integral multiple of π, so that the curve, plotted for the fundamental period 0 to π, will lie in the same range.

The variation of operating frequency of the magnetron with variable phase of the load reflection coefficient is a periodic function whose amplitude increases with increasing amplitude ρ of the reflection coefficient. This function can be determined graphically from a Rieke diagram of the magnetron, like that shown in Fig. 33, by traversing the appropriate circle concentric with the center of the diagram and plotting the frequency of operation against phase. In Fig. 35 are plotted such curves for two values of ρ corresponding to different terminations at the end of the long line.

A more detailed analysis of the condition of oscillation shows that it is possible for the magnetron to oscillate stably at those intersections of the magnetron and load frequency characteristics at which the slope of the load line is greater than the slope of the magnetron characteristic. Thus, as indicated in Fig. 35, oscillation may occur at only one frequency for the line of length ℓ_1 if $\rho = 0.2$ but at two frequencies if $\rho = 0.5$. In the latter case the middle intersection, indicated by an open circle, does not correspond to stable oscillation. For a line of length ℓ_2, on the other hand, two oscillation frequencies are possible at both $\rho = 0.2$ and $\rho = 0.5$. If, in either case, the line lengths ℓ_1 and ℓ_2 are increased by only an approximate quarter-wavelength, corresponding to a phase change of $\pi/2$ radians, the light dashed lines labelled ℓ_1' and ℓ_2' in Fig. 35 represent the load characteristics, and oscillation can occur at only one frequency with ρ equal either to 0.2 or 0.5.

If one considers the relationships depicted in Fig. 35, it becomes clear that there are two critical relationships between ρ and ℓ. The first specifies the values of ρ and ℓ which, if exceeded, makes oscillation possible at more than one frequency at all phases of the load reflection coefficient. The second specifies the values of ρ and ℓ which must not be exceeded if oscillation is to be possible at only one frequency for all phases of the load reflection coefficient. This latter relation between ρ and ℓ is that for which the slope of the load line is equal to the slope of the magnetron characteristic at its point of inflection.

From what has been said, it would appear that the use of long load lines is to be avoided if at all possible. If the magnetron is pulsed and the line is sufficiently long, however, it is possible for the oscillation in a pulse to have been completed before any energy reflected from the termination has arrived back at the magnetron. Under these circumstances, the magnetron operates into an effectively infinite line which presents its characteristic admittance to the magnetron output. For a pulse of one microsecond duration, this would require a line length of about 150 meters. Usually such lengths are not possible or are undesirable by virtue of attenuation, and either the line is made sufficiently short or its length critically adjusted or the standing wave on it reduced so as to cause operation to occur at a single frequency. Studies have been made of the transient conditions prevailing near the beginning of a pulse when, in establishing the steady state, the successive reflections are returning to the magnetron and, as a consequence, its frequency is changing. Except in a limited region on the Rieke diagram where operation is completely uncertain, it has been shown that the magnetron will settle down to operation at one frequency dictated by the phase of the first reflection, even if oscillation at two frequencies by the previous analysis is possible. Gaps in the tuning curve of a tunable magnetron correspond to the periodic traversal of this uncertain region as the frequency is varied and the load reflection coefficient moves around a constant ρ circle on the Rieke diagram.

10.3 *Magnetron Tuning:* To tune the magnetron oscillator it is necessary to vary a susceptance somewhere in its circuit. It has already been observed how variation of load admittance when reflected into the resonator system as a susceptance change results in frequency pulling. Although for other reasons this variation is usually limited by output circuit design to the order of 0.1% of the operating frequency, it could be increased

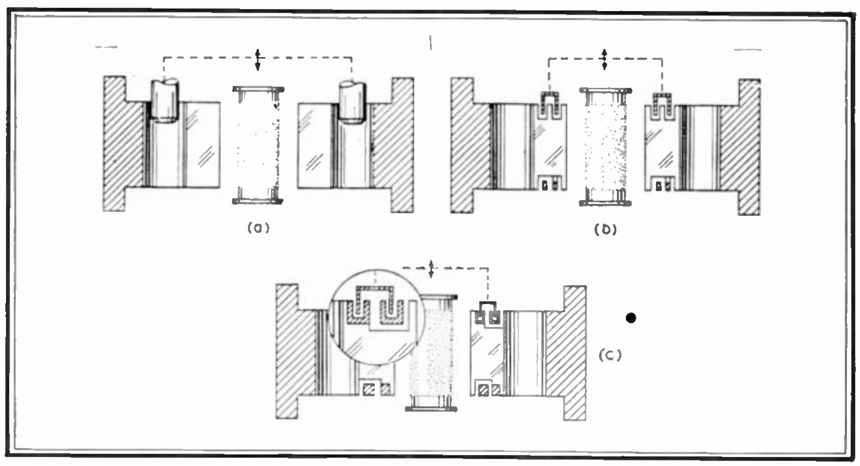


FIG. 36. Schematic diagrams showing three types of tuning schemes which have been used in magnetron resonator systems. The views represent sections on a diametral plane through the anode structure. The cathode is shown in the center of each part of the figure. The resonators are of the hole-and-slot type. *(a)* Shows the scheme involving variation of the inductance by means of tuning pins; *(b)*, the scheme involving variation of resonator capacitance; and *(c)*, that involving variation of strap capacitance. The last two schemes employ a cookie-cutter shaped member.

and used in special instances as a means of tuning the magnetron. Similarly the susceptance of a stabilizing cavity coupled into the resonator system can be varied by tuning the cavity. This method in general enables one to tune over a wider range than does variation of load susceptance, since the resonator system is usually more tightly coupled to the stabilizing cavity than it is to the load.

The largest tuning ranges have been attained, however, when it has been arranged to vary one of the frequency-determining parameters of the magnetron resonator itself. Schemes have been devised which alter primarily either the inductance or the capacitance of the resonant cavities. Variation of the inductance has been found more convenient at the shorter wavelengths, and variation of the capacitance easier at longer wavelengths.

Variation of the inductance can be accomplished by the insertion of a conducting pin into each resonator where the RF magnetic lines of force are concentrated. In a system of hole-and-slot type resonators, it is arranged to move the pins in and out along or near the axes of the holes. Such an arrangement is shown schematically in Fig. 36 (a). As the pins are inserted they reduce the volume available for the magnetic flux, thus reducing the inductance and increasing the frequency. Tuning ranges as great as ±7% of the mean frequency have been attained by this means. In spite of the fact that the ratio of strap-to-resonator capacitance remains nearly constant, the separation of mode frequencies, as might be expected, decreases with increasing frequency because of the increase in strap inductance resulting from increase of its electrical length. The effect is not so large, however, that with reasonable tightness of strapping, difficulty is encountered with mode frequency separation.

Variation of the capacitance can be accomplished by moving a member in the vicinity of the region of large distributed capacitance of the resonators. One such tuning scheme is that shown in Fig. 36 (b) in which a member shaped like a cookie-cutter is moved in and out of annular grooves in one end of the resonator block, the other end of which is usually strapped. As the member is inserted, the mode frequencies decrease. The frequency range available for π mode operation is limited by the fact that the frequencies of modes of smaller n, which are normally higher than that of the π mode, change faster and eventually cross the π mode frequency.

To understand what determines the frequency of resonance in any mode, it is sufficient to consider the inductances and capacitances present in the average sector of the resonator system across which there is a half-wavelength azimuthal variation of RF potential with an extremum at either end. In the π mode of an $N = 8$ resonator system, one can thus consider one-eighth of the system, namely, a single resonator; in the $n = 1$ mode, one can consider half of the resonator system. In the case of the half-wavelength sector for the $n = 1$ mode, across which the potential varies monotonically (see Fig. 23), the four resonators can be considered as connected essentially in series, making up an equivalent resonator oscillating at the $n = 1$ mode frequency. If one considers further, for the sake of argument, that there is no coupling between resonators, all the modes would have the same frequency, but the net inductance and capacitance of the equivalent resonator for each mode of periodicity n would be proportional to $N/2n$ and $2n/N$, respectively. Thus, for the $n = 1$ mode, the equivalent L is four times and the equivalent C is one-quarter of the respective values for the π mode. The tuner capacitance, added to the equivalent resonator for the $n = 1$ mode, on the other hand, can be considered to be approximately a series-parallel arrangement of capacitances, each of which is that between the tuner and one anode segment C_T: the two parallel capacitances at the positive anode segments connected in series through the tuner ring with the two parallel capacitances at the negative anode segments, the combination having a net capacitance C_T. For the π mode, the net tuner capacitance added per half-wavelength potential variation is made up of two capacitances, each of magnitude one-half of that between the tuner and one anode segment, connected in series through the tuner; the net tuner capacitance is thus $C_T/4$.

By similar reasoning for any mode, one can conclude that the added tuner capacitance per half-wavelength sector increases as n decreases, while the net resonator capacitance across which the tuner is shunted decreases as n decreases. In this way, the increased effectiveness of the tuner in varying the mode frequencies of the low periodicity modes is accounted for. In actuality, the resonators in the half-wavelength variation of RF potential are not in simple series connection because of the phase relations between them; the approximation improves for smaller n. Also because of the phase relation between adjacent resonators, the adjacent tuner-to-segment capacitances are not charged to the same potential, and so are not actually in simple parallel connection. Furthermore, the coupling between resonators is important. These considerations modify the above argument somewhat, but do not affect the conclusions reached as to the trend of tuning for the different modes. In all the tuning schemes described, second order effects come in through change in the electrical lengths of the straps and tuner as the frequency is varied.

If one arranges to vary the characteristics of the straps by means of a movable tuning member as in the scheme of Fig. 36 (c), considerably greater tuning ranges can be achieved than by the means just described. In this instance, the straps are enlarged to channels of U-shaped cross section, in and out of which the tuning member of cookie-cutter shape is driven. The effect of insertion of the tuning member is to increase the capacitance per unit length of the strap system by increasing the interstrap capacitance, and to decrease the inductance per unit length by effectively increasing the cross-sectional area of the straps. The effects of these changes upon the mode frequencies can be seen from the considerations of the effect of straps on the mode frequencies of the unstrapped resonator system already discussed. The increase in strap capacitance increases the wavelength of the π mode; the decrease in strap inductance decreases the wavelength of modes of smaller n. As the tuning member is inserted, the mode frequencies separate, and no limitation on the range of operation in the π mode is imposed by interference from other modes. This means has been used for tuning ranges of better than ±6%, but there is nothing inherent in the scheme to prevent its use for ranges considerably in excess of this value.

Tuning of the magnetron resonator system by any of the means described above alters its characteristic admittance $Y_{0c} = \sqrt{C/L}$, and hence the stored energy. For fixed output coupling and load admittance this amounts to a variation of the effective loading as specified by the external Q. In some cases, attempts have been made to compensate for this by designing into the output circuit a frequency characteristic which keeps the external Q, and hence the pulling figure, more nearly independent of frequency.

Each of the tuning schemes described above is adaptable to precise and specific frequency adjustment or to frequency variation at a slow rate. For tuning over small ranges it is possible to vary the magnetron frequency electronically, enabling one to frequency-modulate its output at a high rate. Of the schemes tried for this purpose there may be mentioned that in which an intensity-modulated electron beam of a specific velocity is shot parallel to a superposed DC magnetic field through one of the magnetron resonators or a closely-coupled auxiliary cavity.

Concerning the variation of magnetron operating frequency will be mentioned finally the shifts which are brought about by temperature variations of the resonator block. Since the resonator system is generally constructed entirely of copper, it expands or contracts uniformly with temperature and the frequency shifts are

(CONCLUDED ON PAGE 65)

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Haesler, Paul R. — Newark Bd. of Education, N. J.
Heisler, Charles — Chief Eng., WROW Albany, N. Y.
Holt, Roger — Chief Eng., Yankee Network
Haverkamp, H. — Chief Eng., Bd. of Ed. Brooklyn
Jelly, L. I. — Engineer, KTHT Houston, Texas
Jennings, M. H. — Engineer, REL, L. I. City
Johnson, R. E. — Skyway Bestg. Co., Columbus
Kratt, E. — Engineer, WNYE New York
Knaack, F. E. — Engineer, WHNY Hempstead, N. Y.
Keitch, George — WICC Bridgeport, Conn.
Kollmyer, W. — Sound Eng., RCA Internat'l N. Y.
Lewis, G. — Chief Eng., WCAU Philadelphia
Leitch, John G. — Tech. Dir., WCAU Phila.
Lynch, A. — Sales Mgr., Radio Music Co.
Lindsay, Paul — Chief Eng., WHEB Portsmouth, N. H.
McIntosh, Frank — Cons. Eng., Washington, D. C.
Mayoral, George A. — Agent, New Orleans, La.
MacAndrew — Coordinator, WNYE New York
Mouromtseff, I. E. — Westinghouse, Bloomfield, N. J.
McKnight, C. J. — Engineer, WJLK Asbury Park, N. J.
Markman, E. — Chief Eng., WSTC Stamford, Conn.
Macy, W. K. Jr. — Vice Pres., Suffolk Bestg. Co.
Munhofen, N. B. — Secretary, Suffolk Bestg. Co.
Meares, C. W. — Chief Eng., WCBT Roanoke Rapids, N. C.
Muse, Dewey — Chief Eng., WMVA Martinsville, Va.
Minor, M. J. — Chief Eng., WBT Charlotte
McIntire, G. — Chief Eng., WJEJ Hagerstown, Md.
Mitchell, F. — Jansky & Bailey, Washington, D. C.
Nopper, Carlton — A. S. Abell Co. Baltimore
Owens, W. R. — Chief Eng., WDOD Chattanooga, Tenn.
Ochs, W. R. — Engineer, Yankee Network, Boston
Palmer, Warren — Chief Eng., WECE Rocky Mt., N. C.
Partridge, N. — Chief Eng., WKXL Concord, N. H.
Paterson, S. G. — Agent, R.M.L. Canada
Rogers, Keith A. — Chief Eng., WFMZ Allentown, Pa.
Runyan, C. — Chief Eng., WGH Newport News, Va.
Runyon, C. R. 3rd — Engineer, REL, L. I City, N. Y.
Ray, Garo W. — Cons. Eng., Bridgeport, Conn.
Rawls, L. E. — Trans. Eng., WSM Nashville
Rudolff, E. — Asst. Mgr., WJIK Asbury Park, N. J.
Staub, M. — Skyways Bestg. Co., Columbus, Ohio
Sleeper, M. B. — FM Magazine, Gt. Barrington, Mass.
Steadley, J. F. — Chief Eng., WEXL Royal Oak, Mich.
Smith, Julian — Asst. Chief Eng., WFBR Balt., Md.
Solbrig, Arthur — Chief Eng. WBNX N. Y.
Scullen, Carl — Westinghouse, Bloomfield, N. J.
Stiehl, J. H. — WHA Madison, Wisconsin
Scott, C. K. — Operator, WTIC Hartford
Seid, Fred — Engineer, REL, L. I. City, N. Y.
Small, Irving — Engineer, WELI New Haven, Conn.
Snelgrove, C. R. — RML Canada
Smith, Homer — Gen. Mgr., WKOK Sunbury, Pa.
Swanson, E. — Engineer, REL, L. I. City
Taylor, H. D. — Chief Eng., WTIC Hartford, Conn.
Thorp, W. E. — Engineer, REL, L. I. City
Trueblook, D. — Chief Eng., WGBR Goldsboro, N. C.
Thron, B. — Chief Eng., WFPG Atlantic City
Tilley, Harry — Chief Eng., WEAN Providence, R. I.
Wetmore, George — Asst. Eng., WSTC Stamford, Conn.
Watson, Carl — Chief Eng., WSTP Salisbury, N. C.
Waite, S. A. — Asst. Tech. Dir., Yankee Network
Woods, G. — Chief Eng., Ga. Bd. of Ed., Atlanta
Williams, H. C. — Tech. Dept., WENA Detroit, Mich.
Wesser, Carl — Chief Eng., R.M. Wilmotte, Inc., Washington, D. C.
Wright, T. A. — Washington, D. C.

CAROLINA DISTRIBUTORS ORGANIZE TO PUSH FM

ON February 23rd, the day WBT-FM Charlotte went on the air, some 55 distributors covering the Carolinas formed the Charlotte Radio & Appliance Distributors Association, for the purpose of accelerating FM set sales. This action was taken at a luncheon given by WBT-FM, after WBT general manager Charles H. Crutchfield had outlined a unique plan for cooperation between the FM station and the distributors.

Officers in the photograph above are, left to right: steering committee members C. D. Mitchell, president, Southern Appliances (Majestic), and A. K. Sutton, president, A. K. Sutton (Philco); vice chairman J. L. Pleasants, vice president, Allison-Erwin (Zenith); chairman J. P. McMillian, president, Southern Radio (RCA); steering committee chairman R. L. Chapman, president, Chapman-Wilhelm (Stromberg); and secretary-treasurer Enloe McClain, president, McClain Distributing Company (Admiral). This is probably the first distributor organization of its kind in the United States.

REL *is the ONLY transmitter manufacturer offering the unequalled advantages of the* Armstrong Dual-Channel Modulator

THERE are probably a dozen different ways to modulate an FM transmitter. On paper, each may have some theoretical advantage.

During the present rush to get *any* kind of FM signals on the air, the many shortcomings of contemporary transmitters are bound to be overlooked by FM listeners.

However, the FM transmitter you buy now can't be written off until long after this temporary condition has passed.

What then? How will your transmission quality compare with other stations when listeners have a choice of fine, live-talent shows?

Specifically, how will your programs sound in comparison to stations using REL transmitters and the simplified Armstrong Dual-Channel Modulator? And will your program quality be an asset or a liability to your time sales department?

The Armstrong Dual-Channel Modulator is a simplified circuit which 1) provides direct crystal frequency-control without the uncertainties of motor-driven correctors or tubes of complex design, 2) reduces distortion to a maximum of 1% at 50 cycles, dropping to a value too small to measure in the middle and upper ranges, and 3) affords such a wide latitude of non-critical adjustment that all tuned circuits in the modulator can be detuned 30% without any audible change in program quality!

Before you decide on *any* type of FM transmitter, ask us to give you detailed information on REL transmitters with the simplified Armstrong Dual-Channel Modulator, and complete REL microphone-to-antenna installations.

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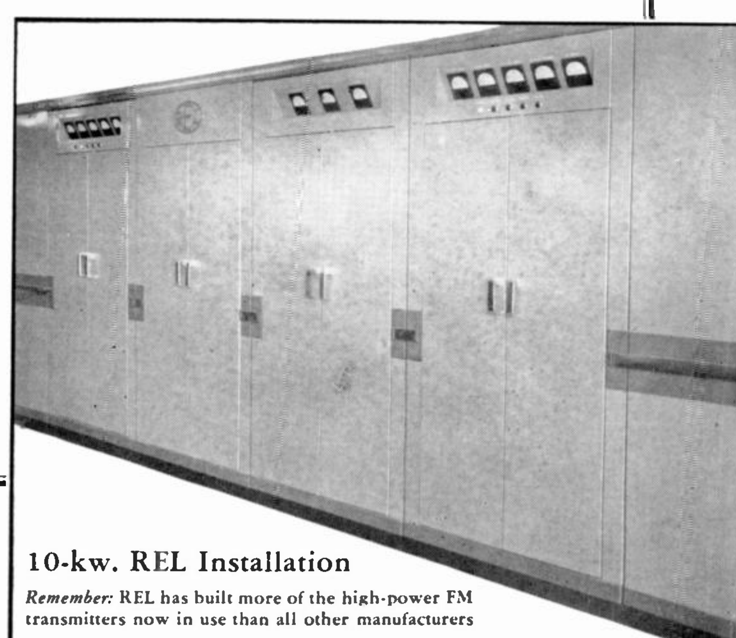
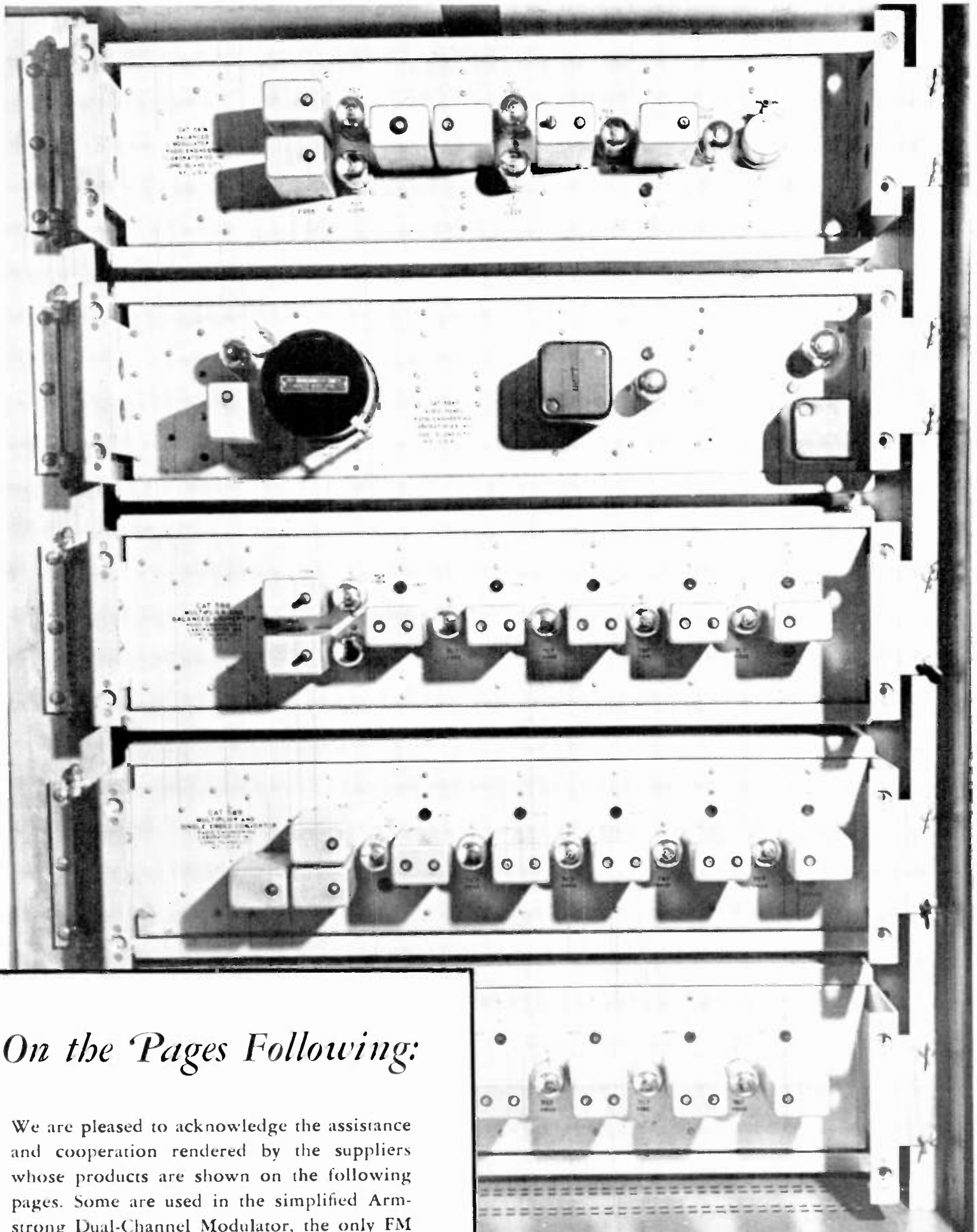


10-kw. REL Installation

Remember: REL has built more of the high-power FM transmitters now in use than all other manufacturers



ABOVE: THE SIMPLIFIED ARMSTRONG DUAL-CHANNEL FM MODULATOR UNIT, FURNISHED IN REL TRANSMITTERS OF ALL POWER RATINGS

On the Pages Following:

We are pleased to acknowledge the assistance and cooperation rendered by the suppliers whose products are shown on the following pages. Some are used in the simplified Armstrong Dual-Channel Modulator, the only FM system of crystal frequency control. Others are employed in the audio and power circuits to provide the stamina for which REL FM transmitters have been famous during the past 9 years.

HIGH-FIDELITY FM DESIGNS

(CONTINUED FROM PAGE 35)

model could so outperform any AM radio, at any price, that it would be easier to sell it on time payments than those table models now retailing for $34.50.

2. Price Range ★ A complete price range of FM-AM models would include two, or at the most, three chassis, with a choice of speakers and amplifiers. These units could be combined in various ways to provide a selection as to sensitivity, audio quality, and power. This would enable dealers to trade up their customers. The low end of the price range would be within the means of almost any customer. The high end would deliver performance to suit the most exacting customer as to sensitivity and high-fidelity reproduction.

3. Yearly Models ★ Conventional cabinets, unless they are very expensive, have a style life of only a year. Some prove to be lemons from the start. Few models can be carried from one season to the next by the dealers. Those left over must be dumped at a loss. Styles that looked good to a dealer may be those that his customers won't consider. Probably he'll want to exchange them. At least he'll be reluctant to pay for them. If he's stuck, he may drop the line next year.

In short, cabinet styles are the source of most headaches. Even when a model really rings the bell, that's bad because it is so difficult to step up cabinet production quickly. Taking radio receivers out of the furniture class will simplify the greatest problem which has plagued manufacturers and dealers since radio outgrew its early construction-kit stage.

4. Size ★ Perhaps the principal reason that so many people endure wretched tone quality from broadcasting and records is that they haven't room for those veritable arks required to house good phono-combinations. This applies as much to apartment dwellers as to those who own small homes. There are literally millions of living rooms in apartments and private houses that have all-too-little space left over when a table or two, some chairs, and a couch are moved in. How then, can they add more than a pint-size radio? Those sets that look like chests of drawers, but aren't, or those great cabinets in which nothing can be stored, however beautiful they are, can't be hung from the ceiling!

So people buy little sets that can be tucked away conveniently. As for the service they render — well, they don't sound so bad for getting the news, but they're not much good for anything else. Like the small record-players, the musical reproduction soon inspires most people to the screaming-meamies.

However, there is always a place to put a plain speaker cabinet, even if it has to go

(CONTINUED ON PAGE 53)

HIGH-FIDELITY FM DESIGNS

(CONTINUED FROM PAGE 52)

in the corner behind a chair, and there's always a spot for the small, associated radio chassis, plus a fine record-changer, as the accompanying illustrations show.

5. Flexibility ★ The ease with which this proposed design style can be adapted to any home offers intriguing possibilities which will delight women customers.

The simplest arrangement is shown in Fig. 1. The loudspeaker would be supplied in an unfinished case, to be painted or stained the color of the woodwork of the room where it is to be used. Thus it would be as inconspicuous as a radiator cover. The radio chassis, in its steel box, might be finished in black or brown crackle, with a touch of chromium trim. It could be put on the speaker, or on a nearby table. Mounting the power supply and final amplifier in the base of the speaker would keep down the size and weight of the chassis. Also, it would permit a choice of amplifiers, as to fidelity and power.

Fig. 2 shows simple variations of this plan. The loudspeaker is in a case designed with lines so simple as not to be in conflict with any style of furnishings. The doors, it will be noted, are hinged so that they can be swung back against the sides of the case.

Space above a closet is an excellent speaker location, since it provides an open space at the rear. Again, the cabinet maker can design and construct the grille work and do what is necessary to open up the wall above the door. There is no end to the decorative possibilities of this kind of speaker mounting.

A third type is the wall-mounted speaker. This is the decorator's delight, since the treatment of the frame and grille can be as simple or elaborate as the owner desires.

There is an acoustic advantage to such speaker location, too, since the distribution of the higher frequencies is much wider than when a speaker is mounted near the floor.

Summary ★ The accompanying sketches have been purposely rendered in a very free style, so that each person can read into them his own ideas. It was not my intention to pin down these suggestions as to details of execution. Rather, they are intended to show that the elimination of radio furniture as such, and particularly the extremes represented in borax styles, actually open up a broader scope for the work of the designer. At the same time, the plan offered here has fundamental advantage to manufacturers and dealers, as well as to their customers.

It is a thoroughly practical plan. Of special interest in this connection is the new 60- to 15,000-cycle Western Electric speaker shown in Fig. 5. Also illustrated is

(CONCLUDED ON PAGE 54)

HIGH-FIDELITY FM DESIGNS

(CONTINUED FROM PAGE 53)

a cabinet for this speaker which is ideal for use with an independently-mounted radio chassis.

In case you are inclined to say, "Well, it sounds good, but no one will do it," let me point out that a start has been made already. In fact, Fig. 1 was drawn from the new REL receiver and Altec speaker which Frank Gunther is looking at in Fig. 6! This particular receiver is intended for broadcast station monitoring service. Designed for home use, it could be reduced to perhaps one-half that size.

Finally, in equipment such as this new REL-Altec combination, the emphasis is on engineering and performance, to the advantage of all concerned, and not on furniture, which has been a pain in the neck to everyone. That is why I believe that this angle of approach will answer the industry's No. 1 postwar need, which is to give American listeners the full benefits of FM reception at a price low enough to open up a mass market.

48-CHANNEL TRANSMITTER

(CONTINUED FROM PAGE 30)

variation due to the drift of the elements of the discriminator connections with temperature, etc. The fact that this forms no obstacle to the regulating action of the whole is due to the fact that the discriminator reacts to the absolute changes of the oscillator frequency. Even if the discriminator frequency f_d should drift proportionately just as much as the oscillator frequency f_0 does with no regulation, the absolute variations of the latter are still $36.9/2 \simeq 18$ times as large as the drifts of f_d.

Coupling Between Successive Valves ★ For the coupling together of the various triplicator and amplifier stages, a new method has been employed which offers important advantages. In order to explain the particulars of this coupling, let us consider Figs. 4A and 4B, in which a coupling according to the usual method and one according to the new method are shown side by side. For the sake of simplicity, ordinary stages, not push-pull, are assumed, and all elements only of importance for the DC voltage situation are omitted. In the ordinary coupling, the anode of the first and the grid of the second valves are connected directly with each other, while between this point and earth a tuned parallel circuit is connected. The internal self-inductions L_A and L_G of the valves, which are indicated with dotted lines in Figs. 4A and 4B, may be disregarded for the present. In the new coupling, on the other hand, the tuned circuit is formed by the self-induction L and the connection in series of the internal valve capacities C_A and C_G. In Figs. 5A and 5B the situation in the two cases is

(CONTINUED ON PAGE 58)

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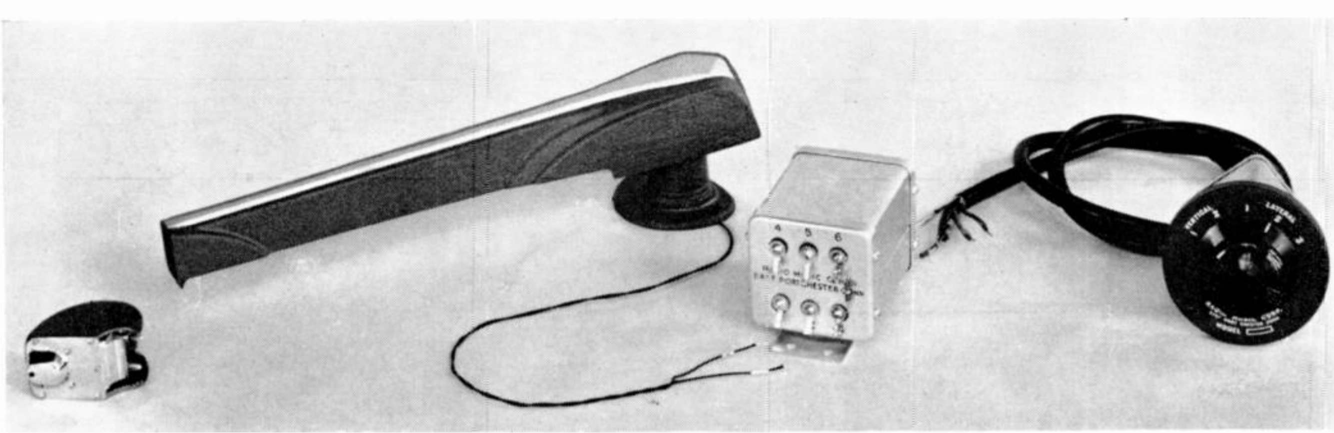

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(a) Water vapor, oxygen, and carbon dioxide exist in all atmospheres; chlorine and sulphur compounds in the air of industrial localities.

(b) The action of these agents, intensified by heat and direct current potentials, corrodes copper coil windings, shortens transformer life.

(c) Moisture, even when not excessive in the air, frequently condenses on the inside of partially sealed or unsealed cases and shields as the result of variations in temperature.

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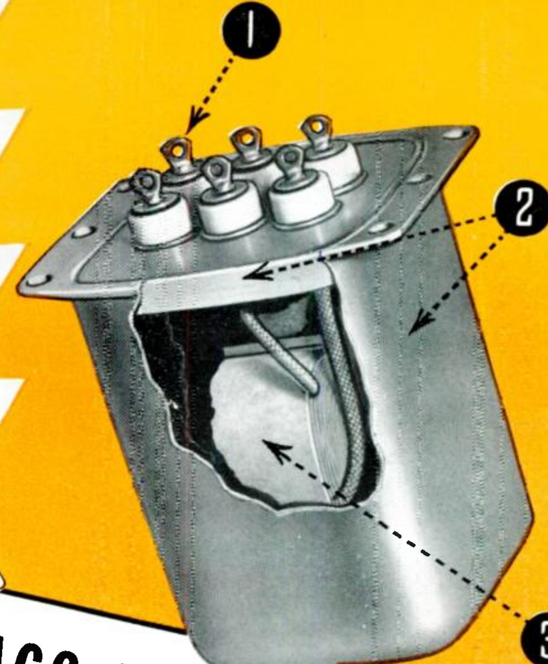
It is good engineering to specify the transformers that have met with outstanding success the most rigid military tests for sealing against corrosion, have been proven to *stay* sealed in extremes of heat and cold . . . Chicago Transformers, *Sealed in Steel.*



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48-CHANNEL TRANSMITTER

(CONTINUED FROM PAGE 54)

shown still more concisely. Let us first consider Fig. 5B. The high-frequency voltage between the points A and B is mainly determined by the oscillation of the circuit, but the potentials of these two points fluctuate in opposite phase with respect to earth due to the obtrusion of earth potential at point 0 in the middle of the circuit capacity. From this it follows that also in the middle of the circuit self-induction there must be a point P which remains at earth potential during oscillation and thus has no high-frequency voltage.[4] The position of P on the self-induction L is determined by the ratio of the capacities C_A and C_G. On the other hand, turning to Fig. 5A, it is evident that in the old coupling connections no such non-voltage point can be found. Even if the self-inductions L_A and L_G are taken into account, this fact is not altered.

The occurence of a non-voltage point in the new method of coupling offers the possibility of dividing the transmitter constructionally into two parts at a non-voltage point between two valves and assembling the two parts, for example, in separate panels. The connection between the two panels then carries no high-frequency voltage (high-frequency current does, however, flow through it) and therefor no undesired couplings or radiation can occur. If such a division were made at a point which was not voltage-free, the connection would have to be shielded against the effects mentioned, and a large extra circuit capacity would thereby be introduced, in general resulting in a loss of amplification. For this reason, it is very difficult to divide the connections when the old method of coupling is used.

Another advantage of the new method of coupling is of particular importance at very high frequencies. Since in this case the capacity and/or self-induction of the coupling circuit must become very small, the contributing, unavoidable capacities and self-inductions of the valves begin to play an important part. Fig. 4A cannot then be reduced to the simple situation of Fig. 5A, because of the presence of L_A and L_G, which can no longer be ignored. The ordinary connections are now in principle more complicated than a simple L-C circuit, and in practice it proves difficult to obtain sufficient amplification with them. This is understandable when it is borne in mind that at very high frequencies L_G may already be approximately in resonance with C_G. The tuned parallel circuit L-C, whose task it is to furnish a high impedance for the circuit frequency, is then, as it were, short-

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[4] Strictly speaking this is not true. If the losses of the circuit elements are taken into account it is found that there is a certain residual voltage. This is very small, however, compared with the circuit voltage.

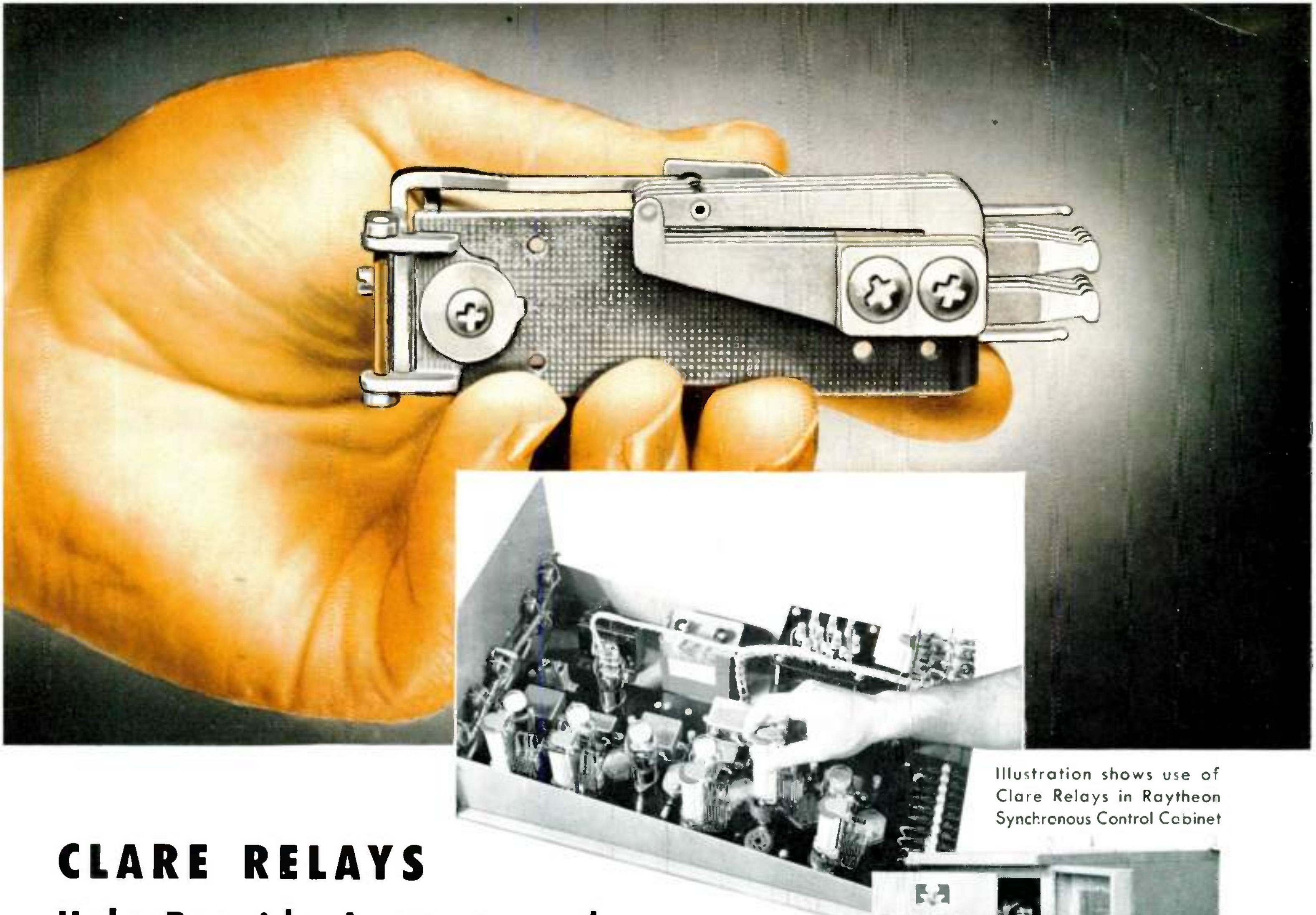
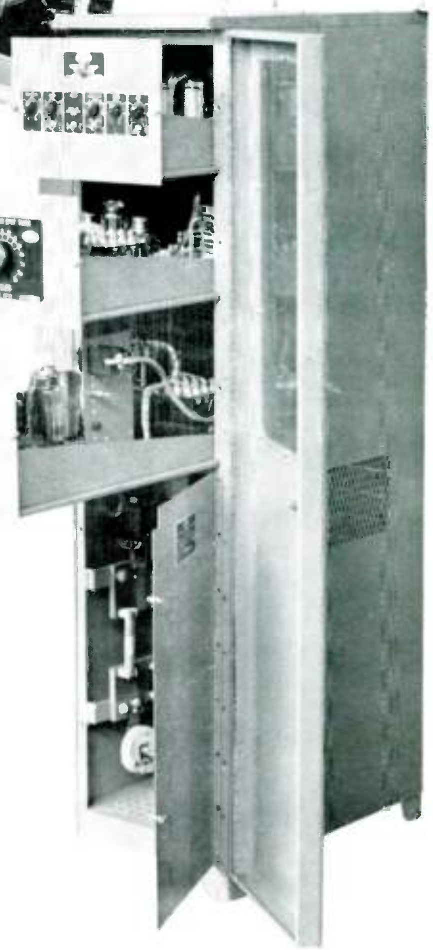


Illustration shows use of Clare Relays in Raytheon Synchronous Control Cabinet



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Clare Relays were chosen by Raytheon Manufacturing Company of Waltham, Mass., for this new modern unit because of their accurate, efficient and dependable operation. Clare compact, clean-cut design met Raytheon demands that all components contribute to the ease and convenience of use, the flexibility of application and streamlined appearance.

Four Clare Type "C" d.c. Relays and one Clare Type "A" a.c. Relay, shown in this drawer type sequence timer, are supplied by Clare with coil windings, contacts and all special adjustments to meet exact Raytheon requirements.

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CLARE RELAYS

"Custom-Built" Multiple Contact Relays for Electrical and Industrial Use

48-CHANNEL TRANSMITTER

(CONTINUED FROM PAGE 58)

circuited by the low impedance of the series circuit L_G-C_G. Measures for overcoming these difficulties are known, but they only result in making the circuit still more complicated, more extensive, and more difficult to manipulate. When we compare this method with the new coupling according to Fig. 4B, we see that the presence of L_A and L_G does not alter anything in the principle of the connections and only makes it necessary to choose the external self-induction L somewhat smaller than the total circuit self-induction desired. Even if L_G or perhaps only a part of it is of itself tuned to C_G, in the main everything remains unchanged. It means really nothing else than that the above-mentioned non-voltage point then lies exactly at the valve terminal or somewhere in the internal grid feed connection, as the case may be. It is then no longer possible to divide the connections at that point, but the action of the amplifier stage is not at all affected. It would only become troublesome if a negative value should be required for the external self-induction L. But since C_A is usually much smaller than C_G, the self-induction necessary to tune C_A, *i.e.*, the self-induction between the anode and the non-voltage point, is generally large enough to cover, in addition to the self-induction L_A of the internal anode feed connection, a positive external self-induction as well.

Fig. 6 shows the complete connections of a push-pull amplifier stage with the new coupling method.

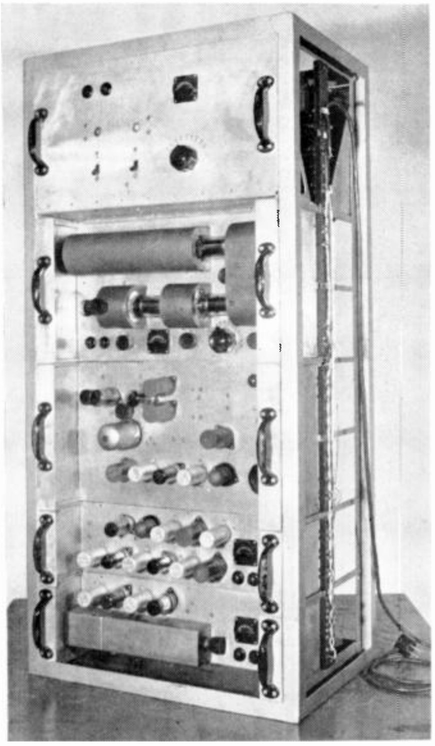
Construction ★ If a transmitter is to serve as part of a carrier telephone system, it is desirable that its external form should be adapted to that of the carrier telephone apparatus. In the case in question, the transmitter had to be housed in a rack of certain dimensions with the components mounted on panels of a certain length and width which could be slid into the rack from front and rear. Similarity in external appearance, however, can never be complete. For carrier telephone apparatus, the available space in every panel is almost completely filled with the parts of the different filters, modulators, repeaters, etc. However, because of the much higher frequencies, the components of the transmitter must in general be spread out over a certain area in order to provide sufficient mutual intervals to prevent undesired couplings. One may speak here of surface assembly in contrast to the volume assembly in the apparatus for carrier telephony.

In this way one arrives at the construction shown in Fig. 7. The components are mounted side by side in each panel in a single plane, or front plate. This lies fairly deep in the rack, so that the different valves, coil cans, Lecher systems, etc., situated on the front of the plate are well protected against undesired contact or shocks without it being necessary to place a cover plate in front of the rack, as this would hinder the dissipation of the heat given off by the valves.

The uppermost panel of the installation is actually double, occupying the entire depth of the rack in order to offer space for the high tension supply unit mounted therein. This is placed at the top in order that the rather large amount of heat developed in it shall not cause any difficulties in the transmitter part proper. The transmitter also contains too many components to be housed on one panel of ordinary size. As a consequence of the above-mentioned method of coupling between successive stages, the transmitter could without difficulty be divided and housed in two separate panels, one above the other. This can be seen in Fig. 7 underneath the high tension supply unit. Fig. 8 shows the rear of the transmitter panels with the parts of the two coupling coils (push-pull connections, Fig. 6) in each panel.

Below the transmitter panels is the corresponding receiver, also on two panels.

Upon inserting a panel all connections of the various signal and feeding voltages are automatically made by means of plug pins in the rack and sockets in the panels. The wires to the plug pins are led out at the side, where the wiring harness for the mutual connection of the panels is mounted. The details can be seen in Figs. 7 and 8. A measuring instrument is mounted on each panel on which the cathode current of each valve can be checked by means of a switch. Thus it is possible to localize the cause of any interruptions quickly, while the ageing of the valves can also easily be ascertained in good time. This is necessary because the same requirements as to reliability are made of the transmitting apparatus as are made of the telephone apparatus itself.



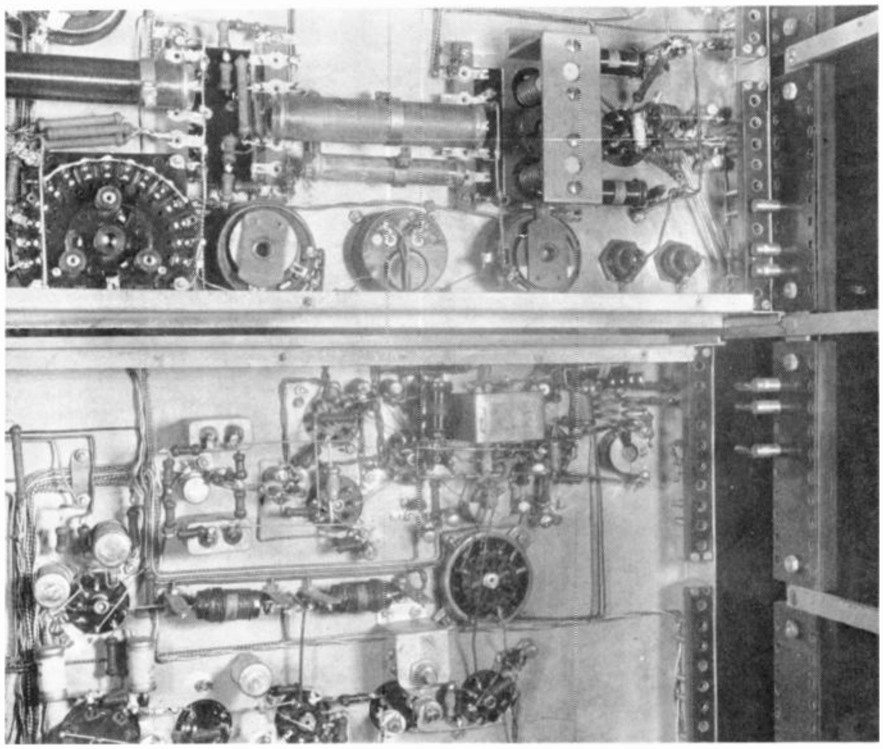


FIG. 7. TRANSMITTER AND RECEIVER ASSEMBLY. FIG. 8. PART OF THE TWO TRANSMITTER PANELS AS THEY APPEAR FROM THE REAR

EDITOR'S NOTE: *We expect to publish a description of the receiving equipment in a subsequent issue of FM* AND TELEVISION.

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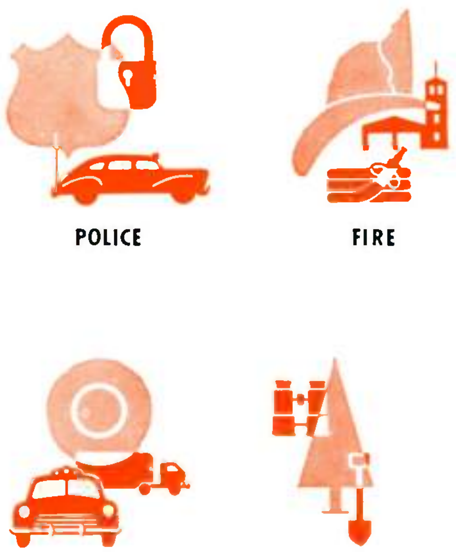

Tested and proved equipment specifically designed for the 152-162 Mc band is now brought you by the engineers who made instant-heating FM practical. The new KAAR FM-175X transmitter and FM-40X receiver are thoroughly engineered to do a *better* job in the urban mobile service band.

You will hear a startling improvement in voice quality. A special circuit boosts the low tones, rounding out the voice quality to a naturalness that actually permits recognition of the speaker's voice! Controls are reduced to a minimum, making operation almost automatic!

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KAAR instant-heating transmitters with zero standby current eliminate the need for costly special generators or extra batteries. Only about 4% of the current used by conventional equipment is needed.

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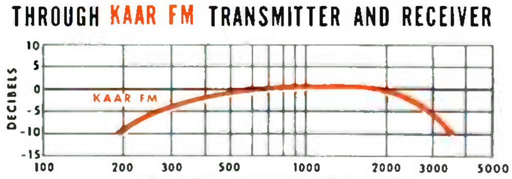

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KAAR ENGINEERING CO.

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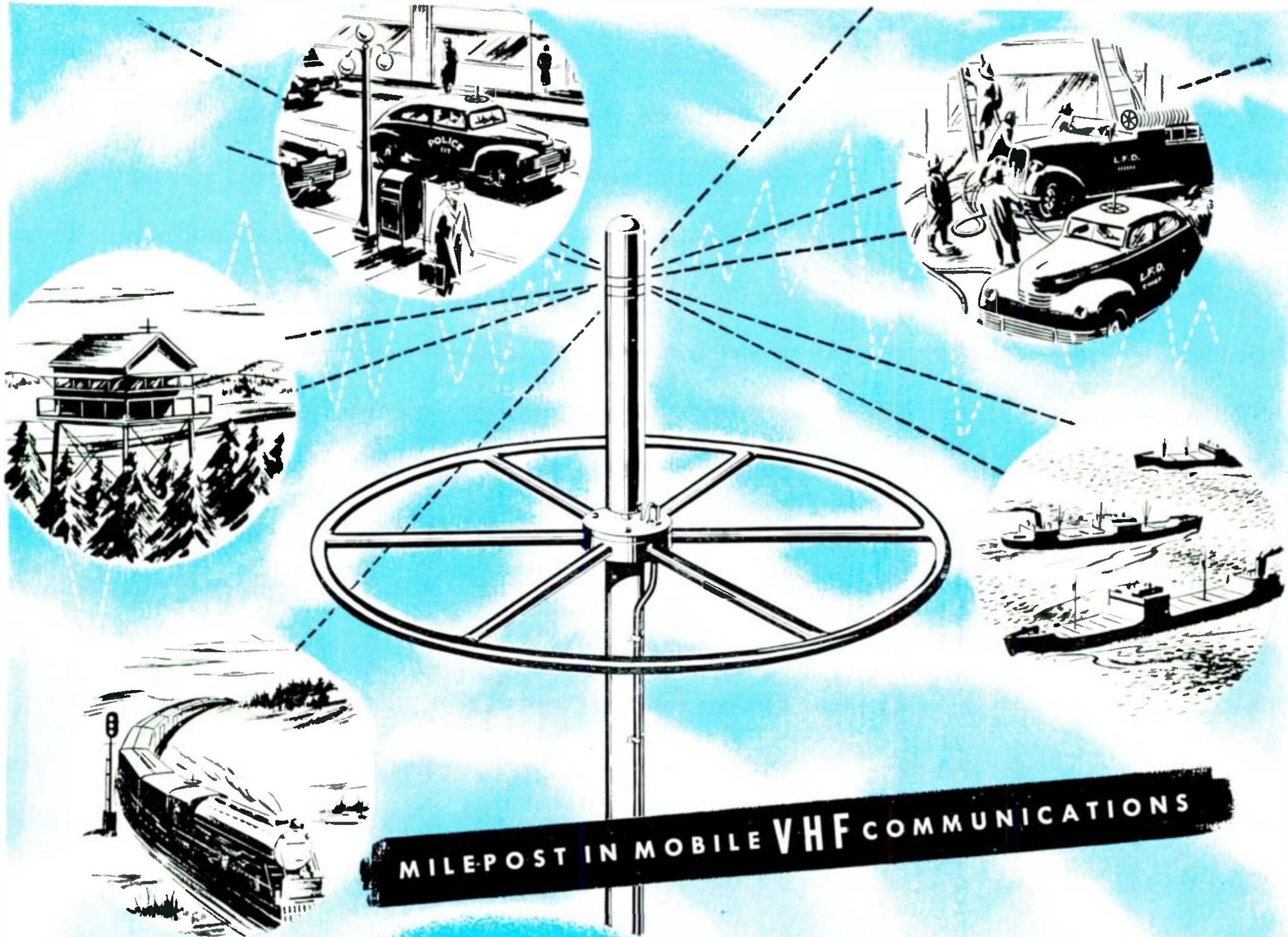


THE NEW AMPHENOL GROUND PLANE ANTENNA

Efficient VHF radio communications is a must in modern railroading. Used to expedite freight and express service, it is cutting hours from schedules, and eliminating waste time and money in switching operations.

Designed principally for use in the 152-162 mc band by railroads for "train-to-fixed-station" and "end-to-end" communications, the new Ground Plane Antenna illustrated is foremost among many new VHF radio components and accessories perfected by Amphenol engineers.

Providing maximum power radiation at low initial cost, this extremely rugged antenna consistently out-performs other antennas under normal and extreme conditions. It is easily and quickly installed, and has been thoroughly tested in main-line railroad installations.

Danger from lightning or contact with power lines is eliminated, as this antenna is at ground potential. The nature of its radiation pattern insures uninterrupted service during sharp "U" or "S" turns.

The Amphenol Ground Plane Antenna is also widely used by police and fire departments, by forestry, geophysical, power and petroleum field crews, for mobile marine installations, and many others. It is available with Ground Plane Skirt, as shown, for installations where a large metallic mounting surface is not available.

Write today for complete technical data on the Ground Plane Antenna, or for engineering aid in solving your VHF radio communications problems.

Depend upon AMPHENOL Quality

AMERICAN PHENOLIC CORPORATION
CHICAGO 50, ILLINOIS

COAXIAL CABLES AND CONNECTORS • INDUSTRIAL CONNECTORS, FITTINGS AND CONDUIT • ANTENNAS • RADIO COMPONENTS • PLASTICS FOR ELECTRONICS

When a little means a lot

Whenever and wherever space is at a premium . . . in shavers, hearing aids, pocket radios, guided missiles and other radio, electrical or electronic devices . . . you can use one or more of these four miniature products IRC makes-by-the-million. For complete information, including dimensions, ratings, materials, construction, tolerances, write for comprehensive catalog bulletins, stating products in which you are interested.

ILLUSTRATIONS ACTUAL SIZE

MPM Resistors

$\frac{1}{4}$ watt for UHF. Resistance film permanently bonded to solid ceramic rod. Length only $\frac{9}{16}$″. Diameter $\frac{1}{16}$″. Available resistance values 30 ohms to 1.0 megohms.

BTR Resistors

$\frac{1}{8}$ watt—insulated composition. Length only $\frac{13}{32}$″. Diameter $\frac{3}{32}$″. Resistance range 470 ohms to 22 megohms (higher on special orders).

TYPE H Fingertip Control

Composition volume or tone control. Its $\frac{13}{16}$″ diameter and $\frac{1}{2}$″ overall depth include knob and bushing.

TYPE SH Fingertip Switch

Similar to TYPE H Control (left) in appearance. $\frac{13}{16}$″ diameter. OFF and 3 operating positions.

$I = \frac{E}{IRC}$

INTERNATIONAL RESISTANCE COMPANY

401 N. BROAD STREET • PHILADELPHIA 8, PENNSYLVANIA

IN CANADA: INTERNATIONAL RESISTANCE COMPANY, LTD., TORONTO, LICENSEE those attained by a uniform scaling of the resonator system by a very small factor. The temperature coefficient of frequency can readily be seen to equal the negative of the linear coefficient of thermal expansion of copper.

10.4 *Electronic Effects on Frequency:* In Section 3.6 *Induction by the Space Charge Cloud*, it has been seen that the electrons moving in the interaction space of the magnetron oscillator contribute an admittance Y_e connected to the resonator system. The magnitude of the negative electronic conductance determines the energy delivered to the circuit and thus the amplitude of oscillation. The electronic susceptance, arising from the phase relation between the space-charge spokes and the maximum of the tangential retarding field, affects the frequency of oscillation. Under equilibrium conditions, the magnitude of the current I_{RF} induced in the anode segments, its phase relative to the RF voltage between the segments, and the operating frequency adjust themselves such that this admittance $Y_e = I_{RF}/V_{RF}$ equals the circuit admittance Y_s. The induced RF current and its phase relative to the RF voltage both depend upon the parameters such as V and B, governing the electronic operation of the magnetron. The frequency change at constant load, arising from changes in V or B when divided by the change in the DC current I drawn by the magnetron, is called the frequency *pushing*, and is measured in mc/s per ampere.

A further effect of the electronic susceptance is the shift of the resonant frequency between the oscillating and non-oscillating conditions of the magnetron. In general, the oscillating frequency is lower than the resonant frequency of the non-oscillating magnetron. Thus the electronic susceptance is capacitive, with the space charge spokes moving somewhat ahead of the field maxima during oscillation. This shift in the resonant frequency is important in pulsed radar systems where the same antenna is used for both receiving and transmitting. An echo of the transmitted pulse on its return then encounters a high, off-resonance impedance at the magnetron which absorbs very little of the returned energy. Most of the received pulse energy is consequently made available to the receiver. For some magnetrons, the shift off resonance is not sufficient, and other means such as the use of the so-called ATR box are required to divert the received pulse energy into the receiver.

10.5 *Frequency Spectrum of a Pulsed Magnetron:* Only if a generator operates for an infinitely long time is its output *monochromatic*, that is, of a single frequency. The period of operation of a CW oscillator is generally long enough to make any deviations from this unobservable.

If, however, the oscillation is modulated, as in the case of pulsed magnetrons for which the pulse duration is of the order of one microsecond, it is readily detectable that the output is *polychromatic*, with the energy distributed throughout a band of frequencies. The plot of the distribution in frequency of the energy generated is called the *frequency spectrum*.

This state of affairs is perhaps made plausible if one considers pulsing the magnetron to be a very drastic means of amplitude-modulating its output. Already, in connection with the case of two coupled circuits, it has been seen how amplitude modulation of an oscillating system in time has associated with it the distribution of the energy over more than one frequency. In an analogous but more complicated manner, a sinusoidal oscillation which is amplitude-modulated by a nonsinusoidal pulse shape like that of

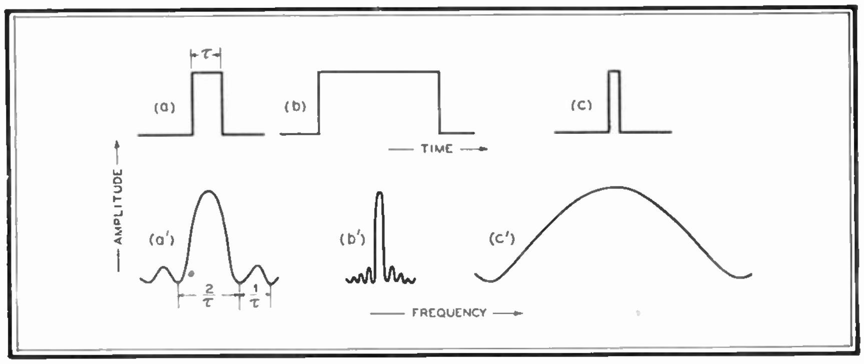


FIG. 37. Plots of DC voltage pulse shapes (*a*), (*b*), and (*c*) and the frequency spectra (*a'*), (*b'*), and (*c'*) resulting from each, respectively. These are shown for the idealized case of perfectly rectangular voltage pulse shapes.

Fig. 37 (a) is compounded of frequencies not now discrete but distributed continuously throughout a band, Fig. 37 (a'). The energy distributions in time and frequency are related mathematically by the Fourier transform.

The breadth of the frequency distribution is inversely proportional to the modulating pulse width as shown in Fig. 37. The spectrum widths of operating magnetrons may exceed the theoretical width by a factor of not more than two for reasons not altogether clear.

10.6 *Oscillation Buildup—Starting:* Of importance in the design and operation of pulsed magnetrons are the phenomena associated with the buildup of oscillation when the voltage is applied. Here will be discussed briefly what is known about the problem, the factors upon which the rate of buildup of oscillation in the circuit depends, how this is related to the rate of voltage buildup and to pulser characteristics, and how these factors result in various types of magnetron starting behavior.

The rate of buildup of oscillation in the magnetron depends not only upon the circuit characteristics but also upon the electronic behavior with increasing DC and RF voltages. Because of the nonlinear nature of the electron interaction, the amount of energy fed to the circuit per cycle is dependent upon the amplitude of the oscillation. Considering the condition for oscillation given by the first of equations (35), and expanding it to include during buildup a term to account for the energy being stored in the resonators, one can derive a simple expression for the rate of increase of RF voltage amplitude. The energy stored in the circuit at any instant being $W = CV^2_{RF}$, the rate at which energy is being stored is $dW/dt = 2CV_{RF}\, dV_{RF}/dt$. This corresponds to a conductance term, G, obtained by equating dW/dt and GV^2_{RF}:

$$G = 2C\frac{dV_{RF}}{dt}\frac{1}{V_{RF}}. \qquad (46)$$

The necessary condition for oscillation during buildup is thus:

$$G_e(V_{RF}) + G_s + G = 0, \qquad (47)$$

from which one obtains

$$G_e(V_{RF}) + G_s + 2\frac{C}{V_{RF}}\frac{dV_{RF}}{dt} = 0. \quad (48)$$

Since oscillation in the magnetron does in fact build up, $|G_e(V_{RF})|$ must be greater than G_s when oscillation starts. When equilibrium is reached, $G_e(V_{RF}) + G_s = 0$. Thus $|G_e(V_{RF})|$ must be a decreasing function of V_{RF} crossing the value G_s at the operating point. By equation (48), V_{RF} thus builds up rapidly at first and then more slowly as $|G_e(V_{RF})|$ approaches G_s.

Increase in load, resulting in an increase of G_s, decreases the rate of oscillation buildup.[22] The dependence on the total resonator capacitance indicates that for magnetrons of different sizes related by a simple scale factor, G_e and G_s under such scaling presumably remaining invariant, the rate of buildup decreases with increasing wavelength. Unknown in relation (48) is, to be sure, the exact transient dependence of G_e on RF and DC voltages, magnetic field, and interaction space geometry.

This Magnatron series will be continued in the April issue.

[22] This is directly the opposite of the behavior with respect to load variations of a circuit being driven in such a way that a constant amount of energy is fed in per cycle, in which case the rate of buildup is inversely proportional to Q.

TELEVISION HANDBOOK

(CONTINUED FROM PAGE 43)

$$E_{Mn} = 2rE_p \times \sum_{m=1}^{m=M}$$

$(\sin \phi/\phi)\ (\sin \phi_1/\phi_1)\ \ldots\ (\sin \phi_n/\phi_n)$ (2.1)

where $\phi_1 \ldots \phi_n$ refer to electrical widths of apertures, $w_1 \ldots w_n$.

The widening effect of one aperture, and of two equal apertures in tandem (the aperture widths being identical to picture-element width), on the reproduced electrical pulse from a picture element is shown in Fig. 15. Curve A of Fig. 15 represents the electrical signal arising from a rectangular pulse in passing through an electrical system which removes all the harmonics above the first zero-frequency. This curve is a replica of curve B in Fig. 11. Curves B and C of Fig. 15 represent the modification of this pulse if it is scanned by one aperture or two apertures in tandem, respectively.

The expression *in tandem* means that the apertures act successively upon the form of the electrical signal during transmission, rather than simultaneously. This is representative of what occurs during the transmission of a television image, where the camera tube aperture modifies the picture-element light pulses entering the camera, and the receiver tube aperture modifies the electrical signals applied to its grid before reproducing the images on the fluorescent screen.

In Fig. 16, Curves B and C, are plotted the curves of the functions $(\sin \phi/\phi)^2$ and $(\sin \phi/\phi)^3$. In curve A of this figure $\sin \phi/\phi$ is plotted for reference, from Fig. 9. These curves represent the effect on the harmonics of a picture-element pulse of the finiteness of the pulse, of the finiteness of one aperture scanning the pulse, and of the finiteness of two identical apertures scanning the pulse in tandem. It will be noted that the first zero-frequency for an aperture occurs at the same point as the first zero-frequency for a pedestal, or rectangular, pulse of the same width as the aperture. If the aperture widths are different from the pulse widths, the first, zero frequencies occur sooner, that is, at proportionally lower values of ϕ than π on the scale of Fig. 15, according to the ratio of aperture width to pulse width.

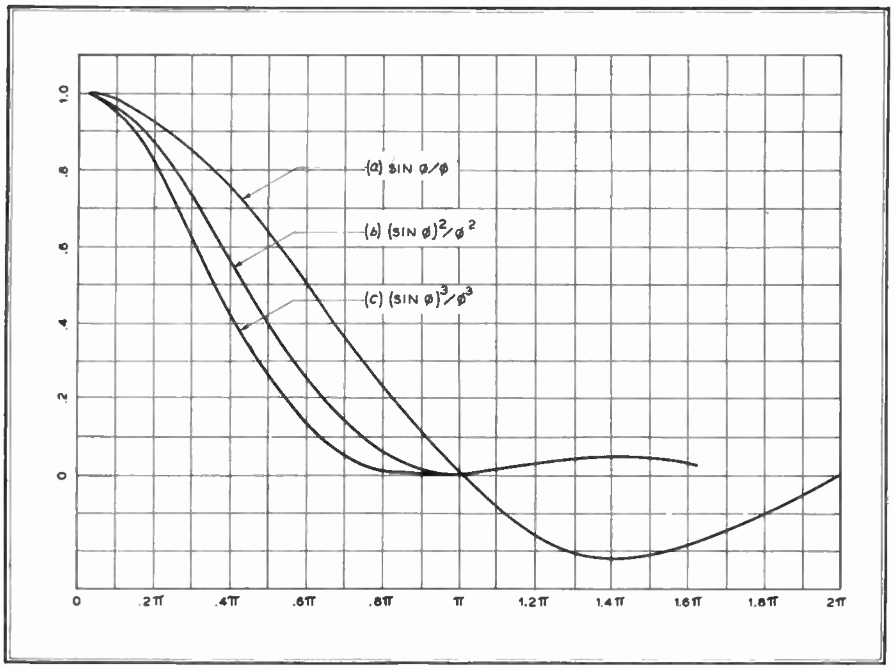


FIG. 16. EFFECT ON THE HARMONICS OF A PICTURE-ELEMENT PULSE, AS DESCRIBED

Thus, the effect of a finite aperture, or finite apertures, in scanning a television image is to reduce the amplitude of the high frequency components arising from the scanning of picture elements. This reduction occurs so that the harmonic content is reduced to zero at the first zero-frequency of the *widest* aperture. At this frequency all harmonic amplitudes can be considered to disappear, for all practical purposes. In fact, the name *zero-frequency* arose in connection with the aperture distortion problem, since the effect of an aperture is to reduce the harmonic components of the electrical signal to zero when the width of the aperture becomes equal to or larger than the width of the picture element which it is scanning.

For this reason it is attempted in all television apparatus to keep the apertures as small as is physically possible in relation to the size of the picture elements which it is desired to scan. The effect of each aperture through which the electrical signal has to pass is to reduce the resolution of the reproduced image by a small amount. If the apertures are large compared with the resolution which it is desired to transmit, the degradation is quite great, and it can be said that no resolution can be transmitted in excess of that allowable by the finite size of the aperture itself. This means that if a 0.001-in. aperture scans a 1-in. image, it will be impossible to resolve more than 1000 picture elements along the length of the image.

To be continued next month.

The concluding sections of Chapter 1, Part 2, cover Contrast and Gamma, Brilliance and Flicker, and Size and Shape.

For a complete table of contents of the TELEVISION HANDBOOK *series, see page 26, December, 1946 issue.*

TELEVISION MARKET SURVEY IN NEW YORK CITY

THE Schacter, Fain, and Lent advertising agency interviewed 338 people at 22 dealer demonstrations to get their ideas on television receivers. By occupation, 25.3% were civil service, sales, and clerical workers, 18.7% professional, 18.7% proprietors and managers, 16.8% housewives, 15.7% laborers, and 4.8% others. Two-thirds of the people questioned had seen television on previous occasions. When asked, "Did you like this demonstration?" All but 6.5% said, "Yes."

As to the purchase of television receivers, 89.6% said they plan to buy sets. Of these, 6% intend to buy now, 18.7% within a year, and 71% just said, "Later."

Most of the people, 46.3%, said they want sets combining television, radio, and phonograph operation, for which 4.3% were willing to pay $250 to $400, while 35.9% would go to $400 to $650. Of these, 43.2% wanted 12-in. pictures, while 46.7% wanted them still larger.

Only 18.7% would be satisfied with television alone, while 34% wanted television and radio reception. Of the latter, 52% would pay $200 to $350, and 39.2% would pay $350 to $600. However, 48% insisted on 12-in. images, and 38.3% wanted them still larger.

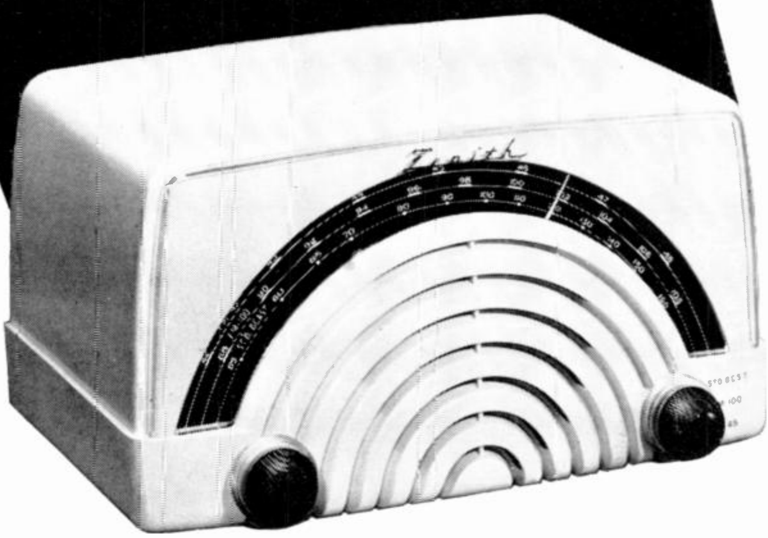
It looks as if the people interviewed want a lot of equipment for the money they are willing to spend, since the preponderant demand was for television-radio-phonograph units with pictures larger than 12 ins. at a price of $250 to $400, to be bought at some unspecified, future time.

Also, it appears that there would be little demand for the small-screen CBS color receivers, even if the sets could be put up with radio receivers at $350 to $600, or with phonographs added at $400 to $600.

This investigation, conducted for Viewtone Television, Inc., is of particular significance because it was conducted immediately after the people questioned had witnessed television reception at stores located in all five boroughs of New York City.

ZENITH

FM RADIOS



FM

THE ARMSTRONG SYSTEM

LICENSED UNDER ARMSTRONG PATENTS

...featuring the Genuine Armstrong Circuit in Both the 50 and 100 Megacycle Bands

$59.95

And Up!

The Public Is Demanding FM ...And Zenith Has The Answer

It will shortly be very difficult to sell any radio (except in the lower price brackets or portables) which does not incorporate FM. Zenith has long recognized the universal appeal of this new kind of static-free, true fidelity broadcasting as developed by Major Edwin H. Armstrong. To meet it, Zenith engineers have perfected two-band Armstrong FM in table model sets designed to appeal to the mass, volume market, as well as in the finest console combinations . . . all with Zenith's patented built-in light-line antenna. That is why Zenith is recognized by broadcasters, dealers and the public as the outstanding manufacturer of FM receivers.

Zenith Is Building A Mass FM Audience:

70.10% of all the FM equipped table model sets produced during the period from January 14, 1946 to January 4, 1947 were Zeniths. These latest available figures (February 5, 1947) are from Haskins & Sells, the official reporting agency of the Radio Manufacturers Association.

ONLY ZENITH HAS THIS!

- ★ Genuine Armstrong FM On Both Tuning Bands
- ★ Super 6-Purpose Tube
- ★ Built-in FM Antenna, Even for Table Models
- ★ Big, Easy-Tuning Dial
- ★ Permeability Tuning
- ★ Compact Chassis
- ★ Built-in Wavemagnet
- ★ Sensitive, Selective Circuit

ZENITH •LONG DISTANCE• RADIO

ZENITH RADIO CORPORATION CHICAGO 39, ILLINOIS

ENGINEERING SALES

(CONTINUED FROM PAGE 8)

Sylvania: Robert E. Lamar, formerly editor of Sylvania's company publications in the industrial relations department is now on the advertising staff of the radio tube division.

Mallory: New appointments by the wholesale division are Clint Bowan as representative for Mallory products in Chicago, northern Illinois, Iowa, and Wisconsin; Allen Shaw in Pennsylvania, Maryland, Delaware, Virginia, District of Columbia, and eastern New York; and Ray Bridge in the New England states.

Interstate: Fred E. Garner is handling sales in the middle west for Interstate Manufacturing Corporation components and antenna systems. His headquarters are at 333 N. Michigan Avenue, Chicago.

RADIO MARKET SURVEY

ALTHOUGH market surveys are always subject to interpretation by those who are to use them, they are valuable as a starting point for arguments, at least. Latest radio survey has just been released by Collier's Magazine. In this case, 2,927 questionnaires were returned out of 4,000 sent to Collier's subscribers in all parts of the U.S.

In 99.3% of the homes reporting, there was an average of 1.8 sets, of which 8% were out of order. By types, 47.8% were table models, 32.8% consoles, 8.1% console combinations, 3.9% table combinations, and 7.4% portable radios. As to location, 89.8% of the homes had sets in the living rooms, 43.2 had sets in bedrooms, 22.9% had sets in kitchens, and 16.7% had sets in other rooms.

Brand names showed 18.6% of the sets to be Philco, 10.6% RCA, 9.2% Zenith, 5.7% Emerson, 5.6% G.E., 5.2% Silvertone, 37% other names, 8.1% no name given.

People planning to purchase sets this year ranged from 37.6% in the income bracket below $2,000, up to 54.7% of those earning over $5,000 per year. Of these, 46.3% want console radio-phonograph combinations, 17.9% table combinations, 7.8% consoles, 22% table sets, and 5.3% portables.

Public understanding of FM is growing, as indicated by the fact that 38.5% want FM reception in their new sets. However, 33.3% reported that they "Don't know what FM means." Among those who want FM, 73.9% mentioned freedom from static as a reason, 28.5% mentioned greater tone fidelity, and 8.7% better slectivity.

Of the sets now in use, 21.2% were bought in radio stores, 19.3% in furniture stores, and 16.4% in department stores. Only 5.9% were purchased in music stores.

Whether the people who replied will carry out their plans to buy new sets, only

(CONCLUDED ON PAGE 70)

RADIO MARKET SURVEY

(CONTINUED FROM PAGE 69)

time will tell. There is no question that the demand for phonograph combinations is increasing. However, FM may have some effect on this. The reason is that FM reception of phonograph-record broadcasting is much superior to records played in the home on combinations. This is due partly to the use of superior turntables and pickups at the broadcast stations, but more particularly, perhaps, to the fact that when the records are played in the home, the tone-quality is poor at moderate volume level.

Of course, radio reception does not permit a personal selection of records. However, it is undoubtedly true that many people buy combinations because they do not like the tone-quality and interference on AM reception. It is quite possible that, as various FM models come into substantial supply, there will be an increasing demand for consoles in preference to phonograph combinations, both as a result of new listening experience and because of the difference in cost.

WHAT'S NEW THIS MONTH

(CONTINUED FROM PAGE 4)

And there you are. If you want to spend your money, you can take your choice. As for us, we'll stay in a neutral corner where we won't get cut by flying glass.

At this time, we'll only venture to second Mr. Engstrom's recommendation to the FCC: "That standards for color television not be established at this time. — That the radio industry be encouraged to reach an agreement on standards which will provide satisfactory performance, and that the radio industry be encouraged to conduct adequate field tests."

We might add that it would help a lot if someone would produce a color television receiver of any type that could be manufactured at a price to assure enough color-televiewers to make color program transmission commercially practical.

2. On January 28th, the FCC announced that, "because of many administrative problems involved," it is unable to comply at this time with FMA president Hofheinz' request that the FCC delete from existing rules all reference to "standard broadcast" stations, and to substitute the words "amplitude modulation" or "AM".

As we understand the request, it calls for scrapping printed matter already prepared, just to change the designation of broadcast service in the AM band.

It appears to us that Judge Hofheinz should have asked the FCC to adopt the plan of identifying *both* types of broadcast stations by their method of modulation in all official notices, correspondence, actions, reports, regulations, and forms in the future, and to revise existing regulations and forms, to this extent, when and

WHAT'S NEW THIS MONTH

(CONTINUED FROM PAGE 70)

as they are prepared for reprinting.

So universal have the designations AM and FM become throughout the industry and the press, and in common public use that most people in this country would ask the FCC: "What is meant by standard broadcasting?"

There is nothing to prevent such a change by the FCC. Until recently, the FCC used the awkward expression "special emission (FM)." This has been changed, and with no inconvenience or confusion, to plain "FM."

The current public notices from the FCC show, for example: Report No. 966-FM and TELEVISION ACTIONS with the heading "FM CONDITIONAL GRANTS." Report No. 2138, BROADCAST APPLICATIONS ACCEPTED FOR FILING, lists: "Valdorsta Broadcasting Co., Construction Permit for a new standard broadcast station to be operated on ......," and next below appears, "Plains Radio Broadcasting Company, Construction Permit for a new (Class B) FM broadcast station ...."

Since a station employing Frequency Modulation is identified by "FM", it would be much more consistent and less confusing to use "AM" to indicate stations employing Amplitude Modulation.

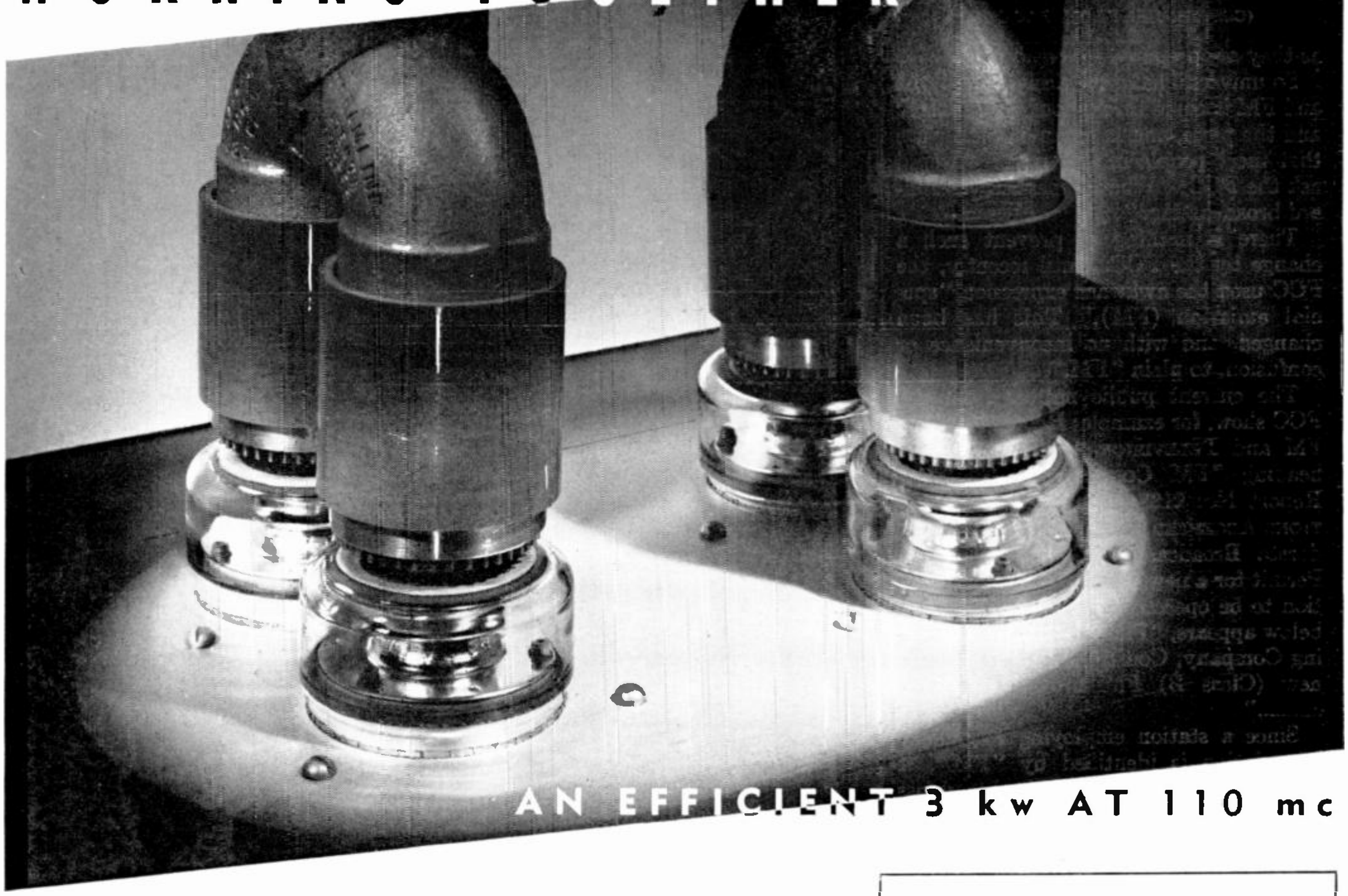
For those who want to be technical on this point, *Webster's New International Dictionary, Second Edition, Unabridged*, gives no support to "Standard broadcasting". The adjective form of "standard" is defined as "Being, affording, or according with, a standard for comparison and judgment; as, *standard* time; *standard* weights and measures; a *standard* authority; *standard* gold or silver." Also: "Usable as a standard of measurement or comparison."

Since the Commission is on record with the opinion that "FM is the finest aural broadcast system obtainable in the present state of the radio art", FM might be considered a standard of comparison, but it wouldn't make sense, as a matter of practical nomenclature, to use such a designation for FM.

We were greatly surprised that our esteemed contemporary *Broadcasting* worked up an editorial lather over Judge Hofheinz' request, and made an emotional issue of it, implying that the FM Association may be attempting to "precipitate internecine strife that will pit the AM operator against the FM zealot." Publisher Sol Taischoff must have strained his galluses to think up that one. We think too highly of him to believe that he was sincere.

Our own opinion is that, as a matter of convenience and common sense, the FCC will soon follow the general practice of the industry, the press, and the public and identify *both* types of broadcast stations by their system of modulation.

WORKING TOGETHER



AN EFFICIENT 3 kw AT 110 mc

Four Eimac 4X500A tetrodes provide a standout answer to the question of getting 3 kw of useful output power in the new f-m band and above. In a push-pull parallel arrangement these remarkable tubes generate this power with only 50 watts of drive. Operating data on the tubes in this actual installation are listed in the accompanying table.

Some of the design features of the Eimac 4X500A can be seen in the adjoining illustration. Short squatty geometry contributes to high-frequency capabilities by bringing the grid and plate lines close up to the elements themselves. The screen is brought out to the concentric contact ring surrounding the base. This makes it easy to seat the tubes into a ground-plane deck for effectual isolation of input and output circuits with consequent operating stability.

Low driving requirements of the 4X500A have obvious advantages for designers of original equipment. They also present operators of low-power f-m stations with an easy and efficient means of converting to 3-kw operation by letting their existing final amplifiers loaf as drivers for a set of Eimac 4X500A tetrodes in parallel push-pull.

Write for full details on Eimac 4X500A tetrodes and 3-kw f-m operation.

EITEL-McCULLOUGH, Inc., 1444 San Mateo Avenue
San Bruno, California

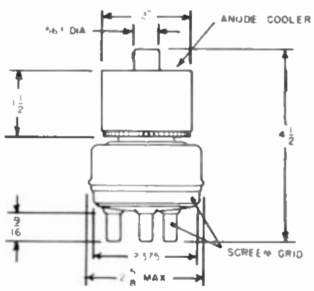
Follow the Leaders to Eimac TUBES *The Power of FM*

EIMAC 4X500A TETRODE
Electrical Characteristics

Filament: Thoriated tungsten	
Voltage	5.0 volts
Current	13.5 amp
Screen-grid amplification factor (av.)	6.2
Direct Interelectrode Capacitances (av.)	
Grid-plate	0.05 μμf
Input	12.8 μμf
Output	5.6 μμf
Transconductance (i_b :200 ma; e_b :2500 v; E_{c2} :500 v)	5200 umhos

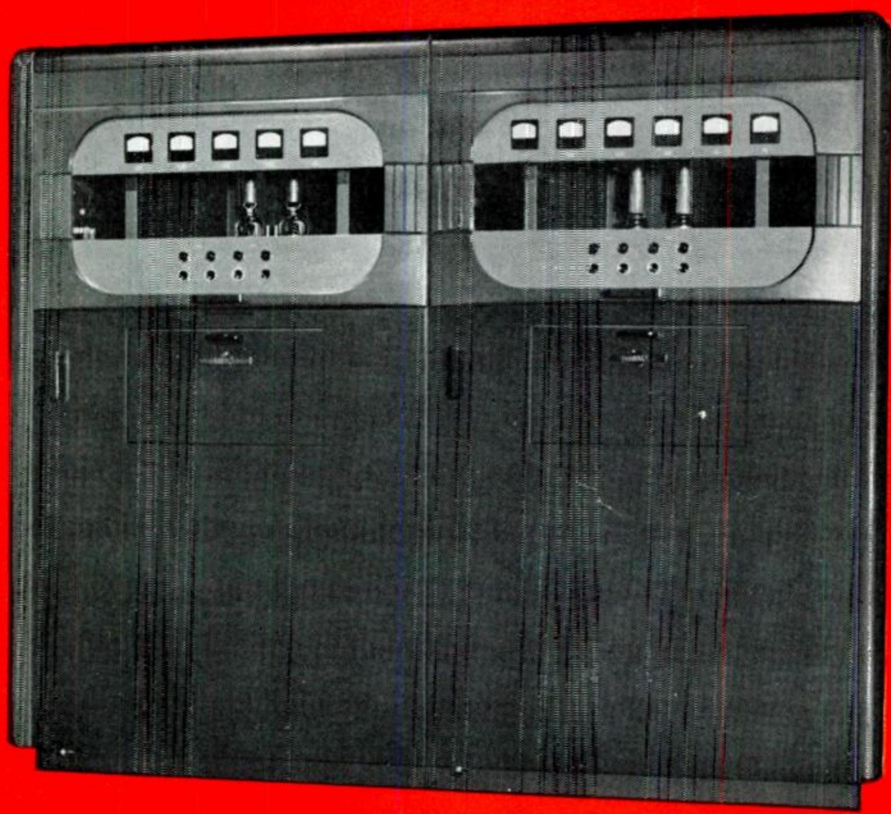
Typical Operation
(Four tubes push-pull parallel, 110 mc)

Plate voltage, d-c	4000	volts
Plate current, d-c	1.25	amp
Screen voltage, d-c	500	volts
Screen current, d-c	160	ma.
Grid voltage, d-c	250	volts
Grid current, d-c	70	ma.
Driving power (approx)	50	watts
Plate power output (approx)	3900	watts
Useful power output	3500	watts



4X500A

EXPORT AGENTS: FRAZAR & HANSEN, 301 CLAY ST., SAN FRANCISCO 11, CALIFORNIA, U.S.A.



The Collins 733A 3 kw FM Transmitter

Collins FM assures you of CONTINUED low cost operation

FEWER COMPONENTS . . . Collins FM transmitters are designed for the greatest possible economy *consistent with high performance and reliability*. Each stage performs its function completely and efficiently; thus the equipment requires a minimum of components. That's why there are only 26 tubes in the three kilowatt 733A, and only 10 tube types. Excluding power supply circuits, 9 of the 16 tubes used are of the receiving type. All tubes are operated well within their power ratings. The transmitting frequency is controlled directly by a quartz crystal, and no conversion or reference mechanisms are necessary.

HIGHER QUALITY . . . The superior quality apparent in the 733A contributes to its impressive, *substantial* appearance. Conservatively operated heavy duty components—the principal fact in safety factor—insure continuous operation. Quiet forced-air cooling removes heat from the cabinets. Sealed metal case capacitors, chokes, and transformers, together with rugged switches, sturdy relays and other circuit components, provide added reliability.

CONTINUED ECONOMY . . . In the 733A you get continued economy—through exact engineering a low initial cost—through efficient performance and dependability free from expensive "dead air," a profit-making low cost operation. See the Collins FM transmitters at your earliest opportunity. Let us send you an illustrated bulletin describing the 733A. We can supply your entire station requirements.

FOR THE BEST IN FM, IT'S . . . COLLINS

COLLINS RADIO COMPANY, Cedar Rapids, Iowa

11 West 42nd Street, New York 18, N. Y. **458 South Spring Street, Los Angeles 13, California**

RUMFORD PRESS
CONCORD N. H.

with accent on

Furniture Styling

they're at home in <u>every</u> room of the house

In 1947 SELL an EXTRA RADIO

And this is your golden chance: No customer is content with just *one* Motorola radio when he sees the unbelievably varied range of other Motorolas. A cabinet customer is a "portable potential" . . . and vice versa. In either case, he's sold . . . completely . . . on *Motorola Radio.*

Motorola A-M F-M Radio

Feature Radios as *Gifts* for ALL OCCASIONS

Motorola is the Perfect Gift. Your customer will be best satisfied with the choice of a Motorola . . . whether it's an elaborate console combination or a palm-size portable.

GALVIN MFG. CORPORATION • CHICAGO 51, ILLINOIS