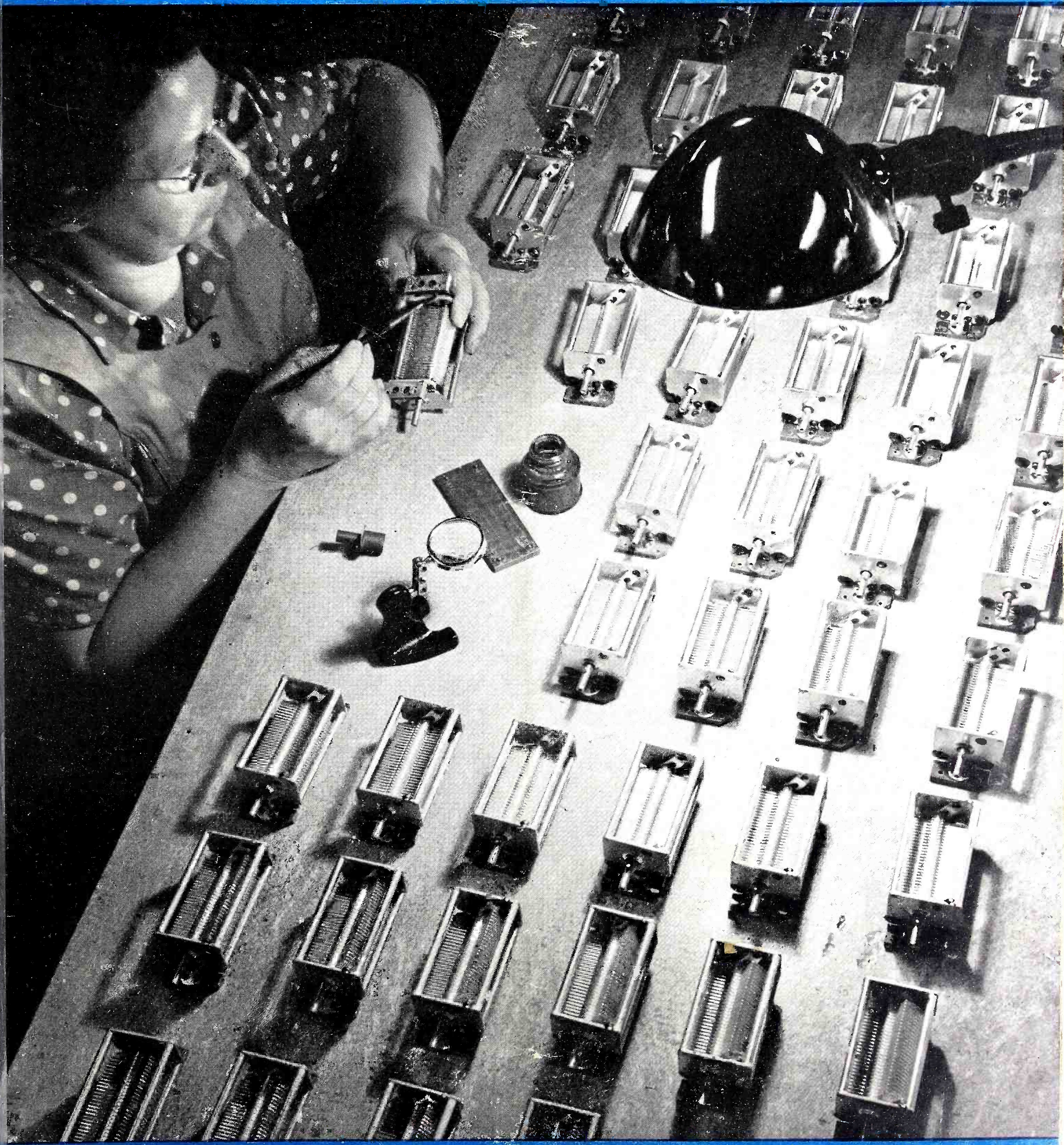
RADIO

NOVEMBER, 1946

MANUFACTURING AND BROADCASTING

The Journal for Radio & Electronic Engineers



Design • Production • Operation

IT'S TOUGH TO FIND A BETTER TRIODE THAN THE BIG, RUGGED EIMAC 750TL

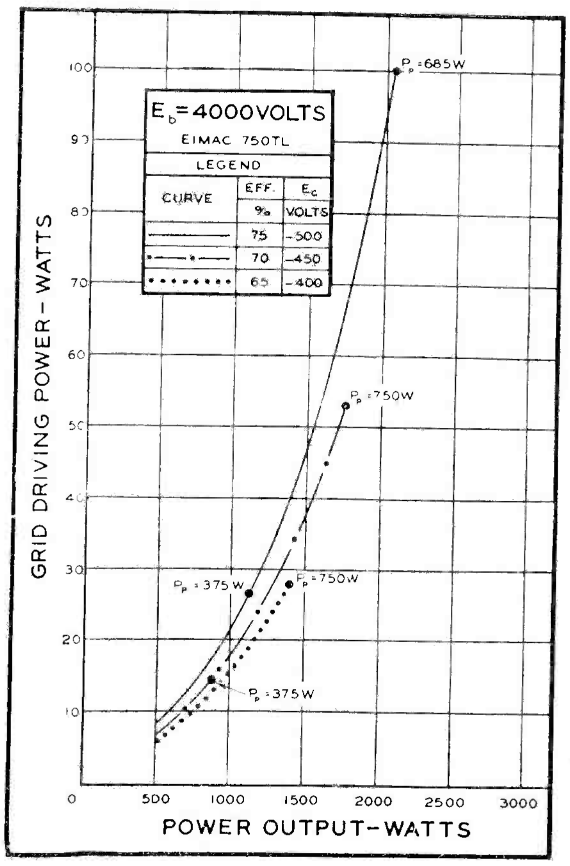
VERSATILE MEDIUM-MU TRIODE

The Eimac 750TL is a medium-mu triode designed for high efficiency operation whether used as a modulator, oscillator or amplifier. This is an unusually versatile tube capable of many kilowatts of output.

Successful high frequency operation of this triode is assured by unusually low interelectrode capacitances, heavy leads, and a big tough cathode.

The chart below shows power-gain characteristics of the 750TL.

As a Class-C amplifier, the Eimac 750TL will provide plate power output of 1750 watts with 4000 volts on the plate and only 53 watts driving power.



At frequencies below 40 mc, or as a Class-B modulator, the 750TL operates at high plate efficiencies, thus permitting r-f and a-f outputs of many times the plate dissipation rating.

3½ KILOWATT AUDIO OUTPUT

As Class-B modulators, a pair of Eimac 750TL's will produce a typical maximum-signal plate power output of 3500 watts, with only 30 watts grid drive.

THESE ARE RUGGED TUBES

These big, powerful 750TL's are built for long, trouble-free service for a wide variety of uses. Many Eimac 750TL's installed months and years ago are still going quietly and efficiently about their business. Why not ask Eimac today for a price and data sheet giving full details of this versatile triode. Naturally, there is no obligation. Eitel-McCullough, Inc., 1298G San Mateo Ave., San Bruno, Calif. Export Agents: Frazar and Hansen, 301 Clay St.,

GENERAL CHARACTERISTICS

Eimac 750TL

Filament: Thoriated tungsten	
Voltage	7.5 volts
Current	21.0 amperes
Amplification Factor (Average)	15
Direct Interelectrode Capacitances (Average)	
Grid-Plate	5.8 uufd
Grid-Filament	8.5 uufd
Plate-Filament	1.2 uufd
Transconductance (I_B=1.0 amp., E_B=5000, E_C=—100)	3500 umhos
Frequency for Maximum Ratings	40 Mc
Base	Special 4 Pin No. 5003B
Basing	RMA type 4BD
Maximum Overall Dimensions:	
Length	17.0 inches
Diameter	7.125 inches
Net Weight	2.75 pounds
Shipping Weight (Average)	8.0 pounds

Follow the Leaders to

Eimac REG. U. S. PAT. OFF. **TUBES**

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RADIO

Published by RADIO MAGAZINES, INC.

John H. Potts.............Editor
Sanford R. Cowan.......Publisher

NOVEMBER, 1946 Vol. 30, No. 11

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COVER

Inspector scans each incoming variable condenser for minute flaws at transmitter department of Collins Radio Co.

ARTICLES

MISCELLANEOUS

RADIO [illegible] is published [illegible] Post Road, Orange, Connecticut, by Radio Magazines, Inc. Executive and Editorial Offices at [illegible] Madison Avenue, New York [illegible] Subscription rates—United States, U. S. Possessions & Canada, [illegible] for 1 year, $5.00 for 2 years; elsewhere [illegible] per year. Single copies [illegible] Printed in U.S.A. All rights reserved, entire contents Copyright [illegible] by Radio Magazines, Inc. Entered as Second Class Matter [illegible] at the Post Office at [illegible] under the Act of March 3, 1879.

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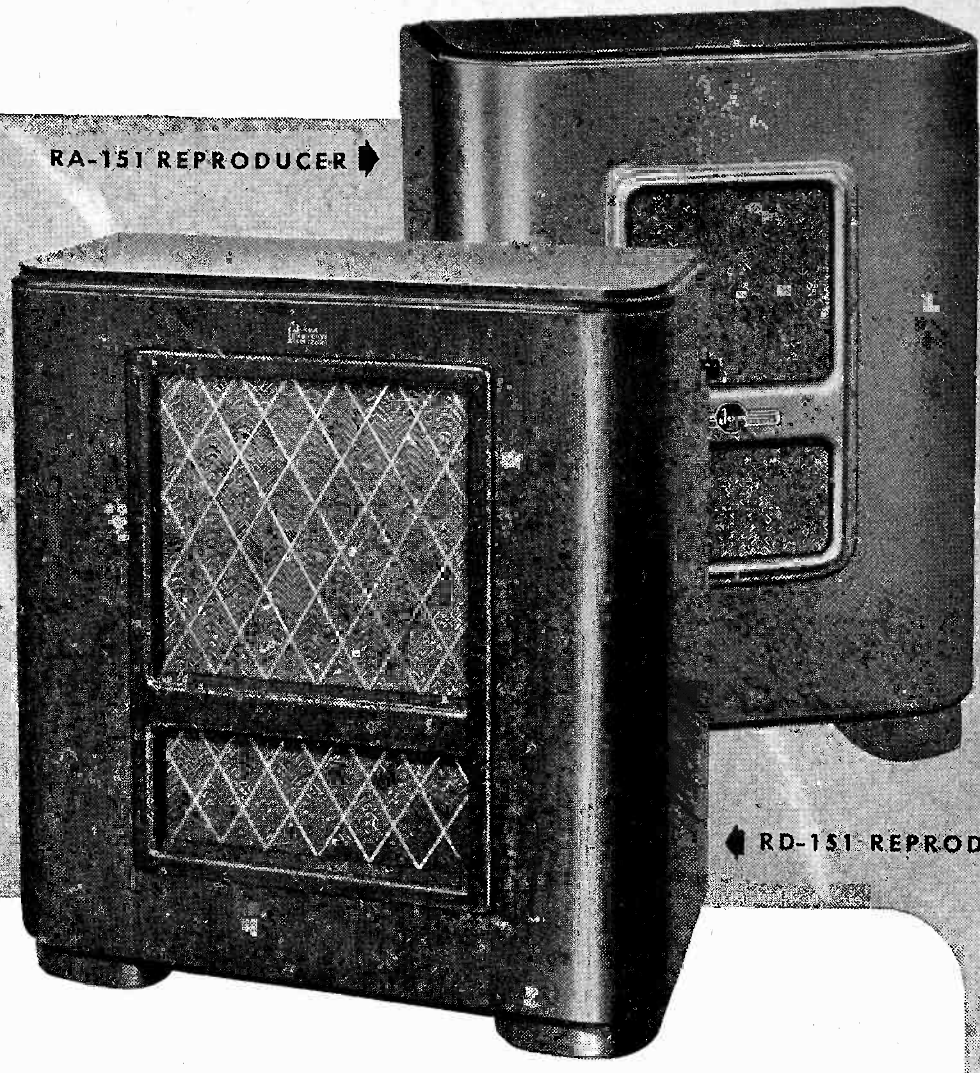

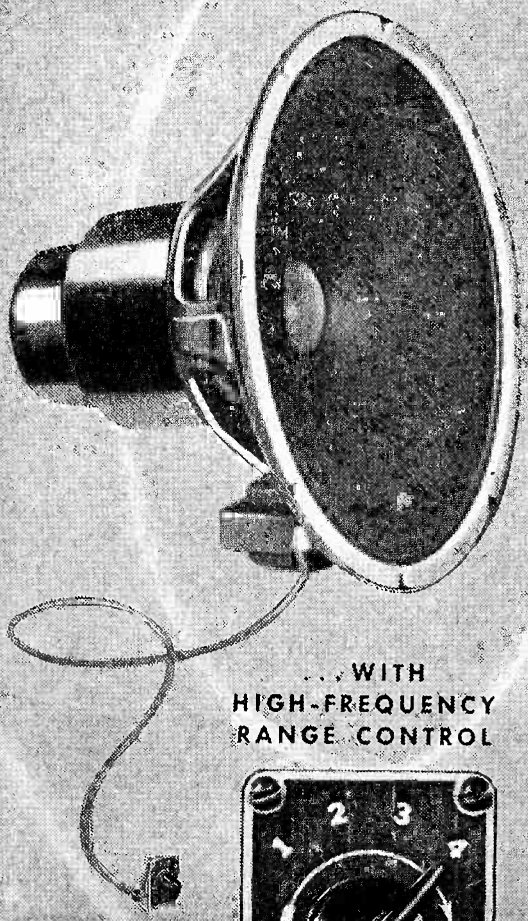

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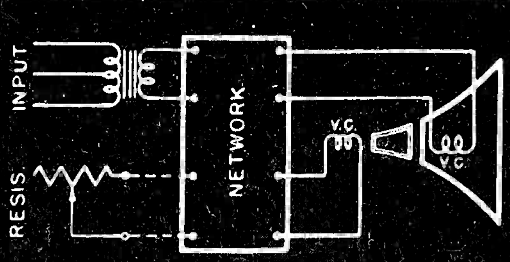

Separate coaxially-mounted speakers for low and high frequencies, with integral two-channel network. (Range control not shown.)

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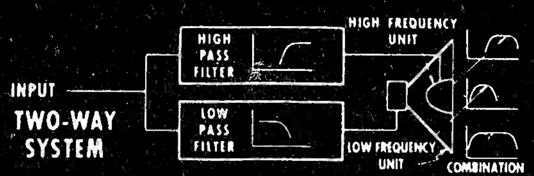

JENSEN BASS REFLEX

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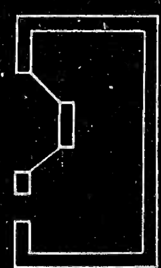


Transients

RADIO DECONTROLLED

★ Announcement of decontrol of prices on radio receivers, followed by similar action in regard to component parts, clears the way for greatly expanded production of radios and associated equipment. Because these actions were expected, they were received with no great surprise by the industry. Already an increase in production of much-needed console receivers has been announced, made possible because cabinet manufacturers no longer find it to their advantage to divert production to the formerly more remunerative furniture market. Shortages of loudspeakers, tubes, and volume controls are becoming less acute, though it will still be some time before production becomes greater than the demand. But even now the rate of production of radio receivers is greater than at any previous time in history. And once again familiar brand names are appearing in stores. If strikes can be kept to a minimum, prosperity for the industry in 1947 seems assured.

ELECTRONIC COLOR TV

★ At Princeton recently, RCA presented a demonstration of electronic color television. Its sponsors had predicted last year that it would take at least five years before electronic color television would be ready for the market, and it was emphasized that this demonstration was being given merely to show that progress had been made, and that at least four years must elapse before it would be ready for distribution to the public.

In this demonstration, RCA used three matched cathode-ray tubes, for red, blue, and green images, respectively. These images were superimposed when projected on a viewing screen. By using a 525-line system operating on a carrier frequency now being used for monochrome television, it becomes possible very simply to adapt the RCA apparatus to receive the present type of television broadcasts, as well as those in color. Thus no new frequency bands are needed for this method of electronic color television and, when ready, the transition to color television would not be quite so painful financially to broadcasters and the public because present-day apparatus would not become wholly useless.

Whether this or some other system of electronic color television will eventually be adopted is problematical. Many feel that any system requiring three carefully matched tubes would be impractical from a production standpoint, and that eventually but one tube will be needed. However, the demonstration does serve to show that RCA has a workable system which requires no new frequency assignments, such as were requested by CBS for their mechanical scanning system of color television. Further, the fact that the RCA equipment may be used to receive monochrome television broadcasts may reassure in some measure prospective purchasers of present-type television receivers who might otherwise hesitate to invest a considerable amount of folding money in such a device if it were felt that monochrome television would shortly be abandoned. Also, many broadcasters who have changed their minds about going ahead with television service because of the threat of the CBS system may now feel more inclined to resume their original plans.

We have consistently felt that the mechanical system of color television, no matter how well it may be made to work, is not the answer to the problem. It is inherently unwieldy, and is destined to be superseded by electronic scanning sooner or later, just as electronic scanning replaced mechanical methods in monochrome television. The RCA demonstration will stimulate others working along similar lines. Personally, we still feel that a practical system of electronic color television will be ready in the near future—perhaps in considerably less than four years.

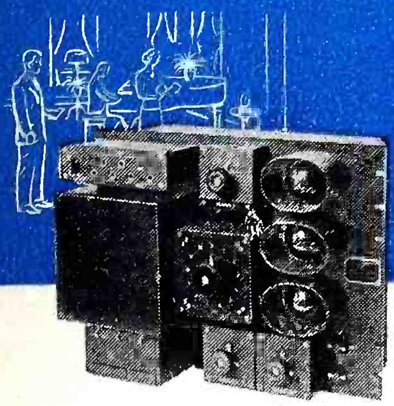
TELEVISION MERCHANDISING

★ Announcement by RCA that their television receivers will be installed and serviced by them for one year for a fixed additional fee seems to be a wise move. In many instances, purchasers of television receivers before the war never obtained wholly satisfactory results from their instruments solely because of unsatisfactory installations or minor defects in the apparatus which were overlooked by dealers' servicemen.

This plan emphasizes the need for an immediate increase in the number of competent television servicemen. For those who choose to specialize in this field, the opportunities seem bright . . . far more so than in general radio servicing because of the higher unit cost and greater complexity of television sets. It would be wise for those who are now experienced in radio servicing to seek special training in this new field, rather than attempt to pick it up solely through experience. High voltages appear in television receivers, and while the ordinary run of defects encountered in television sets parallels those found in ordinary broadcast receivers, many precautions must be observed which are not necessary in ordinary radio servicing, both for the safety of the individual and the apparatus to be repaired.

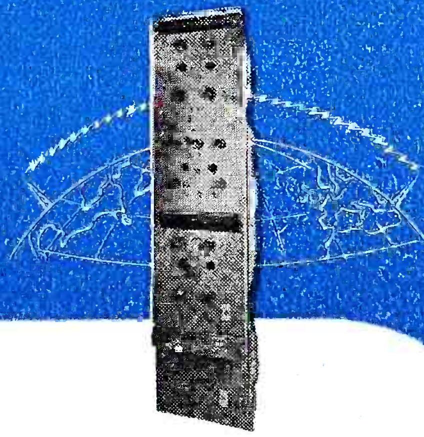
—*J. H. P.*

for *Quality* in Amplifiers

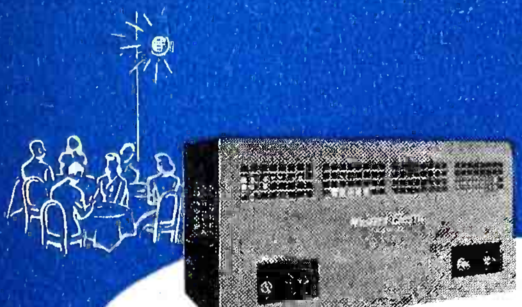


1922. The Western Electric 8A was the first commercial broadcasting amplifier. Today, 24 years later, some of these 8A's are still in use. This long life speaks volumes for the quality built into them.

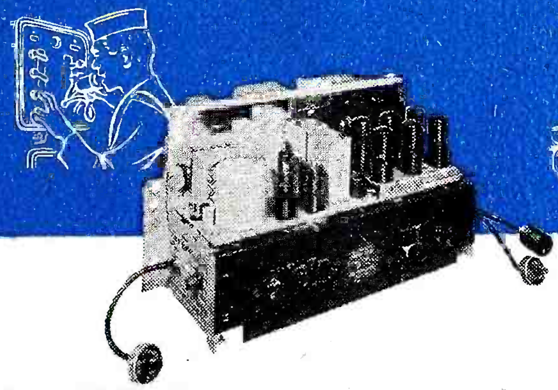
1928. This ac operated amplifier, one of the first made, reduced maintenance costs and did away with cumbersome batteries and charging equipment. It was used to record some of the earliest sound motion pictures.



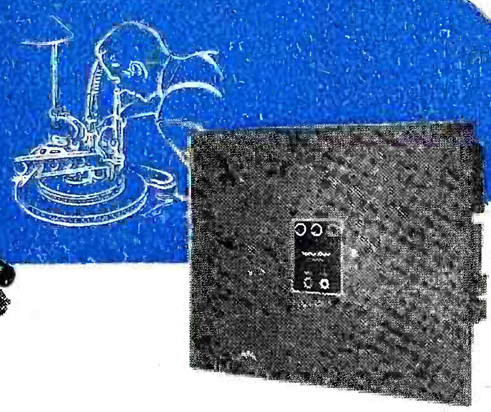
1934. Western Electric was an early leader in making compression type amplifiers to enable higher speech intensity between noise level and overload point. This equipment was used in overseas radiotelephony.



1946. The brand new 124H and J amplifiers for wired music and public address systems are small and light weight, yet deliver 20 watts. They are setting new standards of quality for music reproduction.



1942. This compact and powerful unit for battle announce systems is typical of Western Electric amplifiers designed during the war. It operated dependably when mounted a few feet from the largest guns.



1938. Negative feedback is another of Bell Laboratories' many contributions to amplifier design—now in general use. This amplifier for disc recording was able to supply as much as 50 db of feedback.

1946. The 1126C is the latest design of Western Electric's popular level governing amplifiers. In operation it acts as a program-operated gain control to prevent overmodulation in AM or FM broadcasting. It immediately reduces gain when an instantaneous peak exceeds a predetermined level, slowly restores it when the peak is passed.

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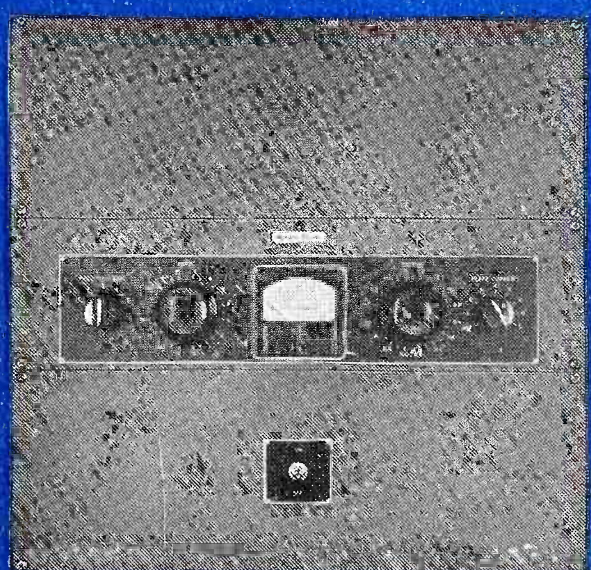


TECHNICANA

VERSATILE OHMMETER

★ A dual purpose meter developed in Germany will measure both low-order electrical resistance from zero to 50 ohms and insulation resistance in megohms, according to a report by the U. S. Army's Engineer Board, Fort Belvoir, Va. The report is on sale by the OPB, Dept. of Commerce. The meter is available for inspection by industry at the Engineer Board, electrical branch.

The weight of the instrument, without batteries, leads, and resistor, is 3 lbs., 11 oz. The unit has an ohmmeter circuit and an insulation measuring meter circuit. It is energized by two 4½-volt cells. A photograph and circuit diagrams of the instrument are included in the report.

Orders for the report (PB-15589; photostat, $1; microfilm, 50 cents) should be addressed to the Office of the Publication Board, Dept. of Commerce, Washington 25, D. C., and should be accompanied by check or money order, payable to the Treasurer of the United States.

LOW-FREQUENCY CORRECTION CIRCUIT

★ To obtain a rising characteristic at lower frequencies, particularly for reproducing recordings, the circuit shown in *Fig. 1* is recommended in the June, 1946 issue of *Wireless World.* While primarily a frequency-correction circuit, it also affords some gain. Bass-boost control is obtainable by making C variable.

Circuit design equations are given for the condition that the tube work into a load impedance of at least twice its a-c plate resistance. In this manner amplitude distortion is kept low. These equations are:

Given R_a = a-c plate resistance of tube in ohms

B_1 = increase of response in db, required at a low frequency f_1 (cps).

B_2 = increase of response required at a higher frequency f_2 (cps).

First, the values of B_1 and B_2 should be checked to determine that the required performance is possible with this circuit. It is necessary that

$$y_1 < 1 + (y_2 - 1) f_2^2/f_1^2$$

where $y_1 = \log^{-1} B_1/10$ = power ratio corresponding to B_1 db

$y_2 = \log^{-1} B_2/10$ = power ratio corresponding to B_2 db

Secondly, evaluate

$$X = \sqrt{\frac{1}{Y_1} \cdot \frac{(Y_2-1) \cdot f_2^2/f_1^2 - (Y_1-1)}{(Y_1-1) f_2^2/f_1^2 - (Y_1-1) Y_2/Y_1}}$$

$$T = \frac{1}{6.28 f_1} \sqrt{\frac{1 - X^2 Y_1}{Y_1 - 1}}$$

Thirdly, determine values of components:

$R_1 = 3R_a$ ohms

$R = \frac{27}{4} R_a x$ ohms

$R_2 = 6R_a(1 - \frac{9}{8} x)$ ohms

$C = 10^6\ T/R\ \mu f$

e_o/e_{in} = voltage amplification of stage at high frequencies = $\frac{3}{4} \mu x$

Fourth, choose R_3 and C_1 in accordance with usual practice for a resistance-coupled stage, so that

$R_3 >> R[1 + 1/\omega_1^2 T^2]^{1/2}$ ohms

$C_1 >> 10^6/\omega_1 R^3$ microfarads

Choose R_5 to yield the specified grid bias for the tube, and make

$C_3 >> 10^6/\omega_1 R_5$ microfarads

Make R_4 as large as possible, while maintaining sufficient plate voltage. A representative value is 50,000 ohms. The value of C_2 depends on the gain following this stage and must suffice to make feedback negligible. A typical value is 8 μf.

When it is desired to find the overall response, it may be calculated from the formula:

$$B = 10 \log \frac{1 + \omega^2 T^2}{x^2 + \omega^2 T^2} \text{ db}$$

where ω = 6.28 times frequency in cps.

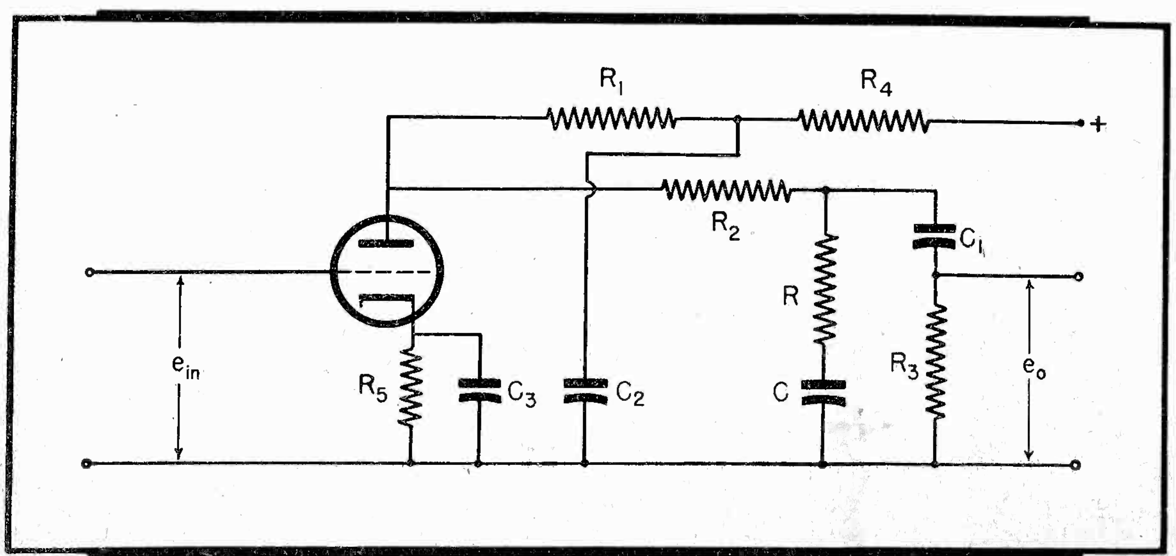


Figure 1

U-H-F MODULATION TESTS

★ Conventional oscilloscopes cannot be used for measuring percentage modulation at frequencies above 20 mc, because stray coupling in the circuit wiring of the scope leads to a distorted image. A modification of the scope circuit which avoids this limitation is discussed by A. J. Main and J. W. Whitehead in an article entitled "Modification to Cossor Oscilloscope Model 339," which appears in the *Journal of Scientific Instruments (London)*, August 1946.

The modification, while developed for the scope mentioned, will doubtlessly be found useful when other conventional types of scopes are to be applied to modulation measurements. The most serious stray coupling occurs in the wiring between the sweep circuit and the X_1 plate shown in *Fig 2*, and between the horizontal centering control and the X_2 plate.

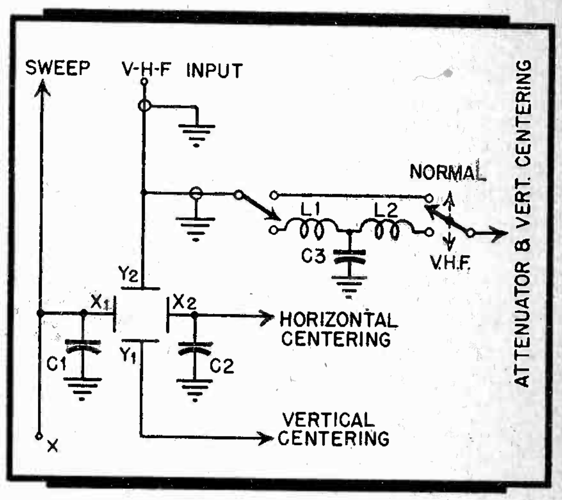
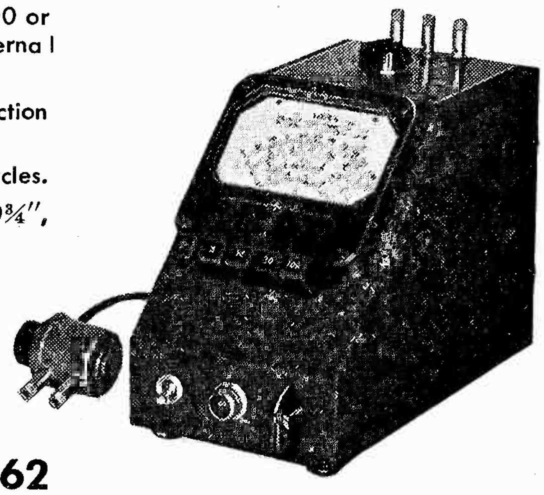


Figure 2

Accordingly, various filtering components are added which reduce the image distortion to a negligible degree, while leaving the sweep and centering facilities of the scope unaltered. One particularly troublesome form of stray coupling occurs from the lead running (usually) the length of the instrument between the Y_2 tube socket and the vertical attenuator on the front panel. A path for d.c. between these points is required, and the authors suggest mounting an auxiliary terminal 'V-H-F Input' on the rear terminal board which connects to the Y_2 plate through a shielded cable.

In order to allow vertical centering, an r-f filter is interposed as shown. This may be switched out of the circuit for unmodified operation by means of the DPDT switch which is also mounted on the rear terminal board. The filter



TECHNICANA

[*from page* 8]

put stage is shown in *Fig. 3*, assuming a perfect output transformer. The value of reflected plate resistance is chosen as half the speaker impedance at 400 cps, in accordance with customary triode practice. The current to the voice coil is then given by

$$I = 1/(r_p + Z\cos\theta + jZ\sin\theta)$$

For the speaker under test, X and R were each 3 ohms at 2000 cps, so that $I = 0.2$ a. at this frequency and the total power to the speaker was 0.12 watt. Calculating the power in similar fashion for other frequencies, considerable variation is encountered, with 0.245 watt at 150 cps and 0.04 watt at 10,000 cps.

The d-c resistance of this voice coil was approximately 1.5 ohms, and when

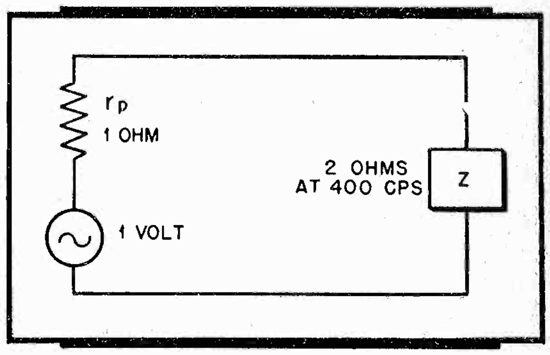


Figure 3

the heat loss was calculated with respect to frequency, it was found that the sound output power was quite uniform between 200 and 7000 cps, varying from 0.04 to 0.06 watt, with considerable dropping off outside these limits. Some of this sound power is lost as friction, particularly at the higher frequencies in the case of poorer speakers, resulting in less than apparent radiated sound power.

Triodes provide better damping for the speaker, and the heat losses at the ends of the frequency range assist in holding up the response.

Similar calculations were carried out for a pentode output tube without feedback. The effective resistance was chosen at five times the voice coil impedance at 400 cps, in accordance with standard practice. A marked increase in output power was found at both bass resonant frequency and at the high end; the efficiency approached 90% at the bass-resonant point, falling to 20% at 400 cps, and to 6% at 100 cps. A treble boost of 8 db as compared with triode performance was found at the high-frequency end.

Mr. Stanley thus concludes that the response curve of the speaker must be considered with respect to the source impedance, or the anticipated output curve will not be realized. Other factors, such as room acoustics and directional radiation of high-frequency sound energy, are not covered in the article.

REGENERATIVE RECEPTION

★ Still used to some extent in specialized services, regeneration at the lower frequencies presents difficulties as a result of oscillation hysteresis. That is, once the circuit 'plops' into oscillation, the regeneration control must be reduced considerably to bring the receiver out of oscillation.

Oscillation hysteresis has been effectively investigated by E. E. Zepler, who reports on this topic in an article appearing in the August, 1946 issue of *Wireless Engineer*. He observes that the problem was far more serious 25 years ago, when large fixed grid bias was common practice in detector design. With grid-leak self-bias, a considerable improvement was effected although the problem was not entirely overcome.

Mr. Zepler's investigation leads to the conclusion that oscillation hysteresis arises because of increase of tuned grid-circuit Q with increasing grid current, and also because of phase displacement of plate current caused by reactance of the feedback capacitor. In actual fact, Mr. Zepler points out, the grid-cathode path of the tube, under oscillatory conditions, is equivalent to a resistance which increases with increasing amplitude of oscillation. Improvement of threshold operation was obtained by lowering the plate supply voltage, and by increasing the value of grid-leak resistance.

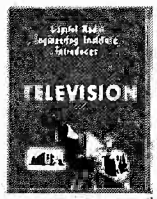
A diode biased to cut-off and connected in parallel with the tuned circuit was found to eliminate hysteresis when the plate load was a high resistance and when hysteresis is caused by phase displacement of plate current with respect to grid voltage. The improvement arises from the influence of the diode resistance upon the tuned-circuit Q, causing it to decrease with increasing grid current.

TUBE PRESS DESIGN

★ When many metal parts must be fused into glass close to one another, it is sometimes found impossible, due to low fluidity of the glass, to force a drop of glass between the metal parts. A favorable solution is discussed by E. G. Dorgelo in v. 8, No. 1 of *Philips Technical Review*, Eindhoven, Holland, who has investigated the use of powdered glass.

The powdered glass is introduced between the metal parts before fusing, and makes possible various bead designs and presses heretofore considered impractical. The glass is not completely clear after fusing and contains multitudes of fine air-bubbles. In this form the glass is termed sintered.

Numerous applications to receiving and transmitting tube manufacture are discussed by Mr. Dorgelo.



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Cylindrical-Cavity
WAVEMETER DESIGN

H. J. PEAKE
Naval Research Laboratory

Factors involved in designing units for frequency measurements in the microwave region. The chart presented on page 15 simplifies design problems.

CAVITY-TYPE WAVEMETERS are now extensively used for frequency determinations in the microwave region. The design of a cavity-type wavemeter involves such factors as frequency range, Q factor, mode of resonance, elimination of spurious resonances, physical dimensions, choice of material, method of excitation, tuning dial accuracy, and effect of temperature on calibration. Due to the interrelated character of most of these design factors, they cannot be determined independently. For instance, the Q factor is affected by the frequency, mode of resonance, dimensions, and material. Likewise, the dominant mode, dimensions, and method of excitation must be chosen so as to preclude, insofar as is practicable or necessary, the possibility of undesired resonances.

The design chart to be described is a means for easily determining several factors simultaneously. From practical considerations, a tunable wavemeter generally will be cylindrical in form, having one fixed end and a movable plate or plunger at the other end.

Modes of Resonance

Resonant modes are of two general types: transverse electric (designated TE or H) modes and transverse magnetic (designated TM or E) modes. TE modes have electric fields transverse to the axis of the cavity, whereas the TM modes have magnetic fields transverse to the axis of the cavity. To completely specify a mode a system of three subscripts is used, as follows:

TE_{nml} or TM_{nml}

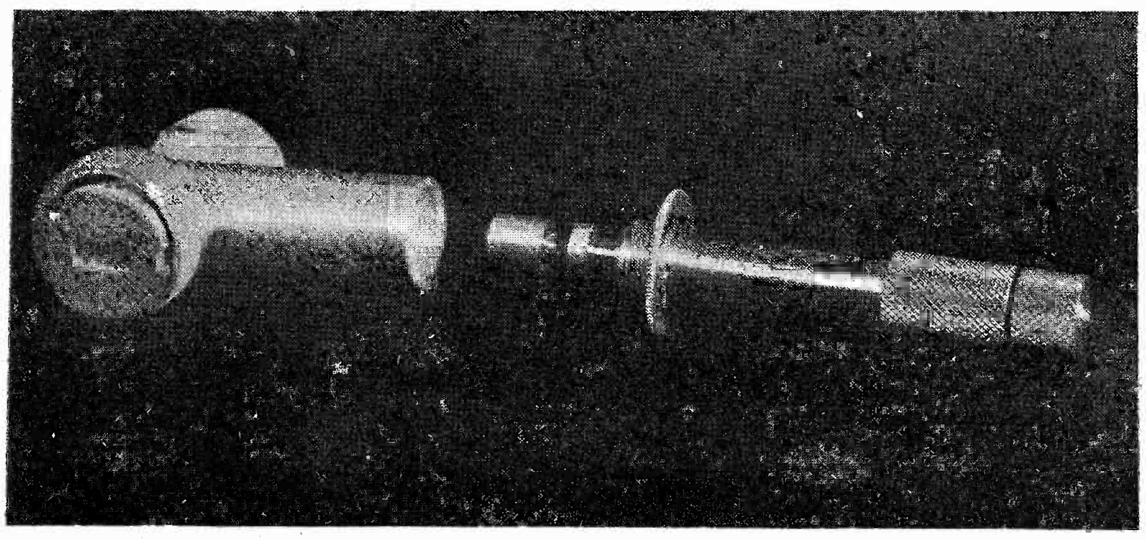
Where *n* denotes the number of full-period variations of the radial component (E_r or H_r) along the angular (θ) coordinate

m denotes the number of half-period variations of the angular component (E_θ or H_θ) along the radial (r) coordinate

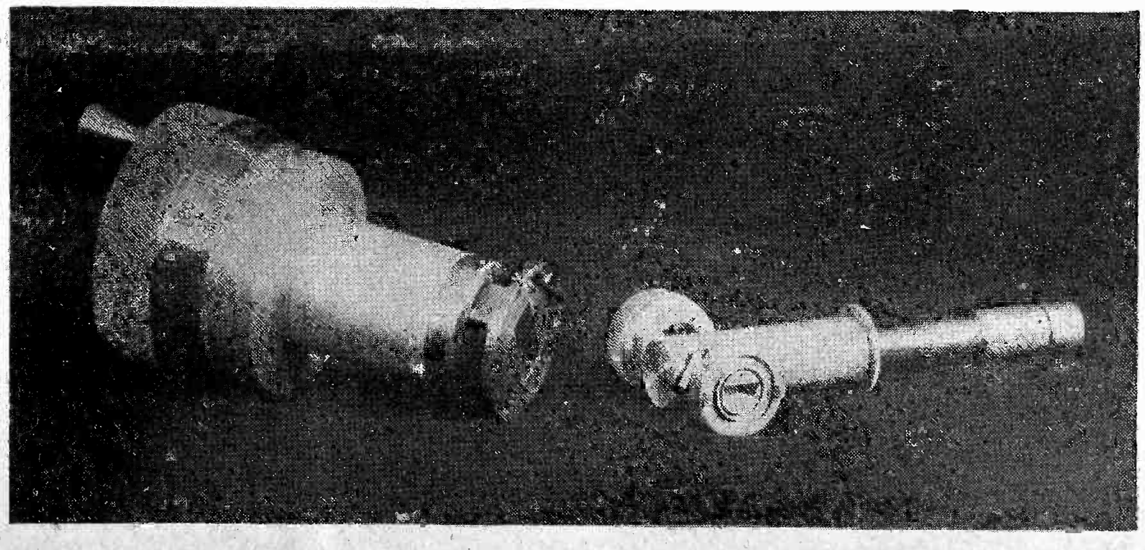
l denotes the number of half-period variations of the radial component (E_r or H_r) along the axial (x) coordinate.

The designation of either TE or TM (with subscripts) fully defines a particular mode since the electric and magnetic fields at all points are orthogonal; i. e., the one field specifies the other.

TE modes are better adapted than TM modes for use in tunable wavemeters. The movable plate shown in *Fig. 1* need not make contact with the cavity wall if a TE mode is used, whereas intimate contact is necessitated if a TM mode is employed. Hence, to avoid use of shorting plungers, transverse electric modes of resonance will be chosen. Further, the use of low-order TE modes will minimize the confusion due to existence of higher-order undesired resonances. The TE_{011} and



(Above) Disassembled view of transmission-type cylindrical-cavity wavemeter. (Below) Cylindrical-cavity wavemeters. Left, reaction type; right, transmission type.



TE_{111} modes in particular have wide application, the former affording the higher Q.

Resonances in modes other than the dominant mode may occur. These resonances will normally have higher circulating currents and, hence, lower Qs. A knowledge of the field configurations of possible undesired modes allows one to discourage them by the following means: careful choice of the method of coupling energy into the cavity; use of damping rods or wires which follow the electric field configuration of the undesired mode; placing absorbing material in the volume behind the tuning plunger (see *Fig. 2*).

Q Factor

The Q of a resonator is a measure of its sharpness of resonance and, hence, a determining factor of the degree of precision to which the resonant frequency may be adjusted. Specifically,

$$Q = f_0/\Delta f = \lambda_0/\Delta\lambda \qquad (1)$$

where

f_0 = resonant frequency, Δf = half-power bandwidth (same units)

λ_0 = resonant wavelength, $\Delta\lambda$ = half-power bandwidth (same units)

Thus it is seen that a high-Q (narrow bandwidth) resonator will be required for a precision wavemeter.

Among the parameters that determine Q is the loss that occurs when currents flow within the walls of a cavity. These currents penetrate the metal to a depth,

$$\delta = \sqrt{\rho/2\pi\omega\mu} \qquad (2)$$

where δ = skin depth of penetration, cm
ρ = resistivity of cavity material, abohm-cm
$\omega = 2\pi f$, f in cycles per second
μ = permeability of cavity material (= 1, for non-magnetic materials).

The resistivity of some commonly used materials is given in Table I. Now Q is found to be inversely proportional to skin depth (δ), since greater losses result when the current flows through a greater cross-section of metal. Consequently, a copper resonator of given size and shape will have a Q about two times that of a brass resonator of the same dimensions since skin depth (δ) is proportional to the square root of resistivity (ρ) for non-magnetic metals. It is desirable that the surfaces of a cavity wavemeter be silver plated to reduce skin depth as well as to minimize oxidation in unsealed wavemeters. Oxides on the resonator walls will result in decreased Q.

TABLE I

RESISTIVITY OF METALS	
Metal	**Resistivity (abohm-cm)**
Silver	1.63×10^3
Copper	1.72
Gold	2.44
Aluminum	2.83
Brass	7.0
Platinum	10.0

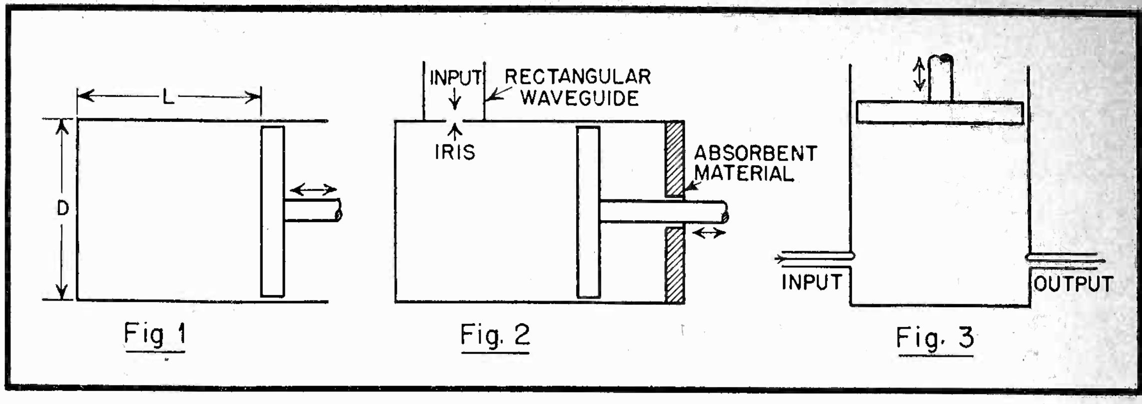


Fig. 1. Tunable cavity resonator. Fig. 2. Reaction-type resonator with waveguide input, iris coupling, and absorbing material. Fig. 3. Transmission-type resonator with coaxial connections and loop coupling.

The shape of a cavity also influences Q. In general, a shape affording a greater volume-to-surface ratio results in increased Q. For a cylinder the volume-to-surface ratio is maximum when diameter equals length. Further, cavities of the same shape but of different sizes have Q's proportional to the square root of the resonant wavelength. For example, if a wavemeter with a Q of 30,000 at 10 cm were scaled down to resonate at 2.5 cm a Q of 15,000 could be expected.

A cylindrical resonator with silver-plated walls and with diameter equal to length will produce the following approximate theoretical Q's:

$$TE_{111} \text{ mode, } Q = 7.4 \times 10^3\sqrt{\lambda_0} \qquad (3)$$
$$TE_{011} \text{ mode, } Q = 18 \times 10^3\sqrt{\lambda_0} \qquad (4)$$

where λ_0 = resonant wavelength, cm.

Although the theoretical values of unloaded Q in (3) and (4) may be obtained, the loaded Q (Q_L) will be less. When connection is made to an external load,

$$Q_L = Q\,\frac{R_L}{R_S + R_L} \qquad (5)$$

where Q_L = loaded Q
R_L = effective load resistance, ohms
R_S = shunt resistance of cavity, ohms

Since R_S is usually in the order of megohms it is necessary to maintain very light external loading if a serious reduction in Q is to be avoided. R_S is analogous to the antiresonant resistance exhibited by an ordinary L-C tuned circuit.

Method of Excitation

Connection to a cavity may be made by means of an iris or aperture, a loop, or a probe. Iris coupling is shown in *Fig. 2* and loop coupling in *Fig. 3*. Loops and probes are best used for coaxial feeds, whereas iris coupling is used with waveguide feeds.

A coupling probe must be so oriented as to parallel the electric field of the desired mode, while a loop must lie in a plane perpendicular to the magnetic lines. The degree of coupling may be adjusted by the depth of insertion of a probe or the exposed area of a loop. The amount of coupling through an iris is determined by the diameter of the opening. The location of the coupling is an important consideration if spurious modes are possible. In general, the energy should be introduced along one or more axes of symmetry of the resonator.

TABLE II

Roots of $J_n'(U) = 0$ and $J_n(U) = 0$.	
$U_{01}' = 3.832$	$U_{01} = 2.405$
$U_{02}' = 7.016$	$U_{02} = 5.520$
$U_{11}' = 1.841$	$U_{11} = 3.832$
$U_{12}' = 5.332$	$U_{12} = 7.016$
$U_{21}' = 3.054$	$U_{21} = 5.135$
$U_{22}' = 6.705$	$U_{22} = 8.417$

Wavemeters may be classified as (1) reaction or (2) transmission type. The reaction-type wavemeter (*Fig. 2*) is placed on a branch or side arm of the transmission line, and resonance is indicated by a minimum deflection of a crystal-current meter or other indicator. The transmission-type wavemeter (*Fig. 3*) is inserted in the main transmission line, and resonance is indicated by a maximum reading of the indicator on the output side.

Accuracy

Accuracy of a wavemeter is determined by the loaded Q (Q_L), the accuracy to which the calibration scale may be read, and the effects of temperature and humidity.

Width of the selectivity characteristic of a cavity determines in part the accuracy to which the resonant frequency may be adjusted. Thus a cavity with a half-power bandwidth of 0.5 mc easily may be set to ±0.25 mc. If the resonant frequency were 3,000 mc, the corresponding loaded Q (Q_L) would be 6,000. Hence, the Q_L required for a wavemeter is determined by the accuracy limit imposed and the highest frequency in the tuning range.

Calibration scales of the micrometer type are convenient for tunable wavemeters. A fixed scale on the body of the cavity can be used with a movable scale on the drum to which the tuning screw and plunger are attached. A vernier scale may be necessary if extreme accuracy is desired. In any case, the significant divisions readable on the tuning scale should correspond to the number of figures to which the frequency must be read; i. e., the mechanical accuracy must equal (but need not exceed) the electrical accuracy of the wavemeter. The unit may then be calibrated, at a convenient temperature and relative humidity, against known frequency standards.

Temperature and humidity changes affect the absolute frequency calibration in two ways: (1) change in physical dimensions of the cavity due to thermal expansion of the metal; (2) change in the dielectric constant of air. The frequency change due to the change in cavity dimensions can be expressed as

$$\delta f \cong -f_0 a (t - t_0) \qquad (6)$$

where

δf = change in frequency } (same
f_0 = frequency at temperature t_0 } units)
a = thermal coefficient of expansion, change in length per unit length per °C.
$(t - t_0)$ = temperature change, °C.

For cavities of stainless steel and invar, respectively, the frequency change is −0.0012 and −0.00009% per °C. If the range of operating temperature will result in a prohibitive frequency error, then, a correction chart normalized at the calibration temperature must be prepared. A cavity may not, after undergoing temperature changes, assume exactly its original dimensions. To counteract such changes recalibration may be necessary.

Cavities can be protected from frequency changes due to the change in the dielectric constant of air with temperature and humidity. The resonator is evacuated, filled with dry nitrogen, and sealed. A desiccant (e.g., silica gel) may be used to insure nearly constant humidity conditions within the cavity. If unsealed cavities are used, corrections for dielectric constant changes may be presented in nomograph form, normalized at the calibration temperature and humidity.

Design Chart

For TM_{nml} modes the resonant wavelength of a cylindrical cavity resonator is given by

$$\lambda_0 = \frac{4}{\left[\left(\frac{2l}{L}\right)^2 + \left(\frac{4U_{nm}'}{\pi D}\right)^2\right]^{1/2}} \qquad (7)$$

where λ_0 = resonant wavelength, cm
l = number of half-cycle variations of electric field along cavity axis
L = length of cavity, cm
U_{nm}' = mth root of $J_n'(U') = 0$
D = diameter of cavity, cm.

For TE_{nml} modes the resonant wavelength is found by substituting U_{nm}, the mth root of $J_n(U) = 0$, for U_{nm}' in equation (7). Values of some of the lower roots are given in Table II.

A convenient form of equation (7) for plotting is

$$(f_0D)^2 = [0.91(U_{nm}')^2 + 2.25l^2(D/L)^2] \times 10^8 \qquad (8)$$

Fig. 4 is a plot of equation (8) for several low-order modes. From this chart one can determine the cavity diameter, plunger travel, and possible spurious modes for a given frequency tuning range. The starting point may be either a desired $(D/L)^2$ value or a value of $(fD)^2$ as determined by the required frequency and a convenient diameter. It will be observed that several undesired TE modes (viz., TE_{113}, TE_{212}, and TE_{311}) are likely when the TE_{011} mode is used in the vicinity of $(D/L)^2 = 1$. These undesired resonances occur at frequencies close to the dominant frequency, whereas, if the TE_{111} mode were used, the nearest spurious resonances (TE_{211} and TE_{112}) would only occur at frequencies greater than 1.4 times the dominant frequency. Thus the smaller diameter allowable with the TE_{111} mode acts to decrease possible unwanted modes for a given tuning range.

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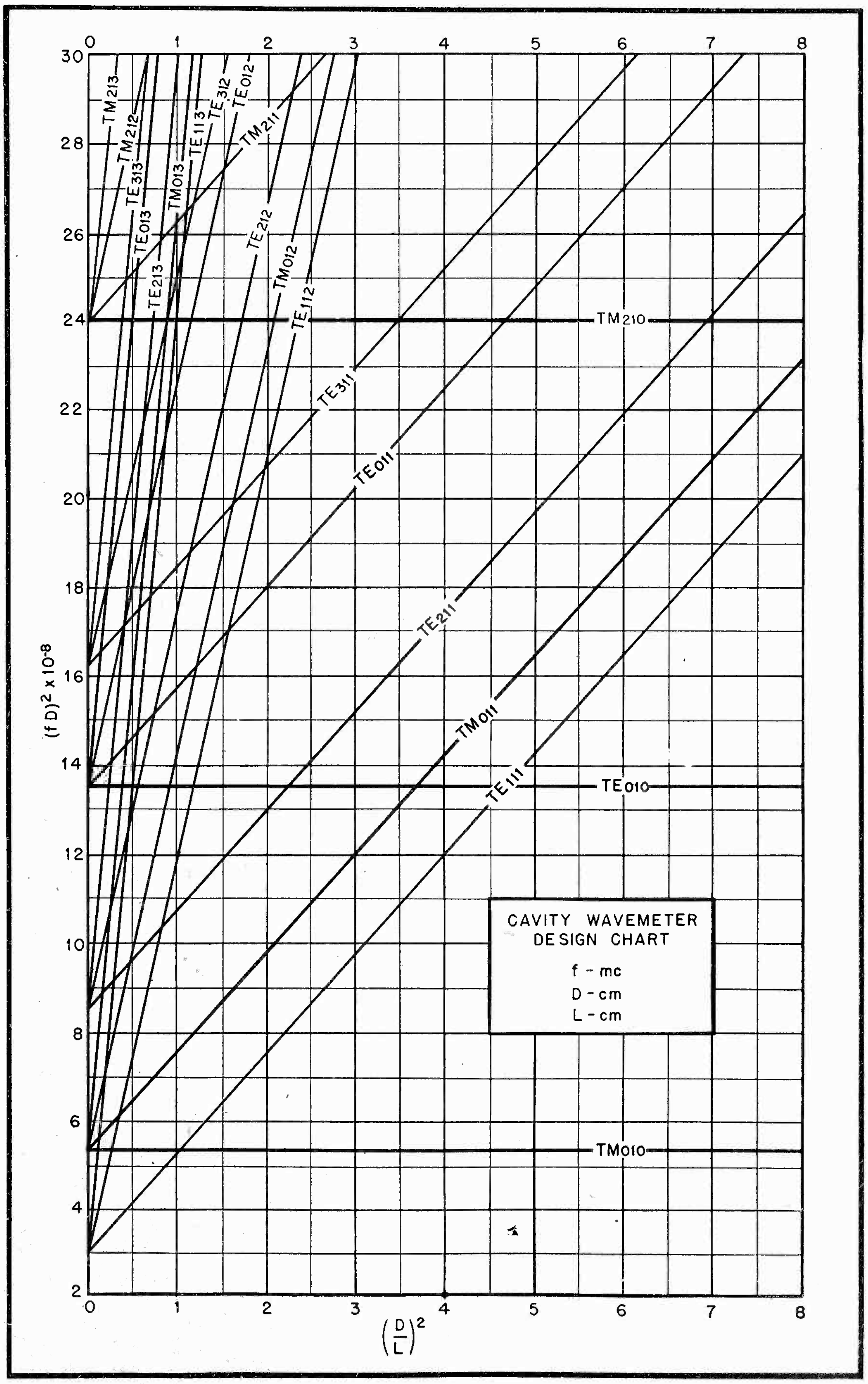


Fig. 4. Plot of (D/L)² as a function of (fD)² · 10⁻⁸ affords rapid solution of equation (8) for various low-order modes.

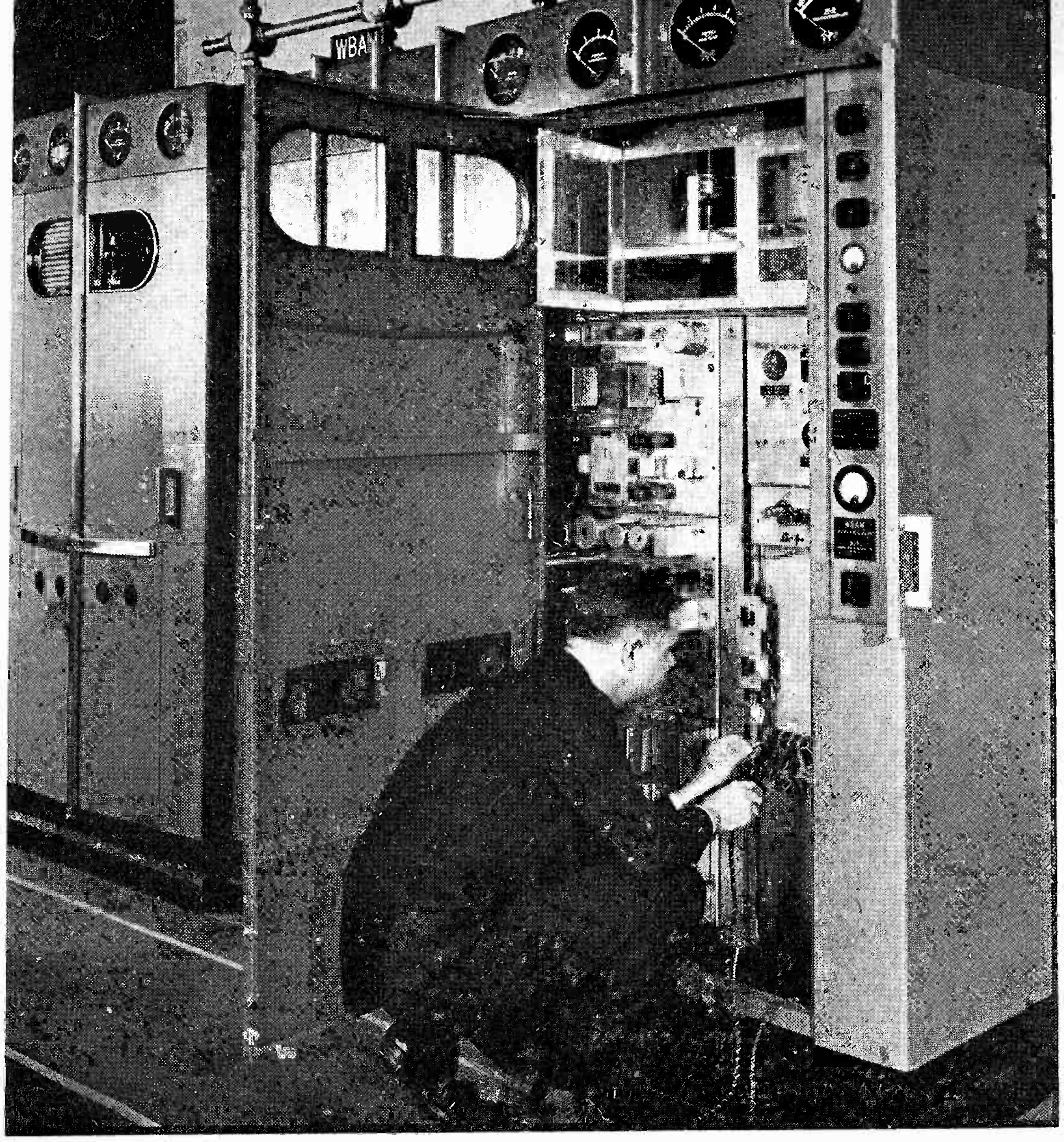


Fig. 2. Engineer completes conversion of Western Electric 10-kw FM transmitter to its new frequency assignment. An electro-mechanical center-frequency-control system is used.

PHILIP H. STEWART

FM Center Frequency Control

Circuits for center-frequency control of FM transmitters challenge the ingenuity of design engineers.

CIRCUITS FOR CENTER-FREQUENCY control of FM transmitters may be divided into two broad groups, depending on whether the carrier is generated by a crystal oscillator or by a self-excited oscillator. In the latter group, control is accomplished by either electro-mechanical or all-electronic sys-

PART 1

tems. The transmitter shown in *Fig. 1* typifies a commercial design utilizing all-electronic control; *Fig. 2* shows an installation using electro-mechanical control.

Self-excited oscillators are usually frequency-modulated by means of a reactance-tube network, although there are other applicable techniques to be discussed later. Crystal oscillators are frequency-modulated by mixing an amplitude-modulated wave with an unmodulated carrier that has been shifted

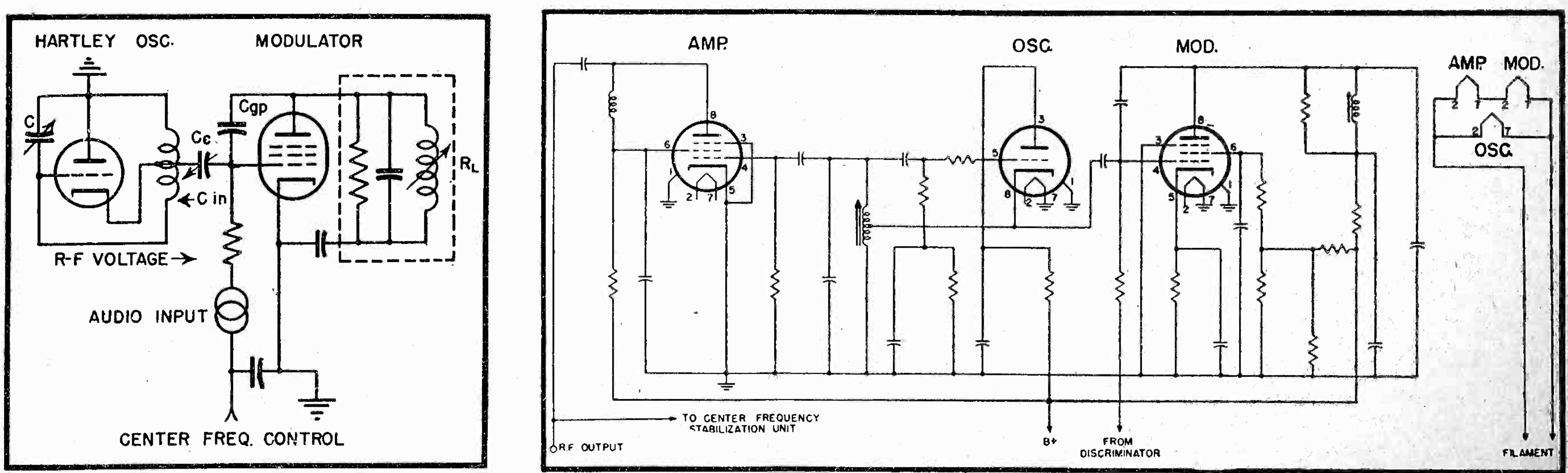


Fig. 3. (left) Simplified schematic diagram of Hartley oscillator modulated by varying input capacitance of modulator tube. Modulator is also a link in the c-f-c system. (right) More detailed circuit diagram of oscillator modulator system. (*Courtesy Federal Tel. & Radio Corp.*)

90° in phase. Upon mixing these two voltages, their vector sum undergoes a phase shift as the amplitude of the variable vector changes with impressed modulation. Since phase modulation and frequency modulation are but two aspects of the same basic principle, this phase variation may be developed into the form of a conventional FM wave by use of circuits which are familiar to workers in the field.

M-O Stabilization Systems

Center-frequency stabilization of master oscillators involves numerous factors, chief among which are the various electronic and electro-mechanical circuits used to correct the resonant frequency of the master oscillator circuit when drift occurs. Other factors include regulation of critical voltages, temperature compensation, and carefully considered mechanical design.

Miller Effect C.F.C. System

An oscillator which is frequency-modulated by the variable input capacitance of a modulator tube with a reactive plate load is shown in *Fig. 3*. This capacitive change, or Miller effect, is proportional to the total voltage on the modulator grid, which consists of the sum of the a-f input and the c-f-c voltages. This c-f-c voltage is obtained from a suitable phase detector. Thus, the modulator serves to convert the a-f voltage into corresponding frequency variations at the oscillator tank, while simultaneously maintaining the center frequency equal to that of a temperature-controlled precision crystal.

Frequencies of crystal and master oscillators are divided to a common frequency as indicated in *Fig. 4* to reduce the deviation for proper operation of the phase detector. These two voltages are combined in the balanced phase-detector circuit shown in *Fig. 5*, and the integrated rectified output is utilized to bias the modulator so that the mean frequency of the master oscillator may be pulled in and locked with that of the crystal.

Frequency division takes place with the aid of multivibrators, which reduce the original 3.7-4.5 mc carrier frequency by a factor of 1/256 to 14.3-17.6 kc. Likewise, the crystal frequency of 114.5-140.7 kc is divided by 8 to the common 14.3-17.6 kc value.

Phase Detector

Input-output voltage relations of the phase detector circuit, and its response characteristic are shown in *Fig. 5*. When the modulated r.f. and crystal frequencies are synchronized, output from the balanced phase detector will depend on the phase-angle difference of the two frequencies. Drift in the master oscillator frequency results in a corresponding

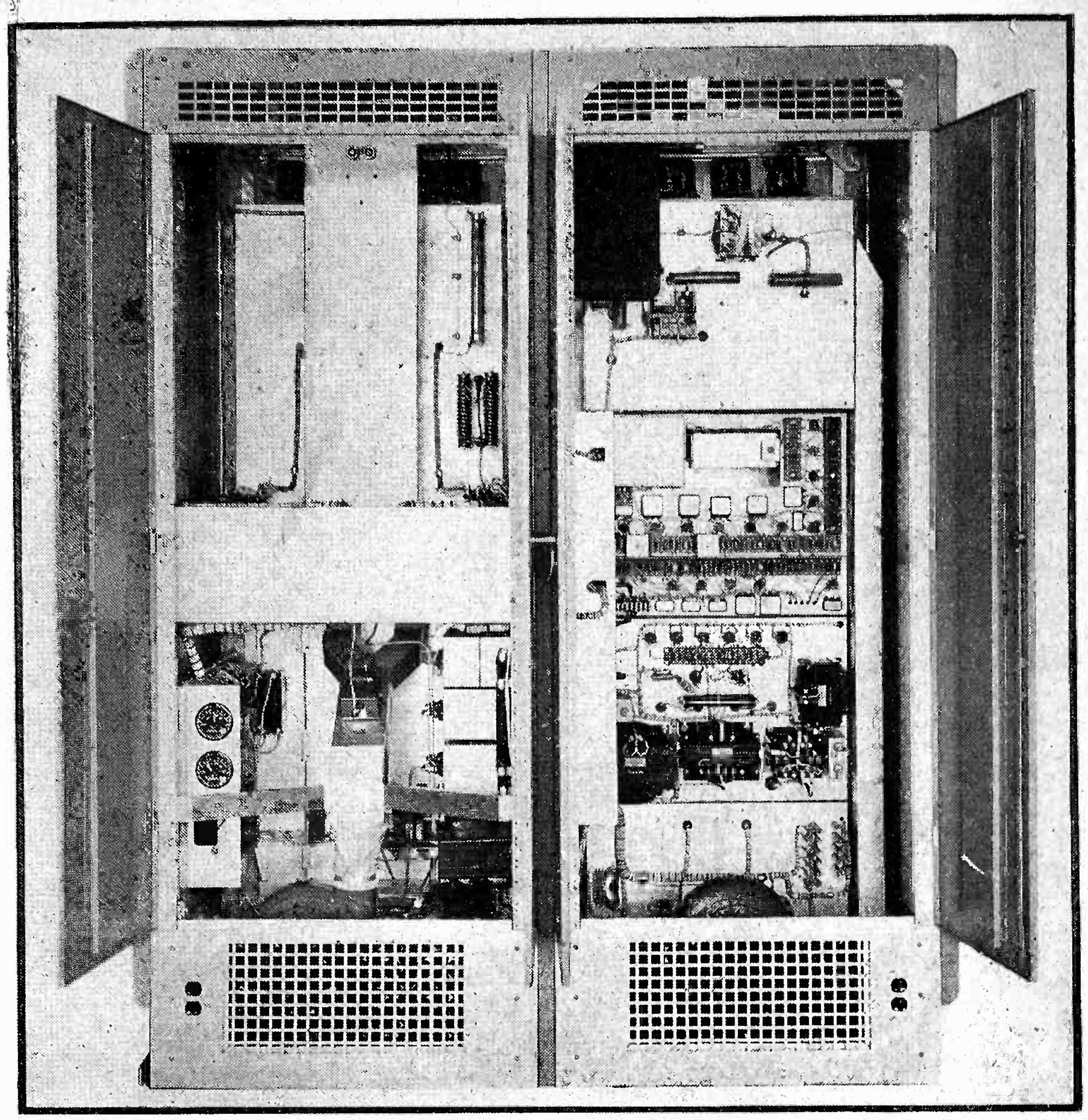
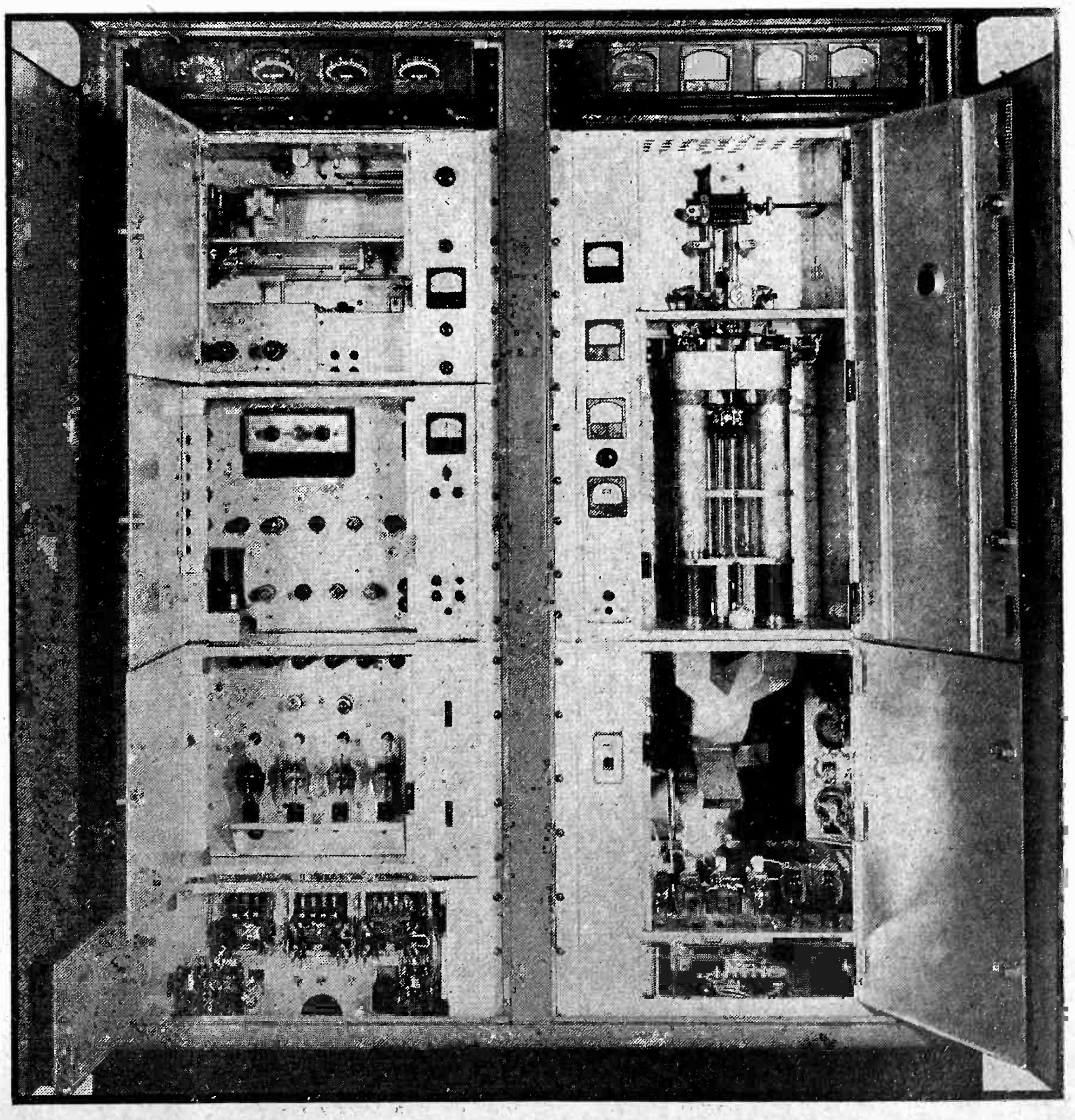


Fig. 1. Front and rear views of Federal T. & R. FM broadcast transmitter, which uses Miller effect center-frequency control.



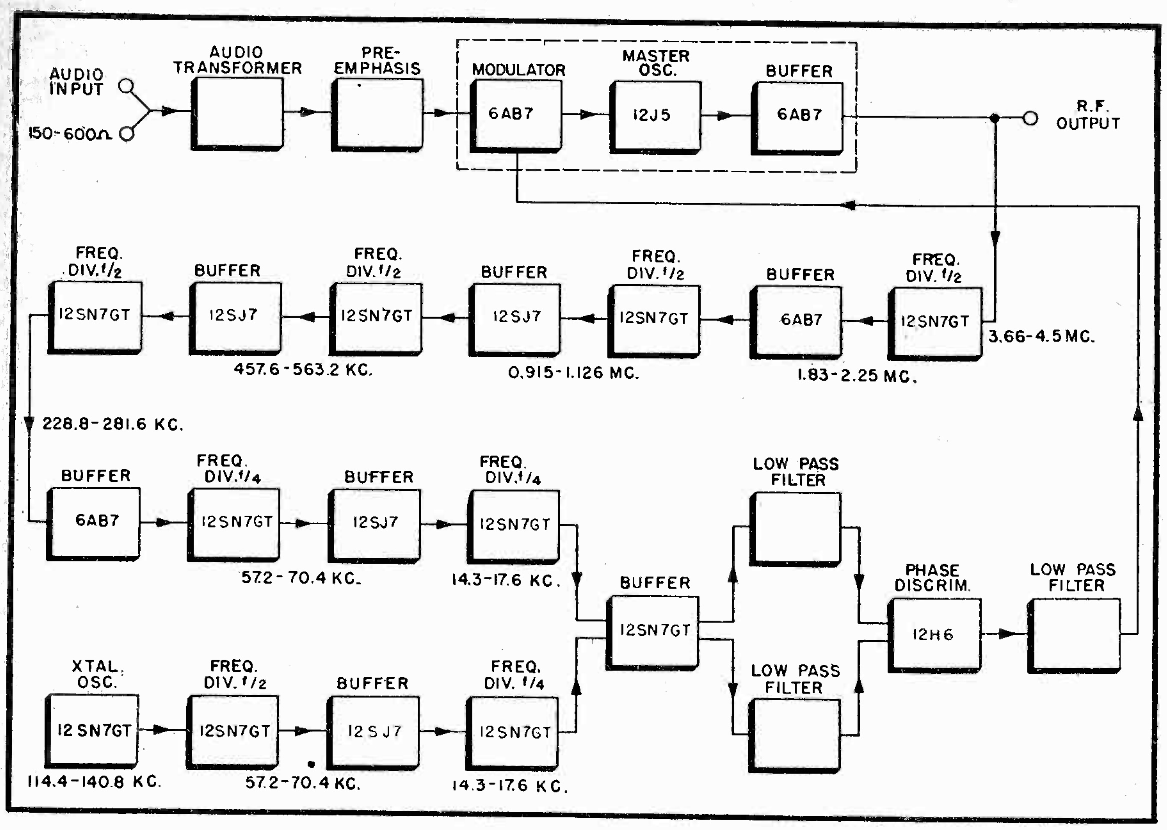


Fig. 4. (above) Detailed block diagram showing frequency intervals of c-f-c and modulator unit. **Fig. 6a.** (below) Basic block diagram of Western Electric electro-mechanical c-f-c system.

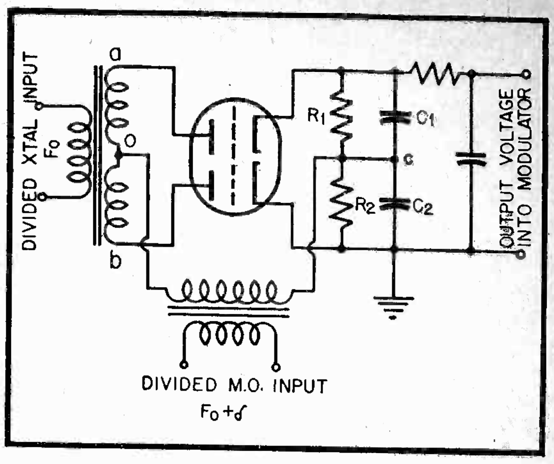
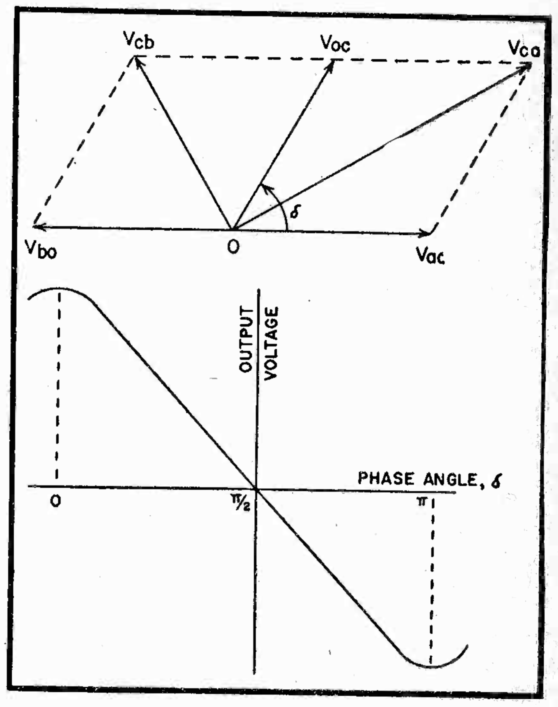
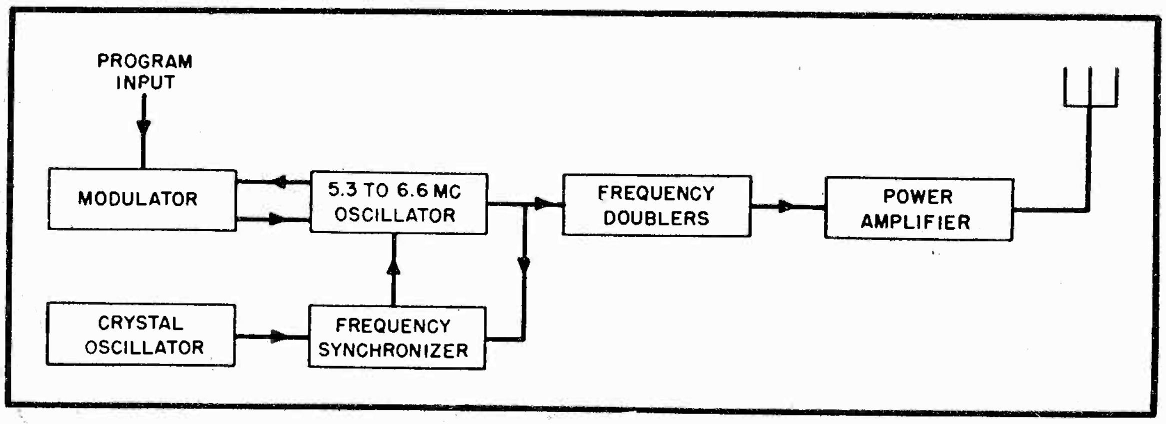
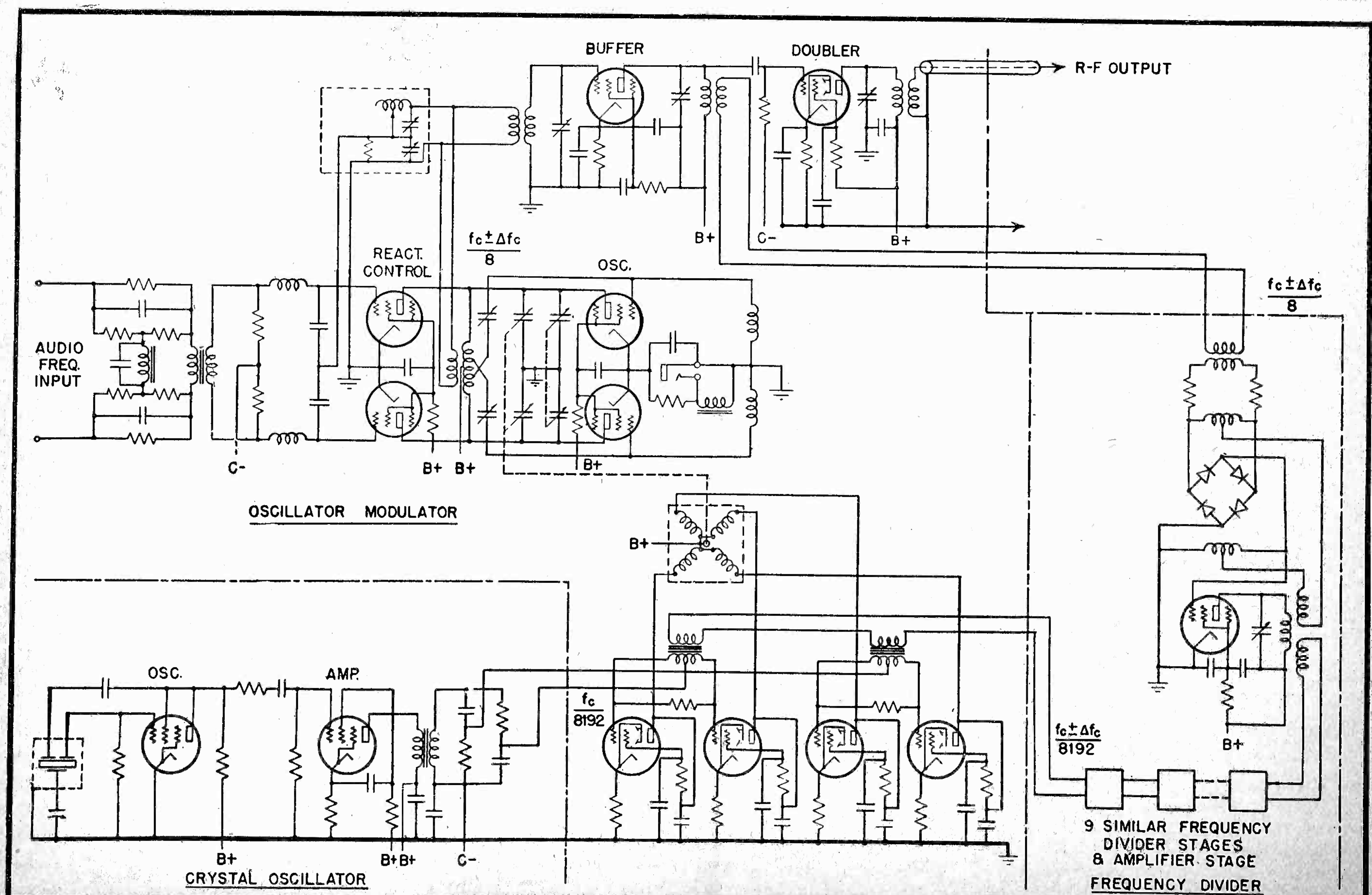


Fig. 5. (above) Basic circuit of balanced phase detector. (below) Vector diagram of phase detector and response characteristic of the phase detector.







phase-angle change, causing a proportional variation in the rectified output of the phase detector. This voltage variation is applied to the modulator grid, changing its input capacitance.

When the two impressed frequencies are not the same, the detector output is the heterodyne difference between the frequencies. This heterodyne frequency, impressed upon the modulator grid, causes the carrier frequency of the m. o. to swing at the heterodyne rate with a deviation which is proportional to the amplitude of the heterodyne voltage. In the event that the deviation is made sufficiently great, and the beat frequency sufficiently small, the modulated oscillator and crystal frequencies lock. Thereafter, control conditions described in the foregoing paragraph come into operation.

As noted above, it is necessary to divide the modulator and radio frequencies for control purposes, because under modulation conditions the carrier vector is deviated through a large angle as well as varied in amplitude, which causes the vector sum of the two voltages to pass through numerous states of zero amplitude. However, after frequency division, the deviation is reduced correspondingly, and the small terminal deviation angle makes possible a resultant vector which varies but slightly in amplitude during modulation.

In this particular case there is a maximum swing of 3 kc about an oscillator center frequency of 4 mc. By dividing 256 times, the maximum swing is reduced to 12 cps. With respect to an a.f. of 30 cps, the maximum deviation becomes 24°, reducing the carrier to only 0.96 of its unmodulated amplitude.

Physically, the action of the phase detector may be compared with that of two peak-reading diode-detector circuits, the outputs of which are combined in opposing polarity. V_{ca} is the peak voltage of the upper diode, and V_{cb} is the peak voltage of the lower diode. Time constants of the output network R_1C_1 and R_2C_2 are adjusted to a value which avoids any appreciable delay during the non-conduction periods of the diode.

Assuming a 90° phase difference between the two identical frequencies, V_{ca} and V_{cb} become equal, with the result that the output voltage is zero; this is the normal operating condition. Should the m.o. drift slowly, the corresponding phase shift will be in a direction to cause a correction voltage to appear at the modulator grid. Operation may evidently be had on any portion of the phase detector characteristic.

Fig. 7. (left) Simplified schematic diagram of Western Electric electro-mechanical c-f-c system.

Electro-Mechanical System

A block diagram of the transmitter illustrated in *Fig. 2* is shown in *Fig. 6*. In this c-f-c system, a two-phase synchronous motor is used to turn the oscillator tuning capacitor in a direction to correct drift in the oscillator center frequency. To reduce the phase shift resulting from frequency modulation and thereby develop a suitable control voltage, a sample of the oscillator frequency is divided a number of times to make this shift less than one radian.

A pair of control voltages is also obtained from a precision crystal oscillator as shown in *Fig. 7*. These two voltages from the crystal are developed in phase quadrature through the r-c bridge, and are applied to the grids of a pair of balanced modulator mixers. The outputs from the balanced modulators, being two-phase, can operate the two-phase synchronous motor.

The frequency of the balanced modulator outputs is the difference between the two impressed frequencies, and the sense of rotation of the two vector voltages depends on whether center frequency is higher or lower than the crystal reference frequency. The direction of rotation of the reluctance-type motor shown in *Fig. 8* is such as to reduce the beat frequency, rotation continuing until the beat frequency is brought to zero. At this point the voltage derived from the crystal through

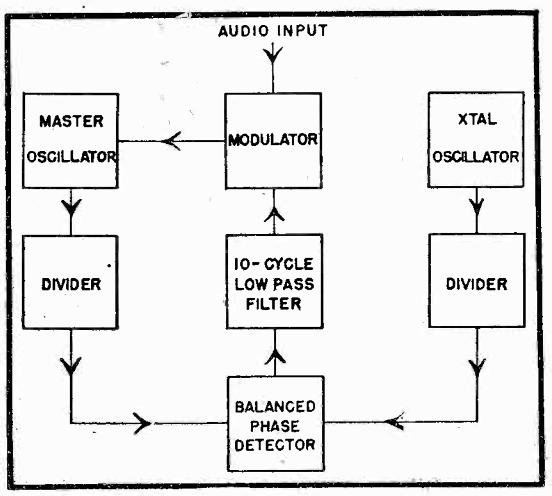
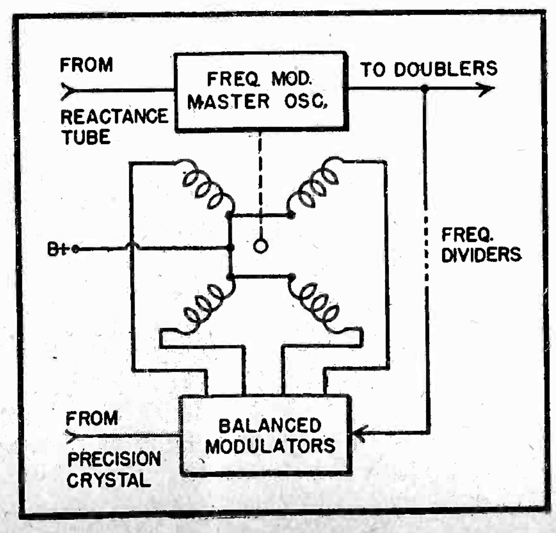


Fig. 4a. (above) Basic block diagram of Federal Tel. and Radio Corp. c-f-c system, using circuit of Fig. 3. Fig. 6b. (below) Block diagram of frequency synchronizer circuit.



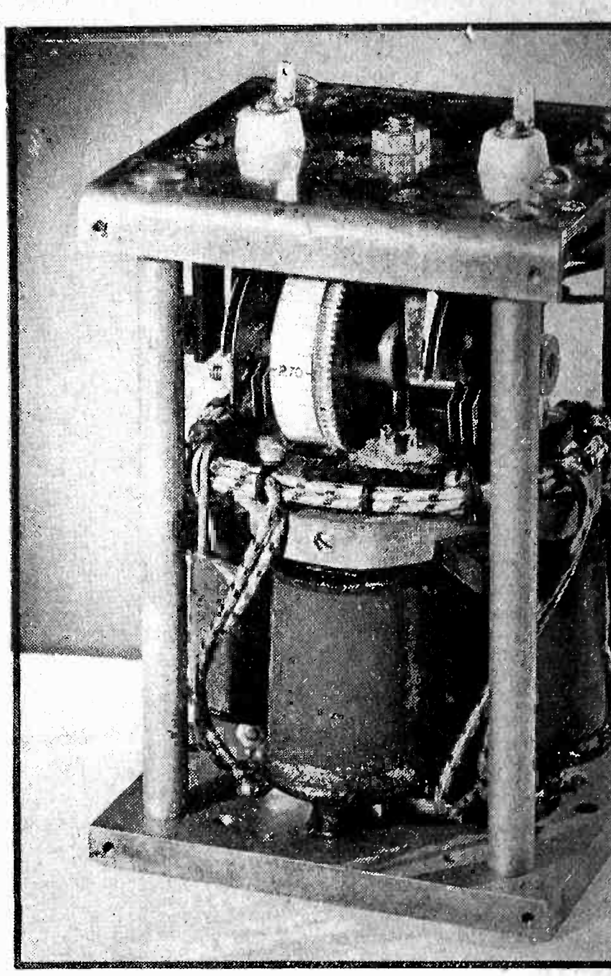


Fig. 8. View of reluctance-type two-phase synchronous motor for center-frequency control system.

the balanced modulator is no longer present in the modulator output, being suppressed for lack of a beating frequency in the symmetrical modulator circuit. Voltage derived from the divided center frequency no longer appears at the modulator output because the modulator grids are driven in opposite polarity with the result that this voltage cancels in the output for lack of a beating frequency.

The motor voltage accordingly drops to zero when the two impressed frequencies are identical, and no further rotation can take place until a drift occurs in the m-o center frequency. It will be observed that the balanced modulator tubes must operate on a non-linear portion of their characteristics to obtain the desired motor driving voltage. Rotation of the motor is dependent, as will be apparent, upon a phase difference between the two impressed voltages rather than upon their exact magnitudes. It is only necessary to have a sufficiently large voltage available to overcome bearing friction and to provide a working torque to the mechanical link of the system.

The motor armature turns in jewelled bearings, and transmits its motion to the miniature tank circuit through a precision worm drive. The system sensitivity is sufficient to maintain the mid-frequency constant within ±1250 cps of its assigned value under all operating conditions. This is well below the ±2000 cps specified by the FCC for FM transmission.

[*To Be Continued*]

Three-Point Tracking Method

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Washington University

Simplified formulas for tracking slug or capacitor-tuned superhets are presented

In a previous article,[1] following the general method of Roder[2] but substituting for his geometric solution a purely algebraic one, the author has developed a theory of three-point tracking for the case of permeability-tuned systems. The same general method can be applied, with proper changes, to capacitor-tuned systems. Analysis of the resulting equations reveals that for a given set of crossover and intermediate frequencies, formulas giving the required circuit constants to make the system "track" at three points are rather simple.

The corresponding formulas for the widely used crossover frequencies of 600, 1000, and 1500 kc and an i-f frequency of 455 kc, for both permeability-tuned and capacitor-tuned systems, are given herein.

It is understood that all capacities are expressed in micromicrofarads, all inductances in microhenries, and all frequencies in megacycles.

I. Permeability Tuned System of Figure 1.

$$\Delta L = L_{max} - L_{min} \quad (1)$$

$$C_{RF} = \frac{25330}{\Delta L}\left(\frac{1}{F^2_{min}} - \frac{1}{F^2_{max}}\right) \quad (2)$$

$$C_{osc} = 0.57222\, C_{RF} \quad (3)$$

$$L_S = \frac{2070.7}{C_{RF}} \quad (4)$$

$$L_P = \frac{88134}{C_{RF}} \quad (5)$$

II. Permeability Tuned System of Figure 2.

(1) and (2) as for Case I

$$C_{osc} = 0.54624\, C_{RF} \quad (6)$$

$$L_S = \frac{2119.4}{C_{RF}} \quad (7)$$

$$L_P = \frac{90205}{C_{RF}} \quad (8)$$

III. Capacitor Tuned System of Figure 3.

$$\Delta C = C_{max} - C_{min} \quad (9)$$

$$L_{RF} = \frac{25330}{\Delta C}\left(\frac{1}{F^2_{min}} - \frac{1}{F^2_{max}}\right) \quad (10)$$

$$L_{osc} = 0.57222\, L_{RF} \quad (11)$$

$$C_T = \frac{2070.7}{L_{RF}} \quad (12)$$

$$C_P = \frac{88134}{L_{RF}} \quad (13)$$

IV. Capacitor Tuned System of Figure 4.

(9) and (10) as for Case III

$$L_{osc} = \frac{5044.9}{(C_P + C_D)} \quad (14)$$

$$C_T = \frac{2070.7}{L_{RF}} - \frac{C_P C_D}{C_P + C_D} \quad (15)$$

$$C_P = \frac{44065}{L_{RF}}\left[1 + \sqrt{1 + \frac{C_D L_{RF}}{22033}}\right] \quad (16)$$

Example of the Application Of the Formulas

Let it be required to determine the circuit constants needed to track a permeability-tuned system connected as in *Fig. 1*, given that the system is to cover a range from 535 to 1725 kc and that the r-f coil covers a range from 106.4 to 1106 microhenries. Formulas (1) to (5) yield:

$$\Delta L = 1106 - 106.4 = 999.6\ \mu h \quad (17)$$

$$C_{RF} = \frac{25330}{999.6}\left(\frac{1}{0.535^2} - \frac{1}{1.725^2}\right) = 80.00 \quad (18)$$

$$C_{osc} = 0.57222 \times 80.00 = 45.78\ \mu\mu f \quad (19)$$

$$L_S = \frac{2070.7}{80.00} = 25.88\ \mu h \quad (20)$$

$$L_P = \frac{88134}{80.00} = 1102\ \mu h \quad (21)$$

Alignment of the R.F. and Oscillator Stages

Besides enabling a calculation of the circuit constants required for tracking, the equations given also prescribe the pattern to be followed in aligning the r-f and oscillator stages. For example, in the case of the permeability tuned system, the r-f condenser should be aligned at one end (preferably the high end) of the band, the other three components should be aligned at the crossover frequencies, and, preferably, as follows: trimmer coil at 1500 kc, padder coil at 600 kc, and the oscillator condenser at 1000 kc.

References:

[1]A. W. Simon—*Electronics*—Vol. 19, p. 138, Sept. 1946
[2]H. Roder—*Radio Engineering*—Vol. 15, p. 7, Mar. 1935

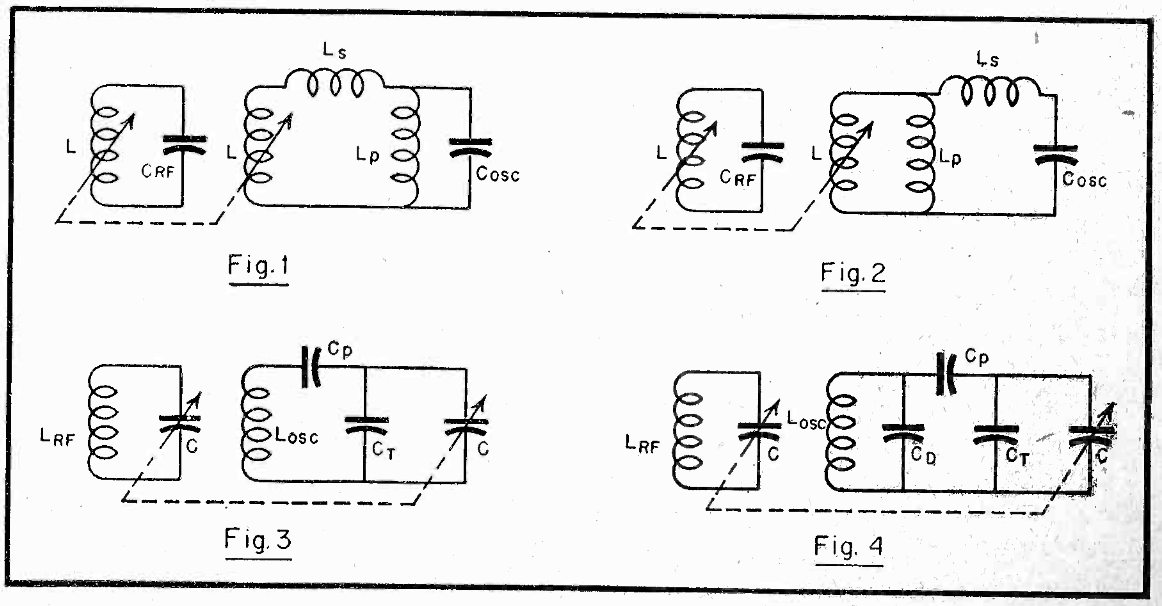


Fig. 1. Permeability-tuned system to be tracked over the 535-1725 kc range. Inductance of r-f coil varies from 106.4 to 1106 μh. Fig. 2. Rearranged slug-tuned circuit, for which tracking formulas are given in text. Fig. 3. Capacitor-tuned system, equivalent to circuit of Fig. 1 from standpoint of formula coefficients. Fig. 4. Rearranged capacitor-tuned circuit, requiring modified tracking formula.

RECENT RADIO INVENTIONS

These analyses of new patents in the radio and electronic fields describe the features of each idea and, where possible, show how they represent improvements over previous methods

Sound and Voice on Single T-V Carrier

★ Time modulation of sound pulses transmitted during blanking intervals is the basis of a patent on a new television system, granted to Norman H. Young, Jr., June 4, 1946. The sound pulses are time-modulated with respect to the horizontal synchronizing pulses.

General operation of the system is shown in the block diagram of *Fig. 1*, while the production of blanking, synch, and sound pulses is indicated in *Fig. 2*. A suitable circuit for the time modulator is seen in *Fig. 3* with the resulting composite television signal illustrated in *Fig. 4*. Referring to *Fig. 1*, the base reference frequency is designated as a stable sine-wave oscillator, the output of which is represented as the base wave *a*, in *Fig. 2*. This frequency is termed *2f*. It controls the production of horizontal, vertical, and equalizing synch signals, blanking pulses for the horizontal retrace intervals, blanking pulses for the frame retrace intervals, and the sound signals.

The vertical and equalizing synch-pulse producer in *Fig. 1* is of conventional design. Horizontal synch and blanking pulses are produced by applying the oscillator output to a multivibrator, which is proportioned to operate in one mode correspondingly to a given point of the oscillator wave. This mode continues for substantially two cycles of the oscillator wave until the grid bias of one of the multivibrator tubes decreases to a point which causes the mode to change. This mode change defines the trailing edge of the waveform shown at *b* in *Fig. 2*, conditioning the circuit for triggering into a new period of operation which starts with the leading next following. This leading edge is associated with a given value of the oscillator wave, *a*.

This multivibrator output energizes a horizontal synch pulse shaper, indicated in *Fig. 1*. The shaper includes the usual differentiators and clippers in addition to a multivibrator (if desired) to produce horizontal blanking pulses. The oscillator wave *a* in *Fig. 2* is also used for controlling the timing of sound sig-

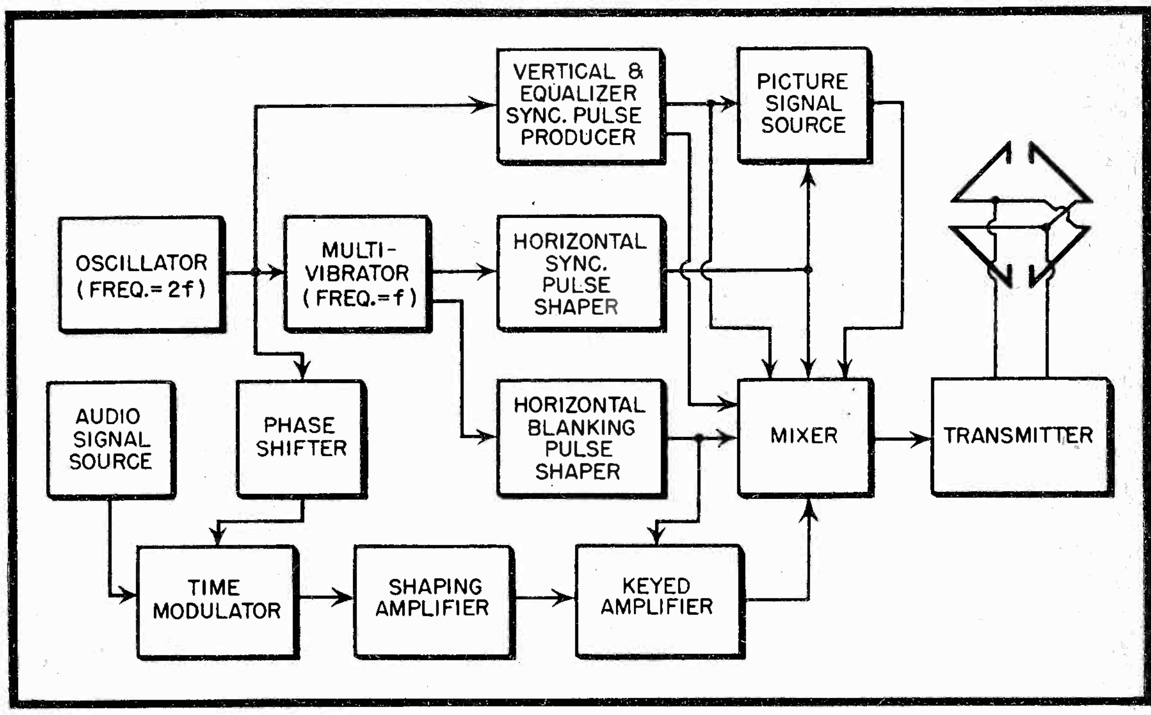


Figure 1, Patent No. 2,401,384

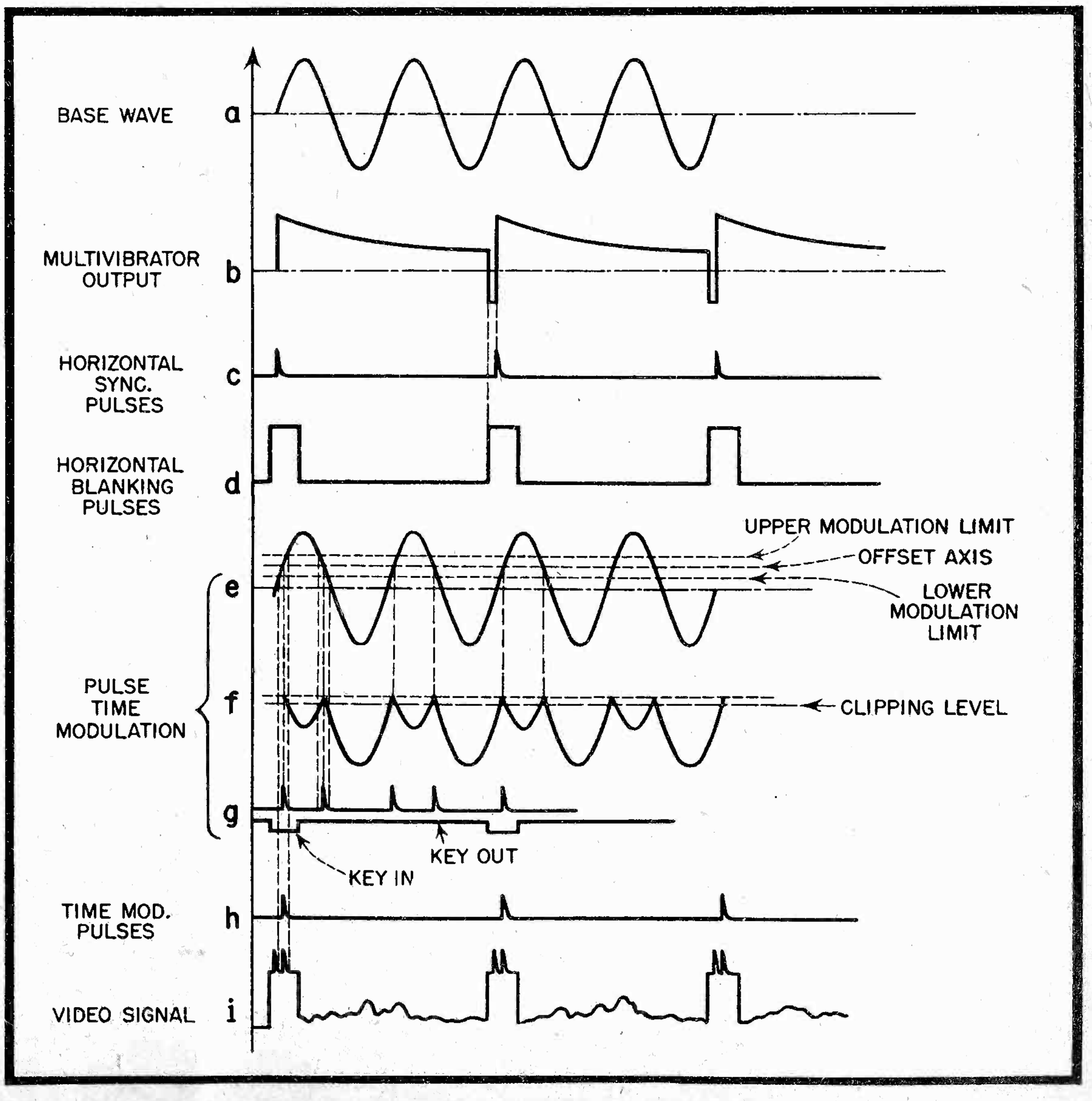


Figure 2, Patent No. 2,401,384

nals by means of the phase shifter shown in *Fig. 1* to obtain the proper phase relation at the time modulator. The time modulator is conventional and displaces the pulses in time according to the instantaneous value of an audio signal obtained from a source as indicated.

One form of time modulator is illustrated in *Fig. 3*, of the "cusper" type. In this modulator, push-pull operation is utilized. It consists of a transformer energized by the oscillator frequency, *2f*, as well as by the audio signals. The output of the time modulator is applied to the shaping amplifier. Referring to graphs *e*, *f*, and *g* of *Fig. 2*, the base wave is shown at *e*, and is the wave energizing the transformer primary. Biases on the grids of the time modulators are chosen to effect an offset relation between the base wave and the tube grids. Push-pull operation of the tubes effectively rectifies the base wave about an offset axis shown at *e*, to produce a cusp wave as shown at *f*.

The shaping amplifier of *Fig. 1* clips the cusps at the level indicated at *f*, and thereby produces a series of narrow-width pulses as indicated at *g*. Modulation of these pulses is effected by the audio voltage applied to the transformer in *Fig. 3*. This audio voltage varies the offset relationship of the base wave with respect to the offset axis (*Fig. 2*); limits of modulation swings are likewise indicated. For upward modulation, displacement of the first pulse is to the right, while displacement of the second pulse is to the left. For downward modulation, displacements are reversed.

In this system, every fourth pulse is utilized for conveying the audio signals. The surplus arises from a choice of high frequency for the base wave; the undesired pulses are suppressed in the keyed amplifier shown in *Fig. 1*, with the corresponding waveforms at *g* in *Fig. 2*. The resulting output is then as shown at *h*.

The picture signal source shown in *Fig. 1* is conventional, and the scanner is synchronized by the vertical and horizontal synch pulses from the vertical-and-equalizer producer and horizontal shaper. The output of the picture signal source is applied together with the horizontal synch pulses from the shaper, vertical and equalizing synch pulses, frame retrace blanking pulses, horizontal blanking pulses from the shaper, and the time-modulated output

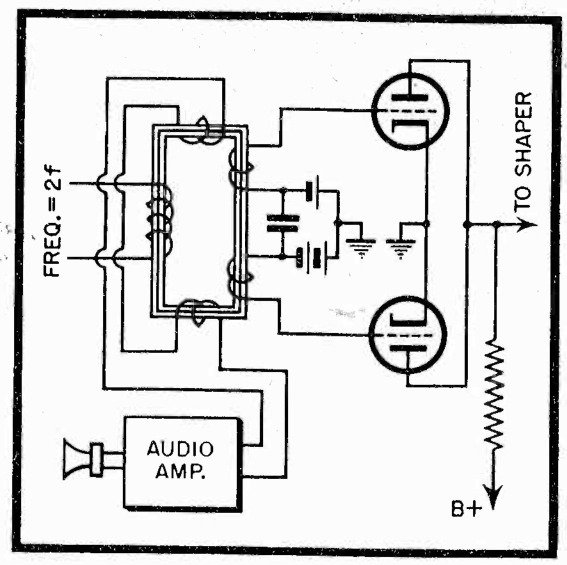


Figure 3, Patent No. 2,401,384

pulses, to the mixer as shown in *Fig. 1*. While the mixer may comprise more than one stage, a single block is indicated for simplicity. If desired, the mixer may be biased to provide threshold clipping for removal of the unwanted time-modulated pulses of graph *g*, thereby replacing the keyed amplifier.

The composite video signal from the mixer, as shown in graph *i* of *Fig. 2*, is applied to a conventional transmitter. The horizontal blanking pulses have superimposed on them two narrow width pulses, the first of which is a horizontal synch pulse from *c*, and the second of which is a time-modulated pulse from *g*. It is noted that the synch pulses occur shortly after the leading edge of the blanking pulse, and maintain a fixed relationship thereto. The time-modulated pulses, however, vary in time displacement relative to the horizontal synch pulses.

The receiver used in conjunction with this system is described in a copending application No. 539,882. It includes a clipper circuit for removing the horizontal and time-modulated pulses from the video signal; the horizontal synch pulses are used to synchronize a sawtooth generator, which controls line scanning as well as translating the time-modulated pulses into amplitude-modulated pulses. The latter energize a low-pass filter and finally a loud-speaker.

A composite video wave is shown in *Fig. 4* which includes the various signal components. The portion of the wave in graph *i* is shown to the left in *Fig. 4*. During the frame retracing interval, the horizontal and time-modulated pulses are shown extending above the blanking level with the equalizing pulses and vertical synch pulses. Equalizing pulses are preferably wider than the horizontal pulses, with vertical synch pulses of still greater width, for width selection.

The patent, No. 2,401,384, is assigned to Federal Tel. & Radio Corp.

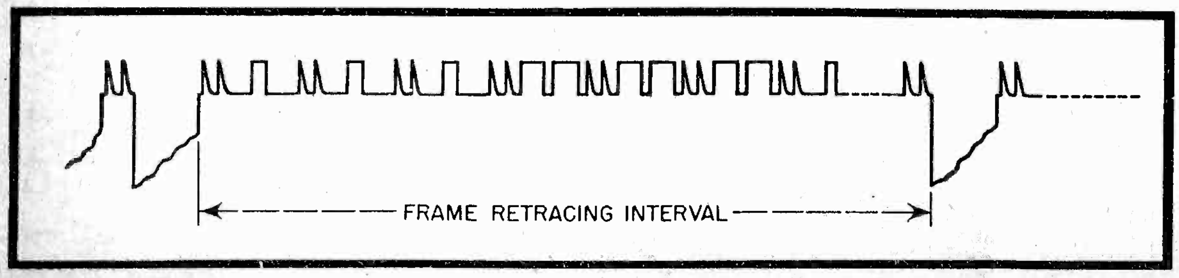
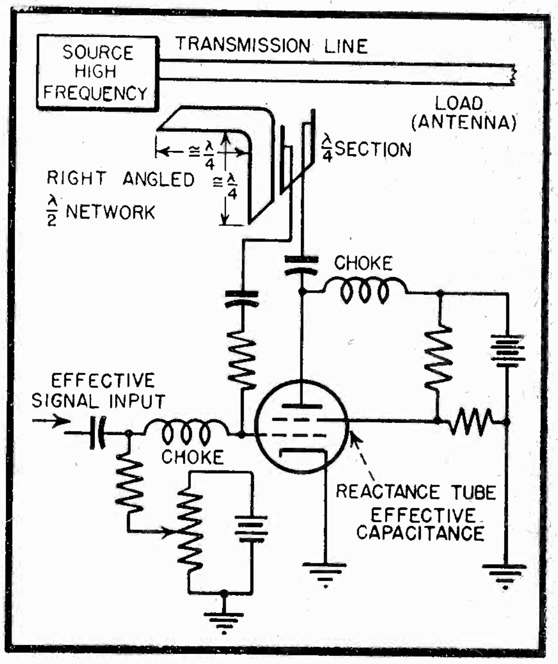


Figure 4, Patent No. 2,401,384

Reactance-Tube Switch For U-H-F Line

★ Control of high-frequency energy in a transmission line by means of small voltages applied to a reactance tube forms the basis of patent 2,401,353, issued June 4, 1946 to R. B. Hoffman. In this system a right-angled half-wave section shorted at either is coupled as shown to both the controlled line and



Patent No. 2,401,353

to a reactance tube. Variations of voltage on the grid of the reactance tube reflect corresponding impedance components into the right-angled half-wave section; accordingly the resonant frequency of this section is varied. At resonance, high voltages are built up at the right angle, causing an effective open circuit to appear in the transmission line.

The load is usually an antenna, as indicated, and the source of high frequency is a transmitter. The right-angled half-wave network consists of two quarter-wave sections which may be caused to resonate with the frequency of operation of the transmission line. One of these quarter-wave sections is mounted parallel to and is thereby coupled to the transmission line, while the other quarter-wave section is coupled to the reactance-tube section. The reactance-tube section is less than a quarter wavelength, but may be brought into resonance by applying a voltage to the grid of the reactance tube to effectively increase the shunt capacitance.

With no exciting signal applied to the reactance tube, its associated line section does not resonate with the right-angled network. The right-angled network, however, resonates with the fre-

[*Continued on page* 30]

RADIO DESIGN WORKSHEET

NO. 54 — NARROW BAND FM

● Narrow-band FM is used to a considerable extent in specialized services such as frequency-shift keying systems. It is a frequency-modulated wave with sidebands no greater than those present when the same signal frequencies are used to amplitude-modulate the same carrier frequency.

In AM, a pair of sidebands appears when a signal frequency f_s modulates the carrier f_c, and these sideband frequencies are f_c+f_s and f_c-f_s. The carrier remains constant at all times; FM, however, produces an infinite array of sideband frequencies $f_c \pm f_s$, $f_c \pm 2f_s$, $f_c \pm 3f_s$, etc. Not all these sidebands must be transmitted for satisfactory fidelity. In fact, all but the first pair of sidebands are rejected in narrow-band FM.

FM is measured in terms of the *modulation index,* which is defined as the ratio of the carrier-frequency deviation to the signal frequency. Furthermore, in contrast to AM, the carrier varies in magnitude during modulation, as may be seen from *Fig. 1.*

Higher frequency sidebands become greater in magnitude as the modulation index increases. The modulation index increases with decreasing signal frequency, but although higher frequency sidebands must now be taken into account, the decreasing signal frequency causes these higher sidebands to move in closer to the carrier f_c, so that the channel requirement for transmission is in general determined by the highest modulating frequency. This may be found from *Fig. 1.*

In the following example, sidebands of magnitude less than 5% as compared with the unmodulated carrier magnitude will be rejected as negligible. Let it be desired to transmit a band of audio frequencies from 150 to 5000 cps by narrow-band FM; it is next required to determine the maximum allowable deviation. At 5000 cps all sidebands are farthest from the carrier; that is, the first-order sidebands are 5000 cps out, second-order 10,000 cps, etc.

By definition of narrow-band FM, therefore, only first-order sidebands can be tolerated for the maximum modulating frequency of 5000 cps. This limits the modulation index to 0.6, which corresponds to a maximum deviation of 3000 cps. Next, the sidebands for modulation frequencies of 500 cps and 150 cps will be determined.

At 500 cps, the modulation index increases to 6 (which does not appear on *Fig. 1*). By reference to a table of Bessel functions, it is found that for a modulation index of 6, the ninth-order sideband is greater than 5% and must be transmitted. But this ninth sideband is 4500 cps out from the carrier, instead of 5000 cps. The channel requirement is accordingly reduced by 500 cps.

At 150 cps, the modulation index is 20, which again does not appear in *Fig. 1,* as the chart is intended only for deviation determinations. Reference to a table of Bessel functions shows that at a modulating frequency of 150 cps the 24th sideband must be transmitted. This 24th sideband is 3600 cps out from the carrier, showing that the lower modulating frequency in turn imposes a lesser channel requirement.

To determine, therefore, the allowable deviation in a narrow-band FM system, the highest modulating frequency is used as a basis of computation. From the curves of *Fig. 1* the magnitudes of the various sidebands may be seen for a given modulation index. It is required, of course, that the first-order sideband shall not be greater than the rejection value selected, which fixes the modulation index. The maximum deviation then follows from consideration of the highest modulation frequency used.

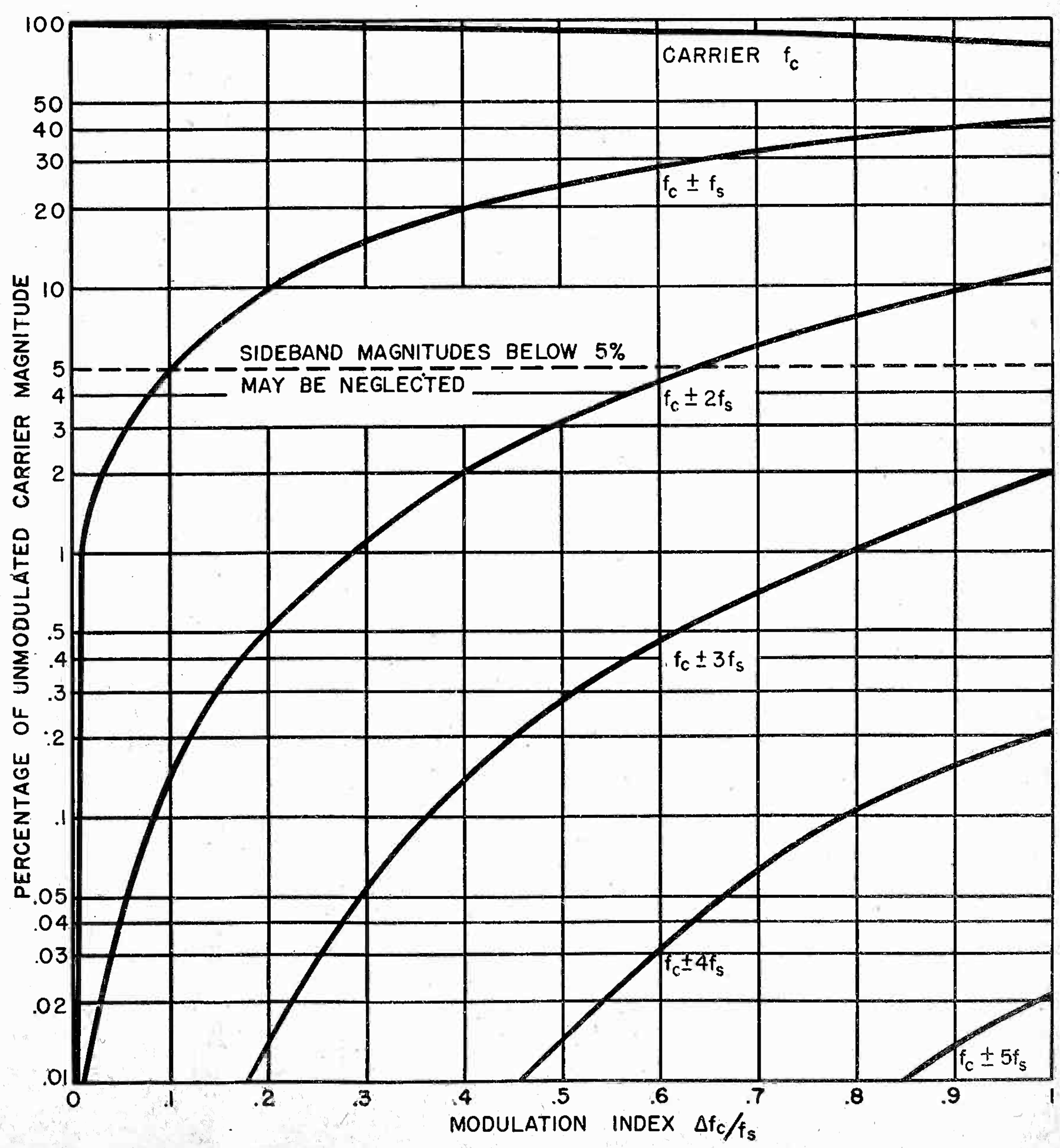
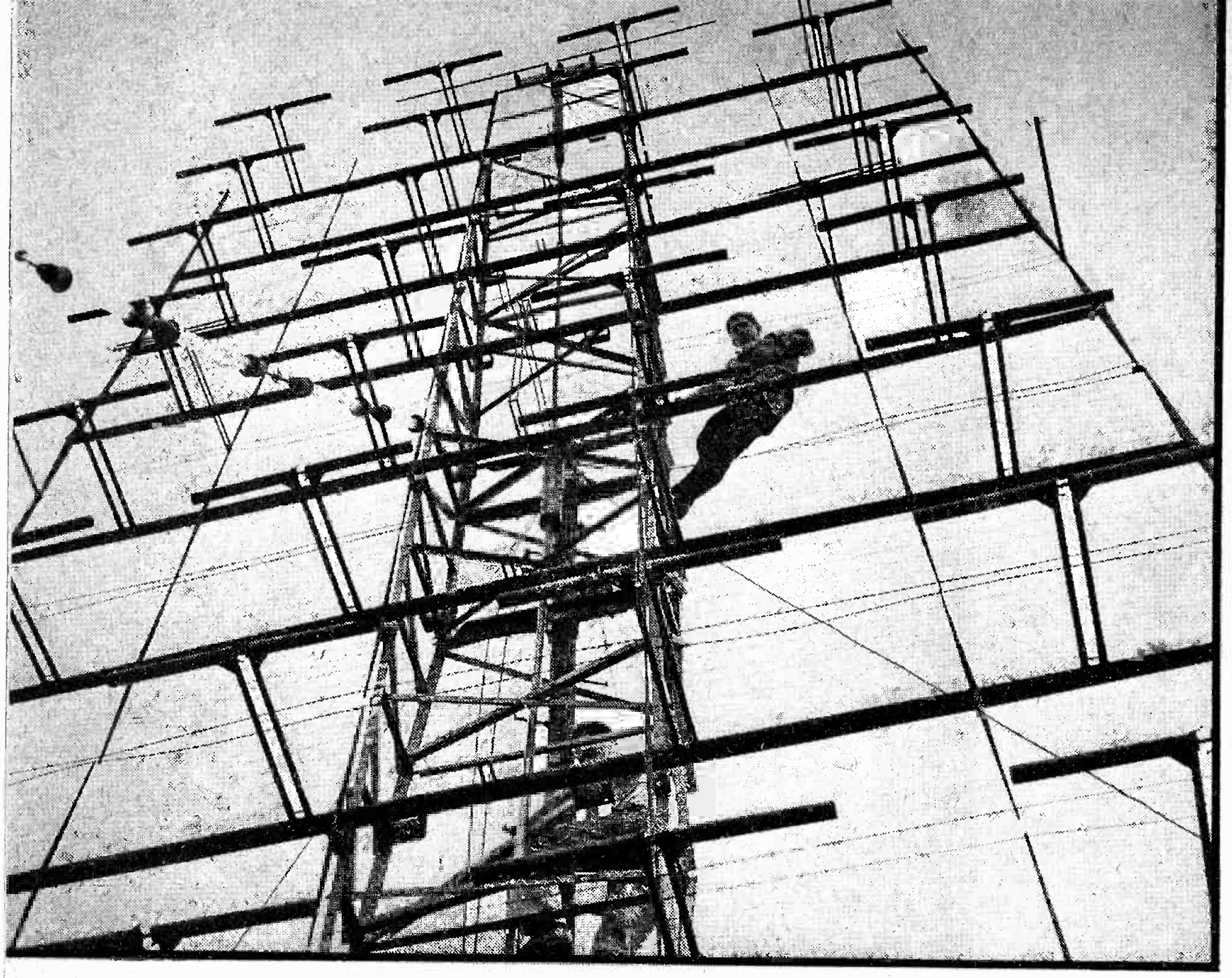


Figure 1



This Month

Transmitting over the old and new FM bands (47.1 and 106.5 mc), WOR's new antenna has a power gain of 60 and is a new addition to the N. Y. sky line at 444 Madison Ave.

TELERAN

The formation of a large engineering group to develop Teleran, a new air navigation system which combines television with radar, has been announced by RCA.

In this system, aircraft position information is presented to ground observers and controllers on a series of plan-position indicators. One indicator is used for each altitude layer, and is superimposed on a map of the region covered by the ground radar; this, together with weather, traffic control, and other desired information, is transmitted by television to each aircraft in the region. Each cooperating aircraft is equipped with a transponder beacon which serves not only to reinforce the radar echo but also to provide an altitude-dependent reply which allows ground station operators to differentiate among aircraft according to altitude.

The new group conducting developmental work on Teleran is headed by Dr. Douglas Ewing, who was formerly assistant director of MIT's Radiation Laboratory.

SHOW DIRECTORS APPOINTED

R. P. Almy, Chairman, Sales Managers Club, has announced the appointment of Charles Golenpaul of Aerovox Corporation, New Bedford, Mass., and Walter Jablon, Hammarlund Manufacturing Company, New York City, to serve as directors for the 1947 Radio Parts and Equipment Trade Show. The Sales Managers Club is one of the four sponsoring groups. The Directorship is made up of two Directors representing each group. Mr. Golenpaul was a director and vice president of the 1946 show. Mr. Jablon succeeds Mr. Almy.

ASCO EXPANDS

The Asco Corporation of Cleveland, manufacturer of mechanical and electrical components for the radio and electronics industry, has moved from its location at 874 E. 140th Street, Cleveland, O., to a new and larger plant at 17702 Waterloo Road, Cleveland 19, O.

NEW FEDERAL PLANT

A modern manufacturing plant in the Montreal area for the production of telephones, radios, and other electronic and electrical equipment has been acquired by Federal Electric Manufacturing Company, Ltd., the newly organized Canadian subsidiary of Federal Telephone and Radio Corporation, associate of International Telephone and Telegraph Corporation.

SYLVANIA APPOINTS CANADIAN DISTRIBUTOR

Electronic tubes, laboratory, industrial and electronic devices for communication applications, manufactured by Sylvania Electric Products Inc., will be distributed in Canada through Stromberg-Carlson, Ltd., according to an announcement made here today by George C. Connor, General Sales Manager of the Electronics Division.

SELENIUM RECTIFIERS

A new 8-page bulletin, just off the press, illustrates and describes in detail various types of standard selenium rectifier equipments. Complete specifications and ratings are included. Address: Seletron Division—Radio Receptor Co., Inc., 251 West 19th St., N. Y. 11, N. Y.

COLLINS "SIGNAL"

The Collins Radio Company will shortly resume publication of *The Collins Signal*, a technical magazine published by that firm prior to the war.

The Signal will contain articles of interest to broadcast and communications engineers, airline communication men, amateurs and radio experimenters in general, and will be edited by Lew H. Morse.

Engineers or others desiring to be placed on the mailing list for the Signal should send a postcard to Collins Radio Company, Main Plant, Cedar Rapids, Iowa, care of the Collins Signal Office.

POLYDICHLOROSTYRENE

Electrical properties, heat resistance, and moldability of a new plastic, polydichlorostyrene, were the principal topics of a paper presented recently before the Chicago Section of the Society of Plastics Engineers by Laurence E. Russell of The Mathieson Alkali Works. The meeting was held in the Merchandise Mart.

Polydichlorostyrene can be maintained at 220° F. without dimensional changes or appreciable loss in strength, and, in addition, it retains a power factor ranging from about .0003 to .0008 between 100 and 1,000,000 cycles, stated Mr. Russell. Its dielectric constant in this range varies from 2.64 to 2.66. It absorbs less water than any other thermoplastic—0.02% on the average—and its strength properties compare very favorably with all the commonly used thermoplastics. On the Rockwell M scale it exhibits a hardness rated at 95 which is not very much decreased at elevated temperatures, and its resistance to acids and alkalis at elevated temperatures is excellent.

CARTER EXPANDS

Carter Motor Company, Chicago manufacturers of rotary electric power supplies for radio communications equipment, are now relocated in their own greatly enlarged quarters at 2644 N. Maplewood Avenue.

RCA "PLUG-IN" AMPLIFIERS

A new line of "plug-in" amplifiers, the first in the broadcast field employing standard type plugs which permit a complete amplifier unit to be removed from the rack and another to be installed in its place with no greater effort than that required for changing

[*Continued on page 26*]

New Products

MICROWAVE TUBES

An entirely new group of microwave tubes, resolved through a new set of design principles and applicable to a wide range of new uses in the industrial electronic, communication and navigation fields were announced by M. A. Acheson, manager of the advanced development laboratories of Sylvania Electric Products Inc. The new tubes which are physically smaller than standard radio tubes, include receiving and low-power transmitting types for use between 1000 and 5000 mc.

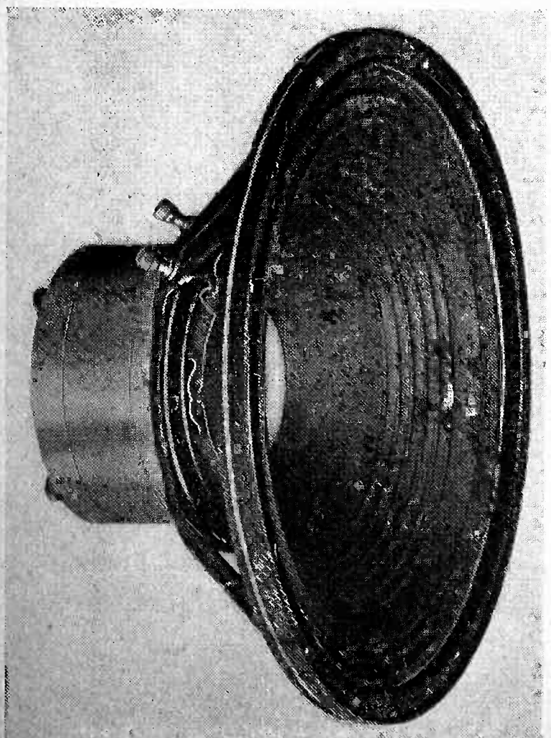
NEW RELAY

The hermetically sealed plug-in relays developed recently by the Ward Leonard Electric Co., Mount Vernon, N. Y. are designed for a-c or d-c operation in small radio transmitters, aircraft control circuits and other applications where space is limited.

Completely encased in a cylindrical can, these compact midget type relays provide excellent protection against adverse atmospheric conditions such as moisture, dust, gases, corrosion, etc. Relay coil and contact connections are totally enclosed within the metal housing and are brought to the prongs of a standard octal plug base. Plug-in relays are available in contact combinations to double pole, double-throw with a-c contact ratings (at commercial frequencies) of 4 a., from 0 to 115 v. and d-c contact ratings of .5 a. from 25 to 115 v. These relays are vibration resistant to 10 G's and are provided with self-aligning silver-to-silver contacts.

NEW DIA-CONE SPEAKER

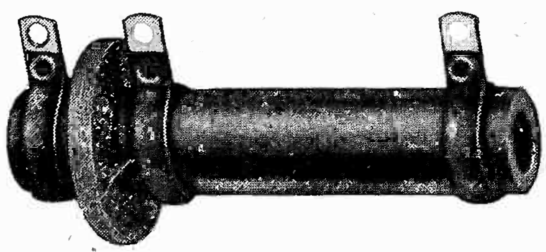
In describing a new speaker, a picture of the 603 Multicell Dia-cone speaker was shown last month instead of the 600. The correct photo is shown below.



VIDEOCOUPLER

P. R. Mallory & Co., Inc., of Indianapolis, announces another television component, the Mallory Videocoupler, Type VC-1.

This is a three-terminal network designed to couple the video amplifier to the



picture tube in television receivers. It is a unique product, in that three units are combined in one assembly, including two peaking inductances and the load resistor.

Complete technical data is now available to interested television engineers and manufacturers, who may write the manufacturer for the Mallory Videocoupler Technical Information Bulletin.

NEW AMPLIFIERS

Altec Lansing announces the availability of a high quality low price, compact, light weight a-c/d-c type A-319 amplifier designed primarily for use in commercial wired music systems and in home phono-

graphs and music systems. It also can be used as a terminal amplifier for paging systems, dance studios and in any other place requiring a medium gain low power amplifier. At the present time the amplifier is manufactured in two models, the A-319A and the A-319B.

For further data, write Altec Lansing Corp., 250 W. 57th St., New York 19, N. Y.

NEW INSULATION TESTER

A new instrument for checking insulation resistance in a-c and d-c equipment is announced by Ideal Industries, Inc., 4027 Park Ave., Sycamore, Illinois.

The necessary power is provided by a small internal hand generator which is operated by a slowly turning crank. The crank can be turned in either direction.

Test range is 0-100 Megohms; case, lightweight two piece aluminum; meter, rugged D'Arsonval type; test leads, 10′ long; dimensions, 3⅜ wide x 6″ long x 3¼″ high; weight with leather carrying case

FM ANTENNA COUPLER

The many broadcasters now adding f-m facilities may effect considerable economy, i.e., the price of another tower, if they are able to erect their f-m antennas atop an existing a-m radiator. This does, however, introduce the problem of feeding the f-m power without short-circuiting the a-m radiator at its frequency or causing cross-talk at the f-m frequency.

Coupling equipment that properly isolates the two systems and feeds the f-m antenna across the base insulation of the a-m tower has been developed and made commercially available by the E. F. Johnson Co. It is the Johnson FM Antenna iso-coupler, rated up to and including 50 kw AM, and 10 kw FM.

For further data, write the E. F. Johnson Co., Waseca, Minn.

RESISTANCE COMPARATOR

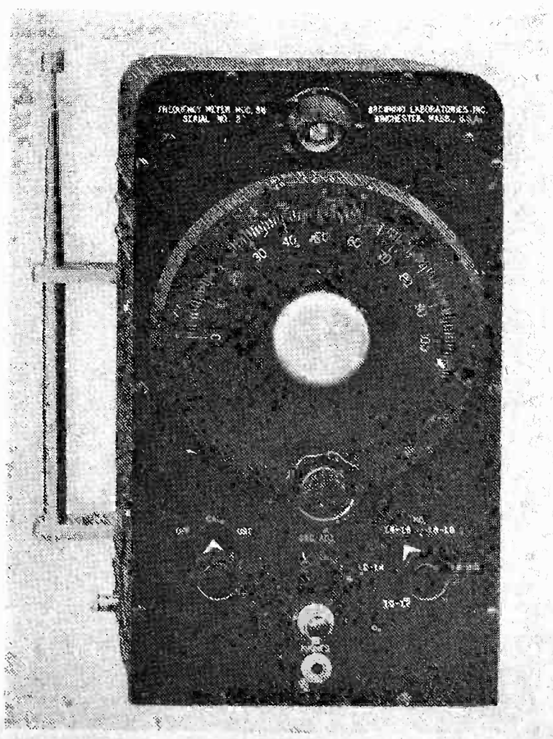
Precision testing of resistors is reduced to simple production routine by use of a new automatic resistor comparator, according to the manufacturers, Clippard Instrument Laboratory, Cincinnati, Ohio.

The instrument is designed to check factory output or incoming shipments of resistors, matching, grading to close tolerances, by means of meter reading in per cent of standard. Resistors between 100 ohms and 100 megohms may be checked.

FREQUENCY METER

A moderately priced, general-coverage frequency meter has been announced by the Browning Laboratories, Inc., 742-750 Main Street, Winchester, Mass. Useful over a continuous frequency range of 100 kc to

[*Continued on page 29*]



THIS MONTH

[*from page* 24]

an ordinary radio tube, was announced by the RCA Engineering Products Department. The equipment is already in production and deliveries are being made.

UNSCC STANDARDS

Unofficially confirmed reports state that the United Nations Standards Coordinating Committee will probably close its New York office and carry on all of the international work through its London office. The resignation of H. J. Wollner, secretary-in-charge of the New York office, has been accepted in line with an agreement made in 1944.

Study of some of the standards projects thus far proposed are being undertaken by the London office this fall. The UNSCC includes the national standards bodies of 18 countries.

IRON-CORE COIL DESIGN

The September meeting of The Radio Club of America, held at Columbia University, was devoted to a paper "Practical Realization of Powdered Iron Core Coils and Tuning Systems", by Robert S. Doak, Engineer, Airadio, Inc.

Among other points, the paper brought out that the ultimate in coil design involves a specially designed core as an integral part of a specific coil requirement. The steps involved in manufacturing cores were covered briefly in order to familiarize coil and circuit engineers with some of the problems confronting the core engineers and manufacturers.

RCA ANNOUNCES NEW TRANSMITTERS

The first postwar RCA television transmitter, providing five kw of output power on any one of the twelve frequency channels assigned by FCC to commercial television in metropolitan areas, has been placed in production, it was announced by W. W. Watts, vice-president in charge of the RCA Engineering Products Dept.

PERSONAL MENTION

L. W. Howard

★ L. W. Howard, formerly vice-president in charge of engineering and sales for a leading transformer manufacturing company, has taken over the inventory and equipment of the Electronic Components Co., and with O. D. Perry has formed the Triad Transformer Mfg. Co., with offices and plant at 423 N. Western Avenue, Los Angeles 4, Calif.

Howard, who has had 16 years' experience in the transformer business, will have charge of engineering and sales, and Perry, one of the founders of Electric Components, will be in charge of production.

Milton E. Lauer

★ The appointment of Milton E. Lauer to the newly created post of product manager of the Radio Tube Division, Sylvania Electric Products Inc., has been announced by H. Ward Zimmer, vice-president. Mr. Lauer will report directly to Mr. Zimmer and will be responsible for close coordination between manufacturing, engineering, sales and administrative departments with respect to all products of the Radio Tube Division.

Milton E. Lauer

Ben Adler

★ Morton B. Kahn, president of the Transmitter Equipment Mfg. Co., Inc., of New York City, manufacturers of commercial and amateur radio communication equipment, announces the appointment of Mr.

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Ben Adler as vice-president in charge of engineering.

Mr. Adler formerly was chief facilities engineer of the American Broadcasting Company.

Jerome R. Steen

★ The appointment of Jerome R. Steen as director of quality control for the Lamp, Fixture, Wire Products, Tungsten and Chemicals, Radio Tube and Electronic Divisions of Sylvania Electric Products Inc. was announced recently by E. Finley Carter, vice-president in charge of engineering. Mr. Steen will be responsible for functional supervision of all quality control personnel within the company.

Jerome R. Steen

New Parts Manufacturer

★ Herman H. Smith, formerly president of Radio Essentials, Inc., Mount Vernon, N. Y., has severed his connection with the company and has established his own organization titled Herman H. Smith, Inc. The new company will manufacture a line of radio and electronic components and hardware and will act as suppliers to radio parts jobbers.

L. Morgan Craft

★ L. Morgan Craft, acting head of Collins engineering division, has been elected to the office of vice-president in charge of engineering and manufacturing.

L. Morgan Craft

NEW PRODUCTS

[*from page* 25]

50 mc, the instrument features a ±.025% accuracy, an instrument dial 6″ in diameter readable to one part in 1000, transformer-type power supply, and rugged construction.

The oscillator range is 1.0 to 2.0 mc in five bands, each tuning 200 kc. A built-in crystal calibrator provides convenient means of assuring long time accuracy. External signals are coupled to the meter through a telescoping antenna which also serves as a carrying handle.

NEW SIGNAL GENERATOR

A new signal generator designed for the radio engineer and service man has a wide range of output of radio and audio frequencies. This new instrument is versatile and practical, with many types of modulation. Its power consumption is 20 watts at 115 volts. Its features are the following:

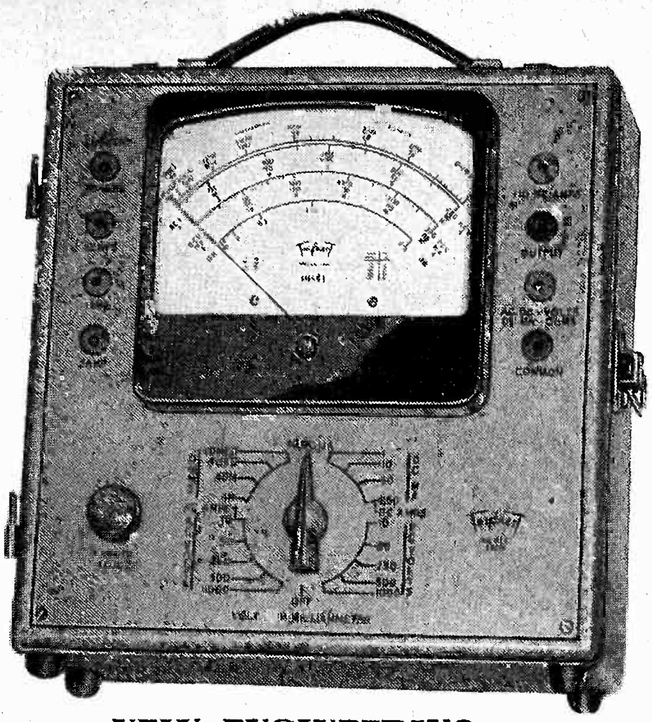
- Complete amplitude modulation coverage from 100 kc to 110 mc.
- Complete frequency modulation coverage 100 kc to 160 mc with three variable bandwidths of sweep: 0-30 kc, 0-150 kc, 0-450 kc.
- Frequency modulation at two self-contained modulating frequencies: 60 cycles and 400 cycles.
- Provisions for external frequency modulation to 15,000 cycles.
- Provisions for external amplitude modulation to 15,000 cycles.
- Self-contained amplitude modulation at 400 cycles.
- 0.01% accurate crystal controlled outputs, both amplitude modulated at 400 cycles and unmodulated.
- Continuously variable audio frequency from 0-15,000 cycles.
- Audio frequency and radio frequency outputs are continuously variable from zero to maximum.
- 60 cycle synchronized sweep voltage is available for use with an oscillograph.
- Self-contained decibel meter with 42″ cable.
- One 42″ shielded cable is furnished for the signal output.

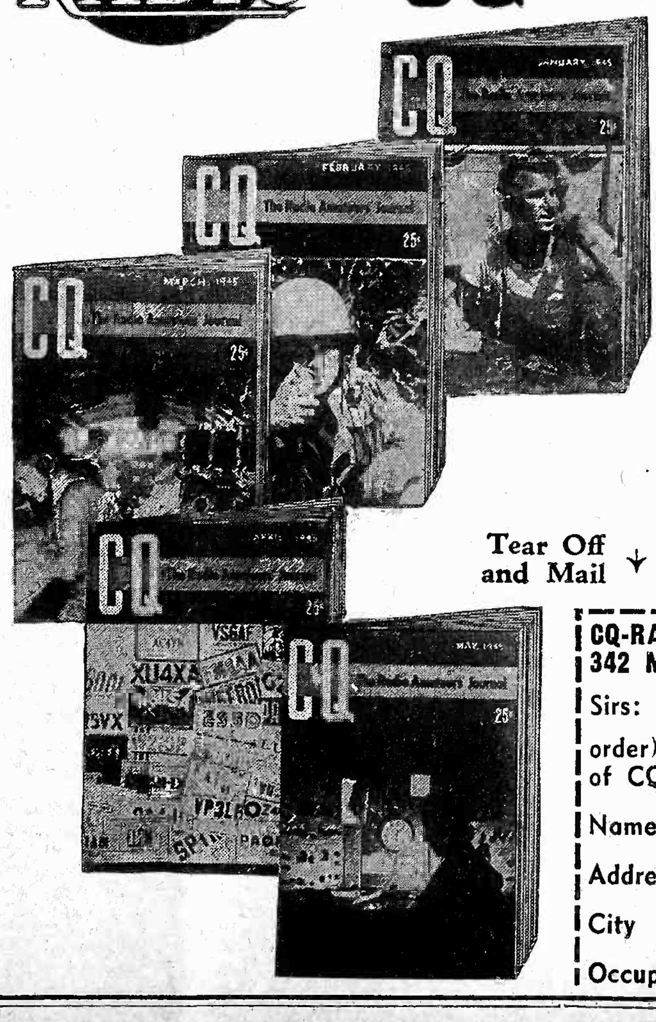
This new signal generator is manufactured by the Hickok Electrical Instrument Co., 10532 Dupont Av., Cleveland 8, Ohio.

T-V RECTIFIER TUBE

The Chatham type 1Z2 is a small bulb, high voltage vacuum rectifier designed as a compact, high-voltage tube of low current capacity. The low cathode heating power and low dielectric losses make this tube suitable for use in rectifiers operating from a radio frequency supply. Two tubes in a voltage doubler will supply 20,000 volts at 2 ma dc.

Maximum Ratings:
Peak Inverse Voltage . . .20,000 volts
Average Plate Current . . 2 ma.
Peak Plate Current . . . . .10 ma.
Characteristics:
Filament voltage . . . . .1.5 volts





Filament current	.29 amps
Min. resistance in series with plate	20,000 ohms
Anode to filament capacitance	0.6 mmf
Tube mounting position	Any
Bulb	T-5 ½
Base	Miniature button 7 pin
Cap	Skirted miniature

Manufactured by Chatham Electronics, 475 Washington Street, Newark 2, New Jersey.

DYNOPTIMUM TUBE TESTER

The Radio City Products Company is now marketing the Tube Tester Model 322. One of the most economical tube testers of the day, this versatile instrument permits testing of practically every known type of receiving tube. The Dynoptimum circuit permits rapid operation with but 4 controls. This unusual simplicity of operation not only saves time but also reduces costly obsolescence.

Descriptive material on this model can be obtained from Radio City Products Company, Inc., 127 W. 26th St., New York City 1.

INVENTIONS

[*from page* 23]

quency of the energy in the transmission line, and a large resonant rise of voltage appears at the right angle. Phase relations of these two voltages are such as to develop an effective open circuit in the transmission line at this point. Thus energy is prevented from flowing between the source of high frequency and the load.

With an exciting signal applied to the grid of the reactance tube, energy is allowed to flow in the transmission line as follows: The reactance tube now develops a capacitance between plate and grid which is applied in shunt with its associated line section. This section, physically shorter than a quarter wavelength, now becomes a quarter wavelength electrically, and is resonant to the same frequency as the right-angled section. The impedance reflected thereby into the right-angled section causes it to move off resonance, with the result that resonant rise of voltage no longer takes place at the right angle.

In the absence of voltage build-up at the right angle, energy now flows along the transmission line between the source of high frequency and the load. Connecting the plate and grid of the reactance tube nearer the open end of the line section results in more positive control, and smaller required exciting input signal voltage.

The patent is assigned to Federal Tel. and Radio Corp.

Sometimes you can break a good rule!

It's usually a wise rule not to plan a chicken dinner before the eggs are hatched.

But not always!

If the "chicken dinner" represents your future, and the "eggs" are financial nest eggs—go ahead and plan!

Especially if your *nest eggs* are U. S. Bonds—all the War Bonds you have bought—all the Savings Bonds you *are buying*. For your government *guarantees* that these will hatch out in just 10 years.

Millions of Americans have found them the safest, surest way to save money . . . and they've proved that buying Bonds on the Payroll Savings Plan is the easiest way to pile up dollars that anyone ever thought of.

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BOOK REVIEWS

Electrolytic Capacitors, by Paul McKnight Deeley. Cornell-Dubilier Electric Corporation, South Plainfield, N. J., second printing, 1946. 270 pages, illustrated, diagrams, charts, $1.50.

This volume, written by the chief engineer of the electrolytic division of the Cornell-Dubilier Electric Corporation, makes available to the radio and electrical engineering fraternity a source of technical information on the theory, construction, measurement, characteristics and application of electrolytic capacitors of all types.

It presents the basic theory of operation, processes of fabrication, the types and characteristics, as well as new applications of electrolytic capacitors. A special feature of this book is an appendix of useful information which includes tables, characteristics, conversion charts and additional technical data.

Electromagnetic Engineering, Vol. 1, by Ronold W. P. King, published by McGraw-Hill Book Co., New York, 580 pages, 131 illustrations, cloth binding, $6.00.

Electromagnetic Engineering is the first of a three-volume series with this title. It offers a systematic introduction to basic concepts of electromagnetism which are fundamental in the study of electromagnetic waves, antennas, electromagnetic horns, wave guides, ultra-high frequency and microwave circuits. Physical and mathematical essentials of electrodynamics are logically developed and critically discussed for the purpose of application to engineering problems.

The author is associate professor of physics and communication engineering, at Harvard University. The book is written on a high mathematical level, and makes free use of vector algebra and calculus. Chapter headings are Mathematical Description of Matter, Mathematical Description of Space and of Simple Media, Transformations of Field and Force Equations, Electromagnetic Waves in Unbounded Regions, Skin Effect and Internal Impedance, and Electric Circuits.

A useful appendix is provided, problems supplied for self-examination of classroom use, and a good index. The book is well executed and deserves a place on every practicing engineer's bookshelf.

ADVERTISING INDEX

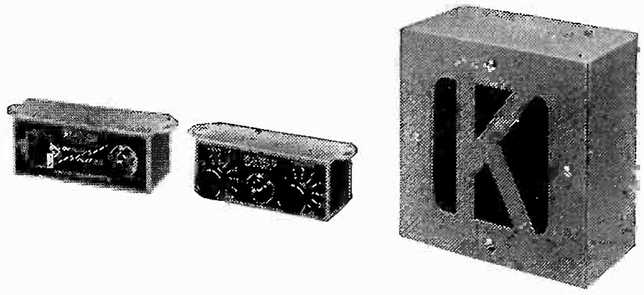
PRESS OF THE WILSON H. LEE CO. ORANGE, CONN. PRINTED IN U.S.A.

Now available! An FM Radiotelephone with a truly NATURAL voice quality!

New KAAR FM radiotelephones offer an improvement in tone quality which is suprising to anyone who has had previous experience with mobile FM equipment. The over-all audio frequency response through the KAAR transmitter and receiver is actually within plus or minus 5 decibels from 200 to 3500 cycles! (See graph below.) This results in vastly better voice quality, and greatly improved intelligibility. In fact, there is appreciable improvement even when the FM-39X receiver or one of the KAAR FM transmitters is employed in a composite installation.

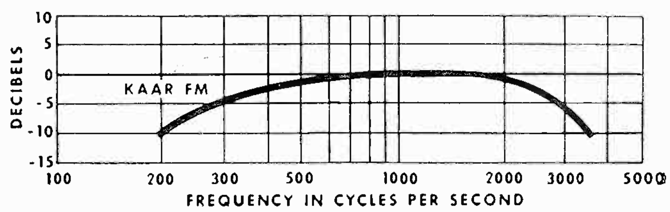
KAAR FM transmitters are equipped with instant-heating tubes, thus making it practical to operate these 50 and 100 watt units from the standard 6 volt ignition battery without changing the generator. Inasmuch as standby current is zero, in typical emergency service the KAAR FM-50X (50 watts) uses only 4% of the battery current required for conventional 30 watt transmitters. Battery drain for the KAAR FM-100X (100 watts) is comparably low.

For full information on new KAAR FM radiotelephones, write today for Bulletin No. 24A-46.



KAAR LOUD SPEAKER, remote controls for transmitter and receiver (illustrated above) and the famous Type 4-C push-to-talk microphone are among the accessories furnished with the equipment.

IMPROVED OVER-ALL FREQUENCY RESPONSE THROUGH KAAR FM TRANSMITTER AND RECEIVER



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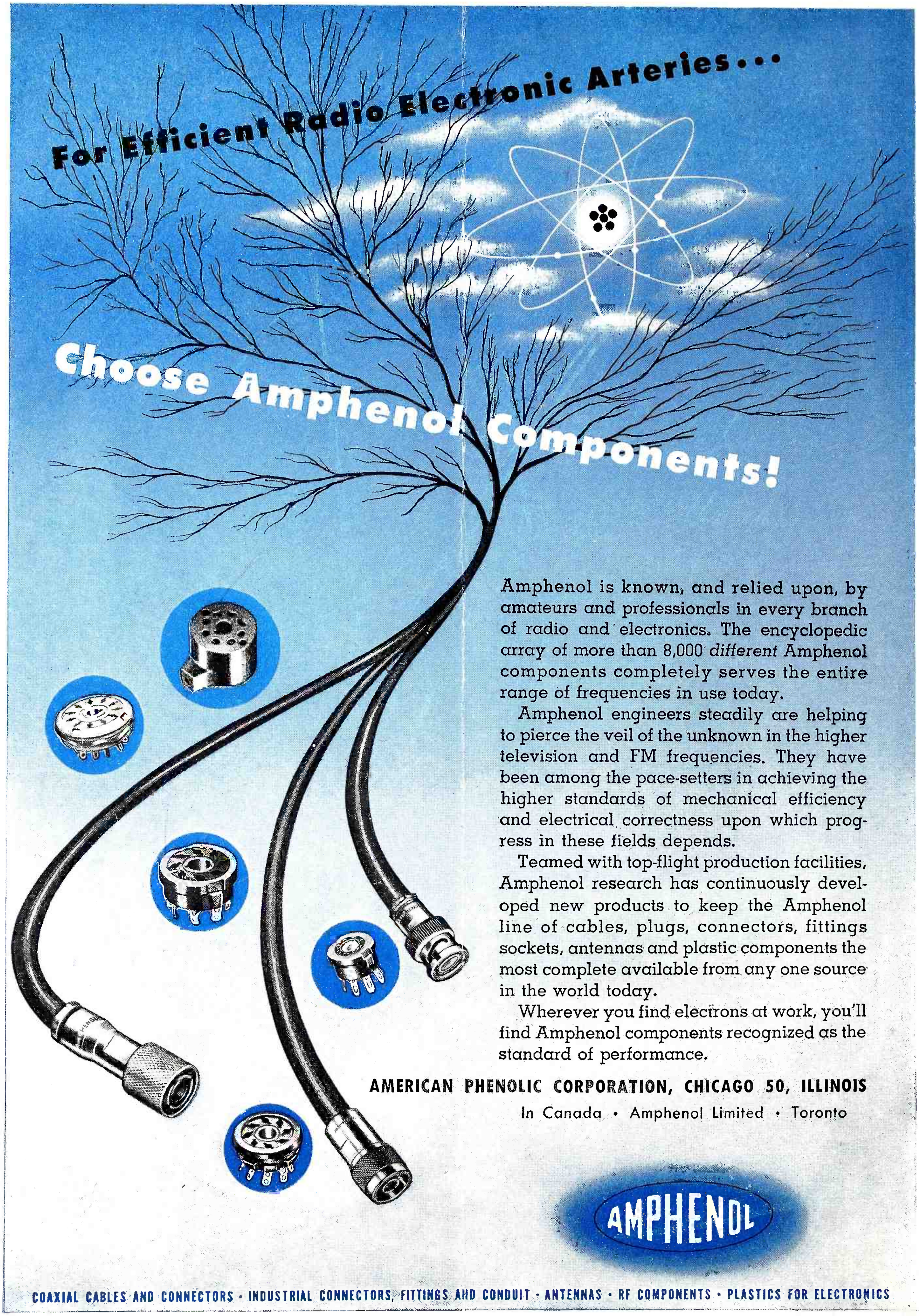
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