RADIO

JANUARY, 1946

Design • Production • Operation

The Journal for Radio & Electronic Engineers

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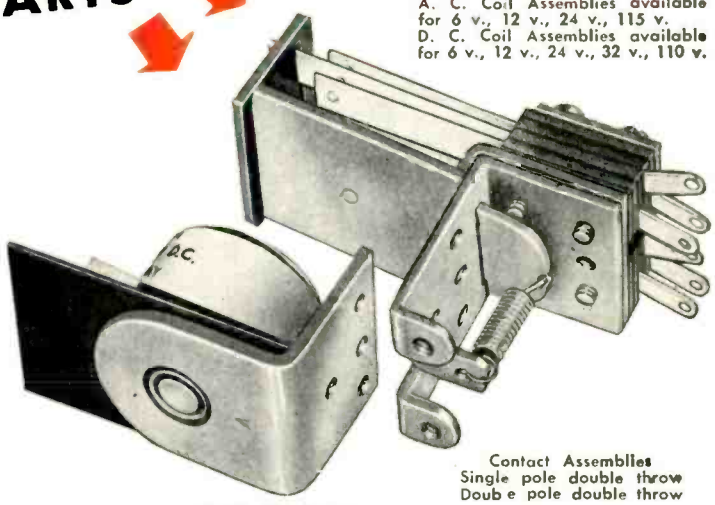

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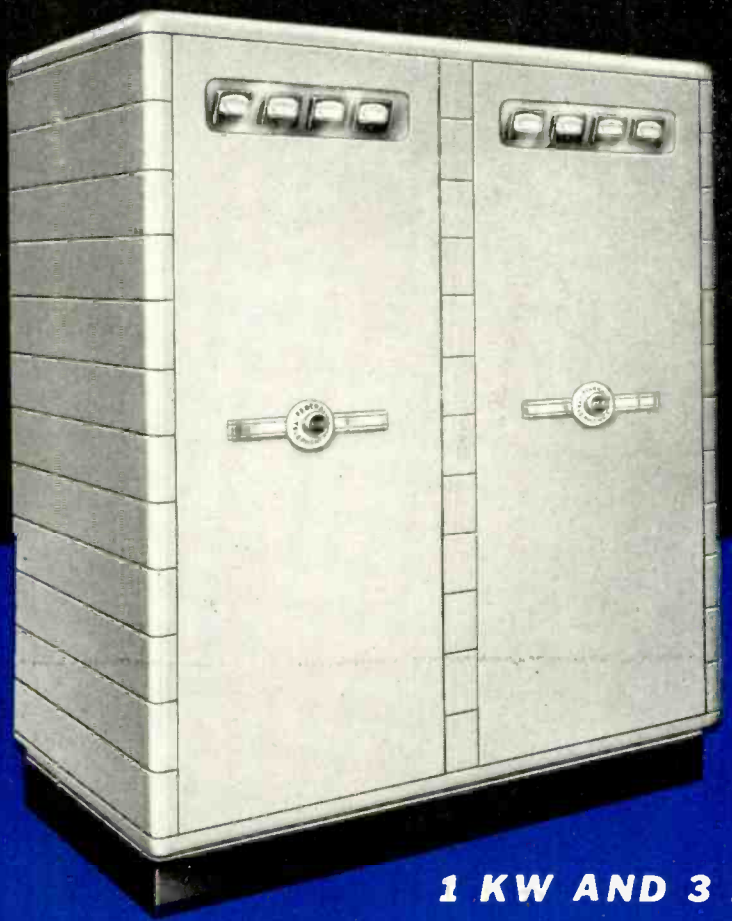

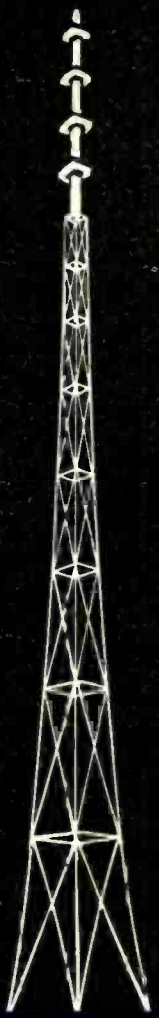

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Transients

STATION LICENSE SCRAMBLE

★Some idea of the magnitude of the coming postwar boom in the radio industry may be gained from figures on station license applications recently issued by the Federal Communications Commission. Requesting an appropriation of $785.000 to process applications for station licenses until July 1st, 1946, the FCC Chairman Paul Porter announced that there were on hand nearly 700 FM station license applications, over 400 for standard stations, and 142 for television. In addition there are many other services, such as urban transit, amateurs, and railroad radio, for which licenses will be required. Porter predicted that the number of licenses of all kinds would increase from 36.000 on July 1, 1945 to more than 140,000 by July 1, 1946, and to over 400,000 by July 1, 1947.

More than half the pending television station applications require special hearings because there are already more applications than channels in a dozen metropolitan areas. There is also similar trouble in the New England area in regard to FM licenses.

Most broadcast station licenses have turned out to be pretty profitable investments, so the interest in securing them is understandable. But those who are contemplating investing in television stations do so with the knowledge that they must be prepared to lose money over a long period until the public has absorbed a sufficient quantity of receivers to interest buyers of station time. It is apparent that these investors have a great deal of faith in the future of television. The bulk and variety of miscellaneous applications for licenses shows a wide potential market for special radio equipment which should make itself an important factor in the prosperity of the industry within the next two years.

MAPPING THE MOON

★One of the most interesting proposed new postwar applications of radar is revealed in the announcement by Sir Edward Appleton in London that it may be used to map the moon. The distance is in itself no barrier, but the big difficulty is in producing a beam sufficiently narrow at this range to do the trick. The feasibility of the project has been investigated independently by individuals in this country and we hope to be able to present in the near future a technical discussion of the subject. Manifestly, if the idea can work over a distance of 250,000 miles, there are undoubtedly many other similar applications at much shorter distances where radar may provide a faster and more accurate method of mapping terrain than has hitherto been available.

POCKET RADIOS

★Adaptation of sub-miniature tubes similar to those used in the VT proximity fuze to pocket radios has been announced by Belmont. The great advantage of these tubes is not only their small size but also their low battery voltage and current requirements. Because of their low power output, an earphone is used for reception. It will be interesting indeed to see how the public takes to this idea. If it is well received, such radios will probably be sold at corner drugstores as casually as thermos bottles.

CRS RELAYS

★One of the limitations of the Citizens Radiocommunications Service will be the short range obtained when using a handie talkie in the 460-470 mc band. A suggestion to increase this range by the use of automatic relay stations has been advanced by Robert C. Smith of the Bureau of Foreign and Domestic Commerce. To finance the project, it is advocated that cooperative groups be formed among individuals. Thus a far greater useful range can be obtained.

Undoubtedly this service will become very popular in the near future provided it does not get off to a bad start. If individuals find that communication is unreliable over a distance of more than a couple of miles, it is likely that no healthy development of the service will result. Automatic relay stations will certainly help, and it might be good business for manufacturers to sponsor such stations as a service to their customers.

—J.H.P.

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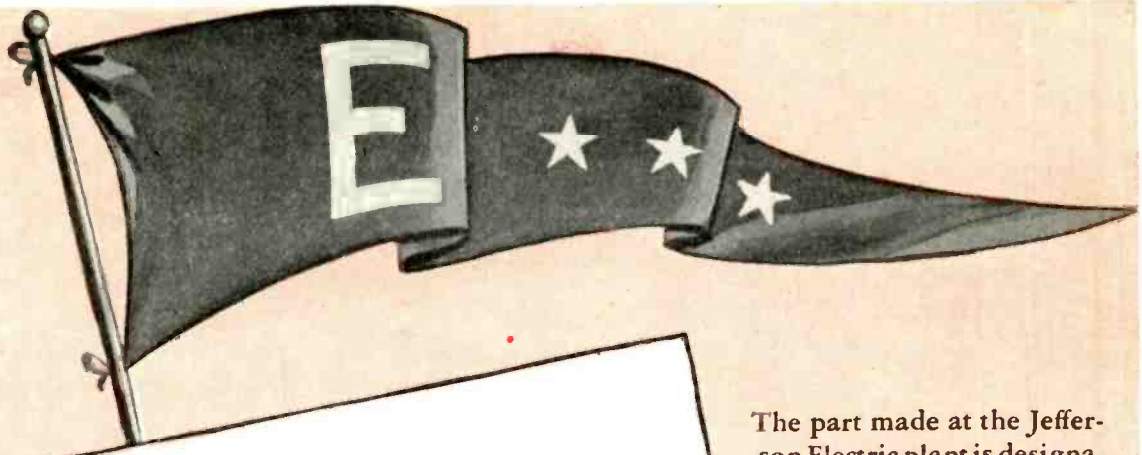

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AND REFER TO

NAVY DEPARTMENT
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WASHINGTON 25, D. C.

September 26, 1945

P15
(Ad5)

Sirs:

It is my great pleasure to announce the award of the Bureau of Ordnance "E" to your company and to other firms who participated in one of the most important of our wartime ordnance projects — the successful development and manufacture of the VT fuze.

The Bureau of Ordnance has never underestimated the value of your services and has regretted the necessity for maintaining secrecy on your product throughout the war and even beyond that, so long as there remained any doubt that security restrictions could be lifted with safety. Maintenance of these security safeguards unfortunately has prevented the award of the Army-Navy "E" to producers of the VT fuze who otherwise would have been eligible for consideration. We have appreciated your understanding of the reasons why your excellent production job had to be performed behind a veil of secrecy.

Now that the story can be told, the Bureau of Ordnance wants to recognize publicly the importance of the part you have played. The Bureau of Ordnance "E" is being revived exclusively as a means of paying proper tribute to the Navy contractors who worked on the VT fuze.

Each plant receiving the award will be furnished with a Bureau of Ordnance flag, a Navy "E" pennant and "E" buttons in sufficient quantity to supply all workers who assisted in making the VT fuze. In the case of plants which would have been eligible for renewal awards, stars will be affixed to the pennants, one for each six months of eligibility.

Please inform the Bureau where your flags should be shipped and how many pins are desired. You will be informed of the probable delivery date of these items.

The Bureau of Ordnance is grateful for your devoted efforts and is happy to congratulate you on the excellence of your performance of a wartime task of the first magnitude. A hearty "Well Done!"

Sincerely yours,

O. F. HUSSEY, Jr.
Rear Admiral, U. S. Navy
Chief of the Bureau of Ordnance

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Amphenol "Twin-Lead" Transmission Line is available in 300 ohm impedance value. RMA standardized on 300-ohm lead-in line for Television as the most efficient over broadband operation.

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30	0.88	1.03	2.0
40	1.1	1.3	2.5
60	1.45	1.8	3.4
80	1.8	2.25	4.3
100	2.1	2.7	5.0
200	3.6	4.7	8.3

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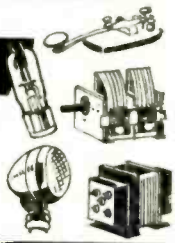

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TECHNICANA

AMPLIFIERS FOR BIOLOGICAL WORK

★ The problems encountered in design of amplifiers for biological research are dependent on the somewhat different voltage and frequency values to be amplified.

An analysis of some of the circuits employed for this purpose is presented in the November, 1945, issue of *Wireless World*, by D. H. Parnum.

Brain potentials are normally about 50 microvolts, at 10 cycles, although in diseased brains the frequency may be as low as 3 cycles. Nerve reactions produce pulses of perhaps 1 millisecond duration and 1 microvolt peak. Again, in cardiography, heart beat impulses of 2 millivolts at 1 cycle are to be expected.

The problem of interference due to unwanted pickup in the subject is largely overcome by the use of a balanced input stage and push-pull amplification throughout. A circuit credited to Goodwin is shown in *Fig. 1*.

The input from the subject, applied at points *A* and *B*, is an antiphase signal, and is amplified throughout. The interference is an inphase voltage between the subject and ground, and is balanced out in the feedback, which is taken from the plates of the two 7C7s to the cathodes of the 6J7s.

The disadvantage of this circuit is that the signal/interference ratio is fixed, so that there is no improvement with a large signal. Gain is controlled by R_3.

The circuit has the advantage that several amplifiers can be attached to a single subject. There will be no interaction between amplifiers because no signal current flows in the ground leads. Again, high subject insulation from ground is not required.

The author also analyzes the possible condition of unbalanced interference, concludes that an interference control is not essential for many applications, though it would probably be desirable.

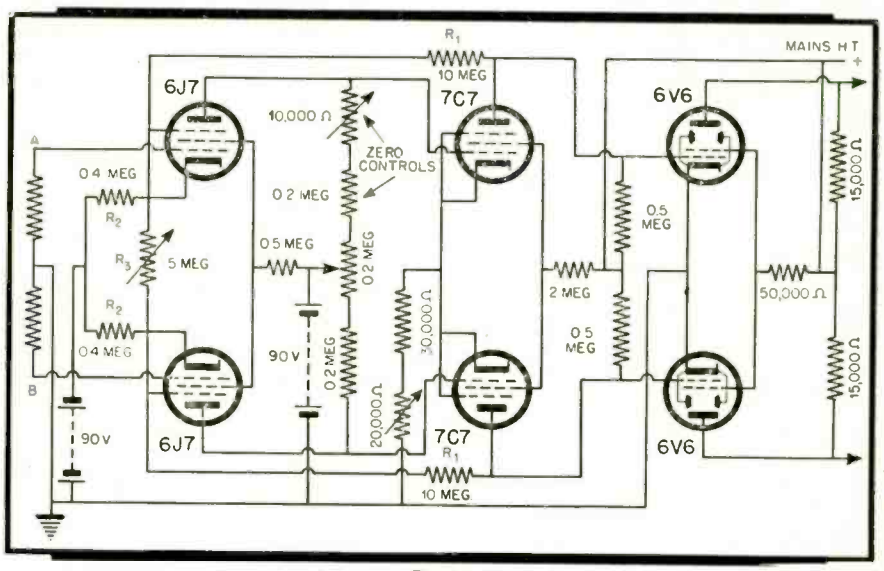

Figure 1

PREFERRED NUMBERS

★ The use of preferred number values for electrical components has become so widely adopted, through standardization, that the original method by which the numbers were obtained has tended to become obscure.

H. Jefferson, writing on "Preferred Numbers and Filter Design" in the October, 1945, issue of *Wireless Engineer*, reviews the preferred numbers theory.

This system is based on the principle that actual circuit values are not always critical, and that performance can be repeated by the application of a tolerance to the preferred number selected. Additionally, some sort of standardization is required if the number of available values is to remain within practical production limits. Outstanding examples are the preferred values for fixed composition resistors and fixed mica capacitors.

The preferred number system was set up on the basis of three primary conditions:

1. One number of the preferred number set must be defined. This was established as unity.

2. Tolerances must be established. Values already in use were 5%, 10%, and 20%.

3. All powers of ten must be mem-

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These new models are now being tooled for production and, when ready, complete specifications and prices will be issued to the trade in Data Sheet TD-133. . . . *Watch for other postwar innovations soon to come from the JENSEN laboratories.*

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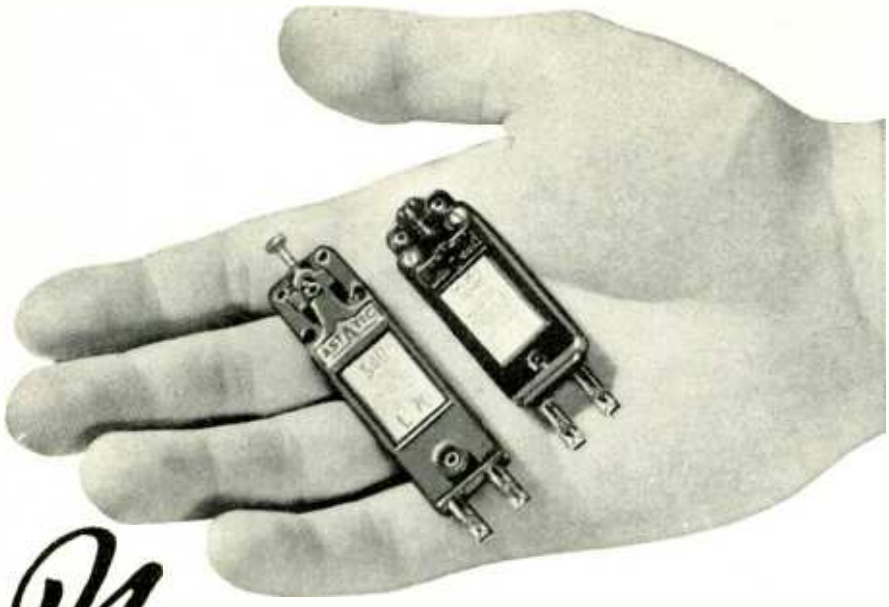

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TECHNICANA

[*from page 8*]

bers of the series. The series would then become a series of significant figures adaptable to any number range. The number series, starting with N_r, was set up as follows:

$N_r \; N_{r+1} \; N_{r+2} \; \ldots \; 10N_r$

If the tolerance is $s\%$, or $s/100$, then if due regard for tolerance limits is employed, $N_r(1+s/100) = N_{r+1}(1-s/100)$.

or $N_{r+1} = \dfrac{1+s/100}{1-s/100} \cdot N_r = kN_r$.

By condition 3

$$k = \sqrt[a]{10}$$

or $1/a = \log_{10} k$.

For $s=20$, $k=1.5$, and $a=6$ approx.

Since only integers can be used, a is chosen as exactly 6, although this will slightly affect the overlap or gap between tolerance limits.

Then if $N_r = 1$, $N_{r+1} = kN_r = 1.5$, $N_{r+2} = k^2N_r = 2.2$, etc. There will be six steps to complete the set of significant figures, for $N_{r+6} = k^6N_r = 10N_r = 10$.

For a tolerance of 10%,

$$k = \sqrt[12]{10}$$

for $s = 5\%$,

$$k = \sqrt[24]{10}$$

The preferred numbers are listed in Table 1.

The logarithmic character of the series is of value in circuit design. For example the product of two preferred numbers is itself a preferred number, to two significant figures. The same applies to division. The square root of a preferred number is a preferred number in the lower tolerance series.

5% SERIES	10% SERIES	20% SERIES
10	10	10
11		
12	12	
13		
15	15	15
16		
18	18	
20		
22	22	22
24		
27	27	
30		
33	33	33
36		
39	39	
43		
47	47	47
51		
56	56	
62		
68	68	68
75		
82	82	
91		
100	100	100

Table 1

THE IMAGE ORTHICON

★ A new television camera tube of unusual design and extreme sensitivity

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The receiver has two r. f. stages instead of the usual one, resulting in better signal-to-noise ratio and greater discrimination against spurious signals. For full details, write for Bulletin 24-45.

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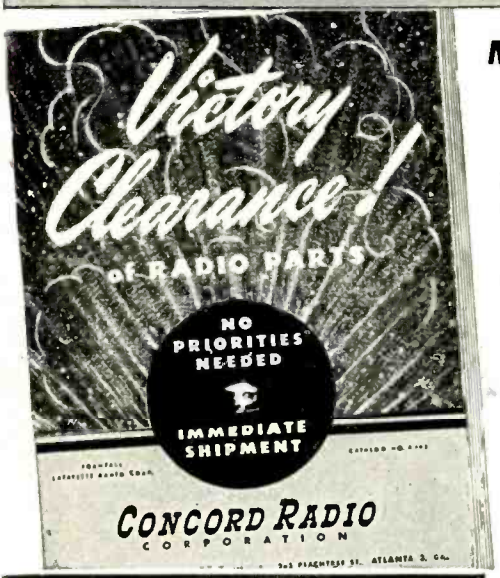

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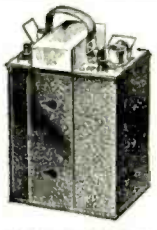

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TECHNICANA

[from page 10]

was recently demonstrated by the Radio Corporation of America in a series of studio and remote pickups in which it not only transmitted scenes illuminated by candle and match light, but also picked up scenes with infra-red rays in a blacked-out room. The new tube is known as the RCA Image Orthicon.

In the exhibition, members of the audience saw themselves televised under lighting conditions that proved the high sensitivity of the new electronic "eye" which solves many of the major difficulties of illumination in television programming and makes possible 'round-the-clock television coverage of news and special events.

RCA-NBC engineers capped the demonstration by blacking out the studio where the writers were assembled, and providing the unprecedented spectacle of picking up television scenes in apparent darkness. Unseen infra-red (black) lights were turned on, but it was so dark that a member of the audience could not see the person next to him.

Then on the screens of television receivers in the studio appeared bright images of a dancer and other persons who were in the room. The Image Orthicon tube, it was explained, achieved the feat through its sensitivity to the infra-red rays.

Declaring the Image Orthicon to be 100 times more sensitive than conventional pickup tubes, E. W. Engstrom, Research Director of RCA Laboratories, Princeton, N. J., explained details of the development of the tube. He said that early models were built before the war in efforts of RCA television scientists and engineers to improve the quality of television transmission. When war came, the armed forces found urgent need for television applications, and throughout the conflict RCA research and development continued at an accelerated pace in response to military requirements. Many advances were made.

The Image Orthicon tube, for example, Mr. Engstrom said, emerged in its present form much sooner than would normally have been the case. A military secret until now, it can be revealed that it makes use of results of more than twenty years of research not only in television pickup tubes but in electron optics, photo-emission processes, electron multipliers, and special materials.

Credit for the tube's development goes to three members of the RCA research staff: Dr. Albert Rose, of Middletown, N. Y.; Dr. Paul K. Weimer,

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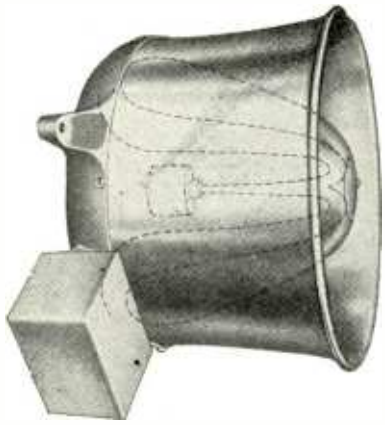

Left: MARINE HORN Speaker, approved by the U. S. Coast Guard. Several sizes available. Re-entrant type, suitable for indoor or outdoor use — may be used as both speaker and microphone. 2½', 3½', 4½' and 6' sizes available.
Right: RE-ENTRANT TRUMPET; available in 3½', 4½' and 6' sizes. Compact. Delivers highly concentrated sound with great efficiency over long distances.

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TECHNICANA

[*from page 12*]

of Wabash, Ind., and Dr. Harold B. Law, of Kent, Ohio. The project is a continuation of RCA Laboratories' work on the pickup tube over the past 20 years under the direction of Dr. V. K. Zworykin, Associate Director of RCA Laboratories. During part of that period, the work was headed by B. J. Thompson, Associate Director of the Laboratories, who was killed in action overseas in July, 1944, while on a special mission for the Secretary of War.

Announcing incorporation of the Image Orthicon in a new super-sensitive television camera to be manufactured by RCA Victor, Meade Brunet, General Manager of the Company's Engineering Products Division, said that deliveries on the camera are expected to be made to television broadcasters in about six months.

"The new super-sensitive RCA Victor television camera will fill a long-felt need in the television broadcasting field," said Mr. Brunet. "This equipment is especially well suited for televising events remote from the studio and those where brilliant lighting is either impracticable or undesirable. The portable camera is lightweight, simple to operate, and can be quickly set up in televising out-of-door sports and news events and for remote indoor pickups such as in theaters, concert halls, schools, churches, courtrooms, and other public buildings."

RCA engineers listed these specific advantages in performance of the Image Orthicon:

1. Ability to extend the range of operations to practically all scenes of visual interest, particularly those under low-lighting.
2. Improved sensitivity, permitting greater depth of field and inclusion of background that might otherwise be blurred.
3. Improved stability which protects images from interference due to exploding photo flash bulbs and other sudden bursts of brilliant light.
4. Smaller size of tube, facilitating use of the photo lens.
5. Type of design that lends itself to use in lightweight, portable television camera equipment.
6. Improved gain control system that provides unvarying transmission, despite wide fluctuations of light and shadow.

As shown in *Fig. 1*, the advanced development model of the Image Orthicon has an overall length of about 15 inches, with the shank about two inches in diameter and the head about 3 inches in diameter and 3 inches long. It has three main parts: An electron image section, which amplifies the photoelectric current; an improved Orthicon-type scanning section, smaller and simpler than those built before the war; and an electron multiplier section, the function of which is to magnify the relatively weak video signals before transmission. See *Fig. 2*.

The principle which makes the new tube super-sensitive to low light levels is similar to that used in the electron multiplier phototube.

Light from the scene being televised is picked up by an optical lens system and focused on the photo-sensitive face of the tube, which emits electrons from each illuminated area in proportion to the intensity of the light striking the area.

Streams of electrons, accelerated by a positive voltage applied to a grid placed directly behind the photo-sensi-

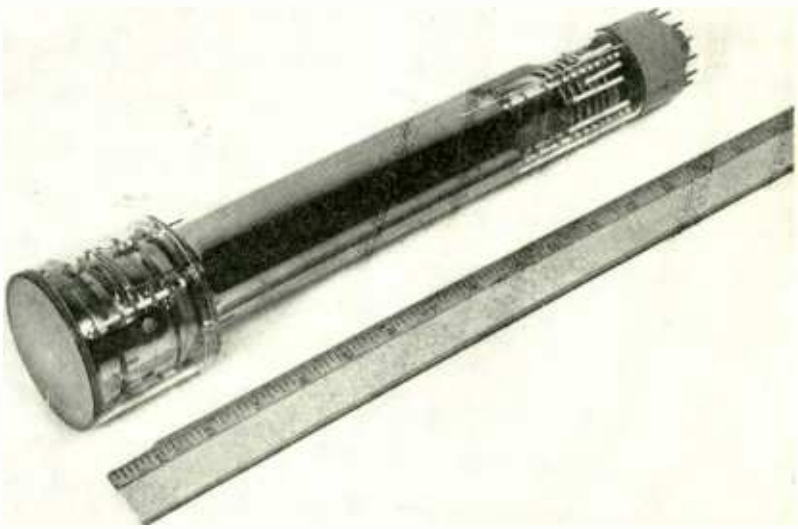

Figure 2

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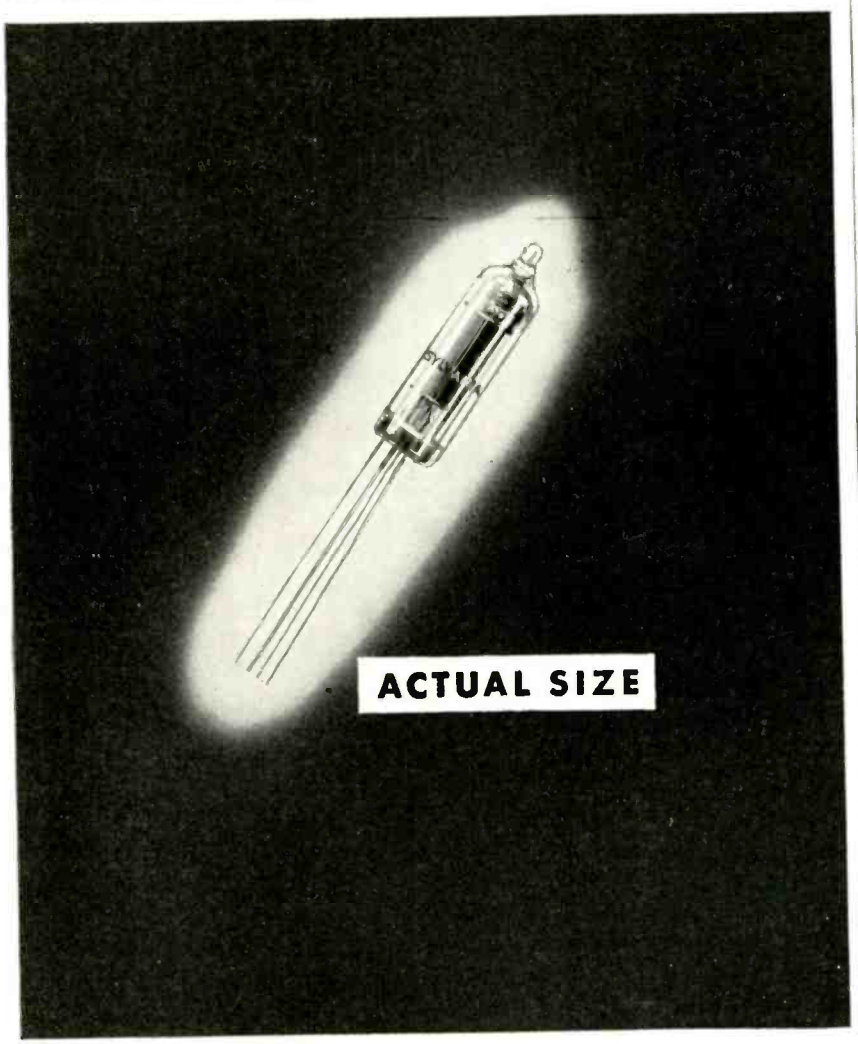
SYLVANIA NEWS

ELECTRONIC EQUIPMENT EDITION

JAN. *Published by* SYLVANIA ELECTRIC PRODUCTS INC., Emporium, Pa. 1946

NEW T-3 TUBE FILLS NEED FOR SMALLER UNIT IN TINY BROADCAST RECEIVERS



For any further details, or questions you may want answered about this tiny, sturdy vacuum tube, do not hesitate to write or call Sylvania Electric Products Inc., Emporium, Pa.

Commercial Version of Proximity Fuze Tube Is Rugged, Has Long Life

Following Sylvania Electric's recent announcement about the sensationally small vacuum tube—originally developed for the now-famous proximity fuze transceiver—have come many inquiries concerning this super-midget.

SET MAKERS ESPECIALLY INTERESTED

Since the commercial version of the "war-baby" is being produced, many set manufacturers are extremely interested in its qualities — with a view toward making radios about the size of the average wallet or package of cigarettes, miniature walkie-talkie sets and other units.

This new tube, then, is being made in a low-drain filament type and is able to operate at 1.25 volts. This takes advantage of a new, small battery developed during the war which, of course, is a further aid in the manufacture of remarkably small radio sets.

WILL BE AVAILABLE FOR ALL TYPES

Future designs of this versatile tube can be incorporated in radios ranging in size from tiny pocket sets up to deluxe receivers. It has a life of hundreds of hours, is rugged and exceptionally adaptable to operation at high frequencies.

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TECHNICANA

[*from page* 14]

tive face and held on parallel courses by an electromagnetic field, flow from the back of the photo-sensitive face to a target. Secondary emission of electrons from the target, caused by this bombardment, leaves on the target a pattern of varying positive charges which corresponds to the pattern of light from the scene being televised.

The back of the target is scanned by a beam of electrons generated by an electron gun in the base of the tube, but the electrons making up this beam are slowed down so that they will stop just short of the target and return to the base of the tube except when they approach a section of the target which carries a positive charge. When this occurs, the beam will deposit on the back of the target enough electrons to neutralize the charge, after which it will again fall short of the target and turn back until it again approaches a positively charged section.

The returning beam, with picture information imposed upon it by the varying losses of electrons left behind on the target, is directed at the first of a series of dynodes near the base of the tube: secondary electrons "knocked out" of this electrode by the bombardment strike a second dynode, and this process continues, with the strength of the signal multiplying at each stage until it reaches the signal plate and is carried out of the tube through an external connection.

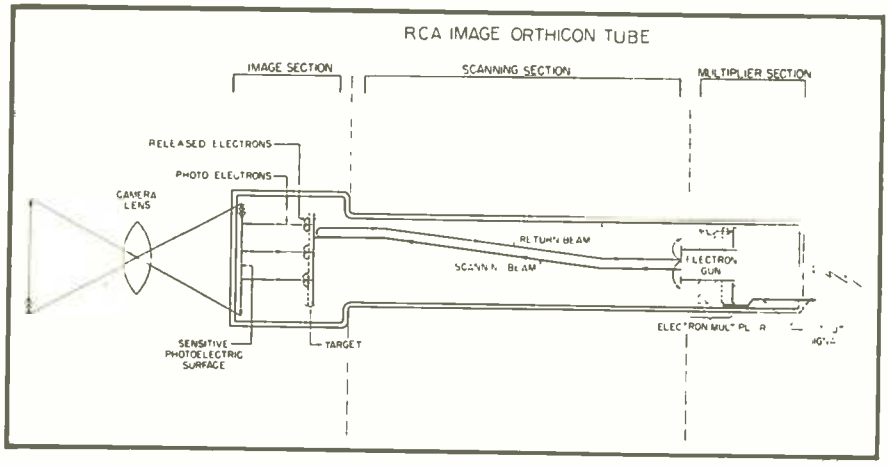

Figure 3

BOOK REVIEWS

Elementary Engineering Electronics, by Andrew W. Kramer, published by The Instruments Publishing Co., Inc., Pittsburgh, Pa, 340 pages, cloth binding.

The material in this book originally appeared as a series of articles published in "Power Plant Engineering". The author explains in simple language and with the use of elementary mathematics, fundamental principles of electron tubes and their applications in industry. The text is particularly directed toward instrumentation. Although the author states in his preface that the book is directed to electrical and mechanical engineers and operators in industrial establishments, the text can be readily understood by anyone with a working knowledge of practical electricity.

The text explains in simple terms how electron tubes function and how their characteristics may be adapted to industrial use. It begins with a simple explanation of the nature of electricity and proceeds to explain the action of the common types of tubes in commercial use. The liberal use of mechanical and hydraulic analogies is used to explain tube characteristics.

There are 24 chapters with 259 illustrations and a 6 page index. Some of the material covered is:

- The two-element tube
- Triode amplifiers
- Ionization
- Thyratrons
- Oscillators
- Neutralization
- Tetrodes
- Pentodes
- Phototubes
- Electromagnetic Radiation
- Photovoltaic Cell
- Dynatrons
- Mercury Arc Rectifiers
- Cold Cathode Tubes
- Cathode Ray Tubes

The concluding chapter, which deals with feedback, is particularly well done although somewhat brief. There are several references and citations but it is this reviewer's opinion that a more elaborate bibliography would have been

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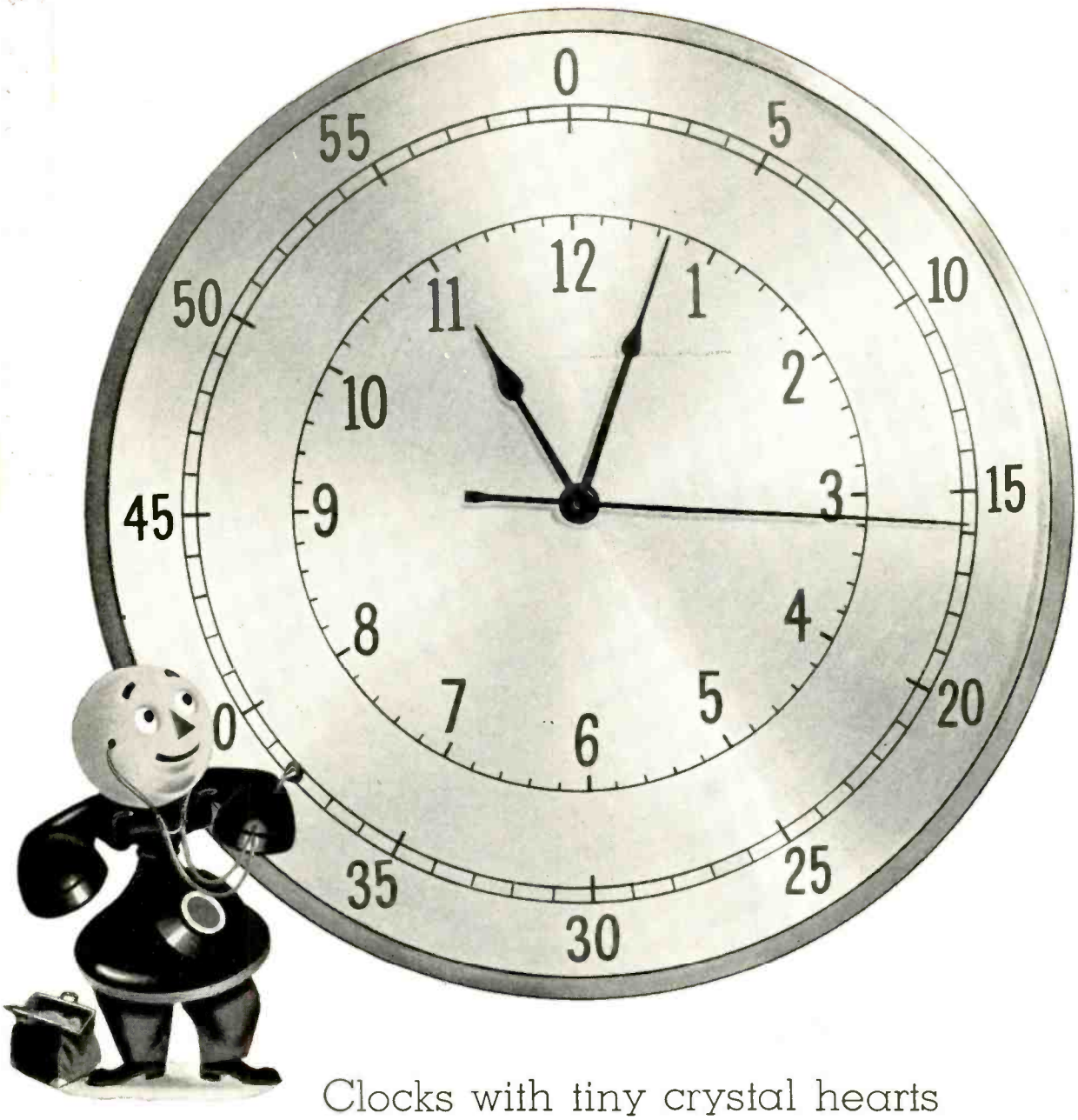

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Precise time measurements may seem a far cry from Bell System telephone research, but time is a measure of frequency, and frequency is the foundation of modern communication, whether by land lines, cable, or radio.

These clocks are electronic devices developed by Bell Laboratories, and refined over years of research. Their energy is supplied through vacuum tubes, but the accurate timing, the controlling heart of the clock, is provided by a quartz crystal plate about the size of a postage stamp.

These crystal plates vibrate 100,000 times a second, but their contraction and expansion is submicroscopically small—less than a hundred-thousandth of an inch. They are in sealed boxes to avoid any variation in atmospheric pressure, and their temperatures are controlled to a limit as small as a hundredth of a degree.

Bell Laboratories was one of the first to explore the possibilities of quartz in electrical communication, and its researches over many years enabled it to meet the need for precise crystals when war came. The same character of research is helping to bring ever better and more economical telephone service to the American people.

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appreciated by many readers. It is seldom indeed that the reader of elementary texts is not particularly interested in some particular aspect of a book which he might wish to pursue further. Here, a comprehensive bibliography can be most helpful.

This book is written in an interesting and easily readable style. It is practical and up to date, and appears to be free of errors. The material is presented in logical sequence and in each case the principle of action is clearly explained before a discussion of application is attempted. It is highly recommended to any reader interested in the particular field it covers.

Inside the Vacuum Tube, by John F. Rider. Published by John F. Rider, Publisher, Inc., 404 Fourth Ave., New York 16, N. Y. 424 pages, 8¾ x 5⅜ inches. Price $4.50

This text on vacuum tubes represents a new and interesting departure from the conventional treatment of the subject. It has been written to provide a firm foundation of elementary theory of vacuum tube operation so that students may proceed to more advanced texts with a clear conception of what goes on in tubes. The author has chosen to present the theory through a discussion of electrostatic fields, and this difficult approach is made interesting and understandable to the student by means of unusual drawings and captions, and simply written text material. Thus the usual dry and unpalatable physical discussions have been avoided, yet an accurate presentation of electron physics pertaining to vacuum tube operation is secured. After these fundamentals have been firmly established, the characteristics and functions of tubes are discussed along more conventional lines.

The book consists of 15 chapters and an appendix giving general plate voltage-plate current characteristic curves with a typical load line for triodes, tetrodes, and pentodes, as well as a complete list of letter symbols used in vacuum tube circuit analysis. The first four chapters deal with electrons, electron emission, movement of charges, space charge and plate current. A discussion of the fundamentals of tube characteristics follows, then diode and triode structures and operation are covered. Dynamic characteristics are then taken up. Voltage and power amplifiers, cathode circuits, miscellaneous vacuum tubes are treated in other chapters.

Three anaglyphs, which show in three-dimensional form pictures that convey more clearly ideas otherwise difficult to understand, are another effective feature of this book.

Mathematical formulae are given, and where their comprehension requires a knowledge of advanced math, simple

[*see page* 59]

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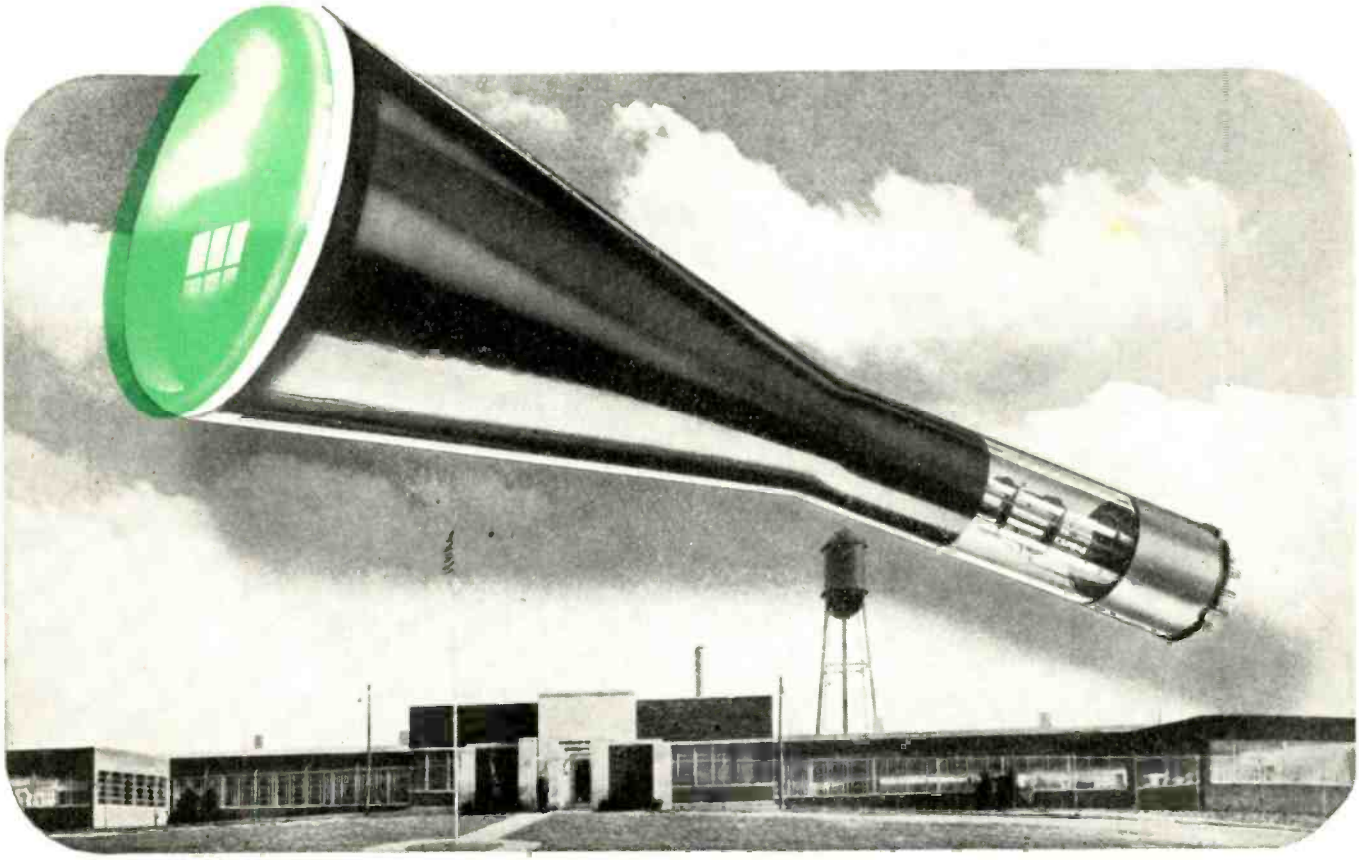

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NOISE FIGURES Of Microwave Receivers

W. G. HAWKINS

Sources of receiver noise and methods of measuring the relative sensitivity of microwave receivers are described

WARTIME APPLICATIONS of radio, particularly in the microwave spectrum, have led to an intensive study of receiver design.

Engineers under the pressure of space, weight and power requirements have had to study their circuits from a different viewpoint than they previously used. In prewar days, in order to meet competition, the emphasis had been placed on obtaining maximum performance per dollar of cost. Now the engineer found himself in the unique situation of not having to worry about costs. Instead he was asked to design the most efficient circuits possible with the emphasis placed on maximum performance and reliability consistent with specified power, size and weight allotments. By careful study and application of principles already known but not generally used, and through the development of radically new circuits and improved tubes he was able to meet the demands and, in so doing, advanced immeasurably the techniques of receiver design.

Receiver Sensitivity

One of the major problems confronting the receiver engineer was that of obtaining the maximum possible sensitivity. Because sensitivity is ultimately limited by the amount of noise present at the receiver output this meant a study of the sources of noise and the design of circuits and tubes with the least inherent noise. In prewar days commercial radio operation had been confined in large part to frequencies below fifty megacycles. In this frequency spectrum atmospheric disturbances and man-made interference are usually of a much higher level than noise generated in the receiver itself. Consequently there was no economic justification for designing receivers with extremely low inherent noise.

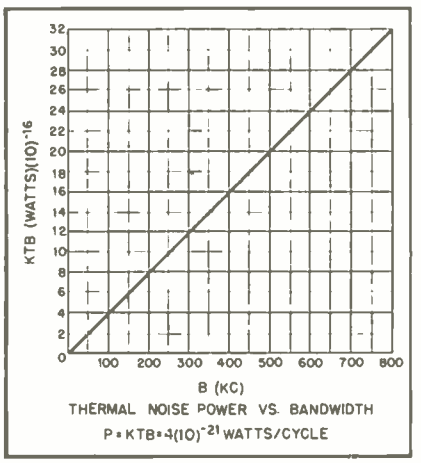

Fig. 1. Graph of thermal noise power vs. bandwidth

With the advent of v-h-f and microwave transmission fostered by war needs this situation changed. At these frequencies there is little or no outside noise. The need and justification for study of inherent noise and development of low-noise circuits and tubes was obvious and urgent. If the receiver designer could build an additional 3 db of sensitivity into his receiver this was exactly the equivalent in system performance of doubling the transmitter power and was much more economical of size, weight, and power-supply requirements.

As a result of these facts much engineering time and talent was directed upon the problem of increasing receiver sensitivity. Investigations progressed rapidly. The major sources of receiver noise, such as thermal agitation noise, tube shot noise, and transit-time grid loading, had been known for some time,[1] but due to their relative economic unimportance at the lower frequencies not much work had been undertaken to minimize them. Now, however, new tubes and circuits were developed rapidly. To name only a few developments that enabled increased sensitivity, the use of neutralized triode and grounded grid amplifier circuits, the development of miniature tubes having high mutual conductance, low plate noise and grid loading, and the perfection of mismatching techniques, all contributed to the art of receiver design.

[1]Radio Engineering Handbook, 1st edition. Terman.

Noise Figure

During this period a new method of stating the relative sensitivity of receivers, called the noise figure (F), came into general use. Expressed in either power ratio or db, it is a comparison of the amount of noise present in the receiver to that present in the ideal or perfect receiver having the same bandwidth.[2]

The relationship between noise figure, bandwidth and sensitivity of a receiver are given by

$$P_n = FKTB \qquad (1)$$

where P_n is the effective noise power in watts referred to the receiver input
F is the noise figure in power ratio
K is Boltzmann's constant, $1.374(10)^{-23}$
T is the ambient temperature in degrees Kelvin, and
B is the noise bandwidth of the receiver in cycles.

Figure 1 is a graph of KTB vs. B based on an ambient temperature of 20° C, which is convenient for rapid calculations. The curve may be extrapolated if desired. For most purposes it is reasonably accurate to use the receiver bandwidth at the 3 db down points as the noise bandwidth.

Although noise figure has the same meaning and value in any type of re-

[2]Noise Figures of Radio Receivers, by H. T. Friis. *Proc. I. R. E.*, July 1944. Vol. 32, p. 419.

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ceiver, its measurement and method of use in determining absolute sensitivity differs slightly at microwaves from lower frequencies. This is solely because of the calibration of the signal generators in common use. All microwave signal generators are calibrated in power whereas conventional signal generators are calibrated in voltage. Thus we must of necessity measure the power sensitivity of microwave receivers and the voltage sensitivity of conventional receivers. However, the noise figure is independent of the method of measurement and is equally indicative of the degree of perfection of a microwave receiver and a broadcast receiver.

It must be pointed out, though, that noise figure describes the relative noisiness of only the r-f and i-f portions of the receiver ahead of the demodulator and is entirely independent of the relative signal-to-noise improvements obtained after demodulation through the use of the various types of modulation. All noise figure measurements must be made with an unmodulated carrier and the output meter used in the measurements must be so connected as to be linear with signal strength. This means that if the detector is used as a carrier rectifier in an AM receiver for output indication it must operate linearly. In an FM receiver measurements must be made preceding the limiter. If rectified first limiter grid current is used as the indicator the same precautions must be taken as with an AM detector. It is equally important that the noise figure measurements include all r-f bandwidth determining circuits.

Noise Figure Measurements

To illustrate the measurement of noise figure at conventional frequencies assume that we have a low-frequency broadcast receiver or the i-f strip of a microwave receiver connected as shown in *Fig. 2*. *"A"* is a standard unmodulated signal generator calibrated in microvolts, *"B"* is the receiver under test, and *"C"* is the meter used for output indication. R_a represents the impedance from which the receiver is designed to operate and consists of the generator output impedance plus any necessary additional resistance. E_n represents the noise voltage due to R_a and is present whether the signal generator is turned on or off. E_s represents the signal voltage generated by the generator. It is assumed that the receiver output is linear with input, which means that any AVC must be disabled. The type of meter to use at *"C"* is optional. A low-level r-f wattmeter or r-f VTVM may be used or a d-c VTVM may be connected to read the rectified carrier voltage.

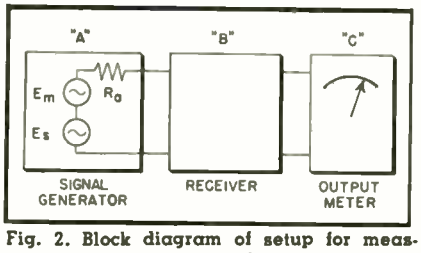

Fig. 2. Block diagram of setup for measuring noise figure

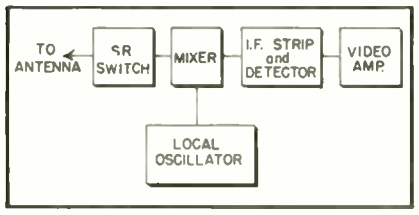

Fig. 3. Block diagram of microwave receiver

The method of sensitivity measurement is as follows: With the signal generator turned off there will be a reading at "C" due to E_n and the noise generated in the receiver itself. With the signal generator turned on, adjust its output to just equal noise power, as indicated by a doubling of the wattmeter reading or a 1.4:1 increase in voltmeter reading. The signal and noise voltages are then equal. Noise figure can now be calculated from

$$F = \frac{E_s^2}{E_n^2} = \frac{E_s^2}{4KTBR_a} \qquad (2)$$

To illustrate, let us assume that we are testing a receiver having a bandwidth of 200 kc designed to work from a 300-ohm resistance. Then R_a must equal 300 ohms. If the generator output impedance is 50 ohms, then 250 ohms must be added in series between the generator output and the receiver input terminals. Assume that we are using an r-f VTVM at "C" and that its reading due to noise alone (signal generator connected but not turned on) is 2 volts. We must then adjust the signal generator output until "C" reads 1.4 × 2 or 2.8 volts. Suppose that in order to do this the signal generator output E_s must be 3 microvolts. The sensitivity of the receiver is 3 microvolts for signal equal to noise and its noise figure from Equation 2 and *Fig. 1* is

$$F = \frac{(3)^2\,(10)^{-12}}{(4)\,(8)\,(10)^{-16}(300)} = 9.38 \text{ (or 9.7 db)}$$

Note that the denominator of Equation 2 represents the sensitivity of a perfect receiver. In the example given a perfect receiver would require $\sqrt{(4)\,(8)\,(10)^{-16}(300)}$ volts or 0.98 microvolts to double noise.

As stated previously, sensitivity measurements at microwaves differ only in that generators are calibrated in power. Actually, they are calibrated in terms of power delivered to a matched load. The test setup used would be basically the same as at lower frequencies but the measurements taken would give the signal power required to equal noise.

Noise Figure at Microwaves

A block diagram of a typical microwave receiver is shown in *Fig. 3*. Since the noise output of the receiver is now influenced by several components, let us study the noise figure of a system made up of several stages, each of which has its own noise figure.

It can be shown[3] that for networks in cascade the overall noise figure is given by

$$F_t = F_1 + \frac{F_2-1}{G_1} + \frac{F_3-1}{G_1G_2} + \cdots + \frac{F_n-1}{G_1G_2\ldots G_{n-1}} \qquad (3)$$

where F_t is the overall noise figure in power ratio
F_1 is the noise figure of network No. 1
G_1 is the power gain of network No. 1
etc.

It is apparent from this equation that for networks in cascade the first one is the most important and the noise contributions of the following stages become significant only if the stage gains are very small. Unfortunately, in a microwave receiver the first networks actually have losses and consequently several components contribute to the noise figure of the receiver. Those stages that do not enter into the picture are the Send-Receive mechanism, the mixer, the local oscillator, and the i-f strip.

The noise figure of a linear passive network is

$$F = \frac{T_n}{G_n} \qquad (4)$$

where T_n is the *ratio* of the effective noise temperature of the network to ambient temperature and G_n is the power gain of the network. For example, the noise figure of a resistive network whose effective noise temperature is the ambient temperature and having a power gain of 0.5 (3 db loss) would be $\frac{1}{0.5}$ or 2.

The noise figure of the Send-Receive network is then $\frac{T_{SR}}{G_{SR}}$ and since T_{SR} is usually unity this reduces to $\frac{1}{G_{SR}}$ where G_{SR} is the power gain (actually loss) in the Send-Receive network. The noise figure of the crystal mixer is $\frac{T_{xtal} + T_{LO}}{G_{xtal}}$ where T_{LO} represents the noise temperature of the local oscillator current flowing in the crystal, T_{xtal} is the noise temperature of the crystal, and

[*see page* 63]

[3] A Note on Definitions of Noise Figure in Radio Receivers, by MacDonald. *Philosophical Magazine and Journal of Science*, (London), June 1944. Vol. 35, No. 245, p. 386.

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Impedance Measurements With The Cathode-Ray Oscilloscope

Describing a new and simple method of measuring impedances with a scope

WILLIAM VISSERS, JR.

Engineer, Johns Manville Corp

AN EASY AND ACCURATE method for the measurement of impedance is of prime importance in many fields of engineering. Although many methods are available, the specialized equipment often involved, combined with frequency limitations of some apparatus, led to the development of a method using the cathode ray oscilloscope and a known impedance standard. It was realized that many impedances encountered are grounded at one end and various reasons prevent their electrical disconnection. Using the method described, grounded impedances can be measured as readily as ungrounded ones. Where the impedance measured is very high, a method of correcting for the input impedance of the oscilloscope has been developed. The equations used have been evolved using voltage ratios rather than actual values to eliminate the need for voltage calibration of the cathode ray tube. This last named feature contributes to rapidity and ease of measurement.

An important property of a cathode ray oscilloscope is its ability to measure phase difference between two voltages of the same frequency. *Figure 1* shows two such voltages applied to the deflecting plates of a scope and the resulting Lissajous figures as both the phase angle and relative amplitude of the voltages are varied. The phase relationship of the voltages is given by the equation:

$$\text{Sin } \phi = \pm \frac{Y}{V} \qquad (1)$$

where V and Y have values shown in *Fig. 1*.

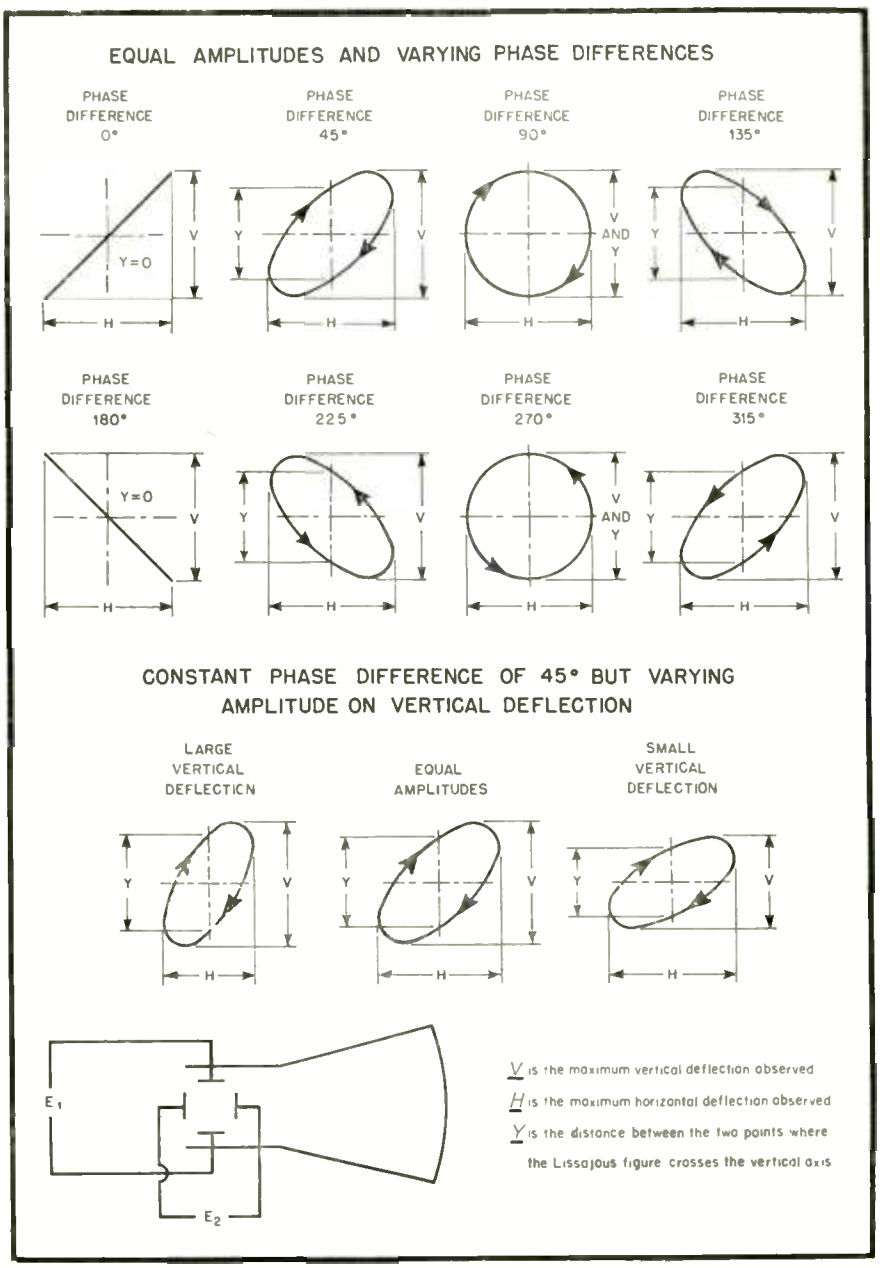

Fig. 1. Representative Lissajous figures resulting from differing phase relationships between voltages E_1 and E_2 when $E_1 = E_2$, and for constant phase difference of 45° when applied voltages vary in amplitude.

Measuring Method

It is important to realize that the phase relationship expressed by equa-

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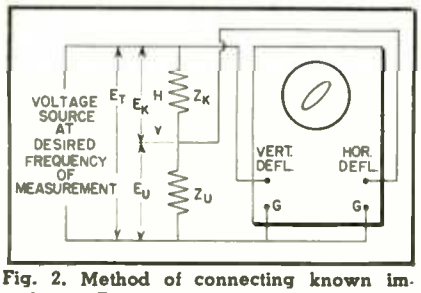

Fig. 2. Method of connecting known impedance, Z_k, and unknown impedance, Z_u, to use the measuring method described

tion 1 is independent of the relative amplitude of the two voltages involved. The quadrant can be worked out from the direction in which the spot travels and the orientation of the major axis of the ellipse. In the measuring method described the phase relationship can readily be found by drawing a vector diagram of the voltages involved, or by the insertion of a known reactance in series with the unknown impedance and noting the effect on the phase shift. In all measurements the intersection of the vertical and horizontal axes from which the measurements V, H, and Y (see *Fig. 1*) are taken must coincide with the center of the Lissajous figure.

Impedances are generally encountered in the form $R \pm jX$, $+jX$ denoting an inductive reactance, and $-jX$ a capacitive reactance. Electrically, such an impedance is shown as a two-terminal network, and it is usually a physical impossibility to measure directly the voltage across R and X to determine their phase angle.

In the method described the known and unkown impedances, Z_k and Z_u respectively, are connected to the cathode ray oscilloscope as shown in *Fig. 2*.

From *Fig. 2* it can be seen that $E_t = E_k + E_u$, and that Z_u and Z_k are in series, having the current I common to both impedances. The angle ϕ is found as shown in *Fig. 1*, and the ratio E_t/E_u determined from the Lissajous figure on the scope. In actual operation when amplifiers are used in both sets of plates of the cathode ray tube it is first necessary to apply the same voltage to both vertical and horizontal deflecting circuits and adjust the gain controls so that both circuits show the same deflection. In that case $E_t/E_u = k\left(\frac{V}{H}\right)$ where the constant k is equal to one. When no amplifiers are used it may be found that one set of deflection plates is slightly more sensitive than the other set. The coefficient k for this case can be found by dividing the horizontal deflection by the vertical deflection when the same voltage is applied to both sets of plates. When measuring an impedance as shown in *Fig. 2*, the true value of E_t/E_u will be equal to the coefficient k times the ratio V/H, or $E_t/E_u = K\left(\frac{V}{H}\right)$. For many oscilloscopes this correction factor will be so small as to be safely neglected.

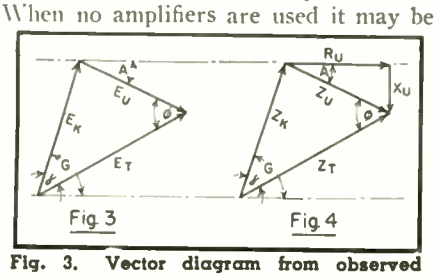

Fig. 3. Vector diagram from observed measurement data on scope. Fig. 4. Showing how value of unknown impedance Z_u may be determined graphically.

The phase angle of the known impedance is given as angle G, and with the information obtained it is possible to draw the vector diagram shown in *Fig. 3*. Arbitrary scalar values are chosen as only the ratio E_t/E_u is known, and not absolute voltage values.

From the geometry of *Fig. 3*,

$$E_k = \sqrt{E_t^2 + E_u^2 - 2E_tE_u \cos \phi} \quad (2)$$

Dividing through both sides of equation

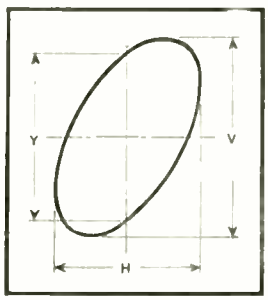

Fig. 5. Resulting Lissajous figure when V/H = 1.43 and Y/V = .83

2 by I, which is common to both Z_k and Z_u, gives equation 3.

$$\frac{E_k}{I} = \sqrt{\left(\frac{E_t}{I}\right)^2 + \left(\frac{E_u}{I}\right)^2 - 2\left(\frac{E_t}{I}\right)\sqrt{\left(\frac{E_u}{I}\right)}\cos \phi} \quad (3)$$

But $E_k/I = Z_k$, $E_t/I = Z_t$, $E_u/I = Z_u$, and from circuit considerations $Z_t = Z_u(E_t/E_u)$. Substituting these values in equation 3 gives equation 4.

$$Z_k = \sqrt{Z_u^2\left(\frac{E_t}{E_u}\right)^2 + Z_u^2 - 2Z_u^2\left(\frac{E_t}{E_u}\right)}\cos \phi \quad (4)$$

which, when solved for Z_u, gives equation 5.

$$Z_u = \frac{Z_k}{\sqrt{\left(\frac{E_t}{E_u}\right)^2 + 1 - 2\left(\frac{E_t}{E_u}\right)\cos \phi}} \quad (5)$$

Attention must be paid to the value of ϕ, because under some conditions when Z_k has a reactive component opposite in sign to the reactive component of Z_u, ϕ can have a value between 90° and 180°. The cosine of angles in this range is negative, and this change in sign from angles which lie between 0° and 90° must not be neglected in using the equations derived. It is advisable to draw a vector diagram to avoid such an error, and also as a check on possible mistakes in calculation. If desired the entire solution can be done graphically. The values of Z_k and Z_u are the absolute values of these quantities.

In the series circuit of *Fig. 2*, I is common to both Z_k and Z_u, and as $E_t = E_k + E_u$, then $Z_t = Z_k + Z_u$. From this relationship a new and exactly similar vector diagram can be drawn as shown in *Fig. 4*.

From the geometry of *Fig. 4*,

$$\text{Sin } \alpha = \frac{Z_u(\sin \phi)}{Z_k}$$

and

$$\angle A = \angle \alpha + \angle \phi - \angle G$$

$$R_u = Z_u(\cos A), \quad X_u = Z_u(\sin A)$$

R_u and X_u are the desired values determining Z_u completely.

As a numerical example: Measurement made directly on scope plates without amplifiers. The correction factor was found to be .94, and the known impedance had a value of 2580 ∠ 76°, which showed it was inductive, and Angle $G = 76°$. The Lissajous figure obtained on the scope is shown in *Fig. 5*, where it was found that $V/H = 1.43$, and $Y/V = .83$.

The vector diagram for the preceding numerical example is shown in *Fig. 6*.

$$Z_u = \frac{Z_t}{\sqrt{\left(\frac{E_t}{E_u}\right)^2 + 1 - 2\left(\frac{E_t}{E_u}\right)\cos \phi}}$$

$$Z_u = \frac{2580}{\sqrt{(1.35)^2 + 1 - (2)(1.35)(.56)}} = 2250$$

$$\text{Sin } \alpha = \frac{(Z_u)(\sin \phi)}{Z_k} = \frac{(2250)(.83)}{2580}$$

$$= .7273, \quad \alpha = 46°30'$$

$$A = \alpha + \phi - G = 46°30' + 56° - 76° = 26°30'$$

$$R_u = Z_u \cos A = (2250)(.892) = 2008$$

$$X_u = Z_u \sin A = (2250)(.445) = 1010$$

$$Z_u = 2008 - j1010$$

When a pure resistance is used as the known impedance, Angle G is equal to 0°, and $A = \alpha + \phi$.

$$Z_u = \frac{R_k}{\sqrt{\left(\frac{E_t}{E_u}\right)^2 + 1 - 2\left(\frac{E_t}{E_u}\right)\cos \phi}} \quad (6)$$

$$R_u = (Z_u)(\cos A) \quad \text{sin } \alpha = \frac{(Z_u)(\sin \phi)}{R_k}$$

$$X_u = (Z_u)(\sin A)$$

The vector diagram is shown in *Fig. 7*, where the unknown impedance is inductive.

When a pure reactance is used as the known standard, Angle G is equal to 90°, and Angle A is equal to $\alpha + \phi - 90°$,

[*see page* 61]

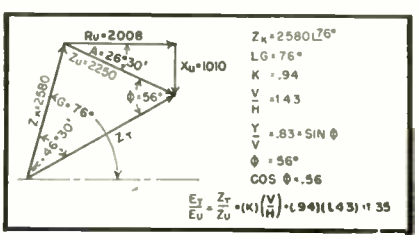

Fig. 6. Resulting vector diagram for the Lissajous figure shown in Fig. 5 when Z_k has the value shown

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Irregularities In RADIO TRANSMISSION

OLIVER PERRY FERRELL

More interesting data on transmission vagaries

PART 2

NO POST-WAR DISCUSSION of the phenomena and irregularities in radio transmission would be complete without mention of the mysterious echo returns and false targets encountered in radar operation. Here in a new field, limited only by the lowest obtainable thermal background noise in the radar receiver, one may justifiably expect many eccentricities in radio wave propagation.

Practice has conceded much to theory for wispy, low amplitude echoes and false targets on the lower frequency (below 150 mc) radar units became so troublesome that a new term, generalized to include all echoes except those from aircraft, ship or permanent structures has been coined — "anomalous propagation"!

"Anomalous Propagation"

Actually, the subject of "anomalous propagation" has brought to light no startling new VHF radio transmission effects. Radio amateurs will find VHF auroral reflections and distortion on frequencies twice as high to four times as high as their 56 mc band, but little different otherwise from the way they had originally pictured it in 1938. Refraction at air mass boundaries or, technically, tropospheric discontinuity surfaces is scarcely anything new to the FM broadcast engineer. Reams upon reams have been written about air-massing bending, while Mitra,[1] Watson-Watt,[2] Colwell[3] and Friend[4, 5] had observed vertical incidences as low as 1.5 km. Friend in one of his last discussions before the Institute of Aeronautical Sciences in 1940 described an effective compact method of measuring cloud heights by minute radio wave reflections. This method was subsequently employed on "weather searching missions" flown by the U. S. Army Air Forces.

Incident at Anzio

That air-mass dielectric boundaries do exist sufficiently to completely reflect radio waves in less than several wave lengths, has been recently described by Charlotte Knight of the Air Force staff[6]:

"Late one afternoon during the critical days at Anzio, one of our radar stations (Probably an SCR516 or SCR602 on about 200 mc. *Ed.*) there picked up a number of targets up north in the mouth of the Tiber River that looked like enemy shipping. The group of ships appeared to leave the Tiber and swing out into the Mediterranean where they were tracked heading south in a semi-circle toward Anzio. Forty-three 'ships' were counted in the 'convoy' as they showed up on the radar scope.

"The word was passed on to headquarters and some Spitfires were sent to investigate. . . . they located three unknown ships shortly before dusk, while the Navy sent out some PT boats to scout around. They finally found one small enemy vessel and exchanged fire, claiming they could find nothing else.

'But the radars continued to pick up the echoes . . . at the rate of speed the ships would be expected to travel. By this time it was really getting dark, and PT reports or no PT reports, the convoy's echo was only 12 miles offshore, heading in towards Anzio. Fifth Army headquarters had not expected this sort of coup from the Germans and were frankly unprepared for it. Things were in an uproar. Most of the artillery was inland on the front lines, so the anti-aircraft boys began ripping down their sand bags on the seaward side and depressing their guns so as to be ready to fire on the attacking surface ships.

"All outfits had been alerted by 2100 hours, and in the darkness they sweated it out. Minute by minute the radar tracked the 'convoy' nearer and nearer. Just about the time the enemy guns had been expected to open fire on the vulnerable beachhead positions the first 'ship' came right over the shoreline, across the beach, directly over Fifth Army heads and on into the mountains, followed by some very inconsiderate clouds at zero elevation."

Other Incidents Of Anomalous Propagation

Similar, though probably not as dramatic, instances have been ofttimes reported in the tropics. The writer during a night air raid in China personally saw what appeared on the radar scope to be a low-flying Jap bomber orbiting over a nearby large city. When a night fighter passed through the target several times and could not see anything (microwave airborne vs. VHF G.C.I.), it was realized that reflection was occurring from the vertical column of hot air above a large fire in the city.

Anomalous propagation does not, however, always refer to echoes from wispy or inanimate objects. The Army Operational Research Group of the British Ministry of Supply has for a number of years studied echoes from birds in flight. The consternation which these migrating flocks, moving with the speed of a fast cargo steamer in heavy aircraft traffic areas, have created has been described by Lack and Varley.[7] Echoes from birds in flight were apparently first observed in England during the summer of 1941. Following similar verified observations in Malta and Gibraltar, a top secret report was made to the Allied Chiefs of Staff. Au-

[*see page 62*]

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REDUCTION OF

FRANK C. JONES

A SINGLE LOUDSPEAKER on a high-quality amplifier output usually introduces several times as much distortion as that produced by the amplifier, radio detector, or phonograph pickup unit. This condition has been tolerated and has probably done more than anything else to make people become used to radio music having a different quality from the original as played in the broadcast studios.

There are two simple ways of reducing this loudspeaker distortion to values low enough to be negligible. The solid line curve of *Fig. 1* illustrates the harmonic and frequency modulation distortion characteristics of a high-quality 12-inch dynamic loudspeaker. The peak at the low frequencies is harmonic distortion, the result of the low resonant period of the moving coil system. It can easily reach 50% distortion with a 12-inch speaker in an open-back radio cabinet, especially if used with tetrode power output tubes.

This low frequency peak distortion is low at low input power and very high at high input to the voice coil. *Figure 1* shows the distortion with ½ watt input. The dotted curve indicates the reduction in distortion obtained by using an entirely enclosed speaker compartment with an air vent slot adjacent to the speaker cone. This form of enclosure is usually called bass reflex. The vent and cabinet enclosure in effect add an additional LRC circuit out of phase with that of the loudspeaker, and if this occurs at the low frequency peak of the speaker, the response will be greatly reduced at this point and the range extended both above and below this frequency. Most of the sound energy for a portion of an octave above and below this resonant frequency is radiated by the port or vent, and this effect results in reducing the low frequency distortion by a factor as much as 3 or even 4 to 1.

Cabinet Tests

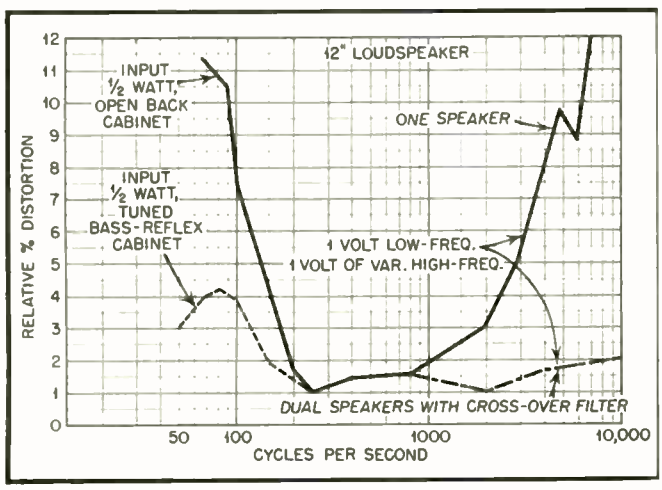
The bass-reflex cabinet should be tuned to resonance with the particular speaker to be used. This is easily done even by ear if an audio oscillator is available. Connect the oscillator to the speaker through an amplifier and run the audio frequency over the range of from 30 or 40 cycles up to 200 or 300 cycles. If the cabinet and vent sizes are correct, the amplitude of sound (at rather high sound level) will be even and the tone sound pure. Incorrect sizes or an open back cabinet will always produce a low frequency peak and the tone will sound more impure as the sound level is increased. If the cabinet is too large, the vent can be extended back into the cabinet for an inch or two with an inward lip of heavy wood. Normally the vent will have an area of at least one-half that of the round loudspeaker opening. If the cabinet is too small, this vent area may be made smaller to tune the cabinet resonance to the speaker peak. During tests, a block of wood may be held against the front of the cabinet over a portion of the vent to arrive at proper tuning (usually the cabinet size is smaller than desired).

The inside back of the enclosed speaker cabinet should be covered with sound-absorbing material such as porous celotex, layers of monk's cloth or a layer of mineral wool, to absorb the high audio frequencies radiated from the rear of the speaker cone. Nearly all sound-absorbing materials are ineffective at low frequencies, so their effect is negligible in the range of low frequency speaker and cabinet resonance.

The harmonic distortion of most moving coil speakers, large or small, is reasonably low at high frequencies, seldom being more than 2% or 3%. The main source of high-frequency distortion is known as frequency modulation of the high frequencies by a low audio frequency. The speaker will not reproduce high audio frequencies without very great distortion when the cone is moving at large amplitudes with low frequencies. The answer to this problem is to use two speakers in a dual system, one for high frequencies and one for low frequencies. The distortion shown at the high frequencies in the solid line curve of *Fig. 1*, then drops down to some value such as that of the broken line curve. It is necessary to filter the high frequencies out of the low frequency speaker and the low frequencies out of the high frequency speaker in order to gain the desired reduction of distortion.

Cross-Over Filter

A standard "constant resistance" type of cross-over filter was built and produced the results shown in *Fig. 2*. The cross-over at about 1600 cps was approximately as calculated and the dip



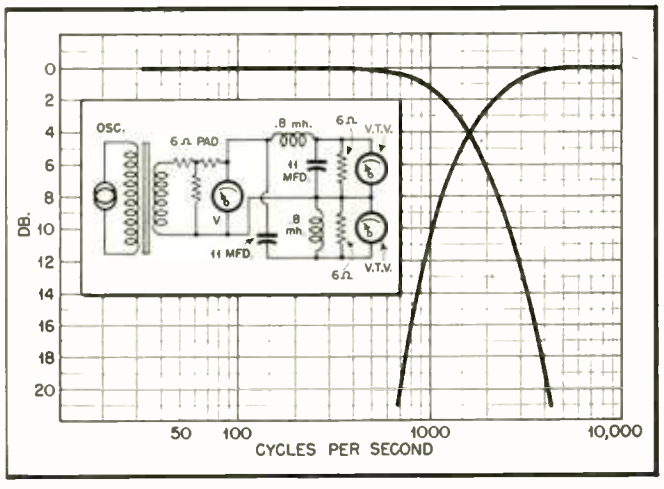


Fig. 1 (left) Distortion characteristics of high-quality 12-inch loudspeaker with (solid line) open back cabinet. Dotted curve shows reduction in distortion obtained by using bass reflex speaker and dashed curve improvement obtained by dual speakers with cross-over filter. Fig. 2. (right) Frequency response using cross-over filter with constants shown when terminated by pure resistances

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LOUDSPEAKER DISTORTION

Describing the design of cross-over filters for dual loudspeaker operation and tests of enclosures for better reproduction

at this point is nearly correct to produce constant sound output for the two speakers if their outputs are aiding. Beyond cross-over, the output of each speaker should be rapidly attenuated so the sum of their outputs will be approximately equal. The curve of *Fig. 2* was excellent but the same filter produced the results shown in *Fig. 3* when connected to two loudspeaker voice coils and a standard high quality output amplifier. The cross-over frequency is changed by the speaker moving coil inductance and the effects magnified by poor impedance match to the output amplifier.

A good tetrode feedback amplifier or triode amplifier with either push-pull or parallel tubes, should always "look into" a load impedance of at least 2 or 3 times that of the tube impedance in order to minimize harmonic and cross-modulation distortion in the amplifier. This means that the cross-over filter is not terminated properly on either side. Similar types of cross-over filter with dissimilar coils and condensers using complementary high and low pass sections in either series or parallel, were tested, and the same poor results obtained as shown in *Fig. 3*.

Next, a simple cross-over network shown in *Fig. 4* was set up. The solid line curves were for resistance load and the dotted curves for loudspeaker loads. This filter was likewise considered unsatisfactory.

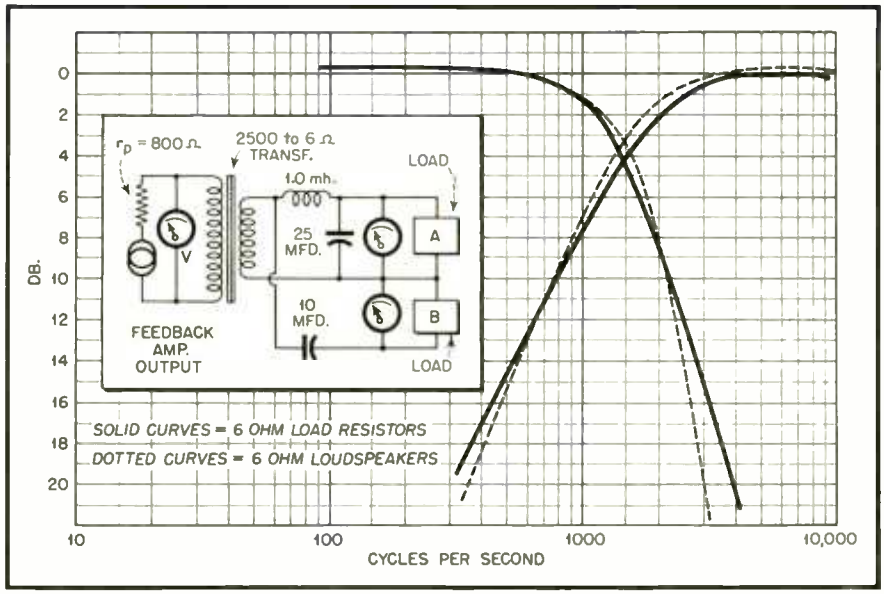
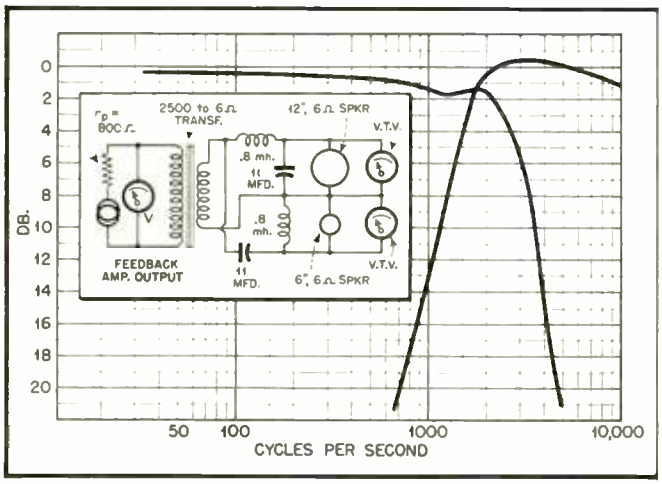


Fig. 5. Improved cross-over filter curves resulting when voice coil inductances are considered in filter design

These results led to the development of the cross-over filter shown in *Fig. 5*, which takes into account the voice coil inductance as well as its resistance in the high and low pass filter. The cross-over point at about 1500 cps. with resistor loads, remains about the same with loudspeaker loads on the filter outputs. The loudspeaker voice coil inductance aids in making the cut-off sharper as can be seen by comparing the solid lines to the dotted lines in *Fig. 5*.

Several filters for combinations of from 12 ohm to 3 ohm voice coil speakers were set up and equally satisfactory curves obtained for various cross-over frequencies between 1000 and 4000 cps. A cross-over at 1500 to 2000 cps seemed to work out most satisfactorily from several viewpoints. If the load impedances are both doubled, *Fig. 5*, the inductance of the "tweeter", or high frequency speaker, was more important than the resistance and a 2½ or 3 ohm voice coil 4 or 5 inch speaker could be



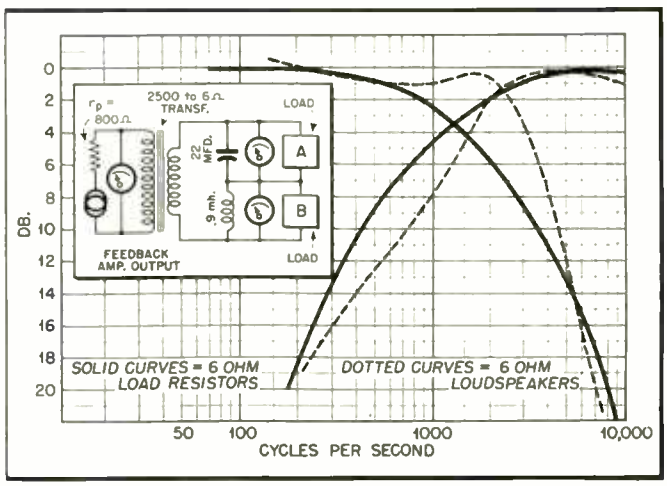


Fig. 3. Frequency response of cross-over filter of Fig. 2 showing poor results obtained when loudspeaker voice coils are substituted for resistances. Fig. 4. Response curves for cross-over network with constants shown for resistance (dotted curve) and loudspeaker loads. This filter is likewise considered unsatisfactory, even worse than that of Figures 2 and 3

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used satisfactorily with a 6 ohm 12 inch "woofer" or low frequency speaker. However, two "woofers" series aiding required two tweeters in series in order to keep the ratio of moving coil inductances constant.

Constructional Data

Several condenser manufacturers produce 50 volt, 5 mfd paper condensers which are low priced and suitable for cross-over filters. Do *not* use electrolytic condensers of any kind in cross-over filters. A 1 millihenry, low resistance choke can be made by winding ¼ lb. (40 or 50 feet) of No. 18 DCC or DSC wire on a wooden form having a winding length of 1 inch and a mean coil diameter of about 1 inch. Standard 25¢ spools of No. 18 wire can be used for this purpose, either jumble or layer wound. The inductance of such a coil will be about ½ mh, and this can be raised to 1 mh by drilling the wooden core hole out to ½" diameter and inserting ⅜" × 1½" iron laminations taken from the end of a midget filter choke. The filter will function satisfactorily with an inductance of from ¾ to 1½ mh with an optimum value at about 1 mh. A ½ lb. spool of No. 16 magnet wire with two or three laminations in its core should be even more effective as the filter coil since its d-c resistance would be quite low. Care should be taken to be sure that each lamination has a good coat of oxide or insulating varnish all over it, since two laminations shorted together electrically or magnetically will greatly reduce the coil *Q* and make the cut-off curves less steep. The coil and core should be wax impregnated to prevent "talking" up like a tiny loudspeaker.

Figure 6 shows the new cross-over filter set up for two six-ohm voice coil speakers, with the equivalent high and low pass filter circuits. The constants shown are not theoretically perfect but do function satisfactorily in actual practice.

The resistive component of the impedance curves, as measured with a Maxwell Bridge, rises at high frequencies (see *Fig. 7*). The increase starts at from 500 to 1000 cycles and may reach a value of about twice at 10,000 cycles. When setting the cross-over frequency, the resistive component of the "woofer" speaker is apparently of more importance than that of the tweeter. A variation of 2 to 1 could be tolerated in the tweeter but a variation of 25% in the type of large speakers seemed to be noticeable on the filter constants. The filter shown will function reasonably well with woofers rated at 6 to 8 ohms and tweeters of 3 or 6 ohms, preferably the latter.

An empirical method of setting up a cross-over filter of the type shown in

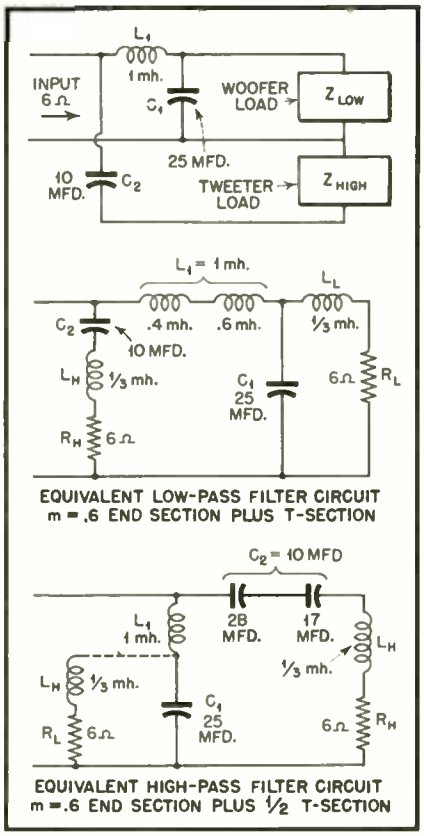

Fig. 6. Cross-over filter design for two six-ohm voice coils with equivalent high and low pass filter circuits

Fig. 6 for loudspeakers of other than "6 ohms" is to take the ratio of the large speaker such as 12 to 6 equals 2. Multiply the filter inductance by 2 and divide the capacities by 2 in this example. If the tweeter voice coil impedance is not approximately equal to that of the woofer (more than 2 to 1 ratio), it would be desirable to use a small auto-transformer to step its impedance up or down to the desired value. This transformer on a small closed core would not need more than 100 to 150 turns of 18 wire to work effectively for frequencies between 1000 and 15,000 cps.

A typical example of dual speaker service consists of two 8-inch speakers with cross-over filter and a bass-reflex cabinet. The distortion drops from over 50% at moderate room volume to less than 5% over most frequencies. It is not necessary to use special "woofer" and "tweeter" speakers to realize considerable improvement in any radio or phonograph set. A standard 6-inch and 12-inch speaker will make a good high fidelity system capable of going up to 8000 or 10,000 cycles. Some small speakers will give good output up to 12,000 or even 15,000 cycles per second. A dual speaker system with an additional 5500 cycle cut-off filter can be used with any sized speakers to greatly improve the quality of standard broadcast receivers or ordinary scratchy shellac records in phonograph combinations. The cross-over filter shown in *Figs. 5* and *6* can be made easily and installed in the speaker cabinets. The regular amplifier output transformer should be used with no change in output taps. The cross-over filter serves to automatically connect in the proper speaker for each band of audio frequencies, without appreciably altering the load impedance connected to the audio amplifier.

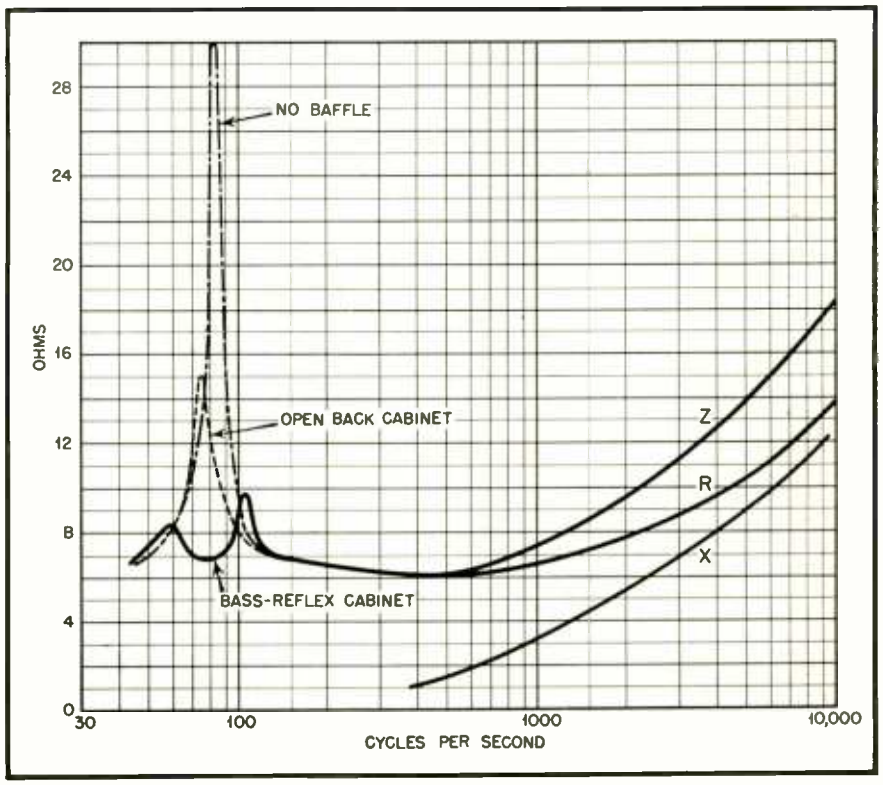

Fig. 7. Typical curves of 12-inch speaker showing variation of impedance with frequency

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Types and Applications of Microwave Frequency Meters

WILLIAM J. JONES

A discussion of recently developed frequency measuring instruments and their use at ultra-high and super-high frequencies

AT ORDINARY RADIO FREQUENCIES (up to about 300 mc) a resonant circuit may consist of a coil and capacitor. At microwave frequencies the components of such a resonant circuit become so small that they are not practical to use or construct. In addition, there are losses associated with a coil and capacitor which become great as the resonant frequency of the circuit reaches into the microwave region.

New types of frequency measuring equipment and new techniques necessary for the proper application of these new frequency measuring equipments. have been developed for use in the ultra-high frequency (300-3000 mc) and super-high frequency (3000-30,000 mc) bands. These instruments for use at microwave frequencies may be divided into three general types:

1. Coaxial-line
2. Cylindrical-cavity
3. Transition

The advantages of these types of frequency measuring instruments are as follows:

a. The dielectric losses are lower.
b. Radiation losses are reduced to a point which may be considered as zero.
c. It is possible to attain very high values of Q.
d. One can construct simple and rigid instruments of physically acceptable size which are extremely stable and easy to use.

Coaxial-Line Frequency Meters

The use of Lecher lines in frequency measuring or frequency determining

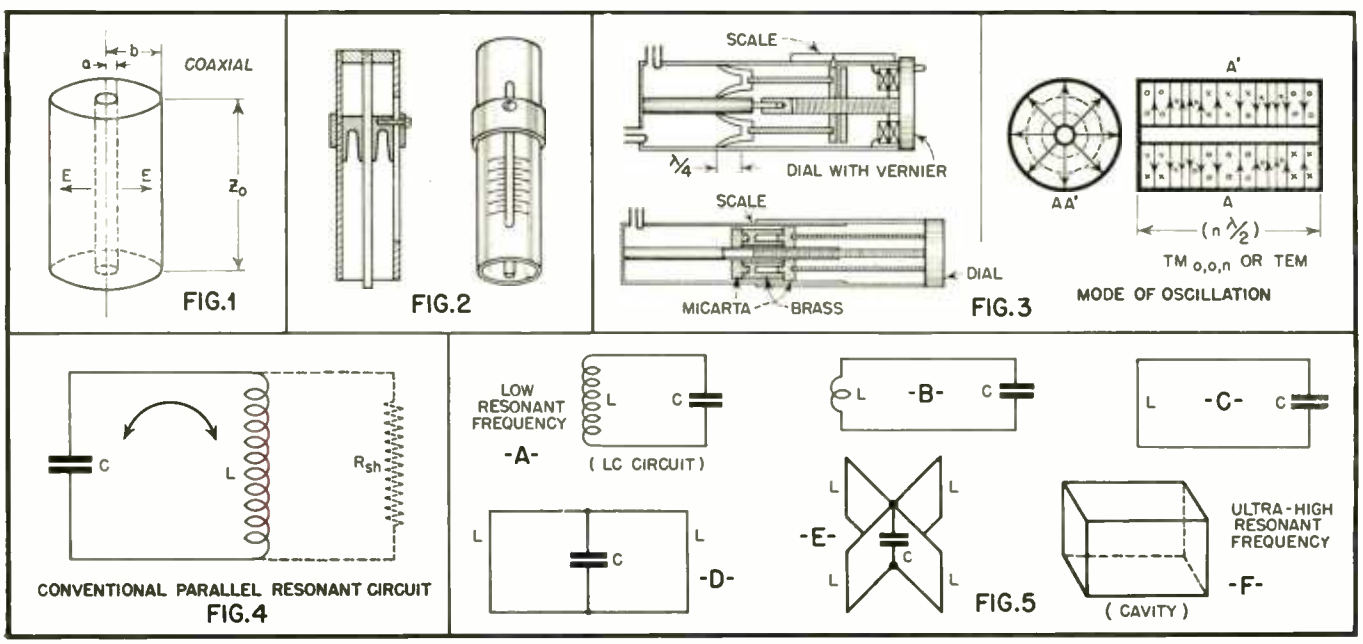

Fig. 1. Notation used in coaxial equations. Fig. 2. Basic type of coaxial wavemeter. Fig. 3. (left) Vernier control of shorting element provides higher accuracy; (right) principal mode components are perpendicular to direction of propagation. Fig. 4. When excited by a varying field, LC circuit is parallel resonant. Fig. 5. Evolution of UHF cavity resonator form LC circuit

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circuits in the VHF (30-300 mc) band has been fairly common practice. The same basic principles are employed in the coaxial-line type of frequency meter but the problems of radiation, coupling and the proximity effects of foreign objects are avoided by the use of coaxial lines. The coaxial-line type of instrument may be used with a reasonable amount of convenience up to frequencies as high as 10,000 mc.

There are an infinite number of modes, or field configurations, in which energy can be transmitted through concentric lines. This is objectionable if the line is to be used to measure frequency. The line is restricted in size so that only the coaxial (principal) mode can exist. The higher modes cannot propagate.

The principal mode is the one in which both the electric and magnetic field have only components that are normal to the direction of propagation. Any modes that are excited by junctions, discontinuities, etc., will diminish exponentially with distance and draw no real power.

The limiting wave length at which the first higher mode becomes possible may be obtained from the formula

$$\lambda = 2\pi \frac{b+a}{2}$$

where b is the inner radius of the outer conductor and a is outer radius of the inner conductor, as illustrated in *Fig. 1*. If the dimensions are in centimeters, the wave length will be in centimeters. If the line is short circuited at one end, and open at the other, resonance at a

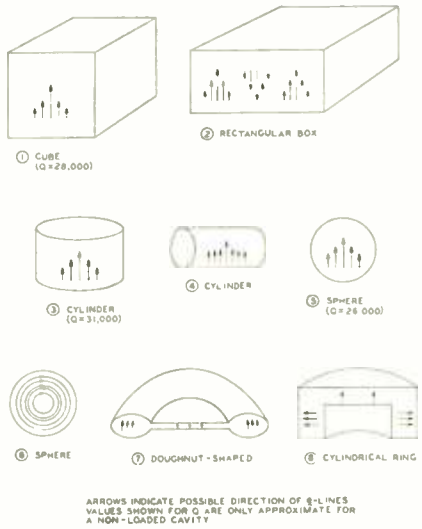

Fig. 6. Physical forms of resonant cavities vary widely; Q may be mathematically derived for simpler shapes

particular frequency can be obtained at odd quarter-wave lengths, ¼, ¾, etc.

A simple form of coaxial wave meter is illustrated in *Fig. 2*. It consists of a length coaxial line with a disc that slides along the outside of the center conductor and makes good electrical contact with the inner wall of the outside tubing. This shorting disc is adjusted by means of an outside ring which is connected to the disc through a longitudinal slot in the wall of the outer tubing.

To measure the frequency of a signal, the open end of the line is brought close to the tank circuit of the signal source being examined. The shorting disc is moved along until a change in the plate or grid current meter of the signal source is observed. This point is noted and the shorting disc is moved still further until another point, which affects the plate or grid current meter of the oscillator, is found. The distance between these two points is equal to one-half wave length.

This instrument is self-calibrating and is independent of the amount of coupling when the wave length of the signal being measured is taken as the difference between the two closest points where resonance was indicated. The distance between nodes or antinodes (one-half wave length) will be the same irrespective of the position of the two points along the line.

If it is desired to measure frequencies without relying on the movement of the oscillator plate or grid current meter needle, one may insert a small loop into the coaxial line, remove a portion of the power, rectify it and connect the output of the rectifier directly to a microammeter. If the r-f signal has been modulated, it may be amplified after rectification. The resonance points are indicated in this case by maximum

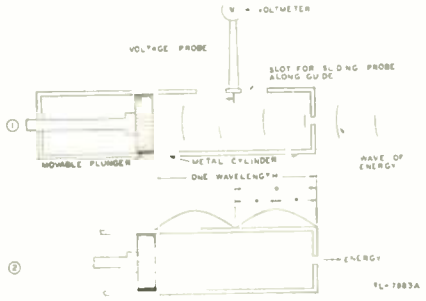

Fig. 14. (1) Field energy may be injected through orifice. (2) Distribution of standing wave in cavity

meter readings. The loop is generally located near the short-circuited end so it will always be in a position of maximum magnetic field.

If the loop is fixed in position, and only one resonance point on the coaxial tubing used, the instrument may be calibrated directly in frequency or wave length. When resonance is indicated with a certain length of line, the shorting disc must be moved so as to shorten the line still more to determine if resonance is indicated for any shorter length of line. This precaution must be taken to insure that the resonant point taken to indicate wave length is only one quarter wave length from the open end of the line.

The short-circuiting element of a coaxial line type of wavemeter carries large currents, hence it is necessary to provide smooth, tight fits and to keep the sliding surfaces free of tarnished material.

Further refinements of the coaxial-line type of frequency meter are illustrated in *Fig. 3*. In these, the shorting element is moved by means of vernier

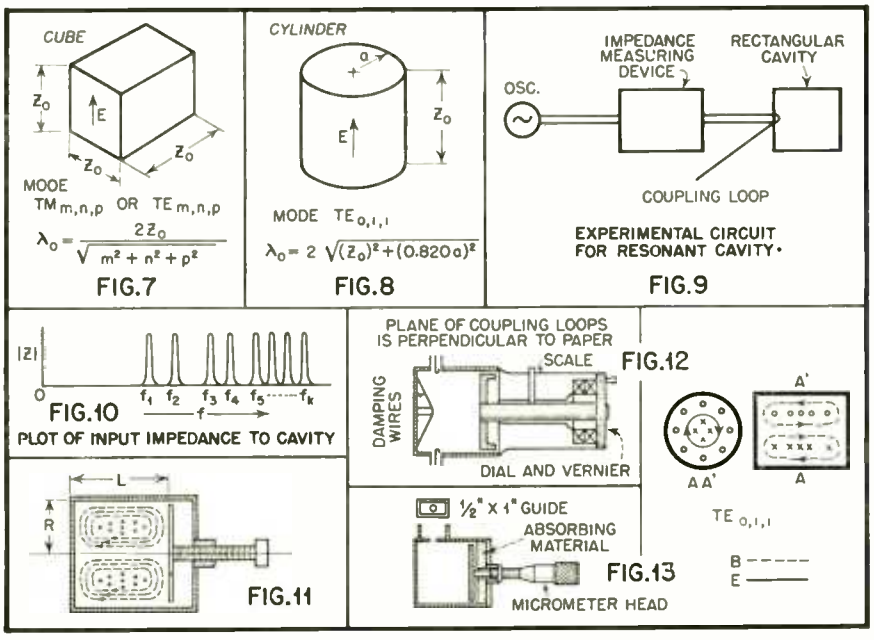

Fig. 7, Fig. 8. Equations for resonant frequency of basic forms of cavities. Fig. 9. Resonant frequency of cavity is readily determined with impedance measuring device. Fig. 10. Cavity can resonate at several fundamentals and harmonics. Fig. 11. Cylindrical cavity designed with non-shorting plunger. Fig. 12. Diagrammatic view of vernier design for non-shorting plunger; mode diagram shows electric flux lines solid, magnetic flux lines dotted. Fig. 13. Vernier may be designed as micrometer

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attachments which provide for measurements of greater accuracy. The method of coupling power into and out of the line is also different. In addition, in some the line is short circuited at both end. Resonance is then obtained at even quarter wave lengths 2/4, 4/4, etc. Accuracies of 0.01% within one centimeter can be obtained. The general formula for a coaxial wavemeter is

$$\lambda = 4Z_0$$

where Z_0 equals ¼ wave length in air.

Cylindrical Cavity Wavemeters

This type of wavemeter is essentially a resonant cavity. Its advantage over the coaxial type is that it has a higher Q and can be used more conveniently at the super-high frequencies (3000-30,000 mc). Its principal disadvantage is that it is not absolute and each instrument must be calibrated against frequency standards.

The similarity between a cavity resonator and an ordinary resonant circuit can be easily shown, but an exact parallel can not be drawn between the two. The following analogy between the cavity wavemeters and the coil and capacitor type of resonant circuit is not to be considered as a rigorous discussion of the characteristics of cylindrical cavity wavemeters as compared with the conventional coil and capacitor resonant instruments.

General analysis in circuit theory at ordinary frequencies are based on Ohm's Law and Kirchhoff's Laws. In the application of these laws, use is made of potential differences that exist across different elements of a given circuit, or currents through these elements.

It is also known that because of the presence of a current in a wire, a magnetic field exists in the region surrounding it. The presence of moving charges, making up the current, implies the existence of an electric field. The power is expressed in terms of the product of the potential and the current, and if so desired, in terms of the product of the instantaneous values of the magnetic field and the electric field. The simplest form of a conventional resonant circuit is shown in *Fig. 4*.

In order to discuss the above circuit, it is desirable to think in terms of electric and magnetic fields and the amount of energy that can be stored in each.

Energy can be stored in the electric field by initially charging the capacitor, and energy also can be stored in the magnetic field by passing current through the coil. Oscillations can be expressed in terms of the transfer of a fixed amount of energy, from entirely electric at one instant, to entirely magnetic at another instant. The length of time it takes to make a complete transfer, from electric to magnetic and back to electric is called a period and the reciprocal of the period gives the frequency. If there are no losses in the circuit, or no energy is removed to actuate any other circuit, the transfer of energy from one form to another is complete. The frequency with which these transfers, from electric energy to magnetic and back again from magnetic energy to electric, take place is known as the resonant frequency of oscillation of the circuit. The frequency is determined by the magnitudes of the capacity and the inductance in the circuit and is given by the expression

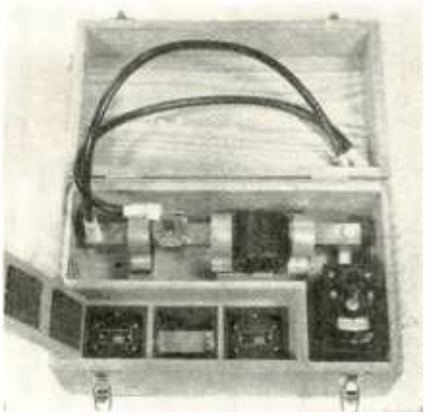

Fig. 15. Standard cavity, with fixed resonant frequency

$$f = \frac{1}{2\pi\sqrt{LC}}$$

As illustrated in *Fig. 5*, if the number of turns in the coil (hence, the inductance L) is reduced, the resonant frequency will increase. The number of turns can be decreased until a single loop of wire forms the inductance.

If it is desired to increase the frequency of a resonant system higher than that possible with a simple single loop circuit, it can be accomplished by connecting two of such circuits in parallel as ilustrated. By continuing the process, the inductance can be decreased more and more, until in the limit, the circuit becomes a closed chamber cavity.

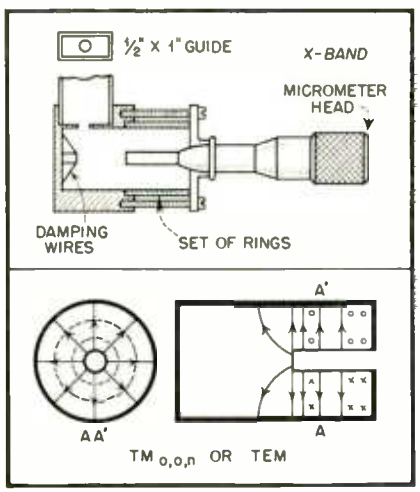

Fig. 16. Cross-section of transition type wavemeter

Such a resonating circuit is desirable because the electric and magnetic fields are confined to the region within the resonator itself. This is a distinct advantage since it prevents loss of energy by radiation, and the effects of body capacity and other proximity effects are no longer present.

Cavities may assume any one of several different shapes or any variations of one or more of them. Examples are cube, rectangle, sphere, cylinder or dimpled cylinder, *Fig. 6*. In addition, they may include shapes which result from taking sections of wave guides and closing the ends.

The Q of cavity resonators originally described and illustrated in *Fig. 4* can be defined as

$$Q = \frac{R_{sh}}{\omega L}$$

where L is the inductance and R_{sh} is an equivalent resistance which takes care of the circuit losses.

The Q of a cavity operating in a given mode of oscillation may be defined as

$$Q = 2\pi \frac{\text{energy stored}}{\text{energy lost/cycle}}$$

The quantity Q is frequently used as a figure of merit for a resonant circuit, for it is a measure of the damping of a freely oscillating circuit. In a conventional coil and capacitor circuit a Q or 400 is considered very good. In a resonant cavity a loaded Q of 3000 is not too difficult to attain.

The Q of a resonator is also a measure of the sharpness of tuning of the resonant circuit, the Q can be represented as a function the bandwidth Δf between 70% response points and the resonant frequency f_0. It is expressed as

$$Q = \frac{f_0}{\Delta f}$$

To calculate the Q of a resonator, the relation must be found between energy stored in the cavity and losses in the cavity. The losses encountered in a cavity resonator (if the cavity contains no dielectric except air) are due to the current flowing in the walls of the cavity and the power that may be extracted to actuate an external circuit.

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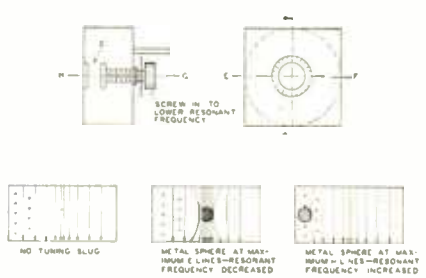

Fig. 17. Capacitive loading of cavity may either raise or lower resonant frequency

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The currents flowing in the walls produce I^2R losses.

At microwave frequencies the conduction current flowing in the conductor is concentrated in a thin surface layer. The current density is a maximum at the surface and decreases exponentially with depth into the conductor. The depth of penetration varies for different metals and changes with frequency. The higher the frequency the less the depth of penetration. Since the flow of electrons is confined to an exceedingly thin layer of metal on the inside surface of the cavity, this layer should present as low a resistance as possible so that the losses will be negligible.

Cavities may be made from thin sheets of copper or from other metals plated with copper, gold or silver on the inside. In some cases cavities may be constructed from non-conducting materials with the inside painted or covered with a thin layer of metal or metal foil.

In addition to dependence on the type of material comprising the inner surface, the cavity Q is also proportional to the volume-to-surface ratio. Generally, the larger the cavity, the higher the Q. Two cavities of the same shape but different size will have Qs that are proportional to the square root of the resonant wave length.

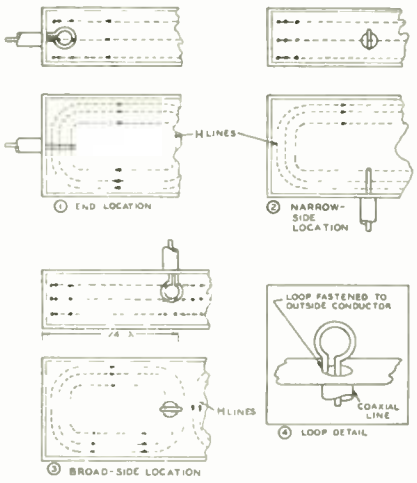
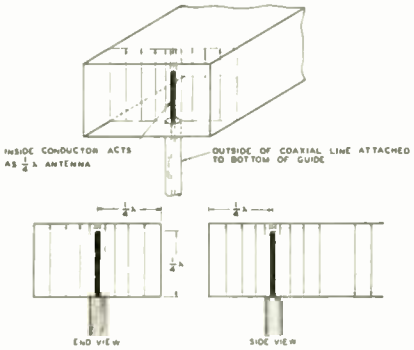


Fig. 18. (above) Loop links magnetic flux lines, at any suitable point

Fig. 19. (below) Probe energizes electric field, which in turn generates magnetic field (not shown)



Determination of Resonant Frequency

To obtain the resonant frequency of a cavity resonator by calculation, solutions to Maxwell's equations must be found which satisfy the boundary conditions imposed by the resonator. An analytical solution is only possible for a limited number of cavity shapes, shapes which can be readily defined in terms of one of the standard co-ordinate systems. *Figures 7* and *8* list the general formulae used and the corresponding cavity shapes for the rectangular prism and the cylindrical type cavities.

The dimensions a and b are in centimeters and Z_0 equals a quarter wave length of a desired frequency in a wave guide.

In coaxial lines, the wave length in the line is always equal to the free space wave length, provided attenuation is small. In hollow pipe wave guides and in cavity resonators, the wave length always exceeds the free space wave length. Therefore, in any calculations or measurements it must be borne in mind that the wave length for the same frequency is different for free space and a wave guide or cavity resonator.

In order to obtain the resonant frequencies of a cavity experimentally, the circuit illustrated in *Fig. 9* may be used.

If the frequency of the oscillator is varied and the absolute value of the input impedance to the cavity is plotted, it will be found that the impedance variation is of the form shown in *Fig. 10*. Each peak corresponds to a resonant frequency of the cavity. It will be noted that there are a great many resonant frequencies and, in general, as the frequency of the oscillator is increased the resonant peaks tend to crowd closer and closer together.

Any hollow, conducting cavity has associated with it an infinite number of resonant frequencies, each corresponding to a different configuration of electromagnetic fields which can be excited in the interior of the cavity. The manner in which the cavity is energized will affect the mode of oscillation. A cavity, therefore, can usually resonate at several fundamental frequencies as well as harmonics of the fundamental.

For frequency measurement, it is desirable to use the lowest possible mode so as to avoid confusion resulting from other modes. This is done with fixed frequency standards, but in order to have a variable cavity with a plunger at one end it is necessary to use a higher mode which has zero surface currents at the point where the plunger meets the sides of the cavity.

When a higher mode is used the lower modes are discouraged in various ways; by the method of coupling, by absorbing material behind the plunger, by absorbing material in grooves parallel to the surface currents on the end plate, etc.

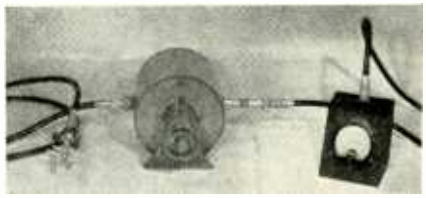
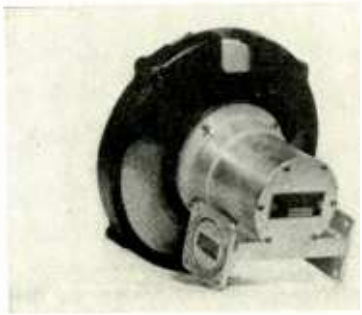


Fig. 23. (above) View of reaction type wavemeter. Fig. 21. (below) View of cavity resonator wavemeter



When mode suppression is properly done, the input signal, if varied over the tuning range will cause only one response for any setting of the frequency meter in the tuning range of the instrument. For any given input signal of a constant frequency, only one point of resonance will occur when the cavity is tuned over its operating range.

A cylindrical type of cavity is illustrated in *Figs. 11, 12,* and *13*. No currents exist in the movable plunger, therefore it is not necessary that this plunger make good electrical contact with the walls in order to have satisfactory operation.

A resonator for wave length measurement is shown in *Fig. 14.(1)*. Energy is allowed to enter the small opening in the end plate from a source of radiated fields. If the plunger is not at the proper position for the frequency of the waves entering, the cavity does not resonate and hence there is no reading on the meter. If the plunger is moved back and forth some point may be found where resonance takes place and the energy wave reflected from the piston aids the incoming wave rather than cancels it. A standing wave of voltage and electric field is then set up and is indicated by the meter.

If the resonating section is long enough so that a voltage maximum and minimum may be found by moving the r-f probe in its lengthwise slot, the wave length may be determined. Thus, in *Fig. 14.(2)* if distance A or B is determined, the wave length in the glide is $2b$ or $4a$. *This value is always greater than the wave length in air for the same frequency.*

Cavities for precision measurement of frequency are often made by hollowing out solid blocks of metal so that the

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dimensions (and hence the resonant frequency) do not change. The extra amount of metal is for mechanical strength and rigidity only and contributes nothing toward reducing the resistance to high frequency electron flow.

Standard cavities, as illustrated in *Fig. 15*, consist of fixed cylindrical cavities. The resonant frequency of each standard cavity is measured and adjusted on a frequency standard which is calibrated against WWV.

Temperature and humidity affect the calibration of frequency measuring cavities. To overcome this, standard cavities are constructed of low thermal distortion materials, the air is pumped out, dry inert gas pumped in and all openings sealed. With this type of instrument only a temperature correction chart must be supplied whereas otherwise a nomograph for relative humidity and temperature correction is necessary.

Transition Type of Wavemeter

This type of wavemeter can be thought of as half coaxial line and half cylindrical cavity. It consists of a cylindrical cavity along whose axis projects a piston whose diameter is considerably smaller than that of the cavity. An example is illustrated in *Fig. 16*. All dimensions of both the cavity and the plunger determine the wave length. Consequently, this wavemeter must be calibrated.

Tuning in Cavity Resonators

Other methods besides the movable plunger (changing dimensions) can be used to tune a cavity. One method is to introduce a variable capacitance at the point of highest voltage as in *Fig. 17*. If the metal mass is at the position of maximum *e*-lines, the lines are shortened, the capacitance is increased, and therefore, the resonant frequency is lowered. If the metal mass is at the position of maximum *h*-lines, the lines are shortened, the inductance is decreased, and therefore the resonant frequency is raised.

Types of Coupling or Excitation

There are three principal ways in which energy can be put into and removed from wave guides and cavity resonators. The first is by placing a small loop of wire so that it "cuts" or couples the *h*-lines of magnetic field as in a simple transformer.

The second is by providing an "antenna" or probe which can be placed parallel to the *e*-lines of electric field. In this case, the probe has an electric field of its own which adds to or subtracts from the *e*-lines of the guide or cavity and thus permits energy to be delivered or removed. A variation of this second method is to provide plates on which the *e*-lines of the guide or cavity by external fields through the use of slots or holes (irises) in the walls.

Figure 18 shows loop coupling (inductive coupling to the *h*-lines. The loop may be placed anywhere on the guide or cavity as in (1), (2) and (3) as long as sufficient *h*-lines go through the loop. It is usually placed at a location where the *h*-lines are at a maximum. If less coupling is desired, the loop can be rotated so that a smaller number of lines can go through it, or it can be shielded, or it can be moved to a position in the guide where there are fewer lines. If the loop is rotated 90 degrees from its position, no lines pass through it and practically no coupling is available. In the case of wave guides transmitting energy, there are traveling waves, and the loop is placed for maximum coupling where it would be cut by the most *h*-lines.

Figure 19 shows maximum coupling by means of *e*-lines (electric coupling). Less coupling can be obtained if the probe is moved away from the position of maximum *e*-lines or if less of its length is exposed to the field in the guide.

Application of Wavemeter

The method of coupling of the wavemeter to the circuit under test and the manner in which resonance is indicated is known as the application of the wavemeter.

It has already been shown how a coaxial or cavity resonator type of wavemeter may be used by measuring the distance between nodes or anti-nodes of standing waves introduced into the coaxial line or cavity. The distance between the nearest pair of nodes or anti-nodes is equal to one-half the resonant wave length. The following are additonal methods of application.

[*please turn page*]

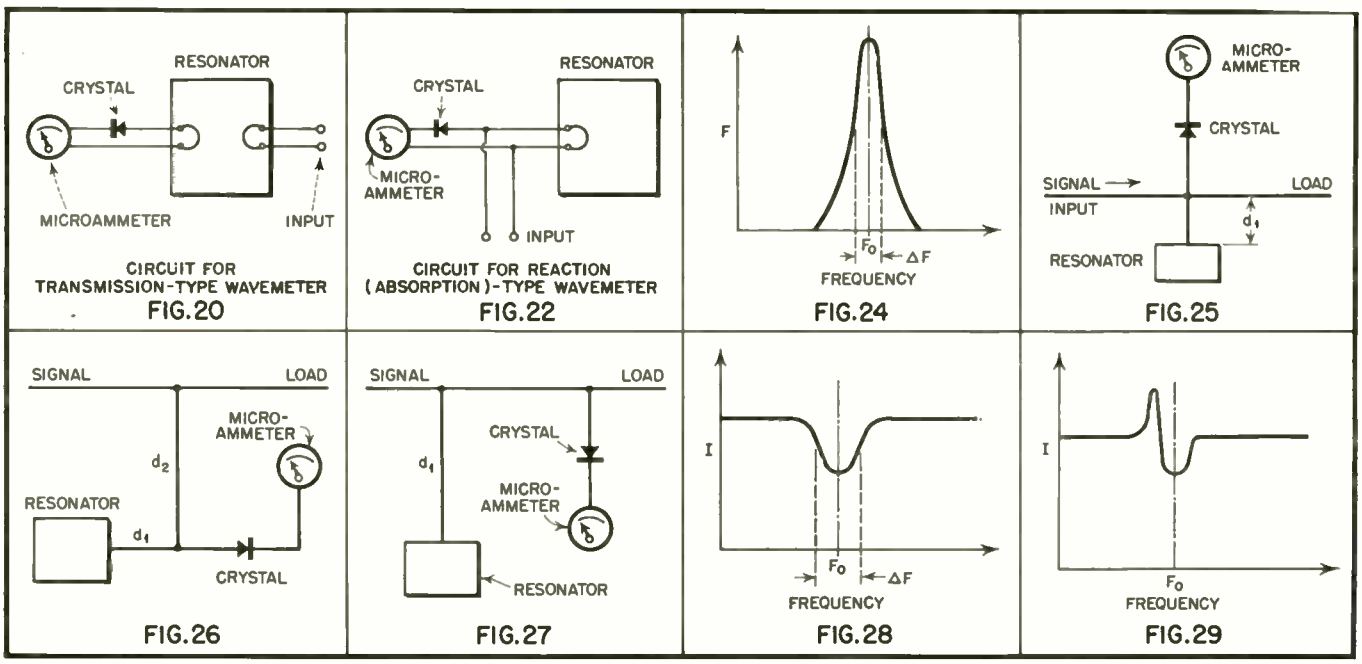

Fig. 20. Transmission type wavemeter establishes field in cavity, to which meter circuit is coupled. Fig. 22. Reaction wavemeter is analogous to LC VHF technique. Fig. 24. Frequency response curve of wavemeter; Δf is half-power point. Fig. 25. Signal flow in reaction type wavemeter assembly. Fig. 26. Alternative signal flow design for reaction wavemeter. Fig. 27. Rectifier may be located as shown, if desired. Fig. 28. Proper frequency response curve for reaction wavemeter. Fig. 29. Too tight coupling yields anomalous frequency response curve

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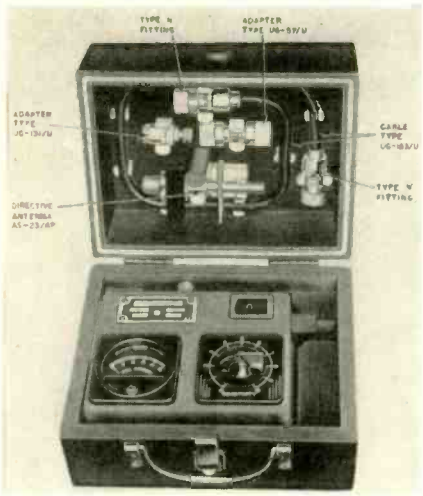
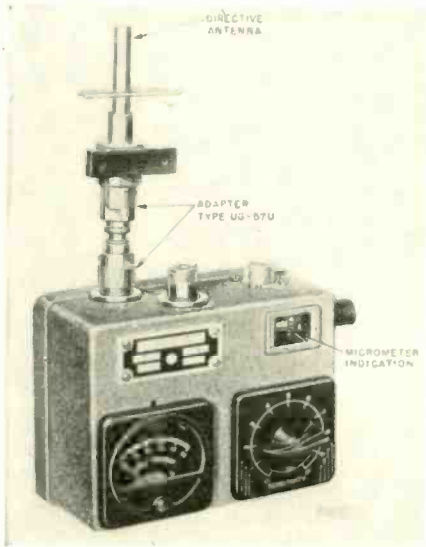


Fig. 30. (above) Frequency meter for use in the 2400-3400 mc band

Fig. 31. (below) Design of frequency meter for operation in field of microwave energy



Resonators may be used as transmission instruments or as reaction (or absorption) instruments. Circuits and examples of each are illustrated in *Figs. 20, 21, 22* and *23*.

In *Figs. 20* and *21*, the microammeter will indicate only if the resonator is tuned to the frequency of the energy applied to the input. When the wavemeter is not resonant, it presents a high impedance between the indicating circuit and the signal. When the wavemeter is tuned to resonance, it presents a low impedance and power is coupled through to the indicating circuit. Wavemeter readings are observed when the meter deflection is a maximum. *Fig. 24* illustrates how the indicator varies with wavemeter setting in a transmission circuit. F_o is resonant frequency and Δf the bandwidth at the half-power points.

The sharpness of the tuning, the width of Δf, is dependent upon the Q of the wavemeter. The Q, as mentioned before, is dependent upon a number of things. In some instances the Q could be so great that it would be difficult to find the point of resonance. On the other hand, the Q may be so low (the tuning response so broad), that the point of resonance can be determined only as being between two widely separated points of the dial.

An example of a wavemeter used as a reaction (or absorption) is illustrated in *Figs. 25, 26,* and *30*. For an analysis of its action let us refer to *Fig. 25*. In this application, the distance, d_1, is such that the wavemeter arm presents a high impedance at the junction with the main line when the wavemeter is not resonant. At resonance, however, it presents a low impedance so that less power gets to the load and to the indicating instrument. It can be seen that the wavemeter does not really act on the absorption principle and such a designation is somewhat of a misnomer.

In the circuit for the wavemeter used as a reaction instrument, the crystal branch could be placed elsewhere. It might be placed on the wavemeter branch, if it is placed at a point of normally high resonance on that branch. It may also be placed anywhere on the main line between the wavemeter and the load. These alternative set-ups are shown in *Figs. 26* and *27*.

In *Fig. 26*, the length d_1 must be such as to present a high impedance looking towards the wavemeter at the junction with the crystal branch. The distance d_2 is independent of d_1 for when the wavemeter is not resonant. The impedance at the junction with the main line depends only on the impedance of the crystal and the length of the line up to it.

In the reaction type of circuit an indicator varies with wavemeter setting as shown in *Fig. 28*. However, if the coupling loop, probe, or iris is too large, the indicator may vary as shown in *Fig. 29*. This coupling is too tight and should be reduced.

Accuracy

In general, the transmission type of circuit is more accurate than the reactance type. However, the accuracy of a wavemeter also depends upon the accuracy with which its scale can be read and the loaded Q of the wavemeter itself. If the loaded Q is small the resolution of the wavemeter will not be great. The points at which the frequency response curve drops to the half power value will be very widely separated.

One frequency meter developed and used during the war is Test Set TS-117/GP illustrated in *Fig. 30*. It was designed for frequency measurements of radar systems operating in the band from 2,400 mc to 3,400 mc. The unit is self-contained and requires no source of power. The total weight of the instrument in its carrying case with accessories is about seven pounds.

The unit has a Q from 1,800 to 2,000. Its accuracy is one part in 2,000 or $\pm$ 0.75 mc at 3,000 mc. A change in ambient temperature from $-40°$ to $+40°$ C produces a maximum frequency change of one part in 4,000. The dial is a micrometer head. Conversion to frequency is made with the aid of the chart on the back of the instrument.

To operate the frequency meter in a field of microwave energy the unit is assembled as illustrated in *Fig. 31*.

In measuring the output frequency of a klystron the equipment is used as illustrated in *Fig. 32*.

It was often desired to measure the frequency of a signal the strength of which was not sufficient to activate the meter needle. In this case the output of the crystal rectifier is amplified and displayed on an oscilloscope screen or other meter. There are two r-f input jacks, E and N, as illustrated in *Fig. 33*. When jack E is used the instrument acts as a transmission instrument and only when tuned to resonance, is there any indication on the meter and/or output at the terminal J-103. When input jack N is used, the instrument acts as a reaction (absorption) instrument. Meter deflection and/or output at jack 103 occurs as long as r-f energy is applied and changes when the wavemeter is tuned to resonance.

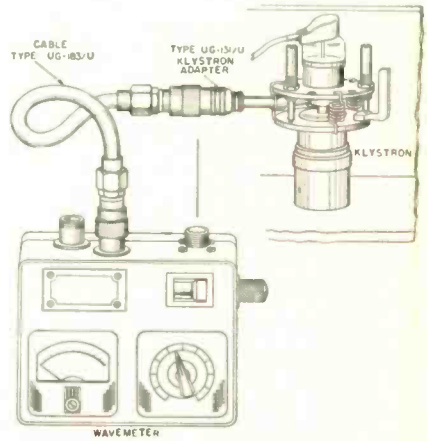
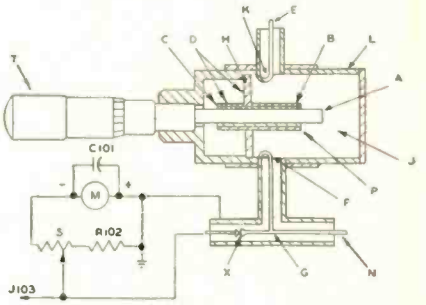


Fig. 32. (above) Setup for measuring Klystron frequency

Fig. 33. (below) Instrument operates as transmission type through jack "E", and as reaction wavemeter through jack "N"



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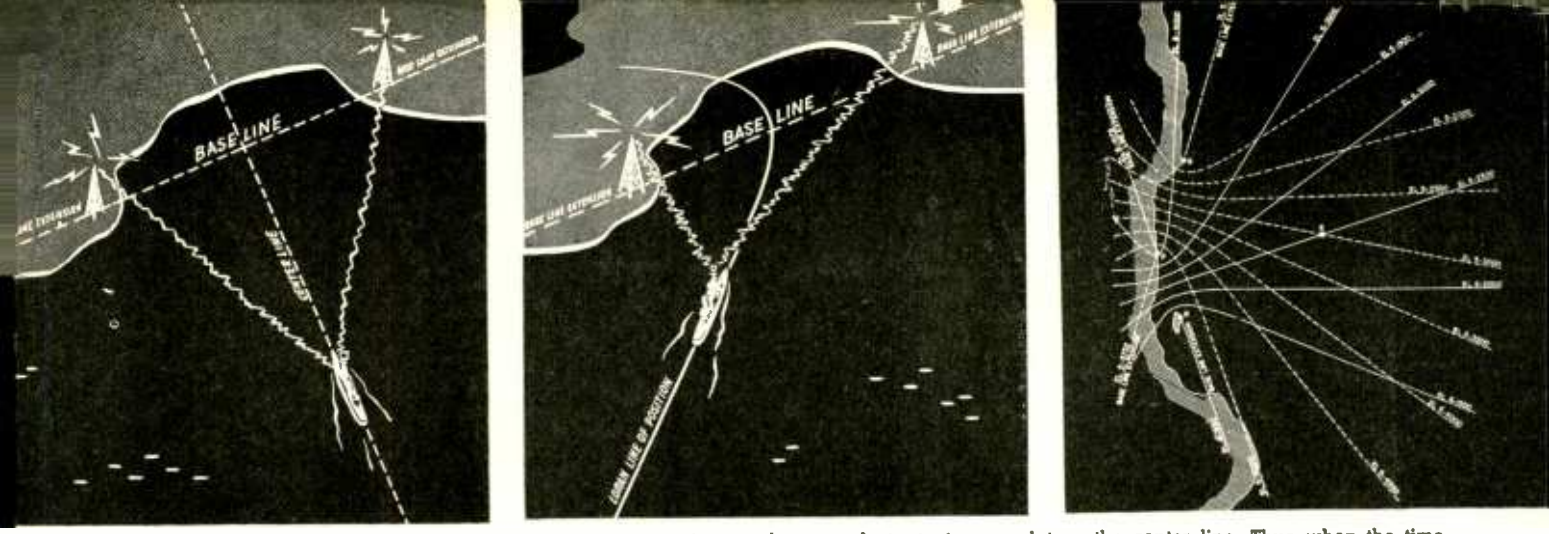

(Left) Simultaneous pulses transmitted from two stations arrive at the same instant at any point on the center line. Thus when the time difference is zero, the ship is somewhere on the center line. (Center) A ship or plane receiving a pulse from one station earlier than from the other is on the line of position shown. The line of time difference is a hyperbola around the nearer station. (Right) Position X is obtained by reading on the ship's Loran receiver the time difference of signals between master station P and slave staion Q, then the time difference for stations P and R

[U. S. Navy Photos]

Radio & Radar Aids to Aerial Navigation

ROBERT L. ROD

Loran, Radar and Racon are important guideposts to future radio and electronic engineering techniques. Professional opportunities in this direction are constantly expanding

DURING THE PAST few years, wartime advances in the science of electronics have further simplified the art of navigation to the extent where passengers debarking after long aerial flights no longer marvel at the excellent adherence to posted schedules. Flying across great expanses of water has become a routine experience mainly because each air crew is at all times fully cognizant of its position in space with respect to the earth below.

Whenever either the sun or the stars are visible, a navigator may resort to the centuries-old technique of establishing a position "fix" by noting either the elevation of the sun above the horizon or the configuration of the celestial bodies. Generally most navigators are confident to dispense with these arduous tasks, relying entirely upon dead-reckoning and electronic aids to navigation for their position data.

Some of the more commonly utilized navigational systems are relatively difficult to use; others are extremely simple. Small plane owners are content to "hedge-hop down highways, rivers, and railroad tracks locating themselves with the aid of ordinary road maps. This rather unreliable system is known as "pilotage" and is not relied upon to any great extent by the crews of commercial and military aircraft.

Before taking off on a long flight, generally an overwater operation, either the navigator or the pilot will prepare a "flight plan" which will indicate the magnetic headings it will be necessary to fly to achieve a desired "true course" (projected on the surface of the earth below) under known and predicted wind conditions along the route. The wind. when determining its effects. is treated as a vector quantity possessing both magnitude and direction (measured from true north in a clockwise direction). If the wind direction along the entire planned route is uniform, for example, and is such that it is a perpendicular bisector of the bearing between two map points listed in the flight plan, the heading of the aircraft must be made into the wind in order to achieve a true course. This vectorial problem is, in actual practice, solved in flight by means of a small circular computer.

Once the wind problem is solved, the navigator estimates "expected time of arrival" (ETA) at prominent points along the route by determining his ground speed and true course, and combining these figures with the clocked elapsed flying time from a previously observed ground reference or "check" point. The entire problem just described is known as navigation by "dead-reckoning", and for accurate flight visual (or radar) fixes must be made on all available check points. If the wind maintained the same velocity and direction over an entire route, the use of check points and fixes would not be mandatory, but in practice the wind shifts constantly.

Radio Range System

On short overland flights, the services of a navigator are not required, and instead the pilot determines his own navigation requirements while relying heavily upon the large network of Radio Range stations for "directions". These ranges consist in effect of two narrow overlapping radio beams laid down on the assigned cross-country flying routes. A pilot flying down the overlapping equal-signal-strength line of the two beams audibly detects a solid a-f note of approximately 1,000 cycles in the headphones of the range receiver. Deviations from this center line, or course, produce the same note with varying am-

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plitude which is being keyed either as the Morse letters N or A, depending upon the direction of deviation from the course. Since these two Morse letters are complementary (— . and . —), the center line representing equal signal strength from each beam produces a steady note indicating correct course. This system of navigation is accurate and requires little in the way of airborne receiving equipment, but it suffers from an inability to definitely fix the plane's position in space and from inaccuracies due to signals reflected from natural ground objects of large areas.

Radio Direction Finder

Most aircraft in commercial or military service are also equipped with a loop direction-finding receiver which allows the pilot to obtain a direct bearing on any station operating within certain frequency ranges. This type of installation is valuable as it allows a fix to be made in flight by noting the intersection of the reciprocals of bearings made on two or more ground stations. The name "radio compass" has been applied to this type of installation.

Many large aircraft are also equipped with a VHF transmitter-receiver installation for use in obtaining landing instructions at the larger airports, and in conjunction with this type of installation a number of ground VHF Direction-Finding (D-F) stations have been established. A pilot desiring a position fix in space, may by using this system obtain the necessary information by "calling-down" to the nearest ground installation for a D-F fix after which he leaves the VHF transmitter on (usually tone modulated for this purpose) for several minutes.The available ground VHF D-F stations within radio range will then reverse the procedure described previously for the airborne loop direction-finding receiver, and a fix of the plane's position in space will be radioed back to the pilot. Two or more

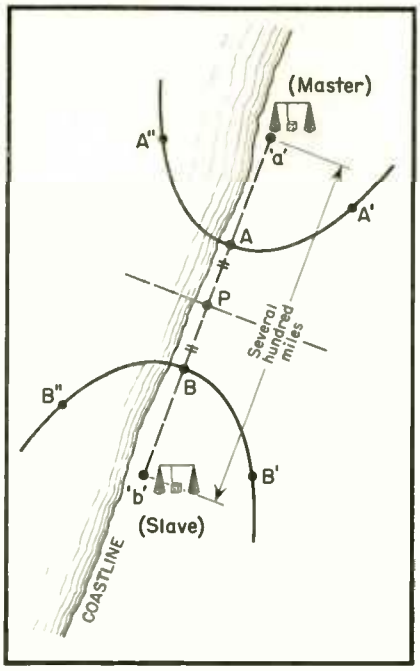

Fig. 1. High-powered transmitters are shown placed several hundred miles apart

D-F stations must be able to monitor the aircraft in order to furnish a fix. The system is advantageous as it offers an additional method of establishing a position, but as yet the VHF D-F stations have not been installed for a complete coverage throughout the country.

The radio navigational systems just described have been supplemented in many new installations by three wartime developments, all of which strive to satisfy the new concept of electronic navigation which calls for quick fixing of position with respect to the earth without rescorting to spoken communication (and if possible without resorting to the use of ground equipment).

The Loran System

The first to be described, an outgrowth of wartime research, is the amazing and valuable LORAN, the LOng RAnge Navigation system, which distinguished itself in both the maritime and aeronautical services. The principles of Loran may be described by noting *Fig. 1* in which two high powered pulse transmitters are shown several hundred miles apart on a coastline at points *a* and *b*. For explanation purposes, assume both transmitters are emitting synchronized pulses on the same frequency in unison. A receiver tuned to the transmitters' frequency will, when located at point *P*, the perpendicular bisector of the theoretical line between the two stations, receive both pulses simultaneously due to equal r-f transit times.

If the receiver is moved from point *P* to point *A*, the pulse from station *a* will arrive at the receiver a definite number of microseconds (which for explanation purposes will be set as 263 microseconds) ahead of the pulse from station *b*. A difference of 263 microseconds between receipt of these two pulses also exists anywhere along the hyperbola *A A' A"* (a hyperbola being defined as a line of constant (time) difference), and similarly a hyperbola representing a difference of 263 microseconds may be drawn through points *B B' B"*, where $aA = bB$. Therefore, a full family of hyperbolas may be drawn upon a map of the area anywhere within radio range of both stations for any desired differences in transit times. And a receiver, which is capable of measuring this time difference between receipt of the pulses, when located anywhere in the area may be established on either one or the other of two "lines of position" (LOP). In practice, if both transmitters were pulsed simultaneously the ambiguity between an LOP on hyperbola *A A' A"*, for example, and hyperbola *B B' B"* would prove confusing to an operator who could not determine his true LOP. The ambiguity is resolved in practice by delaying the pulsed output of one of the two transmitters over the output of the other by a fixed time

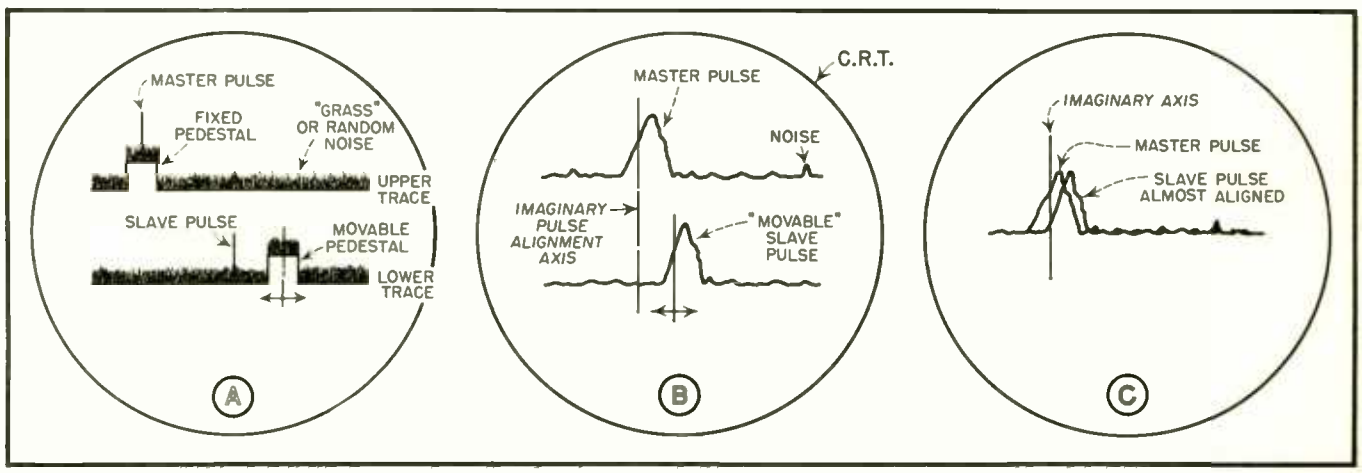

Fig. 2 (a) The master pulse is correctly placed atop the fixed pedestal, but the movable pedestal must be under the slave pulse before calibration can begin. (b) Each sweep is in reality the top of a pedestal. (c) Both sweeps combined. The individual pulse amplitudes may be controlled by a balancing system to facilitate perfect alignment of both the master and slave pulses

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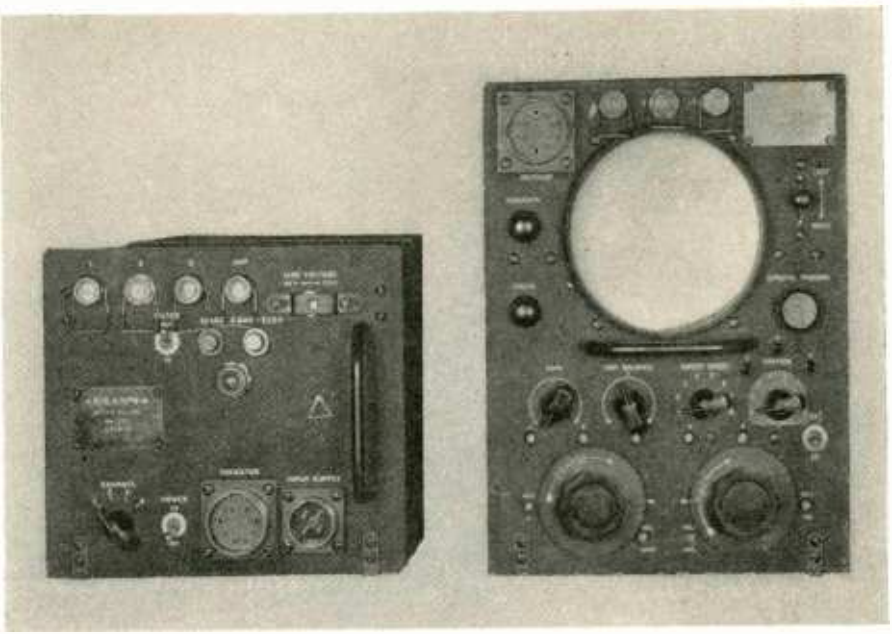
considerably greater than the r-f transit time between the two stations.

The control station is referred to as the "master", while the station delaying its pulse is termed the "slave". In *Fig. 1*, we will label station *a* the master and *b* the slave. Therefore, with a sufficient delay time inserted between the pulsing of slave and the master, the pulse from station *a* will always arrive at any receiver location within radio range of both stations prior to the pulse from station *b*. No ambiguity can now exist as to which side of the center line dividing the distance between stations the receiver is located.

Since a fix is a bisection of two or more LOP's, two pairs of Loran transmitters must be used to locate a receiver anywhere in space. In practice, two or more Loran pairs give complete coverage in all service areas, and the charts provided with the receivers are overprinted maps having the hyperbola families for each pair colored for easy identification.

The Loran picture is completed by a description of the combination receiver-indicator. Both the airborne and shipborne versions of the Loran receiver-indicator utilize a modified A-Scan sweep (usually on a 5" CRT), as shown in *Fig. 2a* in which the lower trace on the CRT is in reality a continuation of the upper trace "broken" in half, displaced down and to the left for the purpose of achieving a longer sweep without increasing the size of the cathode-ray tube itself. A pedestal is fixed at the left of the upper trace, while a movable pedestal (adjusted by the operator using two knobs, a "fine" and a "course" adjuster respectively) is placed so as to slide along the lower trace at will. Upon these traces, the pulses from the master and slave stations are placed for observation and time difference analysis. Synchronism between the pulse recurrence frequency of the transmitter pair and the indicator sweep, which is necessary in order to make the received pulses stand still, is obtained by use of a standard frequency generator and a series of counting down multivibrators within the receiver-indicator. A slight amount of deviation from this synchronism is available to the Loran operator who utilizes this feature to move effectively the master pulse (as well as the slave pulse) until the former is placed atop the fixed pedestal on the upper trace. In this position, the slave pulse falls somewhere along the lower trace.

The time, in microseconds, along the sweep from the leading edge of the master pulse to the leading edge of the slave pulse is the time difference between the arrival of the pulses from stations a and b. In order to measure this time difference, the receiver-indicator electronically measures not the actual distance between leading edges of the two pulses, but rather the time interval along the eweep between the two pedestals when the pulses, are correctly positioned atop the pedestals.



Loran Type AN/APN-4 airborne receiver (left) and indicator *[U. S. Navy Photo]*

When the correct pulses are atop their respective pedestals (the various system of time delays are arranged so that the operator may never place the slave pulse atop the upper pedestal and secure the master pulse on top of the lower pedestal), the sweeps are expanded to show only the tops of the pedestals and the mounted pulses. This condition is illustrated in *Fig. 2b* where the operator adjusts the "fine" control to secure the slave pulse at precisely the same relative position on the lower trace as the master pulse on the upper pedestal. The operator matches the leading edges of both pulses by small horizontal movements of the slave pulse along the lower trace. He further increases the alignment accuracy by switching to a new presentation wherein both traces are combined (*Fig. 2c*) and where both pulses may be precisely aligned for leading-edge coincidence.

Since the slave and master pulses usually are of different amplitude (and maching leading edges becomes diffcult under such conditions), a novel gain control and balancing system is incorporated into the receiver-indicator which provides separate receiver gain control settings for both pulses. In this final condition of alignment, the pedestals are spaced a distance from one another, measured from leading edges, equal to the distance, again from leading edges, of the slave pulse from the master pulse. To translate this distance into time, the operator switches through another almost identical set of sweep speeds in which the slave and master pulses have been omitted only to be replaced by marker pulses interspersed by a series of timing pips. By merely counting up the timing pips between marker pulses, the operator is supplied with a numerical figure representing an LOP which may be located on the Loran chart. One of the hyperbolas will be labeled along its length by a time difference corresponding to the figure obtained by the operator from the above procedure. In most instances interpolation between two hyperbolas (labeled in "round" numbers) is necessary to achieve accuracy.

To obtain desired fix, the operator is required to establish a second LOP by the selection of a second pair of Loran transmitters. Once this reading is achieved it is combined with the first LOP to locate the receiver in space. Loran pairs are identified to the operator by variations either in frequency or pulse recurrence frequency. The correct data for each pair is conveniently posted on the Loran charts, and the receiver incorporates simple switching features enabling rapid switch from one pair to another. The entire Loran procedure for obtaining a fix may be performed, after several hours training, in two or three minutes.

At the low frequencies now used in Loran work, the effective daytime range (of the usual ground wave) is of the order of 500 miles, whereas night skywave reflections increase the range to approximately 1,000 miles. Corrections are indicated on the Loran charts for readings obtained from skywave pulses, and skilled operators soon are able to distinguish between ground waves and skywaves by the varying amplitudes of the pulses of the latter type.

Loran is currently used for overwater flying where ground stations may be placed on the coast. In its present

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state Loran finds little use for overland operations, where only simplified navigational techniques are generally required.

Radar Search Systems

Shorter over-water flights are successfully utilizing lightweight airborne centimeter radar search equipments for "observing" prominent land demarcations at ranges of up to a hundred miles or so. By comparing a 'scope presentation, on such a set with either terrain maps or previously executed mosaics of a series of 'scope pictures made over the same route at some previous date with the same type radar, the radar operator is effectively guided by a form of pilotage, regardless of weather conditions. The PPI, or Plan Position Indicator, is the most suitable cathode-ray tube presentation for airborne work, as most prominent ground features show up at their relative positions with respect to the heading of the plane in a fairly accurate projection. *Fig. 3* is a typical PPI 'scope photograph. Slant range from plane to ground "targets" is measured as the distance on the PPI from the center of tube to the echo representing each target. Concentric range circles are applied by circuits within the radar to facilitate slant range measurements. The most modern airborne PPIs automatically orient the presentation so that true North, rather than the plane's heading, is at the top of the 'scope with the plane's heading being shown as a line at the correct bearing measured from North. This

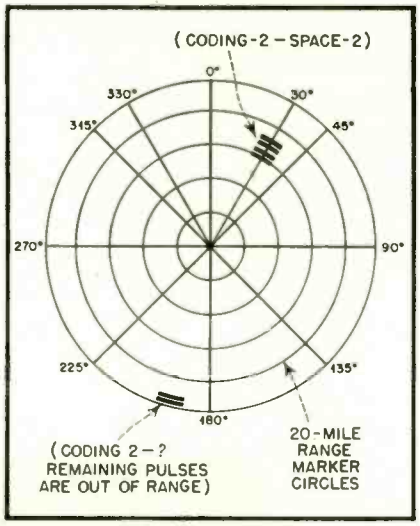

Fig. 4. Radio beacon (racon) signals as observed on a PPI with a sweep length of 100 miles

more complex indication is most suited for bombing-through-overcast and entails the use of a more complex radar than is normally required for pilotage. While discussing the newest equipments, it may be mentioned that the most modern search equipments are now simple enough in operation to allow the pilot himself to perform all necessary adjustments required in use. For daytime use, the PPI is shielded from random light by the use of a long visor; at night, with the 'scope brillance kept at a low value, the pilot may orient himself without experiencing impaired vision or "night blindness". In addition to being simple in operation, the newer equipments are lighter in weight one weighing slightly more than one hundred pounds complete with antenna.

Radar Beacons

In conjunction with ground radar beacons, or racons, the search set becomes even more of a distinct aid to navigation. Most airborne search sets are equipped for beacon operation by the throwing of a single switch. When on beacon operation, the r-f pulse width output of the airborne radar's transmitter is lengthened by several microseconds while the radar's receiver frequency is shifted into what is known as the "beacon band". Racons, now located at many airports, receive within radio range, all search pulses from airborne (and shipborne) radars in the vicinity. However they express interest in only those pulses (i. e. beacon pulses) that have been lengthened by several microseconds. Upon receipt of a beacon interrogation pulse of the correct length, the racon transmitter receives a triggering pulse from its receiver and immediately emits a series of pulses in the beacon band. In effect, the beacon interrogation pulse is detected, amplified and retransmitted almost instantaneously back to the radar by the action of the racon. Whereas some earlier racons replied to each interragotion pulse by one pulse in return, modern beacons reply to the query by transmitting a series of pulses (usually up to a maximum of five) in order to indentify the particular racon being interrogated. Coding is accomplished by varing the number of reply pulses as well as the spacing between the pulses.

Because the start of the PPI sweep of the airborne radar coincides with the transmission of a burst of r-f energy, both for search and beacon operation, and since the racon replies to a beacon interrogation pulse with little or no internal time lag, the racon's output pulse arrives at the radar in the form of an amplified echo at an indicated PPI range equal to the slant distance between radar and racon. On beacon operation the de-tuning of the radar receiver away from the radar transmitter's frequency impairs the normal search function, and hence only beacon pulses (from those racons within radio range) are visible on the PPI. These pulses however, will be displayed on the PPI at positions corresponding to the location of the various ground beacons with respect to the radar. *Fig. 4* shows the PPI of a radar on beacon operation displaying a racon reply at 30° — 60 miles and another at 195° — 92 miles. The top of the 'scope, or zero degrees, is the heading of the plane in this case.

Racons have a useful range of nearly 200 miles when aircraft are flying at

[*see page* 60]

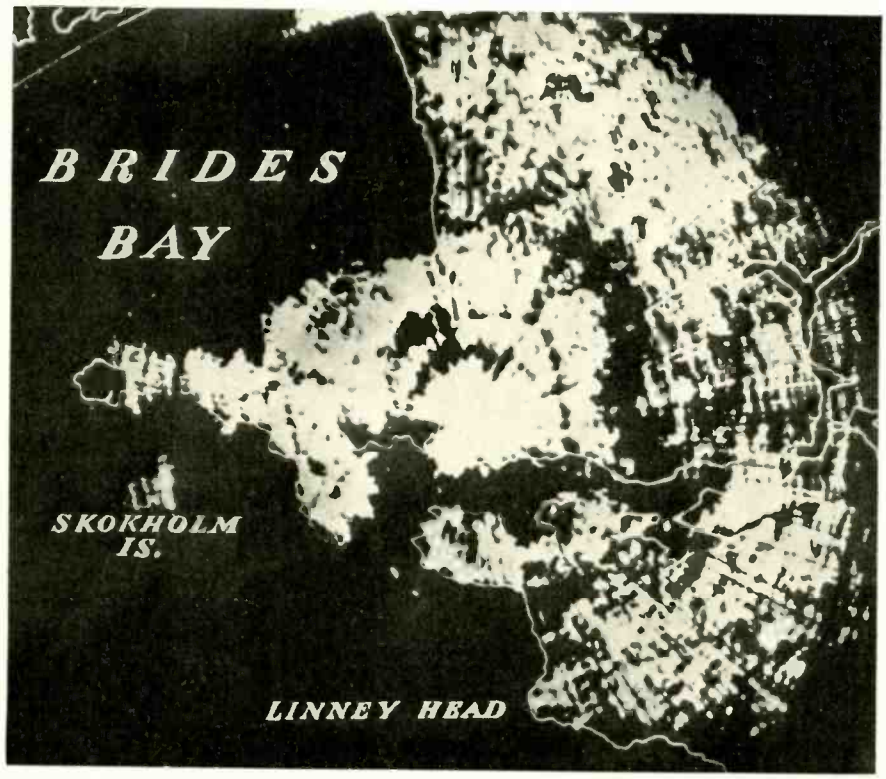

Fig. 3. South-west tip of Wales, as shown on the PPI scope of an airborne search radar carried in an RAF plane

(British Official Photo)

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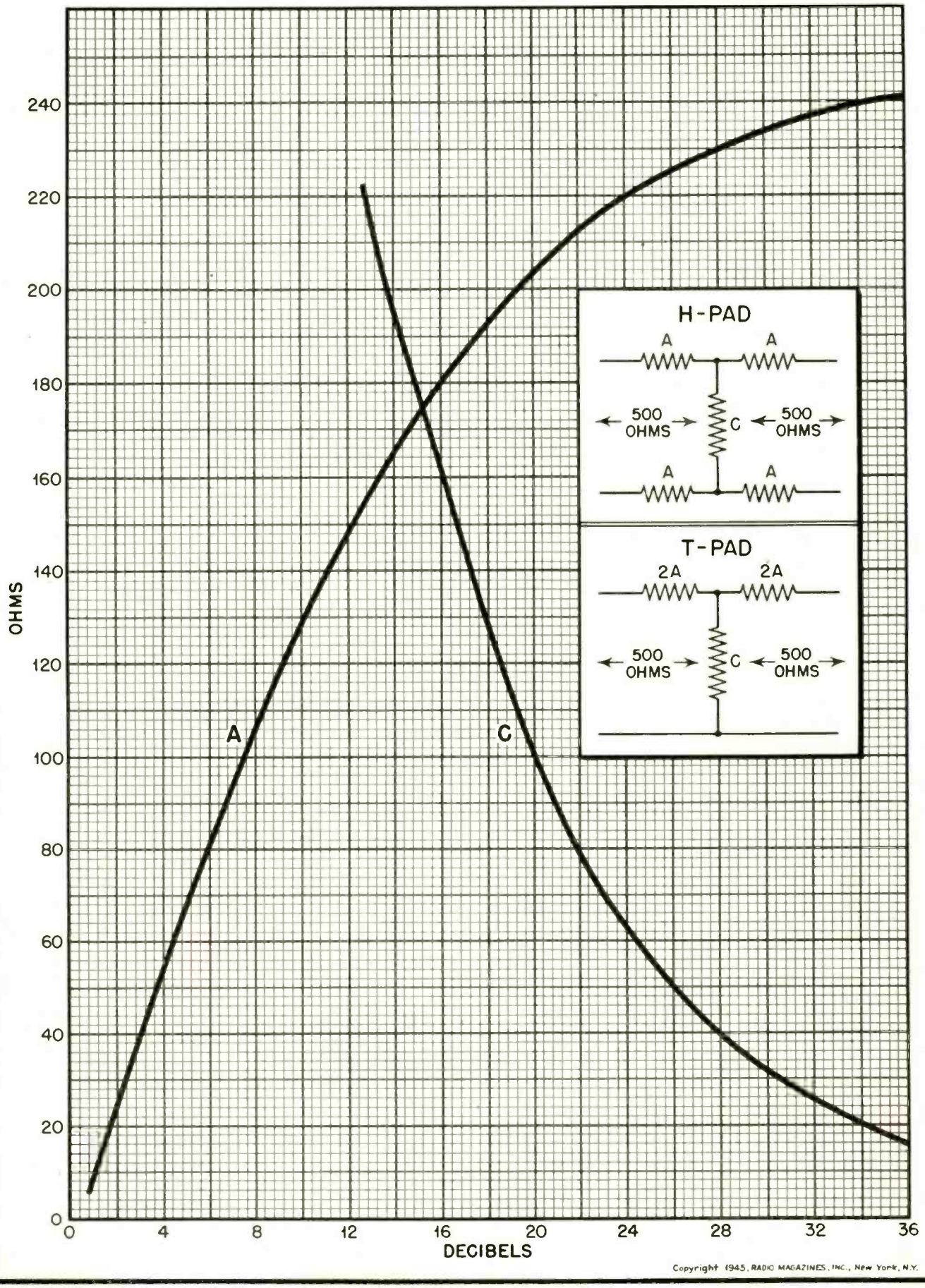
H OR T-PAD RESISTANCE PAD SERIES AND SHUNT ARMS



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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

Reactance System

★ On October 31, 1944, Henry M. Bach was granted a patent on a reactance-tube system. This system employs only a single electron stream in a single tube envelope which acts with the oscillator circuit as well as with the control arrangement.

The oscillator is basically of the Hartley type, modified so that the plate and the screen grid, which serve as anode connections, are kept at an r-f ground while the cathode is ungrounded. As the schematic shows, a phase shift arrangement, consisting of a capacitor and a resistor, are connected across the capacitance of the Hartley tank circuit, and the phase-shifted voltage is fed into a second control grid. The phase shift is so arranged that the r-f signal on the second control grid is in quadrature with the signal on the first grid. The patent claims that this condition causes a reactance term to appear in the plate current, and that the magnitude of the reactance term may be adjusted by varying the bias voltage on the second control grid.

The patent, number 2,361,731, is assigned to the Patents Research Corporation.

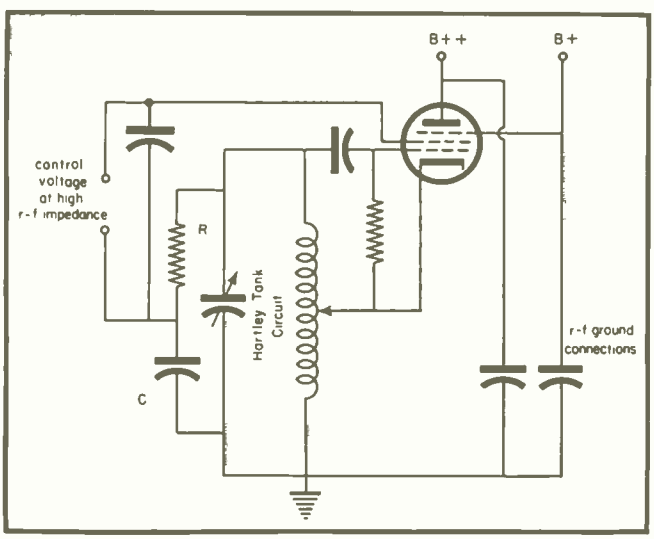
Crystal-Controlled Relaxation Oscillator

★ A form of relaxation oscillator whose frequency can be easily synchronized with a quartz crystal is claimed by Arthur M. Braaten in a letter of patent issued on April 10, 1945. The circuit is shown in the schematic drawing. The capacitor, marked *C*, is charged by the peculiar action of the vacuum tube in reference to grids 2 and 3, and discharges to a fixed d-c level through resistors R_1 and R_2. Grid 1 is kept at a fixed negative potential that only determines the amplitude of the oscillation.

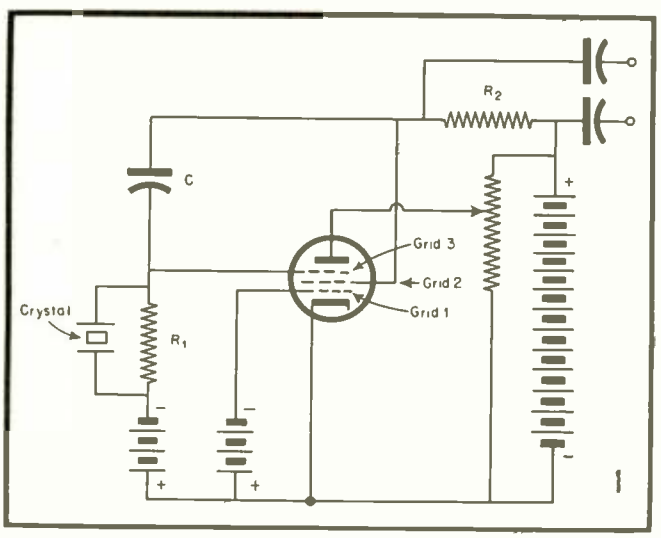
Grid 3, as indicated in the drawing, serves as the control electrode. If it is made negative, part of the electron stream between cathode and plate will be repelled, thereby causing a decrease in the anode current. The repelled electrons are attracted to the positively-charged grid 2 where they cause an increased current. When the circuit is first connected, assuming that some minute disturbance causes a decrease in the voltage of grid 3, the resulting increase in the current to grid 2 causes an increase in the potential drop across resistor R_2. Consequently, the potential of grid 2 is somewhat reduced and, considering the action of capacitor *C*, results in a further negative swing of grid 3 so that the effect becomes cumulative and the current to grid 2 suddenly increases while the potential of grid 3 is made negative. This action corresponds to charging capacitor *C*, as in any relaxation oscillator.

After capacitor *C* is charged, discharge takes place through resistors R_1 and R_2. During the discharge period, the cumulative effect just described takes place again but in the opposite direction. The two cycles of events repeat continually. However, in the absence of the quartz crystal, the operation of the circuit is erratic. Since the arrangement is sensitive to control frequencies of even very small amplitudes, the inclusion of a quartz-crystal, as shown, is sufficient for maintenance of a constant frequency.

The patent, assigned to RCA, is number 2,373,223.



Patent #2.361.731



Patent #2.373.223

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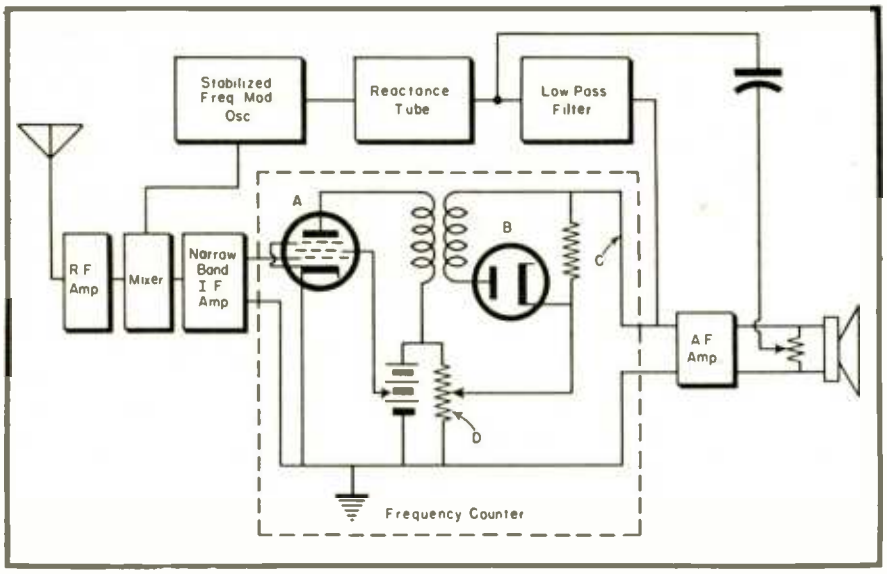


Patent #2,383,359

Frequency Modulation Receiver

★ A patent issued on August 21, 1945, to Marc Ziegler of Buenos Aires, Argentina, deals with a frequency modulation receiver that incorporates a combination of a feedback arrangement, in order to allow the use of a narrow band i-f amplifier, along with a frequency-counter type of detector that replaces the usual discriminator, and makes unnecessary the use of a limiter. The invention is illustrated in the accompanying diagram, in part schematic, and in part block form.

The received signal, which consists of a carrier whose frequency varies over a range of Δf, in accordance with the modulation intelligence, is fed through an r-f amplifier into a mixer circuit, just as in any superheterodyne receiver. After conversion to the intermediate frequency, the signal is amplified and detected; a portion of it is connected through a low-pass filter in order to provide a.f.c for the local oscillator. Following audio amplification, another part is diverted and used to frequency modulate the local oscillator. To a certain extent, this other part causes the local oscillator frequency to follow the frequency of the received signal. Consequently, if the received signal deviates instantaneously from its mean value by 100 kc, then, for example, the local oscillator moves away from its mean frequency by 90 kc and in the same direction, and the i-f amplifier has to pass a signal only 10 kc away from the center of its pass-band. Similarly, if the carrier deviation has an instantaneous value of 50 kc, the local oscillator is moved 45 kc, and a 5 kc signal is obtained. The condition occurs throughout the frequency deviation range and results in shrinking the bandwidth Δf of the r-f stage to a much smaller value in the i-f amplifier.

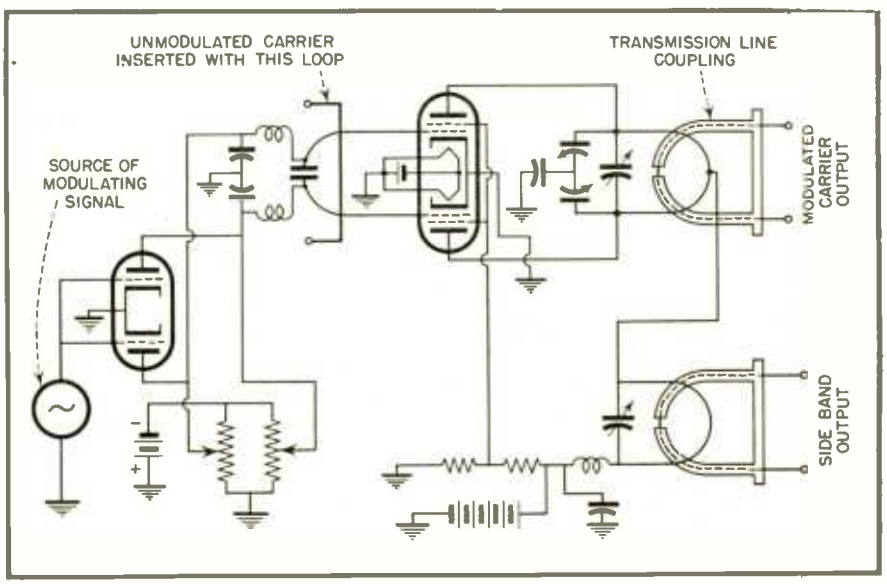
Although this system of bandwidth shrinkage has long been known, and although its advantage as a means of increasing the signal to noise ratio is well understood, it is claimed that in the present invention this system is particularly useful because of the nature of the detector system. The diagram illustrates the frequency-counter type detector. The signal, applied to the control grid of the tube marked *A*, interrupts the anode current of the tube in synchronism with the half-periods, of like sign, of the impressed wave. In the transformer primary this signal produces current pulses, of substantially equal strength, that occur instantaneously at the rate of the instantaneous frequency of the signal on the grid. By means of the diode marked *B*, these pulses are counted in order to produce on line *C* a voltage that is proportional to the pulse rate. A potentiometer, marked *D*, compensated this voltage so that it was zero valued for a pulse-occurrence rate corresponding to the central frequency of the i-f amplifier.

The patent, assigned to the Hartford National Bank and Trust Co., is number 2,383,359.

Modulation Circuit

★ A patent issued to Andrew Alford and Guy K. Patterson on August 28, 1945, describes a modulator that not only produces the usual mixture of carrier and sideband frequencies but also, at a separate output connection, yields sideband frequencies without any frequency component at the carrier frequency. Specifically, the invention does this without using bridge circuits having critical balance positions.

It is well known that antenna radiators may be spaced in a linear array and fed so that the whole array has directionally-radiating properties. For example, if two radiators, each having essentially isotropic patterns, are placed a half wavelength apart and fed in the same phase, complete cancellation will take place at all points along a line drawn through the two radiators, and maximum radiation will take place in directions perpendicular to this line. The same situation also exists in one direction if the individual radiators are spaced a quarter wave apart and are fed with energy having a quarter-wave phase difference. Specifically, if in such an arrangement the phase can be continually varied then the position of the pattern maximum from the array may be made to sweep through an arc like a beacon. Furthermore, if only one of the radiators in such an array radiates the carrier frequency, and the rest are restricted to sideband energy, then the beacon may be made to include only the intelligence. Carrier energy to operate the a-v-c circuits of the receivers is always available, and the modulation alone has directional properties. This arrangement is valuable in forming radio beams



Patent #2,383,456

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for aircraft guidance, one possible application of the present invention.

The schematic drawing indicates that the unmodulated carrier is combined with the modulating signal in a pair of coupling loops and is fed to the push-pull control grids of a double tetrode tube. The modulating signal changes the bias on the tubes to produce amplitude modulation of the carrier in the usual manner. At the midpoint of the loop, which carries energy from the plates into the usual output to a transmission line, is provided a connection that is tuned by means of a variable capacitor and the energy fed into a second output loop. This connection, and hence the second loop, does not contain any of the carrier frequency beause the push-pull connection causes the frequeny to cancel at the center point. On the other hand, the sidebands are inserted by a parallel connection to the grids and therefore do not balance out.

The patent, assigned to the Federal Telephone and Radio Corporation, is number 2,383,456.

Pulse-Integrating Circuit

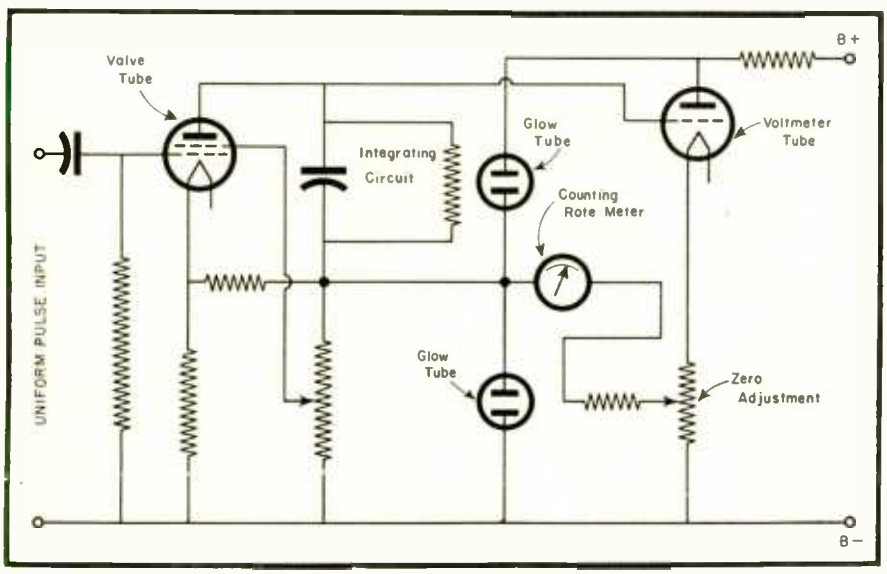
★ A patent issued to William N. Tuttle on April 24, 1945, describes a counting circuit suitable for telling the number of cosmic rays, or similar random events, that are detected per unit time. For example, cosmic rays are often observed with the aid of a gas discharge device called a Geiger-Muller counter. The entry of a cosmic ray particle into such a counter causes the appearance of a transient voltage on the output terminals of the counter. The purpose of the present invention is to measure the rate of appearance of such transients.

This is by no means the first attempt to build such a circuit. A system of using the transients from the Geiger-Muller counter to first trigger a biased multivibrator to obtain a signal in which each transient is replaced by a pulse of definite amplitude and duration is well known to workers in the field, and is also assumed to precede the input circuit of this invention. Such a multivibrator arrangement is very advantageous because it makes the counting problem one that is concerned only with the average frequency of occurrence of identical pulses that are randomly distributed in time.

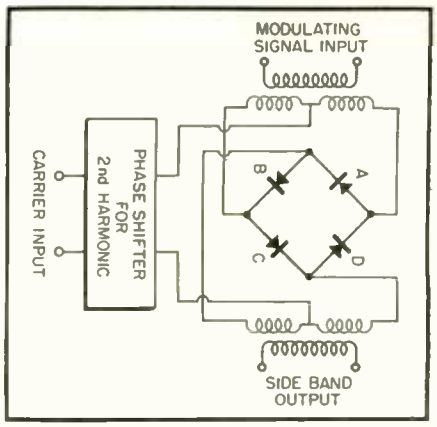
Referring to the accompanying schematic diagram, it is noted that the first vacuum tube, called the valve tube, has no connection between its plate and the positive B supply voltage. The plate serves only to collect from the cathode electrons that are accelerated by the grid potential during the time that pulses are applied to the grid. In the absence of any pulse, the grid is negative with respect to the cathode and no charge reaches the plate. For each pulse applied to the grid of the valve tube a definite amount of charge is transferred from cathode to plate and accumulated in the capacitor of the integrating circuit. This condition causes the voltage of that capacitor to be increased a certain fixed amount for each pulse. The capacitor of the integrating circuit is by-passed by a resistor that allows the charge to leak off at a given rate. Competition between the charging and discharging processes causes the voltage level of the capacitor to measure the rate at which pulses are applied to the input.

The second vacuum tube, and its associated circuits including a meter, constitute a vacuum tube voltmeter designed especially to measure the voltage across the capacitor of the integrating circuit. The meter reading voltage is calibrated in terms of pulses per minute that are applied to the input circuit.

The patent, assigned to the General Radio Company, is number 2,374,248.



Patent #2.374.248



Patent #2.377.858

Carrier Wave Modulation

★ William R. Bennett on June 12, 1945, patented a method of reducing second harmonic distortion, which arises in a ring-type balanced modulator when the signal frequency is close to the sideband frequency so that the two frequencies cannot be conveniently separated with filters. The accompanying diagram shows that the invention provides for a 90-degree phase shift of whatever second harmonic content there is in the modulated carrier. This phase shift causes the effect of the second harmonic to be spread between the two conduction periods of the modulator, and hence to have no effect on the sideband production.

First consider the condition where no modulating signal is present, and where the ideal situation of no second harmonic is also realized. With either polarity of the carrier wave terminals, it can then be seen that the carrier signal is balanced in the output transformer and no output signal is obtained. On the other hand, tracing through either polarity from the modulating signal input yields a net output signal. As in any balanced modulator, this signal, in the presence of a carrier voltage, consists of amplitude modulation sidebands. If a second harmonic is present in the carrier frequency supply, and if that second harmonic has maximum positive values each time the carrier passes through either maximum positive or maximum negative strength, then the harmonic will affect the two carrier polarities differently thereby causing unbalance in the output. This relation, a harmonic naturally bears to its fundamental. However, if a phase shifter is used to shift the harmonic 90° more than the carrier, then the harmonic voltage will have zero values whenever the carrier has a zero or a maximum. The harmonic effect will be canceled out.

The patent, assigned to the Bell Telephone Laboratories, is number 2,377,858.

Selective Amplifier or Oscillator

★ On October 16, 1945, a method of utilizing negative feedback to produce

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an amplifier that will pass only a narrow-frequency band was patented by Bertram Morton Hadfield of Harrow Weald, England. The amplifier has the remarkable ability of allowing the center frequency of the narrow pass-band to be adjusted over several octaves by simply varying a single potentiometer. It is also capable of acting as an oscillator whose frequency is adjustable by a single potentiometer. To make the circuit function in this manner, the input terminals are short-circuited and the positive feedback marked *A* in the accompanying drawing is advanced until oscillation is incurred.

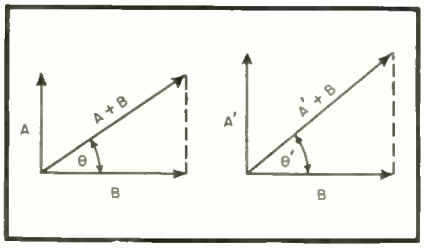
Referring to the drawing that shows amplifier circuits in a well-known form and shows also the novel feedback arrangement, the invention may be described in terms of phase angles measured to indicate whether they represent a leading or lagging of the voltage at the input point marked *B*. At the plate of the first vacuum tube (*C*) there is a phase shift of 180 degrees. The next two vacuum tubes are cathode followers and introduce no phase shift; consequently the phase angle is still 180° at point *D*. Here, after passing through a capacitor to remove the d-c component of the signal, the path is broken into two parts, one advanced in phase and the other retarded, so that for a frequency in the center of the usable range the phase at points *E* and *F* are 180—p and 180+p degrees. After passing through cathode followers to lower the impedance of these signals they are added in the potentiometer. If the potentiometer is placed in the center position the signals are added in equal strength, which restores the 180° phase angle at the level of the conductor marked *H*. Therefore no negative feedback is incurred and the chosen frequency is amplified. If under these conditions any other frequency is fed into the amplifier, then the phases at points *E* and *F* may be represented by 180+p and 180—q where p and q are unequal. In this event *G* has a component which causes negative feedback, and prevents the unwanted frequency from entering the amplifier.

If the potentiometer marked *G* is adjusted to a point off center, then some value of unequal phase shifts, represented by p and q, will give the condition of zero negative feedback. Consequently, some other frequency will be passed while all others are rejected as they were before.

The patent, assigned to Automatic Electric Laboratories Inc., is number 2,386,892.

Frequency Modulator

★ A method of obtaining frequency modulation, or phase modulation, by producing two amplitude modulations that are then combined, is shown in a



Patent # 2,384,789

patent issued to David Arthur Bell of London, England, on September 18, 1945. In one form, the invention consists of a pair of oscillators that are tuned to points beyond the extremes of the desired FM excursion, and are respectively modulated in amplitude by a modulating signal that is applied in opposite phase to each of the oscillators. The two amplitude-modulated signals are then combined in a limiter to produce the desired FM signal that becomes a fairly pure FM product, provided that the amplitude changes are kept within certain limits. Specifically, in this simple scheme the two amplitudes must never become equal nor exceed 20% deviation from their mean amplitude. If the amplitudes become equal then the desired frequency component has zero amplitude. To overcome this limitation, a scheme is also shown in which the output of the system is supplied with an additional frequency component from an oscillator tuned to the center FM frequency.

The circuit of this invention is varied and complex. The arrangements are based upon the condition that two approximately equal frequencies may at any instant be considered to be of the same frequency but having a phase relationship that changes progressively with time. If two such signals of substantially the same frequency but of different phase are added, then their sum is at a new phase value depending not only upon the original phase difference but also upon the respective amplitudes. These features may be observed in the accompanying drawing where one signal is represented by vector *A*, another by *B*, and their sum by *A*+*B*. If the amplitude of *A* changes to *A'*, then the amplitude of *A*+*B* may change a little but its phase may change a substantial amount. That is, *A'*+*B* differs from *A*+*B* by a magnitude increment of such value that the differential may be removed in a limiter, while the difference between θ and θ' represents the desired phase modulation.

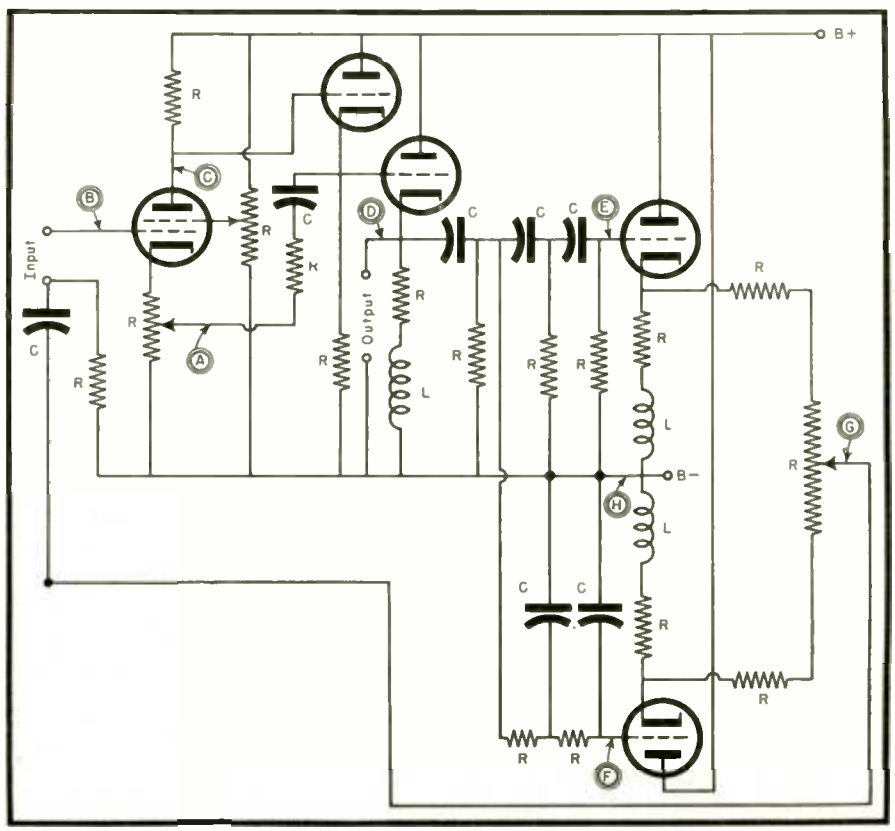
The patent, assigned to the Radio Patents Corporation, is number 2,384,789.

Antenna Construction

★ A patent isued jointly to Andrew Alford and Morton Fuchs on October 2, 1945, describes a coaxial-type radiator shown in the accompanying drawing. This arrangement is particularly advantageous for use at very high frequencies where the coaxial sleeves may be made as long as a half wavelength.

A metallic mast is used and is ex-

[*see page* 58]



Patent #2,386,892

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RADIO DESIGN WORKSHEET

NO. 44 – THE CATHODE FOLLOWER CIRCUIT

The cathode follower is a degenerative amplifier in which the load may be at ground potential and in which the advantages of inverse feedback may be realized. Coupling to coaxial lines is therefore much simplified. Such a circuit has been used to advantage as the first stage of a video amplifier fed by an iconoscope.

The significance of the characteristic of the cathode follower can be demonstrated by comparing it to the conventional resistance coupled audio amplifier, the schematic for which is shown in *Fig. 1*.

If the plate impedance of the triode

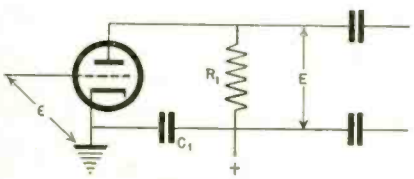

Figure 1

of *Fig. 1* is R_p and its amplification factor is μ then

$$I_p = \frac{\mu_1 e}{R_p + R_1}$$

$$E = I_p R_1 = \frac{\mu_1 e R_1}{R_p + R_1}$$

$$\frac{E}{e} = \frac{\mu_1 R_1}{R_p + R_1}$$

Figure 2 shows the schematic of the cathode follower circuit. The output voltage E will be equal to the product of the plate current I_p and the cathode load resistor R_1. Hence

$$I_p = \frac{\mu(e - I_p R)}{R_p + R_1}$$

$$I_p R_p + I_p R_1 = \mu e - \mu Z_p R_1$$

$$I_p(R_p + R_1 + \mu R_1) = \mu e$$

and

$$I_p = \frac{\mu e}{R_p + R_1 + \mu R_1}$$

Whence

$$\frac{E}{G} = \frac{\mu R_1}{R_p + R_1(1 + \mu)}$$

For purposes of comparing the performance of *Fig. 1* and *2* assume

$$\mu_1 = \frac{\mu}{\mu + 1}$$

and

$$R_p = R_p/\mu + 1$$

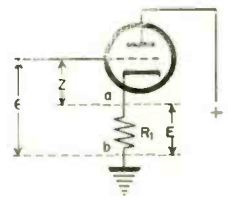

Figure 2

Substituting in

$$\frac{E}{e} = \frac{\mu_1 R_1}{R_p + R_1}$$

We have:

$$\text{Stage gain} = \frac{\mu}{\mu + 1} \cdot \frac{R_1}{R_p/(\mu + 1) + R_1}$$

$$= \frac{\mu R_1}{R_p + R_1(\mu + 1)}$$

which is identical to the voltage gain for the cathode follower circuit of *Fig. 2*. Whence we may conclude that the gain of the cathode follower circuit is equivalent to the gain of a conventional resistance coupled amplifier in which the amplification factor of the tube is

$$\frac{\mu}{\mu + 1}$$

and the plate resistance of the tube is

$$R_p/\mu + 1$$

Let the gain of the single stage cathode follower circuit of *Fig. 2* be designated by G. Any impedance Z between grid and cathode of the cathode follower will appear higher because of degeneration. This apparent impedance then becomes

$$Z' = \frac{Z}{(1 - G)}$$

From this it follows that a grid coupling resistance C (if connected between grid and cathode of the cathode follower) can be made quite low and yet appear quite high insofar as the effect on the signal is concerned. Obviously the same reasoning applies to grid-cathode capacitance. The grid cathode capacitance C of the circuit of *Fig. 2* will therefore appear to be

$$C' = C(1 - G)$$

The grid-to-ground capacitance and the grid-to-plate capacitance will, however, be unaffected. If a coaxial line (which is usually of low impedance) is to be connected to terminals a - b of *Fig. 2*, that is, across the cathode load resistance R, the impedance looking into terminals a - b must match the characteristic impedance of the line. This impedance is equal to R_1 and $R_p/\mu+1$ in parallel. Since R_1 may be larger in the cathode follower circuit than in a conventional resistance coupled stage, the voltage applied to the input of the line is about the same in either case. The other advantages of the cathode follower circuit however make it preferable to the conventional resistance coupled amplifier for such use. The omission of coupling capacitors in the case of the cathode follower is also a matter of importance.

Figure 3 shows one application of the cathode follower circuit used as the first video stage of an iconoscope amplifier. This arrangement is quite effective in that the apparent input capacitance is appreciably reduced. The proper bias for the iconoscope is obtained by tapping the cathode load resistor. Such an arrangement materially improves operation and can be followed by sufficient stages of conventional video circuits to build up the necessary gain in the iconoscope amplifier.

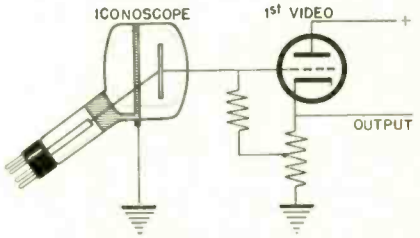

Figure 3

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This Month

Relay Tower in RCA'S New Microwave Communication System

Relay stations like this one, used since early this year in a test circuit operated by RCA Victor with the cooperation of Western Union between New York and Camden, N. J., may ultimately replace thousands of miles of telephone and telegraph wires in a new microwave radio relay system announced by the Radio Corporation of America. On the outside of the 8-foot-square enclosed cabin, perched atop a 100-foot steel tower, are seen the bowl-shaped reflector-antenna units which receive and transmit many voice and telegraph channels simultaneously. Towers are situated on hilltops or tall buildings, 25 to 50 miles apart. Such systems may also carry FM broadcast and facsimile channels, and ultimately, when bandwidth can be increased, would accommodate television.

SYLVANIA FM SURVEY

During the next two or three years, FM set production may add a new $600,000,000 market to the radio set business, it was revealed by Frank Mansfield, director of sales research for Sylvania Electric Products Inc. today. "This means that 10,700,000 FM sets can be sold out of a total market for 17,400,000 sets," he said, in stressing the tremendous acceptance of FM by the public. He based his predictions on a special survey of radio set owners recently completed to determine the immediate outlook for FM receivers.

Not only do people definitely want FM receivers but they are willing to pay more for them, according to Mr. Mansfield, who said that the survey showed that 56% of the prospects are willing to pay $100 to $150 more for an FM set with true high fidelity; 27% will pay $30 to $50 extra; and only 13% say they don't know how much more they are willing to spend.

Reasons why the majority of FM set owners prefer FM to AM were shown by 85% of those interviewed who said that it reduced static and noise; the 61% who said it gave greater realism; by 37% who reported less interference between stations; and by 20% who said they liked FM programs better. Only 14% said they liked FM best because AM reception was poor in their locality.

The consensus of FM set owners indicated that they like them and they use them; they have no serious trouble operating their receivers; and they believe that FM is superior to AM in many respects.

In addition to actual FM set owners many other listeners representing a good sample of the radio audience were interviewed. Of these in this group who had listened to FM programs, 70% said that they preferred FM to AM. Only 21% were unable to distinguish the difference between FM and AM reception. When asked where they had heard FM programs, 68% said they had heard programs in friends' homes; 19% in retail stores; and slightly less than 10% in broadcasting stations.

One of the FM features that appeals to those who do not have FM receivers, according to Mr. Mansfield, is high fidelity. 72% of those interviewed said they think it is a distinct advantage. Only 26% consider it unimportant. However, interviewers of actual FM set owners who watched them tune their receivers observed that only 19% actually took advantage of FM's high fidelity feature. 71% did not and 10% did not know how to tune in programs with high fidelity.

The survey is the third of a continuing series being conducted by Sylvania Electric Products Inc. It tends to indicate a tremendous new market for FM receivers. Radio set manufacturers plan to make postwar FM receivers available to the public early in 1946.

ICA POSTWAR PRODUCTION

Like most industrial plants filling war contracts, ICA found it expedient to add a great number of new machines and finishing facilities to their plant. Holding to the conviction that their peacetime production can equal their wartime record, the Insuline Corporation of America, Long Island City, N. Y., is gearing its postwar program to fit the war-added facilities which were added to their original equipment.

Insuline is already producing more radio parts and auto antennas than it has ever done before. But in addition, to avoid labor layoffs, Insuline is also accepting orders for sheet metal stampings of all types and sizes. Every facility formerly made available to the government is now being turned toward supplying manufacturers with made-to-specification stampings, chassis, cabinets, terminal boards, boxes, and even huge transmitting cabinets.

Mr. Sam Spector, President of Insuline and a pioneer in the radio parts industry is confident the next few years will be profitable to both management and labor is industry, in general, will follow his example.

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NEW FREQUENCY ALLOCATIONS

The Federal Communications Commission has announced several minor modifications in its plan of frequency allocations from 25,000 to 30,000,000 kilocycles which was issued on May 25, 1945. The modifications were the result of recent conferences betwen representatives of the Commission and the Interdepartment Radio Advisory Committee at which it was disclosed that developments in various types of equipment used as aids to air and marine navigation made the changes desirable.

The services and bands affected by the changes are shown in the following tables:

NEW

Band (mc)	International Service	U. S. Allocation	Remarks
960-1215	Navigation Aids	Navigation Aids	
1215-1295	Amateur	Amateur	
1295-1375	(a) Fixed (b) Mobile except Aero.	Non-Govt.	Television Relay
1375-1425	(a) Fixed (b) Mobile	Non-Govt.	Fixed & Mobile
1425-1600	(a) Fixed (b) Mobile	Govt.	

FORMER

960-1145	Navigation Aids	Navigation Aids
1145-1245	Amateur	Amateur
1245-1325	Fixed and Mobile except Aero.	Television
1325-1375	Fixed and Mobile	Non-Govt., Fixed & Mobile, Including Aero.
1375-1600	Fixed and Mobile	Govt.

The changes between 960 and 1600 mc are designed to provide additional spectrum space for navigation aids which recent developments have shown to be desirable.

NEW

2900-3700	Navigation Aids	Navigation Aids	Racons 3256 ±3 mc. with Guard Band 3246-3266 mc.
3700-4000	(a) Fixed (b) Mobile except Aero.	Non-Govt.	
4000-4200	Air Navigation Aids	Air Navigation Aids (Altimeters)	
4200-4400	(a) Fixed (b) Mobile except Aero.	Non-Govt.	

FORMER

2900-3700	Navigation Aids	Navigation Aids
3700-3900	Air Navigation Aids	Air Navigation Aids
3900-4400	(a) Fixed (b) Mobile except Aero.	Non-Govt.

Recent developments in altimeters have indicated the desirability of moving the air navigation aid band from 3700-3900 mc to 4000-4200 mc.

NEW

8500-9300	Special Navigation Aids	Govt.	
9300-9600	Navigation Aids	Navigation Aids	Racons 9310 ‡3 mc with Guard Band 9300-9320 mc
9600-10000	Special Navigation Aids		

FORMER

8500-10000	Special Navigation Aids	Govt.

The changes between 5008 and 10000 mc were made to permit the licensing of radar installations between 9300 and 9600 mc for use by the merchant marine.

Personal Mention

Carter and Zimmer Promoted

★ Walter E. Poor, President of Sylvania Electric Products Inc., has announced that E. Finley Carter, formerly Vice President in Charge of Industrial Relations, has been named Vice President in Charge of Engineering following the resignation of Roger M. Wise.

E. Finley Carter

Mr. Carter was Assistant Chief Engineer of the Radio Division of Sylvania for a number of years. Earlier. he had been engaged in radio development for General Electric Company.

Mr. Zimmer, with a record of over twenty-six years of service with Sylvania and its predecessor companies, has been General Manager of Operations of the Radio Division since 1943. He now becomes Vice President in Charge of the Radio Tube Division.

H. Ward Zimmer

RADIO PARTS SHOW

The board of directors of the newly formed Radio Parts and Electronics Equipment Shows Inc. have announced the definite date and tentative plans for the 1946 trade show at Chicago. The sudden ending of the war with Japan necessitated revision of the original plan to hold the 1946 show in October. Realizing the desirability of holding the show at the earliest practical date, May 13th through 16th (Monday through Thursday) has been set. Chicago, the site of many pre-

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Eimac TUBES — THE COUNTERSIGN OF DEPENDABILITY IN ANY ELECTRONIC EQUIPMENT

NEW EIMAC EXTERNAL ANODE TRIODE 3X2500A3

Rugged mechanical construction
Outstanding electrical efficiency

In the new 3X2500A3, Eimac engineers have developed a highly efficient external anode triode which, in Class C service, delivers up to 5 KW output at a plate voltage of only 3,500 volts. The mechanical design is radically simple, incorporating a "clean construction" which gives short, low inductance heavy current connections that become an integral part of the external circuits at the higher frequencies.

The external anode, conservatively rated at 2500 watts dissipation, has enclosed fins so as to facilitate the required forced air cooling.

Non-emitting vertical bar grid does not cause anode shadows ordinarily created by heavy supports in the grid structure.

Thoriated tungsten filament. Note unusually large filament area, and close spacing.

Filament alignment is maintained throughout life of the tube by special Eimac tensioning method.

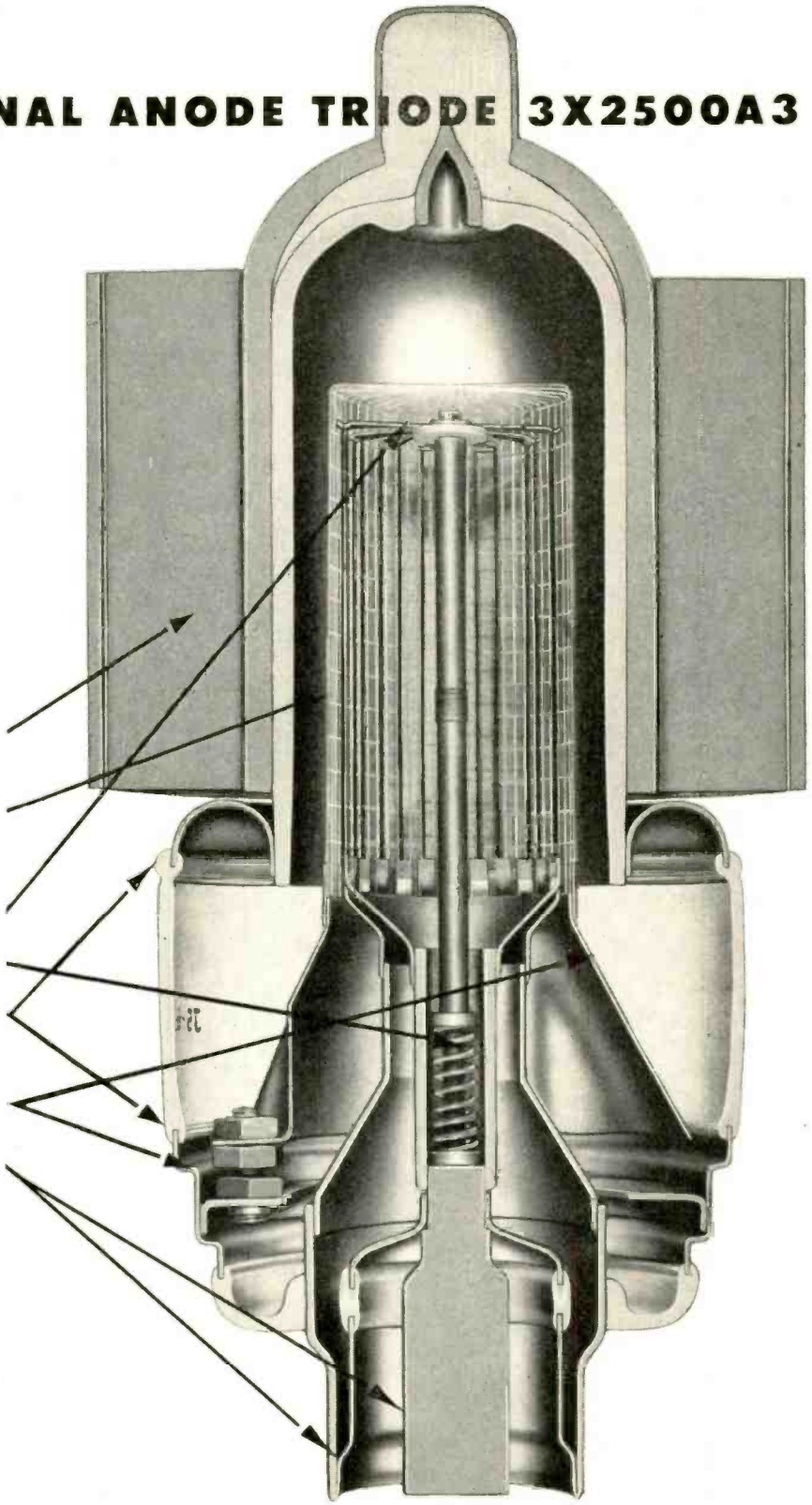
New glass-to-metal seals do not have the RF resistance common to iron alloy seals, nor the mechanical weaknesses of the feather-edged types.

Grid ring terminal mounts a cone grid support which acts as a shield between plate and filament.

A coaxial filament stem structure forms the base of the tube. This makes possible proper connections to the filament lines.

Grid and filament terminal arrangements make it possible to install or remove the 3X2500A3 without the aid of tools.

The new mechanical and electrical features of the Eimac 3X2500A3 external anode triode make it valuable for use on the VHF as well as low frequencies. More complete data and information yours for the asking.



TYPE 3X2500A3 — MEDIUM MU TRIODE

ELECTRICAL CHARACTERISTICS

Filament: Thoriated Tungsten	
Voltage	7.5 volts
Current	48 amperes
Amplification Factor (Average)	20
Direct Interelectrode Capacitances (Average)	
Grid Plate	20 $\mu\mu$fd.
Grid Filament	48 $\mu\mu$fd.
Plate Filament	1.2 $\mu\mu$fd.
Transconductance (i_B=830 ma., E_B=3000 v.)	20,000 μmhos

1123

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EITEL-McCULLOUGH, INC., 1123 San Mateo Ave., San Bruno, Calif.

Plants located at: San Bruno, Calif. and Salt Lake City, Utah

Export Agents: Frazar and Hansen, 301 Clay St., San Francisco 11, Calif., U.S.A.

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THIS MONTH

[*from page* 46]

vious radio trade shows was selected because of its geographically central location and availability of the Hotel Stevens facilities.

The trade show corporation is represented by eight directors appointed by the four sponsoring organizations, two from each group. These men, all well known among the trade, are:

From Parts Division of Radio Manufacturers Association:

Leslie F. Muter—The Muter Company, Chicago, Illinois.

Jerome J. Kahn—Standard Transformer Corporation, Chicago, Illinois.

From National Electronic Distributors Association:

W. O. Schoning—Lukko Sales Corporation, Chicago, Illinois.

Sam Poncher—Newark Electric Company, Chicago, Illinois.

From Association of Electronic Parts and Equipment Manufacturers:

H. W. Clough—Belden Manufacturing Company, Chicago, Illinois.

J. A. Berman—Shure Brothers, Chicago, Illinois.

From Sales Managers Club, Eastern Division:

R. P. Almy—Sylvania Electric Products Inc., Emporium, Pennsylvania.

Charles Golenpaul—Aerovox Corporation, New Bedford, Massachusetts.

Herb Clough, who ably served as Chairman of the 1944 Radio Industry Conference, is President. The other officers are:

Charlie Golenpaul, Vice President.

Sam Poncher, Treasurer.

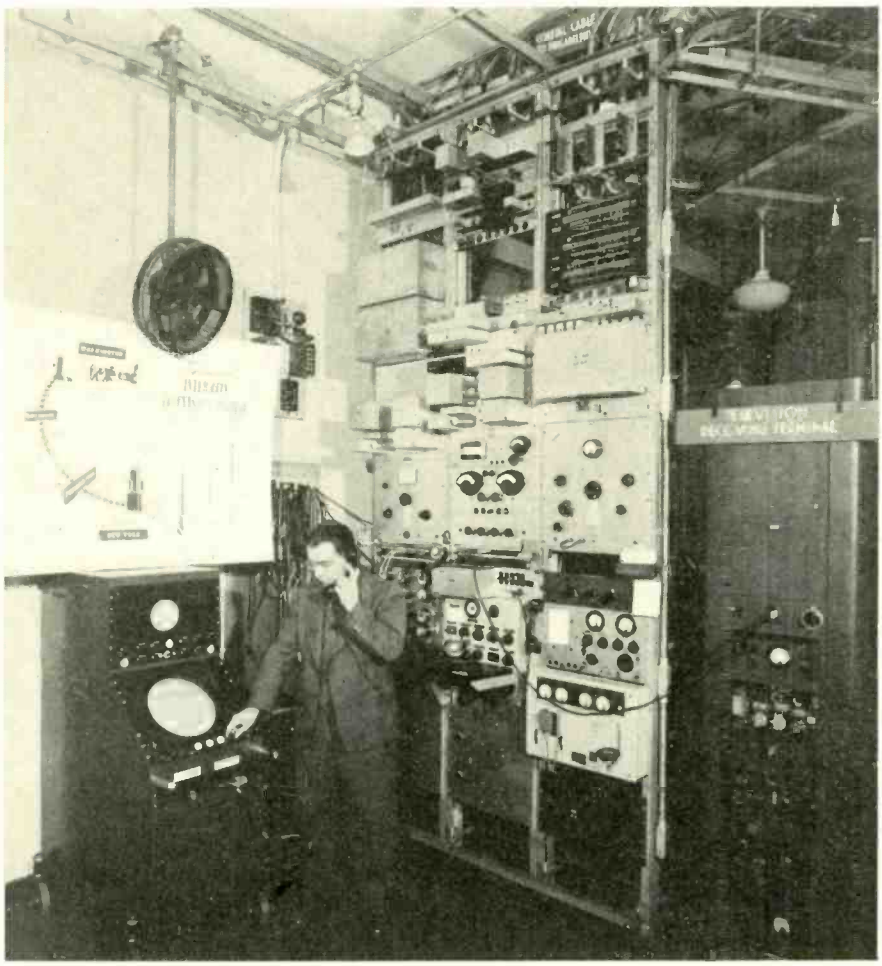
Jerry Kahn, Secretary.

The respective chairmen and membership of the various committees selected from the board and sponsoring groups to handle the many activities will be announced soon.

As soon as the services of a show manager can be obtained, a headquarters office will be established in Chicago.

Exhibitors at the show will be limited to members of the four sponsoring groups. No radio sets will be displayed. Application forms are being prepared and will be mailed to all sponsor members soon.

The October 1944 Industry Conference, which operated under wartime conditions, pulled an attendance of approximately 1,700 members of the trade including 160 booth exhibitors. Indications are that this 1946 show, with interest in peacetime merchandising at its peak, will attract a much larger number.



TELEVISION RECEIVING TERMINAL

This is the equipment in the long distance headquarters of the American Telephone and Telegraph Company in New York where the television images of the Army-Navy football game, played in Philadelphia last December 1, were received via the coaxial cable. From this terminal the television scenes were sent on to the television broadcasting station of the National Broadcasting Company in the Empire State Building. Stephen Vitale of the Long Lines Department is adjusting a television receiver used in checking the performance of the inter-city system.

AIRPORT RADIO STATION

A complete airport radio station ready to plug into a socket and start working is the offering of Aireon Manufacturing Corporation to the thousands of new airports springing up over the nation.

In a preview announcement of the new field equipment, the corporation describes its new Type RS-1 50 watt radio station as a complete combination unit ready for installation—which means plugging it into a socket. The only exception is the antenna supporting poles which do not come with the equipment.

Simple, push-button control keynotes the sets, which require no dialing or tuning as each channel is pre-tuned and controlled by radio crystals, also made at Aireon.

The station is designed for airports, airlines and other similar types of communications systems. It may be used from point to point or ground to plane communication or as a tower control station.

Radio transmitters and receivers, all types of radio communication equipments, hydraulic aircraft controls, radio crystal products, antennas and other radar equipment still on the war department restricted list, comprise part of the products of this company headquarters of which are in Kansas City.

WIRE RECORDER LICENSEES

The licensing of four additional manufacturers, including Bendix Aviation Corporation, to produce Armour magnetic wire sound recorders was announced recently by Lucius A. Crowell, president of the Wire Recorder Development Corporation, 135 South LaSalle Street, Chicago, which handles the licensing program for the Armour Research Foundation of Illinois Institute of Technology.

Other new licensees are Bang and Olufsen, Copenhagen, Denmark; Pyrox Proprietary, Ltd., Melbourne, Australia; and the St. George Recording Equipment Company, New York, N. Y.

Bendix Aviation Corporation, which is reported to have plans to manufacture 1,000,000 home radios yearly as a part of its peacetime reconversion program, expects to produce magnetic wire sound recorders in seven different fields of application.

In addition to incorporating wire recorders in home radio receiving sets, Bendix will manufacture wire record business dictating machines, adaptor units for use with existing home radios; portable, self-contained recorders (including pocket models); recorders for installation on railroad trains, ships and planes for entertainment purposes; recording devices for use in connection with the operation and control of mobile vehicles, and specially designed supersonic magnetic wire recorders for use in various types of research and testing work in pure and applied science.

These four new licensees bring to 24 the

[*see page* 60]

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We recommend these *Gammatrons* for the new amateur bands

In answer to many requests for our recommendations as to the Gammatrons which will give peak performance on the bands released to amateurs on November 15, we have been commenting as follows:

HK-24 and HK-24G "These triodes fill the bill for operation up to and including the 205 megacycle band. Your mechanical arrangement will largely determine your choice. We give the nod to the 24-G for top performance at 205."

HK-54 "Excellent up to 148 megacycles. Just the thing for the chap who wants 300 to 350 watts output from a pair on 28 megs—plate modulated."

HK-254 "If you want to put out a half kilowatt on 54 megacycles, use this big brother of the HK-54 in pushpull. Ratings decrease above this frequency to approximately 280 watts input to one tube at 200 mc."

HK-257B "Don't overlook this beam pentode for your bandswitching job. It requires practically no driving power. A couple of receiving tubes, such as 6V6's, will take you in a hurry from a 3.5 mc. crystal to 28 megs where pushpull 257-Bs will give you up to 400 watts out."

HK-454 "This is the tube for the man who wants a full kilowatt output on 28 megacycles. It's also excellent on 54 megs."

Additional data on Gammatron tubes appears in "The Radio Amateur's Handbook" and in "The Radio Handbook." Data sheets on individual types will be sent on request, and our engineering department will gladly provide special information or advice on your particular applications. You can now obtain Gammatrons at stores handling amateur components.

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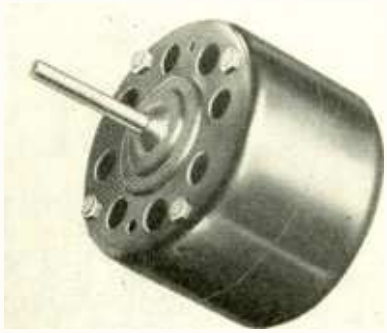
New Products

FRACTIONAL H-P MOTORS

Two new four-pole shaded pole fractional h-p. motors, the SP-37 and SP-38, have been developed by Small Motors,



Inc., 1308 Elston Avenue, Chicago for duties requiring moderate torques. These motors are especially suited for cooling, circulating and ventilating fans and blowers, centrifugal pumps, driers, animated signs, timing devices, drafts and damper controls, unit heaters and coolers, exhaust fans, advertising devices, motion picture projectors, remote control drives, etc.

They are regularly wound for 115 volts, 60 cycles, single phase. Can be wound to stand locked rotor conditions continuously. Laminated field and rotor cores. Ball or oilless bearings. Available with or without fan blades, mounting brackets or bases.

These motors are each made in four sizes: the SP-37 with ratings from 1/100 to 1/40 H.P. and speeds from 1400 to 1650 RPM, the SP-38 with ratings from 1/35 to 1/10 H.P. and speeds from 1400 to 1650 RPM.

145 MEGACYCLE RING TUNER

The Caltron Company, Los Angeles 34, California, announces a complete variable tuning unit in a compact assembly for single hole mounting on receivers, wave meters, frequency meters, low power transformers, and oscillators.

The unit has a tuning range of 140 mc

to 160 mc with 3.5 μf tube capacity, (Later models will be designed to cover any band of frequencies between 50 and 1000 mc). rotation 180 degrees, diameter of body 2", shaft diameter 1/4", mounting hole 3/8".

Among the advantages offered are, no coils to wind, no condensers to trim, no sliding contacts and no bearing contacts. "Q" is many times greater than conventional coil condenser combination. It is easy to asemble with a single hole in panel and close spacing of terminal lugs (approximately ½" between outside and ends of circuit), which allows extremely short leads to tube connections.

PRECISION RESISTORS

New "Series 84" in Type 844B, 844A, and 842A, is the latest addition to the Ohmite Riteohm Precision Resistor line which includes the Riteohm Series 71, 81, 82, 83 and 90. This new series was developed to meet the demand for a precision

resistor capable of being mounted by means of a through-bolt and equipped with a radial lug at each ends.

The Riteohm 84 is pie-wound to 1% accuracy and is available in 3 sizes—9/16" diameter by 9/16" long, 9/16" diameter by 7/8" long, and 3/4" diameter by 1-3/16" long. The smallest is a 2 pie while the other two are 4 pie units. The minimum resistance is 1.0 ohm for the 2 pie unit and small 4 pie unit, and .10 ohm for the large 4 pie unit. The maximum resistance is 200,000 ohms for the 2 pie, 400,000 ohms for the small 4 pie, and 1.5 megohms for the large 4 pie unit.

For further information, write for Bulletin No. 126 to the Ohmite Manufacturing Company, 4835 Flournoy St., Chicago 44, Ill.

MEGOHM METER

Unusual stability, portability, and a range from 400,000 ohms to 100,000 megohms in five ranges on single scale four inch meter, are among the outstanding features claimed for the new Model 1500 Megohm Meter, developed by Communication Measurements Laboratory.

This unit also offers protection against atmospheric conditions where precise testing is required.

Weighing only eight pounds, Model 1500 may be employed in laboratories or on production lines where it is necessary to measure and test in widely scattered locations. CML's 1500 is now being used in a wide range of applications: Measuring of leakage resistance of insulation materials, condensers, coaxial cables, wiring harness, motor and transformer windings. On production checking of resistors the range may be extended below 400K by the increment method. Model 1500 is also recommended for determination of moisture content of wood, paper board, plastics, textiles, and many other materials in which electrical resistance is a function of moisture content.

Model 1500 is extremely stable despite line voltage fluctuations. Manufacturer's test show that a change in line voltage from 90 to 130 volts produces a change of less than 3% in meter reading at midscale. Single zero reset adjustment is provided for all ranges and drift after initial warm-up period is substantially zero. Efficiently guarded on all ranges to prevent distortion of readings due to atmospheric conditions. Accuracy guaranteed better 5% on all ranges at all points on scale.

Line voltage: 115 volts, 60 cycles. Available for immediate delivery without priorities. Descriptive bulletins available from Meter Division, Communication Measurements Laboratory, 120 Greenwich Street, New York 6, N. Y.

AUTOMATIC FEED SOLDERING IRON

A patented, automatic-feed, electric soldering iron, the Eject-O-Matic, is being introduced by the Multi-Products Tool Company, 123 Sussex Avenue, Newark, N. J. This new iron is trigger operated and ejects a measured amount of solder from a

reel concealed in the handle. A special retracting feature prevents the melting of excess solder on the heating tip. The actual amount of solder deposited each time the trigger is pulled is regulated by a micrometer adjusting wheel mounted in the

[see page 52]

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CLAIM STAKING

Hallicrafters and Very High Frequency

Based on the facts in the case, Hallicrafters can stake out a very strong claim to leadership in the very high frequency field. The facts include such things as the Model S-37, FM-AM receiver for very high frequency work. The Model S-37 operates from 130 to 210 Mc.—the highest frequency range of any general coverage commercial type receiver.

Hallicrafters further supports its claim to domination in the high frequency field with the Model S-36A, FM-A M-CW receiver. The 36A operates from 27.8 to 143 Mc., covers both old and new FM bands and is the only commercially built receiver covering this range.

Further developments in this direction can soon be revealed—adding further support to Hallicrafters claim to continued supremacy in the high frequency field.

HALLICRAFTERS NEW $600,000 HOME NOW UNDER CONSTRUCTION.

hallicrafters RADIO

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NEW PRODUCTS

[from page 50]

handle of the iron easily accessible to the operator's thumb. If, during the course of a job, more, or less solder is required, a touch of the wheel changes the amount ejected.

FREQUENCY CONTROLLED DC-TO-AC CONVERTER

A new frequency-controlled d.c. to a.c. rotary converter which permits controlled 60 cycles output has been placed in production by Carter Motor Company, 1608 Milwaukee Avenue, Chicago, Ill.

Designed with the frequency control in the base and including a vibration reed-

type meter to indicate visually the frequency of the output, the unit will find wide uses in the portable-mobile field where exact output frequency is required. The control knob is attached to a power rheostat in series with the field coils, and by increasing the resistance, the fields are thereby weakened, permitting the armature speed to increase to the correct rate, assuring 60-cycle output. The voltage drop across the resistance is negligible, and the control can only be used where the input voltage drops below the normal nominal value.

NEW "LIGHTHOUSE" TUBE

Eitel-McCullough, Inc., of San Bruno, California, announces the 3X100A11/2C39 transmitting tube. The tube is a miniature external anode triode, of the "lighthouse" variety, and offers exceptional performance in applications requiring up to 25 watts of power at frequencies to above 500 megacycles. Its rugged construction, unusually

high transconductance and 100 watts of plate dissipation make it useful over a wide range of frequencies, either in fixed or mobile equipment. It has an indirectly heated cathode with a 6.3 volt heater.

The overall heights is 2¾ inches and the diameter is 1¼ inches.

CRYSTAL DIODES

Germanium crystal diodes suitable for use as second detectors and d-c restorers in television receivers; frequency discriminators in FM circuits; first detectors; modulators and demodulators; low frequency oscillators; voltage regulators; and polarizing devices have been announced by Sylvania Electric Products Inc., Electronics Division, Boston, Mass.

Other applications include volume limiters; square wave clippers; varistors; noise silencers; meter rectifiers; volume expanders and volume compressors.

Supplied in tiny cartridges measuring .75" x .25", they require no heater supply or adjustment and may be wired directly into circuits by means of tinned copper leads. Affected less by conditions of temperature, humidity and age than other types of dry rectifiers, they resist shock

DON'T SETTLE FOR LESS THAN:

the Best

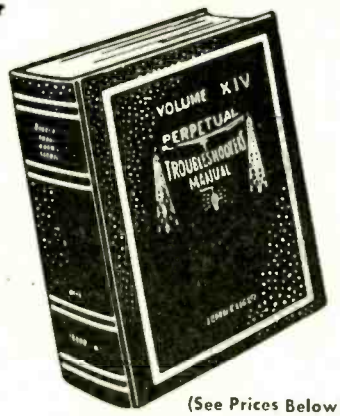
When you must service any and all models of radio sets, only Rider Manuals can fill the need.

For sixteen years Rider Manuals have been furnishing complete and authentic servicing data on American radio receivers. Today they represent the only single source upon which you can depend for all the information you need on such vital material as receiver schematics, voltage data, alignment data, resistance values, chassis layouts and wiring, trimmer connections—in fact all the things that lead to quick diagnosis of troubles in ailing receivers.

—And they're complete! Since the publication of Volume I over 42,000 models have been covered—only Rider Manuals contain wiring diagrams on Scott receivers. (These diagrams were received officially from the E. H. Scott Radio Labs., Inc.)

There are good reasons why better servicing shops have waited during the war until they could get their Rider Manuals. There are better reasons today why you should not settle for less than "The Best." For, the flow of Rider Manuals is again approaching normal.

See your jobber and place your order today to guarantee fastest possible delivery.



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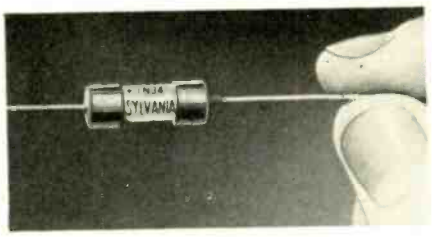


and vibration as well or better than conventional vacuum tubes.

Electrical features include comparatively small inter-electrode capacitance; small shunt capacitance; low forward resistance; high back resistance; ability to work into a low resistive load with reasonable efficiency; and the elimination of heater supply, noise and a-c hum. Elimination of heater supply permits connection of both terminals of the crystal diode far above grand potential.

Used as a voltage regulator for peak voltages between 20 and 50 volts and currents between 7 and 30 ma d.c., crystal diodes eliminate the flicker, high firing voltage and space requirements of conventional gas-discharge tubes.

Operating characteristics of a typical Type IN34 germanium crystal diode are as follows:

Peak Inverse Voltage ..... Anode 50 v. max.
Average Anode Current. 22.5 ma. max.
Peak Anode Current (a-c signal max.) ..... 60 ma. max.
Surge Current (transient peak) ..... 200 ma. max.
Back Conduction at 50 v. 2 ma. max.

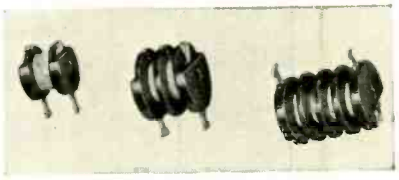
NEW U-H-F WAVEMETER

For rapid measurements of frequency in the range of 240 to 1200 megacycles the Type 1140-A U-H-F wavemeter. The frequency range is covered in a single direct-reading range with an accuracy of ±2%. The tuning element is a butterfly-type tuned circuit which is coupled to a standard cartridge-type crystal detector. Crystal current, as indicated in a microammeter gives an indication of resonance. Where the available power is not sufficient to actuate the microammeter, the reaction of the wavemeter upon the current in the circuit under measurement can be used.

The entire assembly is housed in a small molded plastic case that can be conveniently held in one hand.

NEW KOOLOHM RESISTORS

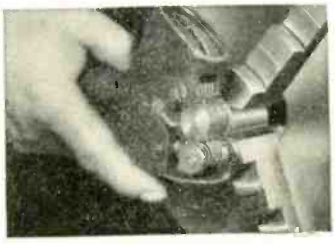
Three compact new units rated at 1, 2 and 3 watts of 80°C. ambient just added to the Sprague Koolohm line of wire-wound bobbin-type resistors find widespread use in industrial applications. They are wound with the well-known Sprague Koolohm ceramic-insulated resistance wire on molded, high-temperature plastic forms and are impregnated for protection against tropical humidity conditions. Resistance tolerance is available from ±½% to ±5%. Standard temperature coefficient wound with nickel-chromium wire is .017%. Lower coefficients can be provided by use of special alloy wires. Maximum permissible temperature, ambient plus rise, is 150°C.



Type RX3, 9/16" diam. x 15/32" long carries a maximum resistance value of 100,000 ohms when wound with 1.5 mil

New Comparator Gage Saves Time
—Gives 6 Inspections in One!

Even the most inexperienced operator can obtain accurate inspection of externally threaded parts, with the Limitrol Comparator Gage—in many instances, increasing the rate of inspection as much as 400%! The Limitrol, proved in hundreds of war plants, permits 6 visual checks in one: pitch diameter, lead, taper, out-of-roundness, angle, and straightness. Its use reduces inspection and production costs, cuts scrap waste while increasing speeds of operation. If a part passes the Limitrol, it will assemble accurately.



Hand Model used for "in process" gaging

Graduated dials are furnished as standard equipment. These dials are graduated in increments which approximate .0005 inch when the magnification is 250 to 1, and serve as a guide in determining just how far over or under the limits the part might be.

Another "help on the job" is chewing gum. Chewing seems to make work go easier, time go faster. Good chewing gum is available, but there's still a shortage. That's why we at Wrigley wish we could make Wrigley's Spearmint now, to help increase the available supply. You may be sure we will, just as soon as sugar restrictions are lifted. Meanwhile, chew any good available brand, because it's the chewing that really does you good.

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ceramic-insulted wire or 25,000 ohms with 2.5 mil wire. Type RX4, ¾" diam. x ¾" long, has a maximum 300,000 ohms with 1.5 mil wire and 75,000 ohms with 2.5 mil wire. Type RX5, ¾" diam. x 1" long carries 500,000 ohms with 1.5 mil wire, or a maximum of 125,000 ohms with 2.5 mil wire.

Complete details will gladly be sent on request to Sprague Electric Co., Resistor Division, North Adams, Mass.

VIDEO AMPLIFIER

A new video amplifier, designed primarily for use in amplifying complex waves to be viewed on an oscilloscope, is announced by the United Cinephone Corporation of Torrington, Connecticut. The amplifier is also extremely useful in laboratory work as an audio amplifier, for tracing and measuring small r-f voltages (as in the early stages of radio receivers), and many similar applications.

The frequency response is flat within 1.5 db of the 10 kc response from 15 cycles

to 4 mc, and 3 db from 10 cycles to 4.5 mc. The phase shift is reduced to a minimum to provide satisfactory reproduction of pulses on the order of one microsecond, and square waves at repetition rates as low as 100 a second.

The gain is approximately 1000 when direct input is used. Input is normally through a probe, furnished with the equipment, having an attenuation of 10 times. The amplified direct input (without probe) is approximately 2.2 megohms of resistance in parallel with 40 mmf. This compares with 1.1 megohm resistance in parallel with approximately 18 mmf. when the probe is used. The output voltage can be adjusted from zero to 50 volts r.m.s. with sine wave signals. The ripple output is less than 0.5 volt for all operating conditions and all positions of gain control.

AUTOMATIC TAPPERS FOR TUBE TESTING

Solenoid-operated tube tappers for uniform control of force, angle and timing of blows on electron tube envelopes to detect shorts, r-f and audio noises, and other faults due to tube structure have been developed by Sylvania Electric Products Ins., Emporium, Pa.

Specially designed to eliminate variations resulting from the use of hand mallets by individual operators, these solenoid tappers

provide six timed strokes which are alternately applied between two points on tube envelopes. The force, angle and timing of automatic blows may be adjusted to meet test requirements of different receiving tube types.

Developed by Sylvania just prior to the war, solenoid tappers were perfected for quality control of mass-produced tubes for the armed forces. Their use assured faster uniform inspection of all tubes produced.

REVERSING CONTACTOR

A new heavy duty Type 135CXX Reversing Contactor just announced by Struthers Dunn, Inc., 1321 Arch Street, Philadelphia 7, Pa., is only 5¾" wide x 4" high x 1⅞" deep, weighs approximately 2½ lbs., and is priced proportionately lower than bulky conventional contactors of its general type.

The Reversing Contactor is designed for use with polyphase motors up to 1 h.p.,

single-phase motors to 3/4 h.p., and is available from 110 volts to 600 volts a.c. It consists of two 3-pole contactors mechanically interlocked.

Complete details on the contactor may be obtained from the manufacturer.

MIDGET VIBRATOR

The Radiart Corporation, 3571 W. 62nd St., Cleveland 2, Ohio, announced that the Radiart Midget Vibrator, VR-2, is now available for civilian applications.

This midget vibrator is believed to be the smallest vibrator made. It measures 2⅛" high by 1⅛" in diameter. It is one of the new radio developments of the war, being designed for operation from a small 6 volt storage battery in furnishing power to replace dry battery power in certain communications equipment. The entire power supply including the storage battery had to be made for a space of 6½" x 3½" x 1¾". Naturally the vibrator had to be as small as possible.

[*see page* 56]

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Let your HEAD take you

(The average American today has a choice of just going where "his feet take him", or choosing wisely the course to follow. Let's skip ahead 10 years, and take a look at John Jones—and listen to him . . .)

"SOMETIMES I feel so good it almost scares me.

"This house—I wouldn't swap a shingle off its roof for any other house on earth. This little valley, with the pond down in the hollow at the back, is the spot I like best in all the world.

"And they're mine. I own 'em. Nobody can take 'em away from me.

"I've got a little money coming in, regularly. Not much—but enough. And I tell you, when you can go to bed every night with nothing on your mind except the fun you're going to have tomorrow—that's as near Heaven as man gets on this earth!

"It wasn't always so.

"Back in '46—that was right after the war and sometimes the going wasn't too easy—I needed cash. Taxes were tough, and then Ellen got sick. Like almost everybody else, I was buying Bonds through the Payroll Plan—and I figured on cashing some of them in. But sick as she was, it was Ellen who talked me out of it.

" 'Don't do it, John!' she said. 'Please don't! For the first time in our lives, we're really saving money. It's wonderful to know that every single payday we have more money put aside! John, if we can only keep up this saving, think what it can mean! Maybe someday you won't have to work. Maybe we can own a home. And oh, how good it would feel to know that we need never worry about money when we're old!'

"Well, even after she got better, I stayed away from the weekly poker game—quit dropping a little cash at the hot spots now and then—gave up some of the things a man feels he has a right to. We didn't have as much fun for a while but we paid our taxes and the doctor and—we didn't touch the Bonds.

"What's more, we kept right on putting our extra cash into U. S. Savings Bonds. And the pay-off is making the world a pretty swell place today!"

The Treasury Department acknowledges with appreciation the publication of this advertisement by

★ RADIO MAGAZINE ★

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Specifications of the VR-2 are as follows:

Vibrator Frequency	185 cps ±10%
Input Voltage Nominal	6.0 V.
Input Voltage Range	4.5 V. to 7.5 V.
Input current	1.5 amps Max. at 6.0 V.
Output Voltage	200 V. D.C. Max.
Potential Difference Between Primary Reed and Secondary Reed	25 V. Max.

Manufacturers who would like more information may write to The Radiart Corporation for blue prints and engineering cooperation.

TELEVISION TUBES

Allen B. DuMont Laboratories, Inc., Passaic, N. J., are offering a choice of cathode-ray tubes in both the electrostatic and the magnetic reflection and focusing types, and in the 5", 7", 10", 12" and 20" sizes. Still another size, the 15" tube with magnetic deflection and focus, will be added to the present selection shortly, after it has completed its development stage.

In addition to supplying the more significant characteristics of each tube type, DuMont engineers are also providing data on the useful picture area, as follows:

5" tubes	3 x 4"
7" tubes	4 x 5⅜"
10" tubes	6 x 8"
12" tubes	6⅝ x 8⅞"
20" tubes	12 x 16"

Relatively flat faces are used in all of these types. For instance, there are 5" and 7" tubes with 24" radius screens. The 10" tube has a 42" radius, which means a relatively flat face of good picture area. The 20" tube has a 30" radius. This last-mentioned tube with a useful picture area of 13½ x 18" is designed for direct-viewing, large-screen television receivers of the deluxe class, which are characterized by exceptionally brilliant and detailed pictures, together with a minimum of adjustments and maintenance.

Theo perating voltages for these tubes range from 1500 for the 5" tubes without the intensifier feature, to 15,000 volts for the 20" tube with intensifier.

The Type K1003P4 is of special interest to owners of pre-war DuMont telesets originally equipped with a 14-inch electrostatic tube. This new 12" tube of the electrostatic type is intended as a replacement for the original 14" tube, and provides more brilliant pictures of good gradation, while the sharper trace results in considerably improved definition.

HERMETICALLY-SEALED RESISTORS

Another addition to its line of hermetically-sealed Akra-Ohm Resistors has been announced by the Shallcross Mfg. Company, Jackson & Pusey Avenues, Collingdale, Pa. The new unit is known as Type 1105, is rated at 1.5 watts and is designed for Style RB14A under JAN Specification R93. Thus it fills in the gap between the present Shallcross Akra-Ohm Type 1196

at 0.75 watts (JAN RB13) and 2.0 watts Type 1110 (JAN RB14).

A copy of Shallcross Resistor Bulletin R gives complete data on this as well as the full line of Shallcross Akra-Ohm Fixed Wire Wound Resistors for all close-tolerance applications.

ELECTRONIC SWITCH

A new electronic switch, model no. 8336, has been announced by United Cinephone Corporation.

This unit has been designed to meet the demand for an electronic switch which can be used in the presence of explosive gases. This was not possible with the old type of switch, due to open contacts. The new model uses a relay with contacts which are hermetically sealed.

These switches are used primarily for pressurless Limit switching, floatless control of liquid levels and to eliminate contact arcs and welds. Maintenance beyond replacing the type 2050 thyraton tube at infrequent intervals is not required.

STUPAKOFF CERAMICS

In a new bulletin Stupakoff Ceramic and Manufacturing Company of Latrobe, Pa., describe their complete line of products for use in the radio and electrical industries, including ceramics, metallized ceramics, Kovar, (an alloy for sealing metal to glass) and Kovar-Glass Hermetic Seals.

An interesting line of Stupakoff products shown in the bulletin consists of ceramic items having metallized surfaces which may be used for electrical or mechanical connections.

Write direct to Stupakoff Ceramic and Manufacturing Co., Latrobe, Pa., for your copy of this new bulletin.

B & W SIGNAL GENERATOR

A new precision-built, high-level r-f signal generator covering the range from 400 kc to 60 mc in six steps has been announced by Barker & Williamson, 235 Fairfield Avenue, Upper Darby, Penna. Modulation of 30% at 1000 cycles is optional by means of a panel switch. Output is 3 volts r.m.s. at all frequencies and is read directly from a panel voltmeter. Output is through an output jack and coaxial cable terminated in a 75 ohm resistive load. Calibration is accurate to better than ½ of 1% and is read from a large individual calibrated chart mounted on the lid of each cabinet. The six ranges are as follows: 400 kc — 1000 kc; 1000 kc — 2500 kc; 2500 kc — 6 mc; 6 mc — 13 mc; 13 mc — 28 mc; 28 mc — 60 mc. Complete details will gladly be sent on request to the manufacturer.

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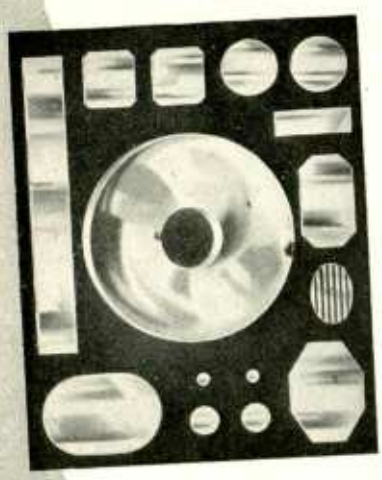

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INVENTIONS

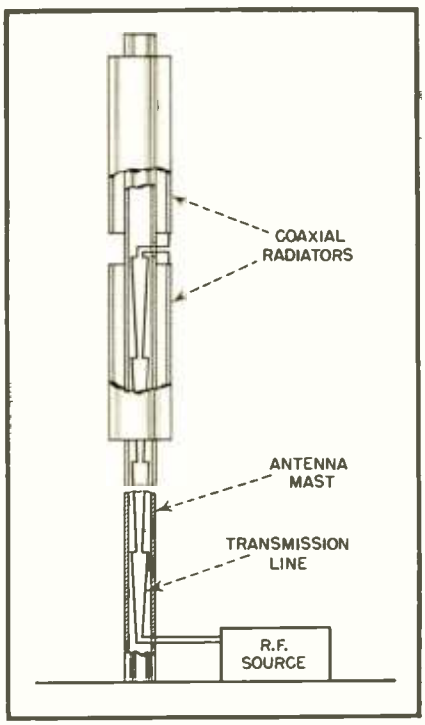
[*from page* 43]

tended a few inches beyond the top of the upper radiator. This is the chief feature of the present invention, which has the advantage of providing symmetry between the radiation characteristics of the two radiators; this relationship is not achieved with constructions that mount one radiator beyond the end of the mast while the second is at a lower point. Extending the mast beyond the uppermost radiator causes the impedance of the two radiators to be kept alike and allows symmetrical and efficient feed to both of them.

By making the radiators a half wavelength each, open ends of both radiators are at a high impedance point and the flow of electrical energy in the mast, which otherwise forms an effective shunt impedance, is reduced. The antenna system will work with radiator lengths as short as one tenth wavelength, but somewhat reduced efficiency must be expected.

The transmission line used to feed the radiators may take the form of a periodic impedance transformer having periodic occurring sections as indicated in the drawing, or it may simply consist of two wires spaced to have low characteristic impedance (less than 400 ohms). It is desired to substantially match the transmission-line impedance to the surge impedance of the radiators.

The patent, assigned to the Federal Radio and Telephone Corporation, is number 2,385,783.



Patent #2.385.783

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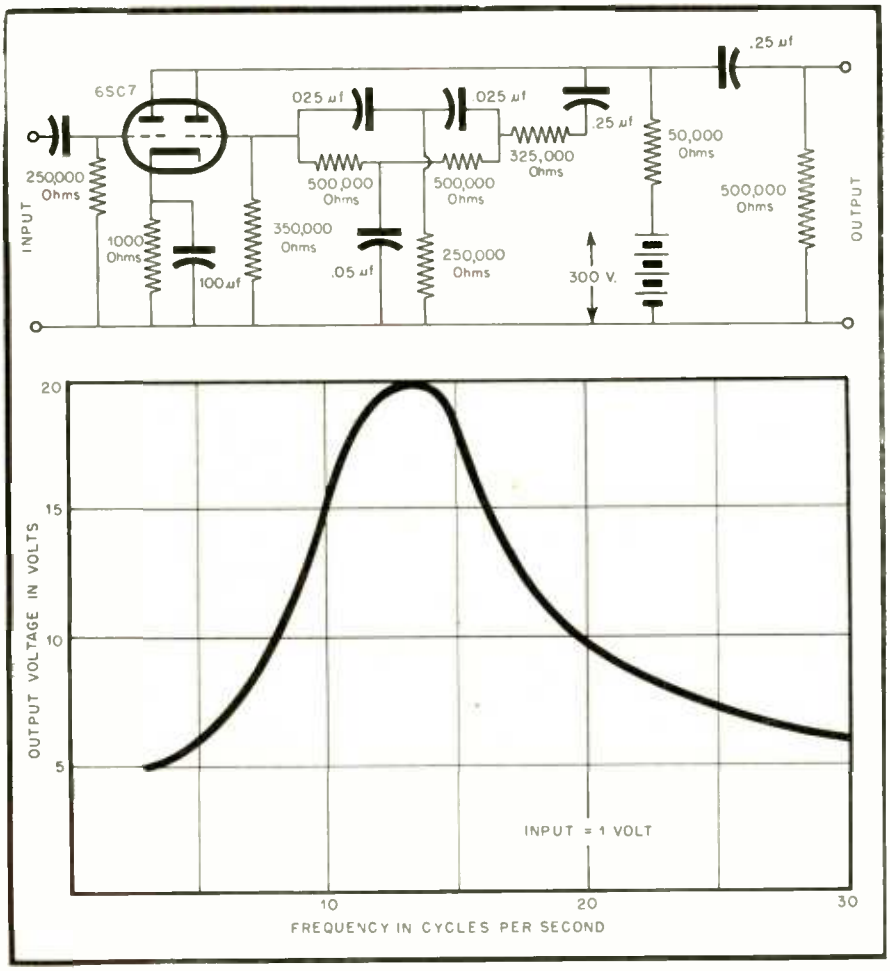
Selective Control Circuit

★ A circuit containing a relay that will close only when an alternating voltage of specified frequency is connected to the input, was patented by Ellison S. Purington on August 14, 1945. When the frequency selected to close the relay is higher than a few hundred cycles per second, the task is easily accomplished by building an amplifier with a narrow pass-band that is tuned to the desired frequency. However, when the selected frequency is of the order of 10 cycles per second, such an arrangement is cumbersome; the present invention is primarily aimed at producing a simple arrangement that can be made to select such a frequency.

The accompanying sketch shows one application of this recent invention, along with a curve that indicates output voltage as a function of input frequency, when the input level is at one volt. It is noted that maximum output voltage (which may close a relay) appears at about 13 cycles per second and that for either higher or lower frequencies the output is reduced. The reason is that there are two vacuum tube sections that have a common plate resistor so that both contribute to the output signal. To the extent that the grid of the second vacuum tube section is energized, the effect of the two tubes is degenerative. Except at the desired pass frequency the second tube is energized by a signal on its grid because the phase shift characteristics of the two branches of the feedback link, as shown at *A* in the drawing, do not add to give a zero signal.

The patent, number 2,382,097, is assigned to RCA.



Patent #2,382,097

BOOK REVIEWS

[*from page* 18]

numerical examples are presented and explained in a way which makes the formulae clear to those who have but an elementary knowledge of the subject. Even algebraic equations are interpreted in terms of simple arithmetic. Illustrations of applications of vacuum tubes in amplifier circuits are based on practical examples encountered in radio design.

The author has done a characteristically thorough job on this book and this reviewer has no hesitancy in recommending it as an excellent elementary text on the subject.

[*see page* 60]

In its multiplicity of wiring problems the many new and precious features of Surco Spiralon Keyed Insulation, with the widest range of identification in all sizes and lengths, is proving invaluable to Farnsworth Television & Radio Corp. of Fort Wayne, Ind. The ease with which this new insulated wire can be used in small compact areas or in large or intricate installations found instantaneous favor with this famous concern which is taking full advantage of Spiralon's diverse uses.

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SHALLCROSS MODEL 630
WHEATSTONE BRIDGE

A basic electrical measuring instrument for laboratory and industrial use, providing accurate and direct electrical resistance measurements from 0.1 to 11,100,000 ohms. Accuracy between 10 ohms and 1,000,000 ohms is normally better than 1 percent. Supplied with built-in galvanometer having a sensitivity of 1 microampere per millimeter division. Weight approximately 6 lbs.....$60.00

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THIS MONTH

[*from page* 48]

total number of manufacturers who have been licensed to produce Armour magnetic wire sound recorders in various fields of application. They are: Aireon Manufacturing Company, Kansas City, Kansas; Ansley Radio Corporation, Long Island City, N. Y.; Automatic Electric Company, Chicago, Ill.; Boosey and Hawkes Ltd., London, England; C. G. Conn Ltd., Elkhart, Ind; General Electric Company, Syracuse, N. Y.; The Hallicrafters Company, Chicago, Ill.; Hammond Instrument Company, Chicago, Ill.

Meissner Manufacturing Company, Mt. Carmel, Ill.; Packard-Bell Company, Los Angeles, Calif.; Radiotechnic Laboratories, Evanston, Ill.; E. H. Scott Radio Laboratories, Inc., Chicago, Ill.; J. P. Seeburg Corporation, Chicago, Ill.; Sonora Radio and Television Corporation, Chicago, Ill.

Stromberg-Carlson Company, Rochester, N. Y.; United States Government, War Department, Army Service Forces, Washington, D. C.; Utah Electronics (Canada) Ltd., Longueil, Quebec, Canada; Utah Radio Products Company, Chicago, Ill.; Webster-Chicago Corporation, Chicago, Ill.; and Wi-Recorder Corporation, Detroit, Michigan.

ACME EXPANDS

Since disposal of its factory at Clyde, New York, the Acme Electric & Mfg. Co. with headquarters at Cuba, New York have begun construction of a new unit to its present Cuba plants, which will more than double its manufacturing facilities.

Second floor section will be devoted exclusively to research engineering on transformer design and performance. The research laboratories will be equipped with considerable specially designed equipment to provide conditions simulating every conceivable transformer operating installation. The general engineering and control laboratories will be located on the first floor of plant number one — to provide for integration of its activities with plant production.

Acme Electric & Mfg. Co. was established in Cleveland, Ohio, 27 years ago, moving to Cuba, New York only eight years ago, and today is one of the largest producers of transformers in the country.

UAL TO USE UHF EQUIPMENT

United Air Lines now is preparing to use VHF communications and navigational equipment on its coast-to-coast and Pacific Coast system, it was disclosed by J. R. Cunningham, director of communications.

Cunningham announced that, as a beginning, United has started a half-million dollar program in the installation of this VHF equipment. To operate the equipment, the electrical system on all United's DC-3's is being changed from 12 to 24 volts, more than doubling its capacity.

The new equipment will be used both for navigation in conjunction with VHF radio ranges and for two-way telephone communication between United's planes and its ground stations.

NEW MICROWAVE RELAY CHAIN

Plans for a chain of microwave radio relay stations between Milwaukee and Chicago which will be employed for television transmission in cooperation with WMJT, the Milwaukee Journal television station, were announced this week by the American Telephone and Telegraph Company.

Applications for permission to build the high frequency system and to operate it on an experimental basis were filed Monday with the Federal Communications Commission, the company said.

The service also will be available to any broadcaster who might be able to use it. The relay system will cost about $500,000. If the Federal Communications Commission approves, it will be ready for tests in the spring of 1947.

RADIO & RADAR AIDS

[*from page* 38]

considerable height, and they offer the radar operator a signpost of great value during those adverse moments when the terrain below, as viewed through the radar, is an unfamiliar mass of bright and dark patches. In conjunction with Loran, the beacon-equipped search radar tends to remove any doubts as to the location of a plane anywhere in space, doubts that are usually on the mind of a pilot flying on luck and a prayer.

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IMPEDANCE

[from page 24]

$$\text{Sin } \alpha = \frac{Z_u(\sin \phi)}{X_k}$$

$$R_u = (Z_u)(\sin B)$$

$$X_u = (Z_u)(\cos B), \text{ where } B = \phi + \alpha$$

The vector diagram is shown in *Fig.*

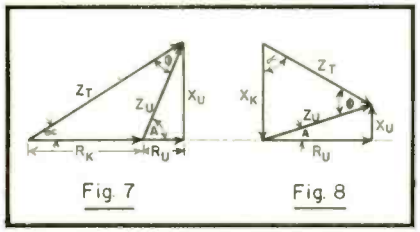

Fig. 7 Fig. 8

Fig. 7. Vector diagram for unknown Z, inductive

Fig. 8. Vector diagram for unknown inductive Z; pure X standard

8, where the unknown impedance is inductive, and X_k is capacitive.

$$Z_u = \frac{X_k}{\sqrt{\left(\frac{E_t}{E_u}\right)^2 + 1 - 2\left(\frac{E_t}{E_u}\right)\cos \phi}} \qquad (7)$$

The discussion thus far has assumed an infinite impedance for the input of the oscilloscope. For many conditions of measurement this assumption is justified, but when the impedance being measured is very high it may be desirable to correct for input impedance.

Input Impedance

The input impedance of the vertical input circuit has no effect on the accuracy of measurement as, being directly across the source of voltage supply, there is no voltage-dividing effect. The horizontal circuit impedance can readily be measured using any of the methods

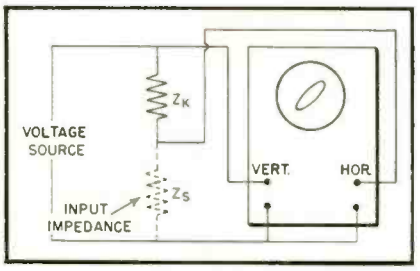

Fig. 9. Oscilloscope input $Z_i(Z_o)$, is easily measured

outlined thus far, and as shown in *Fig. 9*, Z_o is the input impedance of the horizontal deflection circuit.

Once the value of Z_o is calculated, the unknown impedance Z_u is connected as previously and the equivalent impedance Z_e measured. Z_e is Z_o in parallel with Z_u, and from circuit theory,

$$Z_u = \frac{(Z_e)(Z_o)}{Z_o - Z_e}$$

When Z_u is evaluated in terms of the resistive and reactive components of Z_o and Z_e it is found that:

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$$R_u = \frac{R_s(R_s^2+X_s^2)-R_s(R_s^2+X_s^2)}{(R_s-R_s)^2+(X_s-X_s)^2} \quad (8)$$

$$X_u = \frac{X_s(R_s^2+X_s^2)-X_s(R_s^2+X_s^2)}{(R_s-R_s)^2+(X_s-X_s)^2} \quad (9)$$

Attention must be paid to the algebraic signs of X_s and X_s, as the value of X_u may be either plus or minus depending upon circuit conditions.

Signal Source

For all of the measurements discussed a source of alternating voltage of the desired frequency is necessary, and if amplifiers are used in the oscilloscope, the phase shift difference between the two amplifiers should be negligible. The phase shift difference if present can readily be detected by applying the same voltage to both sets of plates, or amplifier circuits, and determining from the Lissajous figure if any shift is present. For zero phase shift difference, the Lissajous figure will be a straight line. as shown in *Fig. 1*. If any appreciable phase shift difference exists, it can readily be corrected for in the calculations. In all oscilloscopes used by the writer, the phase shift difference was so small as to be almost unobservable, and thus was neglected.

The value of the standard impedance used depends upon the magnitude of the unknown impedance being measured. The magnitudes of the known and unknown impedances should not be too far different, otherwise the Lissajous figure on the scope will be of such a shape as to make the measurement of the pertinent data difficult.

A safe rule is to choose the standard impedance so as to give a good workable ellipse on the screen of the scope. This will tend to increase the accuracy of the measurement.

RADIO TRANSMISSION

[*from page* 25]

thorized further study definitely established that dense flocks of birds might return echoes which would be equal to the echo of a ship at sea which was below the lowest maximum lobe of the vertical polar diagram. Microwave radar has tended to increase this hazard. Brooks[8] mentions U. S. Navy observations of albatrosses and man-o'-war birds at 5-6,000 yards, while Lack goes on to say that individual large birds have the reflecting power of a metal sphere of equivalent size. Naturally the English Channel coast radar units have suffered most from these low amplitude returns, with many false air-sea rescue searches and one very serious invasion alarm caused by birds.

Aurora Borealis Effects

Some time after the publication of the writer's 1940-41 observations of FM distortion during aurora borealis displays,[9] communications were received from the Commanding Officer of the Greenland Signal Aircraft Warning Company (SCR270), requesting more information. The story behind this request has remained until recently a strict secret. Had it been possible for the enemy to realize the effect of "anomalous" or "false echoes" received during aurora displays, and before satisfactory microwave radar units were developed, suitably timed air-raids would have cost the Allies heavily in personnel and property losses.

The existence and possibility of radio wave reflection from the ionized regions in the auroral streamers were first observed and conceived by the VHF radio amateur. It is unfortunate that the acceptance and realization of this fact did not occur early enough to have prevented the Iceland aurora fiasco of 1941. Here is how one of the radar officers present describes it[6]:

"Remember that big convoy that sailed into Iceland in September of 1941 when our troops took over? Well, the convoy arrived at night and the boats were to be unloaded the next day, so practically all of our personnel and equipment was sitting out there in the harbor of Reykjavik. That night our radar operators picked up a large formation of 'planes' heading toward Iceland. These 'blips' on the scope indicated it was a mass raid which was splitting up into separate flights as they approached the coast.

"It is scarcely necessary to add that all hell broke loose around there. There were a few P-40s on the island and the pilots were still on the boats. We got them in record time, got them in the planes and sent them up into the night. None of them had ever flown at night before and few of them knew much, if anything, about celestial navigation, but there wasn't enough time to worry about that. We simply got them over the fields and headed them toward the approaching 'raiders'.

"Frankly it was a pretty bad time and we were all plenty scared. All our ships were sitting there in the harbor, a perfect target for an enemy raid. We knew there must have been some leak about the landing. We also knew that it was impossible to intercept successfully a raid of the size indicated on the radar scope, so we just had to bite our fingernails and wait for the incoming disaster.

"Along about this time, though, the radar operators were going nuts, something very screwy indeed was going on. The 'planes' had first been tracked with an airspeed of about 200 miles per hour. All of a sudden these flights were observed to be travelling anywheres from 10 miles to 2,000 miles an hour!!!!

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Yes, 2,000 miles per hour. This sort of thing kept us on edge all that night but no planes appeared."

With the exception of the aurora effect, none of the "anomalous propagation" effects of radar operation will have any great bearing on the future of FM broadcasting. A distortion factor which has been correlated with aurora borealis is known to affect FM broadcasting, and from radar observations it appears little can be done by raising the frequency to alleviate this reflection. However, measured field intensities so far have been very low (less than 5 μv/m) and the calculated incidence of aurora between 40 and 50 degrees latitude is negligible, amounting to less than 3 disturbance hours per year maximum.

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[9]O. P. Ferrell, RADIO; No. 267; Feb. 1941

NOISE FIGURES

[*from page 22*]

G_{xtal} is the conversion gain (loss) of the crystal mixer.

The noise figure of the complete microwave receiver from Equation 3 is then

$$F_{recr} = \frac{1}{G_{BR}} + \frac{T_{xtal}+T_{LO}-1}{G_{BR}} + \frac{F_{IF}-1}{G_{BR}G_{xtal}}$$

$$R_{recr} = \frac{T_{xtal}+T_{LO}+F_{IF}-1}{G_{BR}G_{xtal}} \qquad (5)$$

As a numerical example, assume we have a microwave receiver with the following constants, which are typical values:

$G_{BR} = 0.71$ (1.5 db loss)
$G_{xtal} = 0.25$ (6 db loss)
$T_{xtal} = 1.5$
$T_{LO} = 1$
$F_{IF} = 2$ (3 db)

then,

$$F_{recr} = \frac{1.5+1+2-1}{(0.71)(0.25)} = 19.7 \text{ (12.9 db)}$$

The noise figures of some representative radar receivers[4] vary from 7 to 22 db. The lower values are for v-h-f receivers. Microwave receiver noise figures quoted there vary from 14 to 22 db, depending upon the bandwidth and

[4]Radar Specifications. *Electronics.* Nov. 1945. p. 116.

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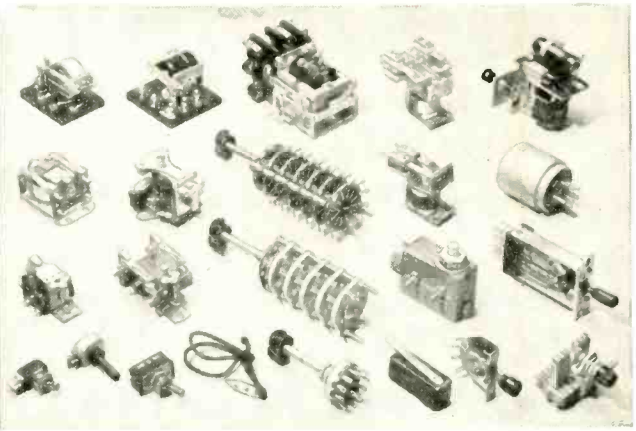

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the microwave frequency. Microwave receivers[5] have been built having figures as low as 6 db, but a 14 db receiver is still considered to be pretty good.

Engineering For Low Noise Figure

Of the factors that affect noise figure in microwave receivers the losses in the Send-Receive mechanism and the mixer are least under the receiver designer's control. Improved microwave plumbing techniques and developments by the companies making T-R tubes and mixer crystals have brought the efficiency of these components up to a high level in recent years. The development of an efficient microwave r-f amplifier tube suitable for receiver use would do much to improve receiver sensitivity by lessening the importance of conversion efficiency but at the present time none is available and there is no immediate prospect of such a development. Likewise, crystals are much better microwave mixers than any tubes now available.

So much good work has been done on i-f strips that there is actually little room for improvement. A 3 db i-f strip is commonplace even at high frequencies and wide bandwidths and figures of 1 db have been obtained.

It will be quite interesting to watch the effect upon commercial receiver design that will follow as a result of all this research and development. Low noise circuits such as the neutralized triode and grounded-grid amplifiers, maximum gain-bandwidth techniques using stagger-tuning, and an expanding line of miniature tubes with low power requirements, low noise and very low transit time loading are just a few of the many developments due primarily to radar research that could find immediate application in the fields of radio and television, if the engineer can calculate and justify the cost in dollars per db of improvement with the reversion to prewar conditions of economic competition.

[5]Microwave Transmission Power Requirements, by Browder and Young. RADIO, Oct. 1945. P. 30.

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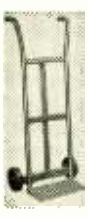
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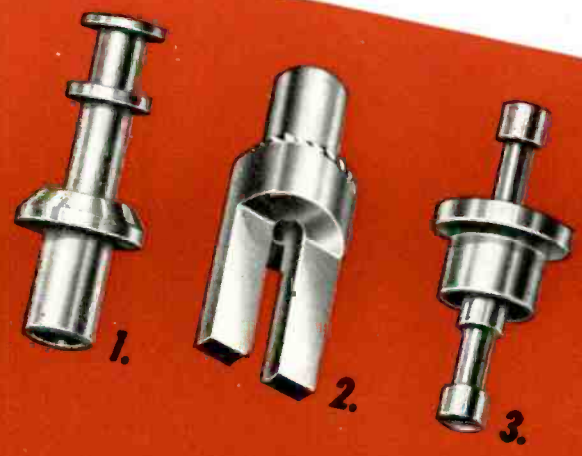

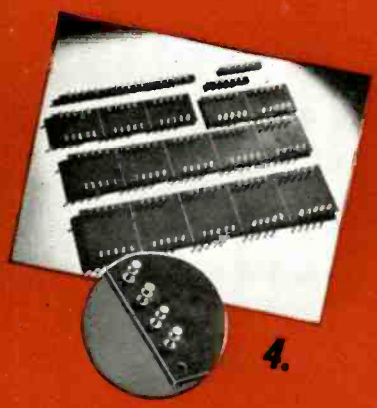

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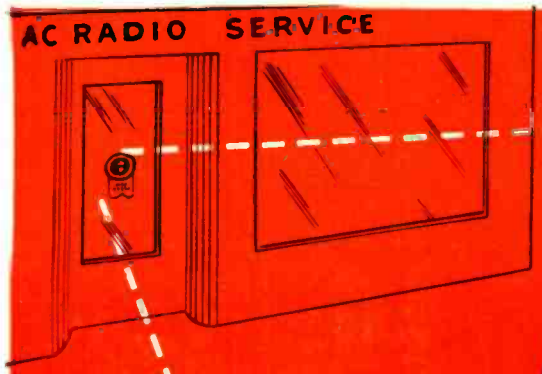

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