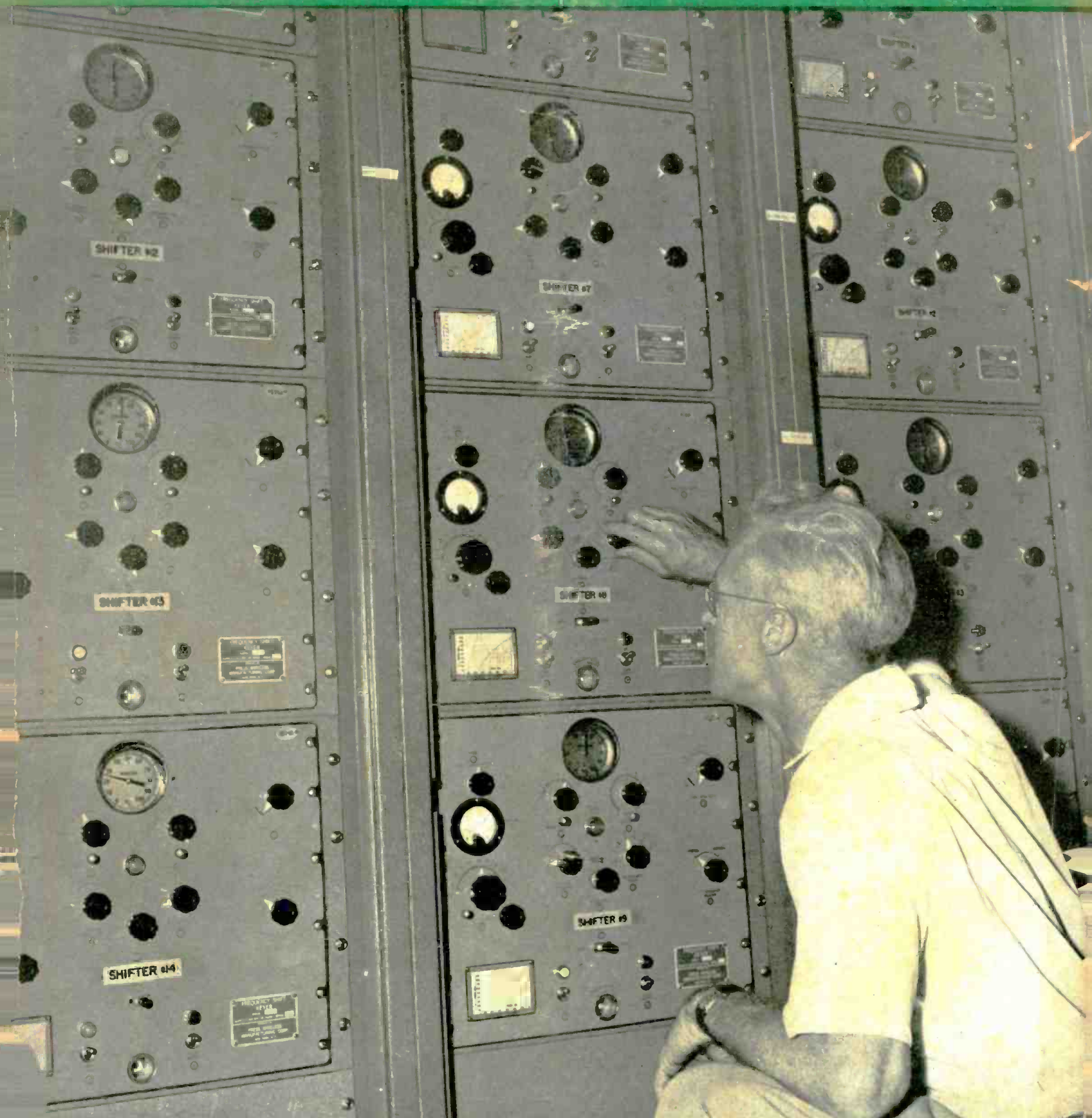
RADIO

AUGUST, 1946

MANUFACTURING AND BROADCASTING

The Journal for Radio & Electronic Engineers



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RADIO

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

AUGUST, 1946 Vol. 30, No. 8

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COVER

A portion of the frequency shifter rack in operation at the Hicksville, Long Is. Communication Division of Press Wireless, Inc.

ARTICLES

MISCELLANEOUS

RADIO Magazine (title registered U. S. Pat. Off.) is published monthly at Boston Post Road, Orange, Connecticut, by Radio Magazines, Inc. Executive and Editorial Offices at 342 Madison Avenue, New York 17, N. Y. Subscription rates—United States, U. S. Possessions & Canada, $3.00 for 1 year, $5.00 for 2 years; elsewhere $4.00 per year. Single copies 35c. Printed in U.S.A. All rights reserved, entire contents Copyright 1946 by Radio Magazines, Inc. Entered as Second Class Matter May 10, 1945 at the Post Office at Orange, Conn., under the Act of March 3, 1879.


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Transients

TRAVELING WAVE TUBE

★ The recent announcement of Bell Labs of the development of the traveling wave tube is a brilliant example of the ability of modern scientists to devise new means of getting results when the need becomes sufficiently great. This is the only tube which can be used in an amplifier to provide high gain over a broad band of frequencies of the order of 4000 mc. The traveling wave tube is destined to become just as important in microwave communication as the magnetron or klystron—perhaps even more so.

We feel fortunate in being able to present in this issue the first technical discussion of this new type of tube to appear in any magazine.

RADIO PRODUCTION

★ Production of radio receivers during June exceeded 1,000,000 sets of all types, according to an RMA report on production statistics. This is about the same as the highest average pre-war monthly rate, but is still far below capacity. Furthermore, production of FM sets amounted to only 17,273, principally because of the cabinet shortage which limits production of all types of console receivers.

Principal cause of restricted production is shortage of labor and materials. Shipment of large quantities of sets has been delayed because of tube shortages, particularly rectifiers.

PRICE CONTROL

★ The OPA situation in the radio industry becomes daily more and more befuddled. While price control is supposed to be removed only when the supply equals the demand, we learn that the first receivers to be decontrolled are household television sets, of which but 200 have been produced this year. Announced purpose of this action is to stimulate production of such receivers. It surely needs it.

But if price decontrol will stimulate production, why not do the same for vitally needed components, such as speakers, tubes, copper wire, gang condensers, console cabinets, which are not available in sufficient quantities to enable full scale production at the present time? Personally we don't think decontrol would help much—some components are now selling below ceiling, and even finished table model, radio-phono combinations are now being advertised in New York well below ceiling price. But the much-desired big sets are still scarce.

We believe in price control, under present-day conditions, as applied to rents and commodities, but it failed to benefit either the radio industry or the prospective purchaser of radios.

GOVERNMENT SURPLUS

★ One of the most feared bogeys of reconversion which has failed of its expected results is the dumping of surplus radio and electronic equipment by the government. Many had advocated scrapping, rather than resale, of such merchandise to avoid injuring the market.

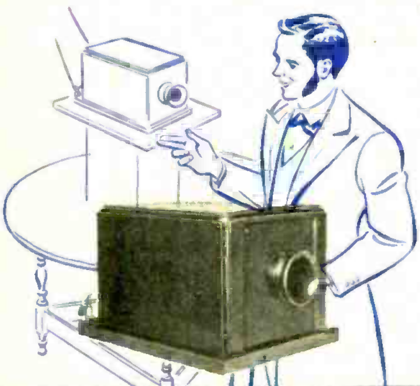
However, not much had been disposed of up until the end of February, 1946. According to the War Assets Administration, total sales up to that time amounted to but $17 million dollars, although $300 million dollars worth (at reported original cost) was available for disposal. Surplus on hand amounted to $115 million in components and lab. assemblies, $60 million in equipment, $48 million in tubes, balance in miscellaneous equipment. Although an undetermined portion of this has already been sold since February, there is still a very large inventory of surplus for sale.

It would be valuable to know in detail just what is likely to be offered in the near future. There are still shortages in tubes of certain types, and if any such are now surplus, immediate sale would greatly help the radio industry.

Estimated future acquisitions of surplus electronic equipment and apparatus range from $1 billion to $2 billion, but the WAA announces that most is expected to be commercially unsalable and will probably be scrapped.

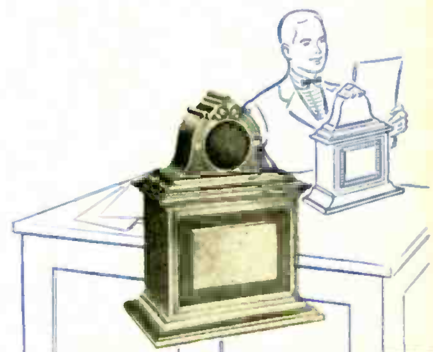
—*J. H. P.*

Why this team sets the

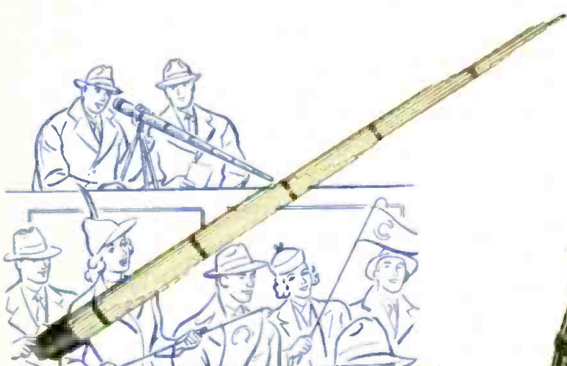


1877: Grand-daddy of all microphones was Alexander Graham Bell's box telephone, into which Thomas A. Watson shouted and sang in the first intercity demonstrations of the infant art of telephony.

1920: Telephone scientists developed the first successful commercial mike—the double carbon button air-damped type. Used first in public address systems, it later became the early symbol of broadcasting.



1921: The condensor microphone, designed by Bell Laboratories for sound measurement in 1916, entered the public address and broadcasting field. It provided a wide frequency range and reduced distortion.



1937: The Western Electric "Machine Gun" mike does for sound pick-up what the telephoto lens does for photography. Sharply directional, this microphone makes sound "close-ups" at unusually long range.

1938: Cardioid directional microphone, with ribbon and dynamic elements, was the first mike ever to combine 3 pick-up patterns in one instrument. The later 639B, with 6 patterns, is also one of the finest all-purpose mikes ever made.

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TECHNICANA

MAGNETIC DEFLECTION

★ Essential design factors involved in obtaining linear deflection with magnetic deflection yokes are discussed in an article by W. T. Cocking in *Wireless World* for July, 1946. The author limits his investigation to tetrode and pentode amplifiers driving the yoke through a transformer, as shown in *Fig. 1*. He points out that with one circuit, more than one mode of operation is possible.

In the analysis, it is assumed that the tube is driven by a sawtooth voltage of good waveform, implying that the sawtooth voltage rises linearly in time during the scan time, falling back in arbitrary fashion (later discussed in the article) during the flyback time. These periods are 84 μs and 14.8 μs, respectively, in the British system.

To obtain a linear current waveform in the deflecting coils, mathematical considerations on the basis of the Fourier analysis indicate that the twentieth harmonic of the fundamental should be passed, accompanied with a minimum of frequency and phase distortion. Such considerations lead to choice of special core materials. On the other hand, practical experience shows that silicon-steel cores are satisfactory, and that few harmonics above the third need to be passed. The discrepancy is due to lack of sharp corners in the practical waveform, and, as the author later points out, the corrective influence of the tube characteristic upon an exponential waveform of current through the yoke.

It is preferable, Mr. Cocking says, to consider the problem from the standpoint of *RLC* response to suitably-timed impulse excitation, using the equivalent

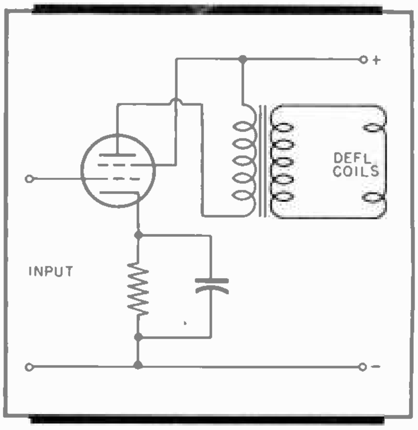


Figure 1

circuit of *Fig. 2*. Here the amplifier tube is represented by $-\mu e_g$ and R_p, and the core losses by R_2 (which includes any shunt damping losses present). L_p, L_s, r_p, r_s, C_p, and C_s are the transformer constants, and R_L and L_l the deflection coil constants. The constant-current equivalent circuit is derived as shown in *Fig. 3*. In this circuit, R_1 is the equivalent resistance of R_p and R_2 in parallel. The transformer ratio is n, and k is the coupling coefficient, $M/\sqrt{L_pL_s}$. The author then defines the problem as follows: during a period of time t_1, it is required that the current through L_l shall change linearly with time.

The magnitude of the change will depend on deflection coil design, tube used, and supply potential. With $L_L = 3$ mh, a typical current change is 600 ma. In the equations which follow, I = change of current, and instantaneous current is denoted by i_L. The time interval under consideration is from $t = 0$ to $t = t_1$.

It is then observed that if the scan is to be linear, $i_l = It/t_1 + I_1$ where I_1 is the d.c. through L_l, which thus constitutes a basic design equation. To simplify the analysis, it is assumed throughout, that the current taken by C_s is very small with respect to i_l, and that r_l is negligible. On this basis, the simplified equivalent circuit of *Fig. 4* is derived.

If the deflection coil current is linear, the voltage E across L and R is

$$E = (IRt/t_1 + LI/t_1)k/n$$

The total current required by the circuit during the scan is

$$i = \frac{I}{n}\left[\frac{L/R_1}{t_1} + \frac{t}{t_1}\left(1 + \frac{R}{R_1} + \frac{L}{L_p} + \frac{t^2}{2t_1L_p/R}\right)\right]$$

It is usually inconvenient to have the tube supply the last term of the current equation, and circuit values are therefore selected to make this term negligible. Although the coil current is then exponential, curvature of the tube characteristics is such as to maintain practical linearity. The required correction is less than 2% if $L_p \nless 4.2n^2(R_l + r_s)$, where L_p is expressed in mh.

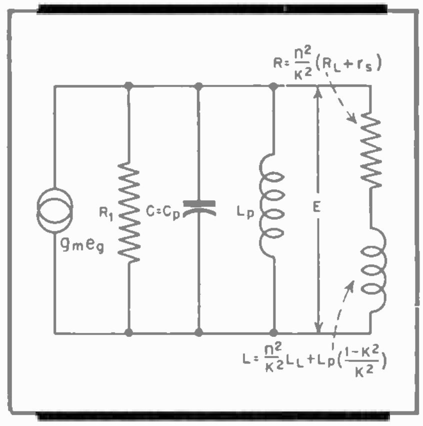


Figure 4

If R (*Fig. 4*) is quite small, only a small value of L_p is needed to achieve linearity, and efficiency is low. L_p should be designed to be at least ten times L. The voltage developed across the transformer primary has a maximum value of $(IR + LI/t_1)k/n$ when $t = t_1$, and re-

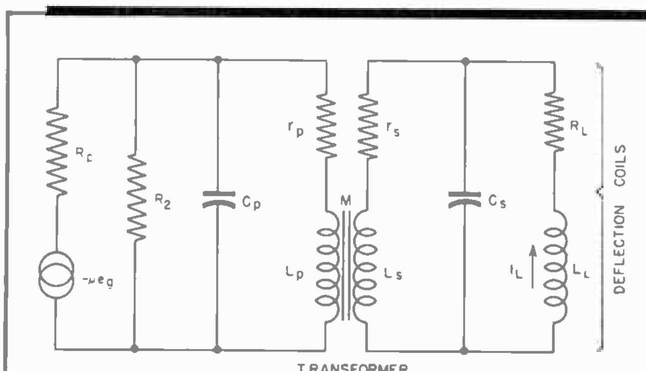


Figure 2

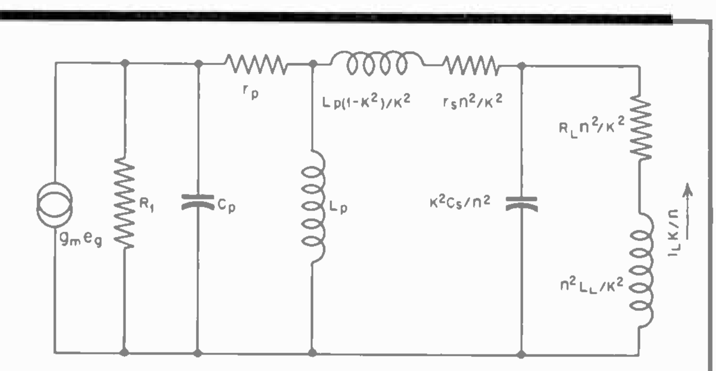
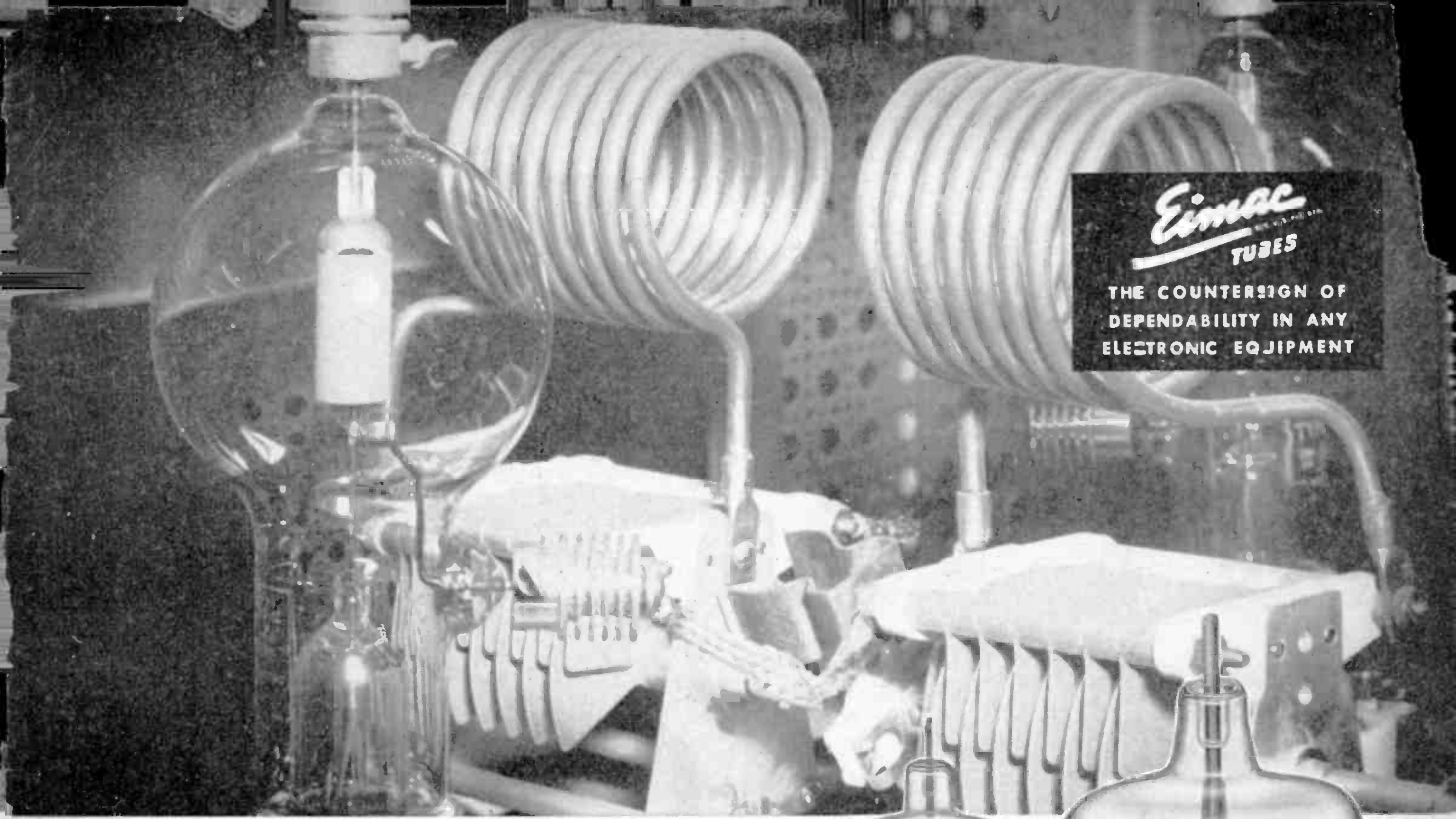


Figure 3



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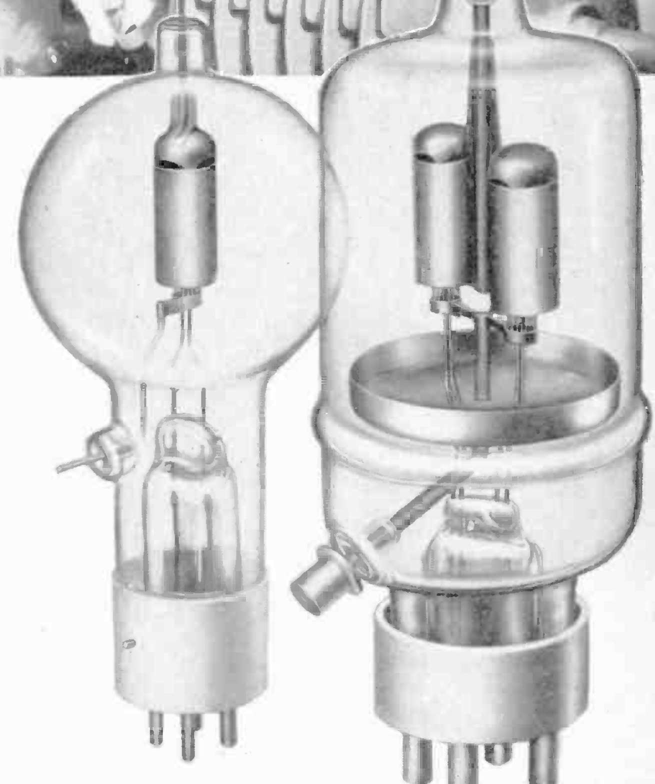

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TECHNICANA

[*from page* 6]

duces the supply voltage by this amount. Should the reduction be excessive, distortion is again introduced and the picture will be squeezed up on the right-hand side.

Mr. Cocking further considers the fly-back period and conditions of oscillation. Diode damping is discussed, with less than critical damping recommended. Used in conjunction with negative feedback, resistance damping is preferred.

The article concludes with a dozen design equations of central interest to the worker in this field.

X-RAY IN TUBE WORK

★ A good theoretical and practical discussion of radiographic techniques as applied to tube development work and production sampling is presented by R. M. Mitchell in an article "Notes on Radiography in the Wireless Industry," in the *Marconi Review* for Jan.-March, 1946. The properties and methods of generating X-rays are examined, as well as the complicated problems of making satisfactory radiographs.

Development of miniature stabilivolt tubes is cited by the author as a useful application of radiography. Electrical tests had shown considerable variation in the performance of specimens from the production line, and this was revealed by radiographs to result from variations in spacing of auxiliary striker pin and striker. The auxiliary striker pin is a fine wire pointing inward from the tubular-shaped cathode, while the striker is a vertical wire between cathode and plate.

Another fault was discovered while studying these gap variations: a filament is fired during manufacture, and if it sags it may cause a short. Radiated heat was also observed to bend the striker, and these points were quickly established with the aid of radiographs.

The writer points out that routine photographing of miniature vacuum tubes, while a valuable technique in development work, proves too costly in routine production. However, for large transmitting tubes, radiographic inspection is frequently justified. For example, a high-power tube which was imperfect in test for an unexplained reason, showed on the X-ray plate to have had its supposedly straight filament distorted into curves, either during manufacture or possibly from spurious v-h-f oscillation during test.

Mr. Mitchell also points out the value of radiography in detecting flaws in molded plastic products with inserts, such as plug and socket contacts, where much time is saved and non-destructive testing realized.

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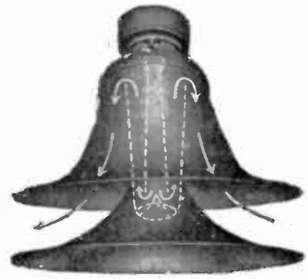

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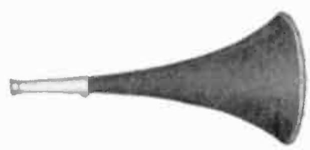

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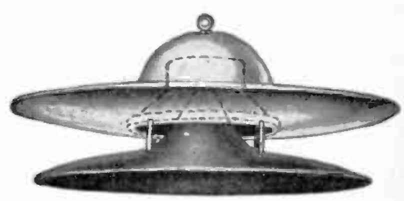

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TRAVELING WAVE TUBES

MARTIN A. BARTON

We believe this to be the first published technical discussion of an epoch-making development in microwave transmission. The traveling wave tube is the first device which enables design of an amplifier to provide high gain over a broad band at an operating frequency of the order of 4000 megacycles

THE RECENT RELEASE by the Bell Telephone Laboratories of information concerning the performance of a sample traveling wave tube has caused much interest throughout the industry. The possibility of building a vacuum tube amplifier in the region around 4000 mc without the use of any sharply resonant structures is of utmost importance. Such a device opens the way to the use of extremely broad-band transmissions over highly directional beams and would allow a radio relay network to be constructed which could handle high fidelity television programs as well as an extremely large number of simultaneous telephone conversations or other equivalent services. Since traveling wave tubes can be built to handle any frequency within 400 mc of a nominal 4000 mc operating frequency, present limitations on the band width which can be effectively used depend more on the wave guide transmission systems used to couple to the tube than upon the operation of the tube itself.

Use in Relay Service

As between the magnetron and the klystron, which are the other two types of vacuum tubes currently available for use at true microwave frequencies, the traveling wave tube comes closer to resembling the klystron although its principle of operation is quite different from that tube too. Like a klystron, the traveling wave tube is well adapted for use as an amplifier as well as an oscillator. This is not true of magnetrons: they are, at least generally speaking, only useful as oscillators and in fact are normally used only for producing high level signals such as those which are needed in a radar transmitter. Like the klystron, the traveling wave tube can be used to amplify a low-level microwave signal provided only that the signal strength is greater than the intrinsic noise introduced by the tube. To date this matter of noise is not completely satisfactory in either the klystron or the traveling wave tube.

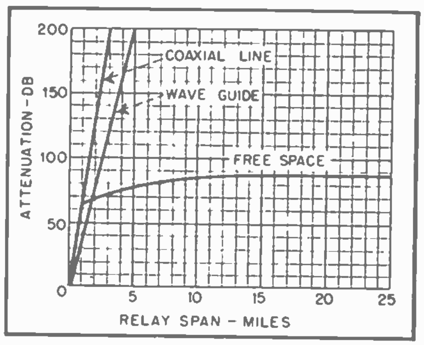

Fig. 1. Relative attenuation of microwaves in free space and in transmission lines.

Magnetron

Neither tube shows much promise of allowing r-f amplifier stages to be built into a receiver as effectively as they are in receivers designed for use in the lower frequency part of the radio spectrum. This, however, is by no means fatal to the use of microwaves for relay service.

When a radio link is to be used to supplant a cable of wires or a coaxial line, high signal-to-noise ratios must be held at all points. The fidelity requirements are quite stringent because any distortion that is introduced is of course cumulative from relay to relay. This condition in turn means that the receivers are not required to work on extremely low level signals. Because of the high gain antennas (sharp beams of radiation) and because the line-of-sight properties of microwaves generally limit the relay spans to 30 miles or less, such relatively high level signals into the receivers are easily obtained.

So much has been said of the superior transmission properties of coaxial lines and wave guides that it is easy to lose sight of the fact that neither is as good as free space. Their advantages are nearly always quoted in terms of other more conventional types of transmission line. Whenever a conductor is present, whether it be in wave guide form or distributed along the transmission path in some other way, currents will flow in that conductor and the resistance accentuated by the skin effect will take its toll and contribute to the attenuation of the signal. In radio transmission through free space there are no such conductors and the only attenuation which is encountered is of a geometric nature associated with the spreading of the energy over larger and larger areas. *Fig. 1* shows this attenuation situation as it exists for two sample transmission line installations and for line-of-sight radio transmission. It indicates that relative to transmission lines, economic considerations do not necessarily demand extremely long relay spans.

Comparison with Magnetron and Klystron

The invention of the traveling wave tube is generally attributed to the English and is a direct outgrowth of a wartime project which, however, had to be somewhat limited in the face of other more pressing tasks. British engineers have emphasized the noise features of the tube in their research. Apparently the Bell Laboratories are the first to realize that other advantages, such as efficiency and broad band width, might be even more important.

It does not appear likely that the traveling wave tube will make the magnetron and the klystron obsolete in the foreseeable future. Each would seem to have uses for which it is certainly superior. There are also some applications where it is not yet known which type is best. The lineup at present would seem to be about as follows:

Magnetron

To obtain extremely brief but high powered pulses of microwave energy the multiple cavity magnetron is by far the best tube available. Although the cathode structure of the magnetron must be kept extremely small and is therefore always a vulnerable point when continuous operation is needed, no such difficulty is met under pulse conditions. The magnetron has never been successfully modified so as to be useful as an amplifier or frequency

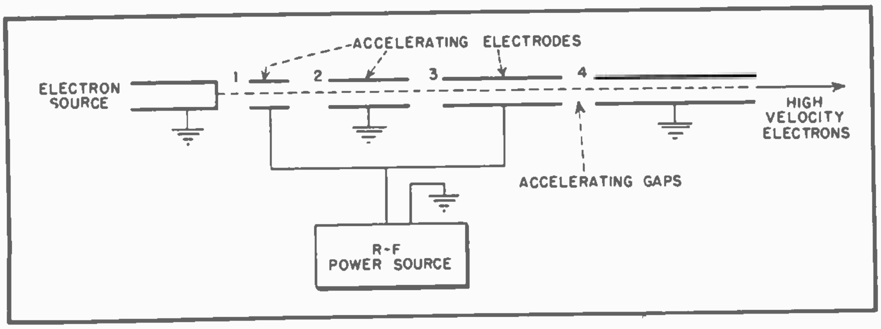

Fig. 2. An electron accelerator design using multiple accelerating paths.

multiplier. It cannot be easily used either for frequency or amplitude modulation systems. For radar or pulse time modulation transmitters, however, it is unquestionably the best type of tube to use.

Klystron

The klystron is an extremely versatile tube because it can be used in almost all the functions of ordinary triodes, screen grid tubes, and pentodes. In particular, it can have an output circuit which is tuned to a frequency different from that of the input circuit and hence can act as a frequency multiplier. This property in conjunction with its operation as an amplifier makes it quite possible to use klystrons with a precise crystal oscillator to yield microwave signals which have a very accurately known frequency. This is in contrast to the very rough frequency control obtainable with the ordinary magnetron and the still fairly rough accuracy possible with the best control schemes. The peak power of the klystron is much less than that of the magnetron although its average power is comparable. Its band width as an amplifier is restricted to a few megacycles although the construction of tubes to operate over any chosen few megacycles up to frequencies as high as 25,000 mc is quite feasible. Klystrons are particularly adaptable to use with frequency modulation.

Traveling Wave Tube

Development has not yet reached the point where performance in all classifications can even be intelligently guessed at. There is every reason to believe that operation as an oscillator as well as an amplifier is relatively easy. Frequency multiplication using the traveling wave tube would not appear to be very straightforward but may be possible. Great band width, good efficiency, and high gain seem to be the most likely virtues of this tube. There seems to be some indication that the traveling wave tube will be easiest to build only for frequencies in the neighborhood of 4000 mc. At both higher and lower frequencies the dimensions required introduce difficulties.

Operational Theory

In just about all vacuum tubes, operation depends upon transferring energy from an electron beam into an r-f field. In a magnetron oscillator, for example, electrons from the cathode are accelerated because of a d-c voltage on the anode. During their acceleration they accumulate kinetic energy from the d-c source and a magnetic field simultaneously causes them to rotate around past gaps that are cut into cavities which form part of the anode structure. The nature of the tube geometry and the d-c voltage is such that most electrons pass by the gaps at times when the r-f field there decelerates them. As they slow down they lose kinetic energy. The energy that is lost to the electron is gained by the r-f field which is strengthened in consequence. A single electron may pass several cavity gaps and give up energy to the cavities several times before drifting out of phase and losing its usefulness in the tube.

In a klystron, a similar situation exists. Electrons from the cathode are initially accelerated by a d-c field and hence given energy by virtue of their velocity. In a multiple cavity klystron, the electrons then pass through a cavity where their velocity is slightly modified. After traversing a drift tube this slight velocity modification is sufficient to cause the electrons to be bunched and phased so that they suffer deceleration by virtue of the r-f field existing in the final cavity. Thus again kinetic energy of the electron is transferred to the r-f energy in the tube output circuit.

The traveling wave tube also builds up its output signal with energy taken from the kinetic energy of the electrons in an electron beam.

Electron Accelerators

A reverse example of the transfer of electron kinetic energy into r-f field energy is that of the so-called electron accelerator tube. It is a device which uses a relatively low voltage and applies it repeatedly along the electron path so as to give the electron a very high velocity. Such high velocity electrons are useful for producing hard X-rays.

Electrons as they are boiled off a cathode surface have relatively small velocities. If, however, an anode is placed near the cathode, the electrons will be attracted by the positive potential of the anode and will gain velocity during their travel toward that electrode. If the anode voltage is E volts, the electron velocity will be given by

$$(1 - v^2/c^2)^{1/2} = 1/2 \times 10^{-6} E + 1$$

where v is the electron velocity and c is the velocity of light. To obtain v/c values of more than a few tenths, inconveniently large values of E must be used.

Figure 2 shows how an electron accelerator tube may be constructed so as to avoid this difficulty. A single voltage obtained from an r-f source is used to accelerate each electron four times. The electrons travel from left to right. Those which emerge from the electron source when the r-f voltage is positive are accelerated through gap 1. By the time they reach gap 2, the r-f voltage has changed polarity so acceleration is incurred there also. The various accelerating sections successively increase in length so that equal time intervals elapse between the transits of the various gaps. The polarity then has changed again when the electron reaches gap 3 and still again when gap 4 is reached. Thus the electron is accelerated four times by the r-f voltage and E in the equation just stated has the effect of being 4 times as great as the r-f voltage actually used.

Such a method of accelerating electrons is a rather exact reverse of a method of slowing down electrons and absorbing the energy into an r-f voltage. As a matter of fact, the gap method just explained is closely an-

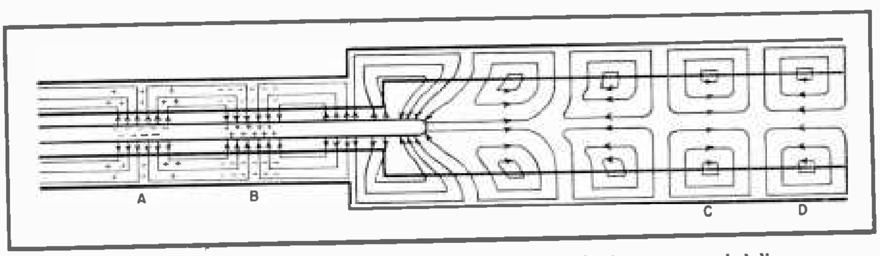

Fig. 3. Launching a traveling wave into a wave guide from a coaxial line.

alogous to the operation of a klystron. There pairs of grids are used to collect the r-f energy just as gaps are used here to feed in the r-f power. Velocity modulation of the electron beam is simply a method of causing the electrons to reach the gaps (i.e., pairs of grids) in bunches and at times when they will strengthen the r-f field rather than be accelerated by it.

Traveling Wave Accelerator

The electron accelerator tube just mentioned speeds up the electrons only during the successive brief intervals that they are in the gaps between the electrodes. It is natural as a next step to see if there is not some way to cause the acceleration to take place all along the tube. In other words, it is desirable to see if there is not some way to make the condition, which periodically occurs at each gap, be one that moves down the tube along with a certain group of electrons so as to constantly urge that group of electrons to move faster and faster. This situation in which a voltage gradient in a

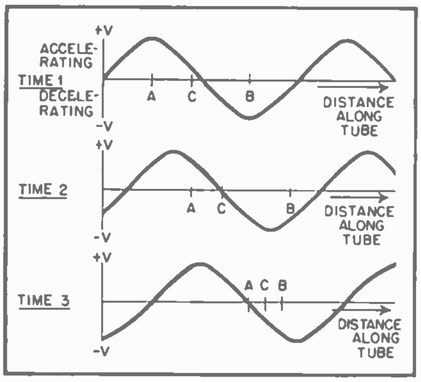

Fig. 4. Electron action along a traveling wave tube.

given direction moves along a transmission line is precisely what happens in a traveling wave. Neglecting such practical details as that of finding a method to make the wave go slowly enough and to gradually speed up to keep pace with the electrons, the problem is an easy one.

In *Fig. 3* is shown one way in which a suitable traveling wave might be launched down a hollow tube in a way that would accelerate certain electrons travelling along with it at nominally the same velocity. The launching arrangement consists of a coaxial line carrying the r-f power and terminated into a piece of cylindrical wave guide. The center conductor of the coaxial line extends a short distance into the wave guide and then ends in the way shown. In a practical device the center conductor itself would have to be hollow and a beam of electrons projected through it into the active field of the wave guide.

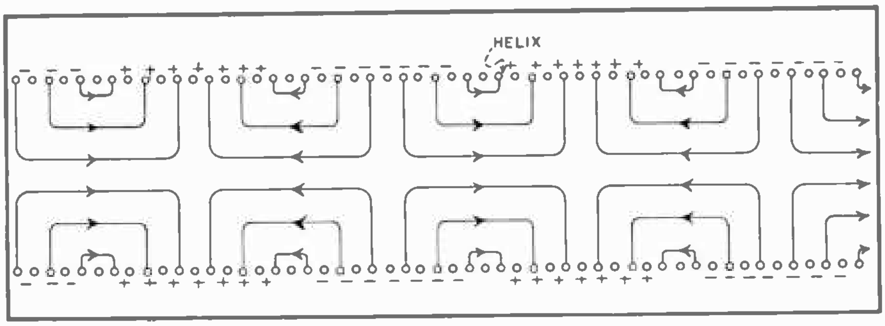

Fig. 5. Use of helix as walls of a wave guide to decrease greatly the propagation velocity.

At the left end of the coaxial line section shown in *Fig. 3*, the r-f voltage is applied between the center and outer conductor. This means that for each alternate half-cycle, a positive charge is supplied to the center conductor and a negative charge to the outer conductor. During the other half-cycle periods the polarity is reversed. As these groups of charges move along the line, so also does a region in which any electron between the conductors would be attracted to one of the conductors. For example, if an electron were placed between the coaxial conductors at a place such as *A*, it would be momentarily attracted to the outer surface as is shown by the arrows. If the electron had no velocity, the attraction would be very short lived because the conditions of region *A* would have moved on to the right, and even a region such as the one at *B* would have come in from the left and have caused an opposite force to be present at *A*. On the other hand, if the electron were moving from left to right through the inter-conductor space at a speed approximately equal to that of the r-f voltage, the electron might keep up with the condition shown at *A* and be continuously attracted to the outer conductor and absorbed there.

Such an arrangement for lateral deflection of electrons in a coaxial line space is of no value, but when the same logic is applied to the wave guide section, two conditions of great value are possible. One occurs when electrons of interest move along with regions like the one instantaneously shown at *C* in *Fig. 3*. Such electrons are continuously accelerated and may under certain conditions be made to obtain very large energies. The other occurs when the electrons of interest move with regions like the one shown at *D*. Such electrons are constantly being slowed down and are constantly giving up energy to the r-f field. This is what happens in the British and Bell Laboratory tube known as the traveling wave tube.

Electron Distribution

From what has been said, it is apparent that the difference between a traveling wave accelerator and a traveling wave generator of r-f energy lies not only in whether d-c or r-f energy is supplied, but also in causing the electrons of interest to be those which move along in a certain phase relation to the traveling wave. To generate r.f., one would ideally like to have the electron source emit bunches of electrons which would travel along with the decelerating regions of the traveling wave and give off no electrons to go along with the accelerating portion hence draining energy from the r-f field. If such an electron source could be obtained there would be no need for the tube. The electrons themselves would supply the needed r-f current. Fortunately, however, the traveling wave tube does not require any such electron source in order to operate. Possibly a rough bunching of this sort in the electron source could be obtained by using klystron techniques and would be helpful. But operation is normally accomplished without any special attention to the electron source except to cause it to emit as many electrons as possible and to supply d-c voltage in the gun assembly which will give the electrons the necessary kinetic energy to transfer to the r-f field.

In *Fig. 4* the conditions along the length of the tube are shown in a somewhat less pictorial way than in *Fig. 3*. Three sine waves are drawn and in each one the portions above the axis represent a region in the tube where electrons would be accelerated while the portions drawn below the axis show where deceleration will take place. In the first curve, for example, the portion of the tube at the extreme left (next to the electron gun) is one where electron acceleration takes place. The center part is one of decelerating properties and the right-hand end is again an accelerating region. In actual practice, a large number of such regions would exist and the drawing would

[*Continued on page* 30]

FREQUENCY SHIFT

CHRIS BUFF

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FREQUENCY SHIFT keying of radiotelegraph transmitters was used in the early days of radio communication when the arc transmitter was in its prime. Because the arc, once started, could not be keyed on and off fast enough for practical communication, means were used to shift the output frequency in accordance with the telegraphic code. This usually consisted of a heavy relay-contactor which shorted intermittently part of the frequency-determining tuning coils, thus varying the frequency many kilocycles. An operator tuning to one of these frequencies could copy all the key-down or "marking" signals which normally were used to carry the intelligence. The "spacing," or key-up, signals could not be heard at the same setting of the receiver, but if the operator tuned to the spacing frequency he could copy all the spaces between characters, letters, and words. If he had had enough practice in copying the spaces he could copy the same intelligence on either frequency!

In those days, however, the state of art was such that only the key-down, or marking, signals were normally used to receive the intelligence. Frequency-shift keying was then only a means to an end. Today this method of keying is fully utilized with both the marking and spacing frequencies playing equal roles, resulting in a method of telegraphic communication which is inherently less susceptible to fading, noise, and other transmission vagaries.

Frequency-shift keying may be called the telegraphic counterpart to frequency modulation as applied to broadcasting.

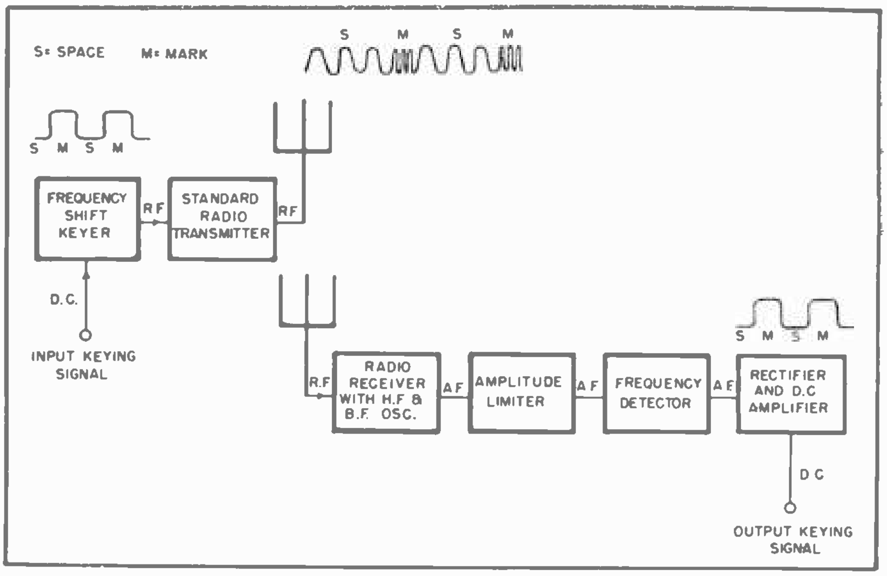


Fig. 1. Block diagram showing essentials of a frequency-shift keying system

Advantages of Frequency Shift

The gain in signal-to-noise ratio of frequency shift versus on-off keying has been variously estimated to be between 11 db and 20 db. Different methods of detection over various transmission paths probably account for most of the discrepancy. The 11-db figure was arrived at by comparing a dual-diversity f-s system with a triple-diversity on-off system and is considered to be on the low side because it is known that under certain multipath conditions the addition of the third receiver will increase the signal-to-noise ratio gain by 3 db or more.

The f-s system provides the greatly increased signal-to-noise ratio necessary for reliable radioprinter operation without necessitating transmitters of tremendous powers. In general, all transmitters in use for on-off keying may be converted to automatic printer by adding the frequency-shift keyer unit and provide reliable radioprinter service without any increase in power.

If transmitter carrier power were depended upon to realize the increase in signal-to-noise ratio required, it would mean that powers exceeding 100,000 watts would have to be used on most circuits.

An important operational advantage results from the fact that the transmitter output keying wave shape can be made identical to that of the input keying signal. The slopes and mark-to-space ratios can therefore be readily adjusted before entering the transmitter and will be exactly the same when they leave the antenna. This is so because the Class C amplifiers, which usually are not of too high a Q, form a linear system for frequency modulation having the narrow deviation used for this method of keying.

With on-off keying of a low-power stage in the transmitter, the final output wave shape can never be precisely adjusted because of the limiting action of Class C amplifiers which keep squaring up the wave in each successive stage, so the final wave shape is never identical to the input signal.

Excessively squared waves with steep rises and decays cause transients which increase the bandwidth greatly beyond that which is required for the speeds being transmitted. Adjacent channel operation is more unpredictable because day-to-day neutralizing and biasing adjustments on any given on-off keyed transmitter are closely related to the amount of key clicks and transients produced.

With f-s operation the carrier is not interrupted. This greatly minimizes the chances of transients being generated due to slight neutralization or bias misadjustments on any frequency, in any stage of the transmitter.

Basic System

Although there are several methods of producing frequency shift signals at the transmitter and of converting them at the receiver, *Fig. 1* shows the elements common to all frequency-shift systems. These are the frequency-shift keyer at the transmitter which takes ordinary on-off d-c or tone pulses and converts them into two distinct radio frequencies, the amplitude limiter at the receiver which levels out fading signals, the mark-and-space frequency detectors, and the differential rectifier which changes the mark-spaced audio tones into positive and negative d-c values for rekeying a d-c amplifier.

The effectiveness of this system may be enhanced by introducing a band-pass

KEYING TECHNIQUES

Circuit data and design factors of the new frequency-shift transmitters are discussed

filter ahead of the limiter to restrict the frequencies accepted by the limiter to those needed to detect the desired intelligence. The design of this filter must take into consideration the following factors:

1. Value of frequency shift.
2. Maximum keying speed.
3. Maximum drift in transmitter and receiver.

Secondly, a low-pass filter in the final d-c output of the converter may be used to eliminate any transients above the maximum keying frequency. The design of this filter may be governed solely by the maximum keying speed, taking into account the passage of only those harmonics of the keying frequency necessary for adequate fidelity of copy.

The use of band-pass and low-pass filters may also be applied to on-off keying systems.

For all types of telegraphic communication, including automatic printers, a two-frequency shift keyer and converter will suffice. That is to say, it is not necessary to have a linear relationship between the amplitude of the input keying signal and the output frequency at the transmitter nor the output frequency of the receiver and the rectified output of the converter. The use of frequency shift, however, is proving of advantage, with respect to economy of operation and fidelity of transmission, for facsimile and radiophoto work. For these applications a linear system is required which will convey all the gradations between black and white by means of discrete frequencies.

While some success has been achieved for ordinary telegraph frequency shift by using two crystals differing slightly in frequency and alternately keyed by means of an electronic switch or mechanical relay, such a system is of no value for radiophoto or facsimile work. *Fig. 2* shows a block diagram of a frequency-shift keyer which has proved very successful with both types of signals.

F-S Transmitting Keyer

On-off d-c telegraph signals are applied to the keyer-limiter circuit which keys a pre-set regulated voltage to the reactance tube grid. This circuit is so arranged that any variations in the amplitude of the input keying signal above a minimum threshold level will not alter the predetermined frequency shift produced by the reactance tube on the 200-kc oscillator.

The reactance tube itself should be considered part of the 200-kc oscillator circuit since its presence affects the frequency, stability, and Q of the oscillator. *Fig. 3* shows a reactance-tube-oscillator circuit which produces a linear frequency swing and has good stability. This circuit is unique in that it makes use of the grid-plate capacities of the reactance tube (6SN7) to form part of the 90° phase shifting network necessary for proper operation of the circuit. The circuit is biased so that positive and negative voltages with respect to zero volts input, will produce negative and positive frequency swings. An increase in positive bias results in a decreased capacitive reactance being presented to the oscillator tank circuit, lowering the frequency. For negative voltages the converse is true. *Fig. 1* shows the frequency shift characteristic obtainable with this circuit.

For facsimile and radiophoto operation the d-c keyer-limiter stage is not used and the linear d-c pulses are applied directly to the reactance tube grid circuit.

Because of the excellent linearity obtained and the fact that no current is drawn by the reactance tube grid, it is possible to use a frequency-shift dividing resistor network to reduce a basic predetermined frequency shift to any value desired. Frequency multipliers in the transmitter multiply the shift as well as the carrier frequency, ordinarily necessitating a readjustment of the frequency shift control potentiometer each time the number of frequency multipliers is changed.

With the circuit shown a basic output carrier shift, for instance 600 cycles, may be divided into any number of subdivisions, each selected by a switch contact. Multiplication in the transmitter brings the shift back to the desired value (600 cycles) on the final output frequency.

A dividing network calculated to provide subdivisions of 1/2, 1/3rd, 1/4th, 1/6th, 1/8, 1/9th, and 1/12th the basic shift will accommodate the multiplying stages of practically all transmitters in existence.

Since the system is linear and no current is drawn from any of the taps, the resistor values may be readily calculated, being exactly proportional to the frequency-shift divisions desired.

The push-pull, 200-kc oscillator energy is applied to the grids of a balanced mixer stage where it is combined with energy from a high-fre-

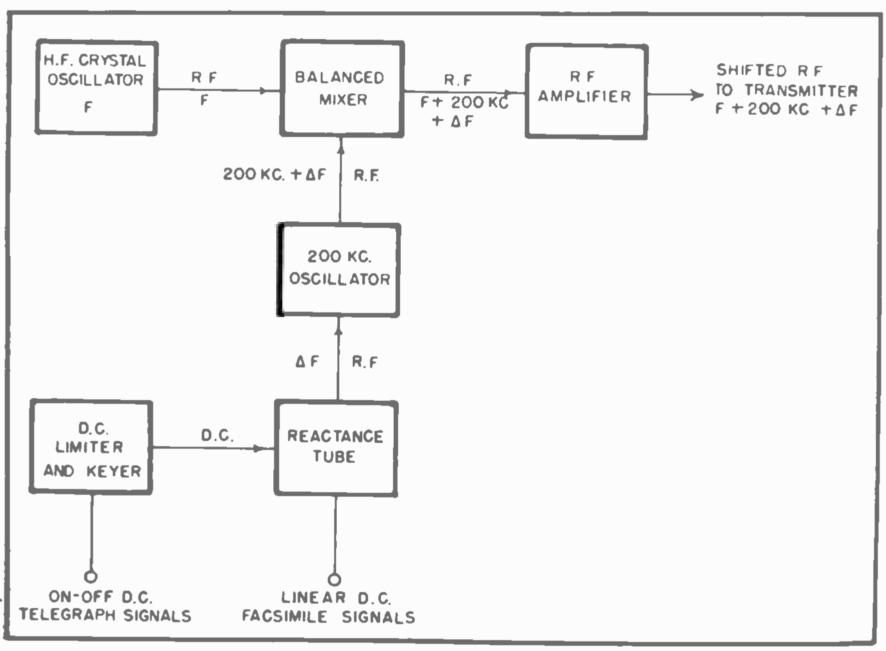


Fig. 2. Frequency-shift keying system which may be used for either code or facsimile transmission

quency crystal oscillator operating 200-kc lower than the desired fundamental output frequency. The plate circuit of the mixer stage may be tuned either to the high sideband, crystal carrier, or low sideband frequencies. In the interests of standardization the high-frequency sideband is normally used as the output frequency. Through the use of a balanced mixer circuit with a plate current balancing control the crystal carrier may easily be reduced to 50 db below the sidebands in the 2 to 4 mc range.

The high-frequency sideband is then amplified and transmitted by coaxial cable to the buffer-amplifier stage in the transmitter.

Succeeding stages in the transmitters are tuned to resonance exactly as for on-off keying and the power input is adjusted for continuous key-down operation.

F-S Receiving System

Several types of frequency detectors are in use for converting frequency-shift signals back into on-off pulses for actuating automatic printers, ink recorders, and facsimile equipment. In order to obtain the required stability, the detection is usually accomplished at audio or frequencies below 100-kc. Unattended receiver operation requires that the high and beat-frequency oscillators be crystal controlled or controlled by master oscillators having stabilities approaching those of AT-cut crystals, temperature-controlled.

Systems which permit operation with unstable oscillators, do so with great sacrifice in the signal-to-noise ratio because the input band-pass filter must then accept the widest possible drift band with its attendant decrease in noise rejection.

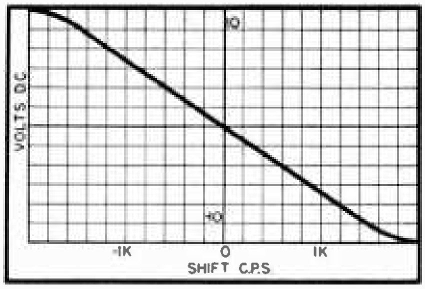
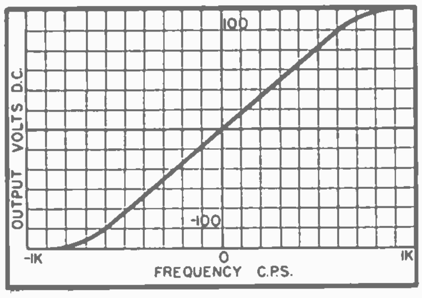


Fig. 4. (Above) Voltage input vs. output frequency for circuit of Fig. 3. Fig. 5 (Below) Audio discriminator characteristic suitable for facsimile application



Space diversity technique may be used to great advantage with frequency-shift telegraph signals. In most systems each receiver is followed by an f-s converter channel consisting of an amplitude limiter, a frequency detector, and a differential rectifier. The two channels are combined after rectification by means of a gating system which allows the stronger of the two signals to pass and rejects the weaker. Direct combination of the receiver outputs is not feasible because phase shifts existing between the two signals due to multipath conditions may cause partial or complete cancellation of the signal or produce severe distortion of the keying signal. After rectification to d.c., the phase shifts represent only a small fraction of the total pulse lengths and are, therefore, usually not detrimental to keying speeds up to approximately 600 w.p.m., or 240 cps. Because of the high keying speeds used for facsimile and photo-transmission (up to 800 cps) multipath phase shifts cause severe distortion even when diversity action is affected in the d-c stage. Therefore, dual diversity operation is not used for the reception of these signals.

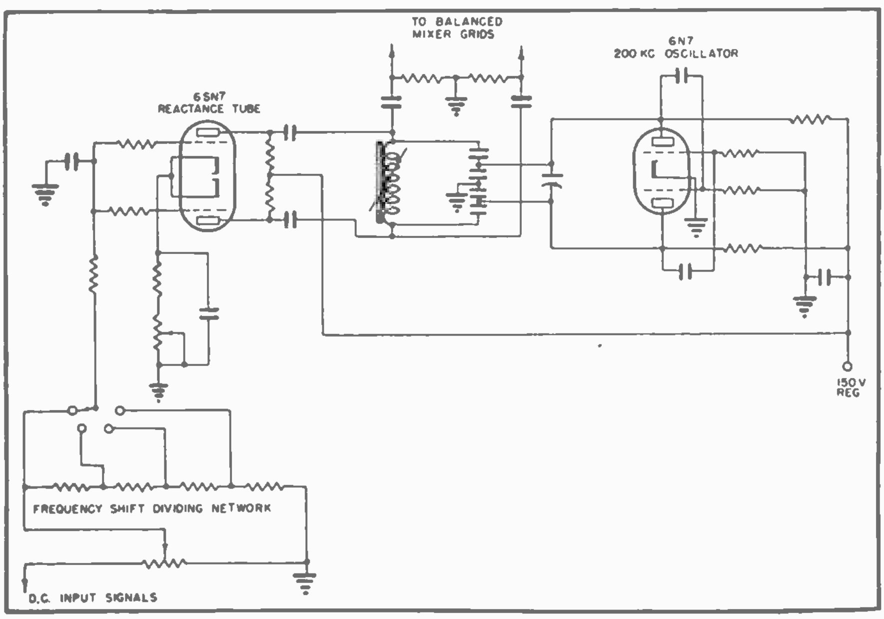


Fig. 3. Linear frequency shift and high stability are realized in this reactance-tube-oscillator circuit

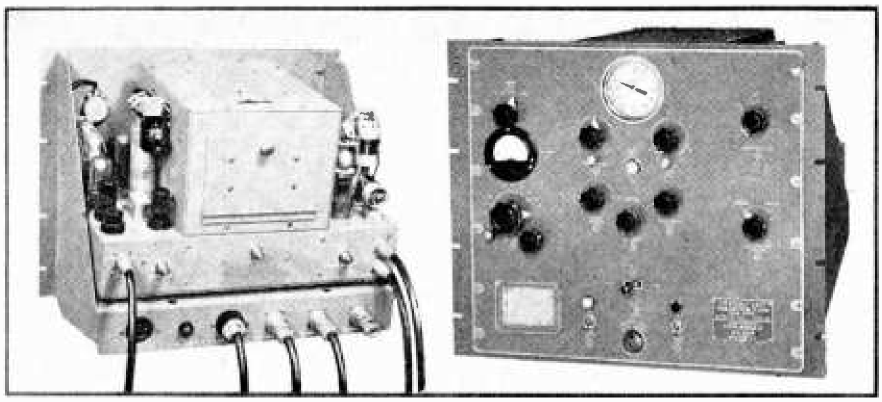
Figure 5 shows an audio discriminator characteristic which is suitable for the translation of frequency shift facsimile and photo signals into d-c amplitude variations which control the recording lamp. Values of frequency shift commonly used for facsimile are 900 cps and 1200 cps. For facsimile work, the gating system and d-c amplifiers shown in *Fig. 6* are not used. Linear d-c voltages may be taken directly from the discriminator, passed through an appropriate low-pass filter, and used to actuate a tone keyer which produces an output frequency whose amplitude is directly proportional to the d-c input. The input circuits of most facsimile and photo-recorders operate with an amplitude-modulated tone input.

Frequency Stability

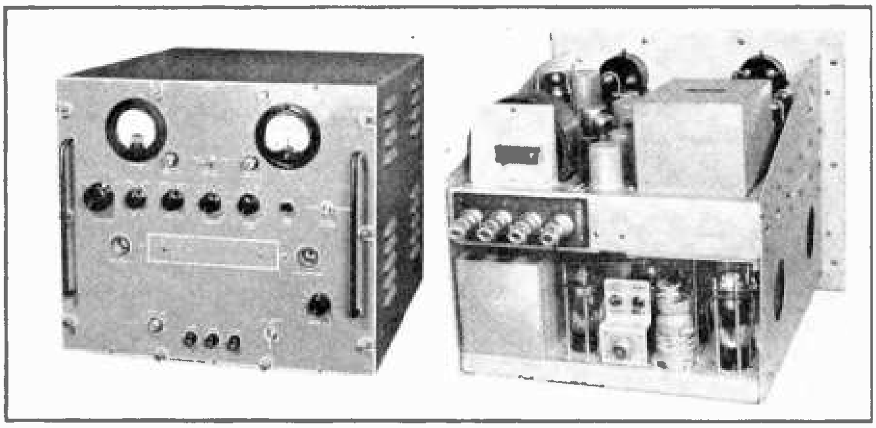
Frequency detection in the standard communications spectrum of from 2 to 30 mc implies the use of a high frequency-stability system in order that the FCC tolerances originally assigned for make-and-break keying shall not be exceeded when frequency-shift keying is used. The standard FCC frequency tolerance for most point-to-point radiotelegraph transmitters is ±.01%. Until frequency shift keying is more adequately defined by the FCC and new tolerances are set up, certain communications companies are bound to adhere to the present ±.01% figure. This means that the total bandwidth of a frequency shift transmitter must lie between these limits. At the present time, frequency shift is considered to be a form of A1 emission using an unstable oscillator! Actually the stabilities required of the mark-and-space frequencies are much greater than those required for make-and-break keying.

During the war, an 850-cycle frequency shift was decided upon and used by most of the military services. This has proved to be a good choice so far as overall performance goes and probably took into consideration the limitations of frequency stability of the equipment in use at that time.

For commercial services between 4 and 30 mc a 600-cycle shift has been found to result in no deterioration of



(Above, left) Rear view of frequency-shift transmitter keyer. (Above, right) Front view. (Below, left) Front view of frequency-shift converter. (Below, right) Rear view.



signal-to-noise ratio gain and is widely used. This figure was arrived at to meet the FCC .01% tolerance requirement as well as an endeavor to cut down the bandwidth required to the minimum necessary to maintain a given grade of service.

The stability of frequency-shift keyers of the type described and illustrated by *Fig. 3* is dependent for the greater part on the design and temperature control of the reactance tube-oscillator circuit considered as a unit. The high frequency crystal oscillator, which is mixed with the 200 kc frequency to obtain a shifted high frequency, employs an AT cut crystal, also temperature controlled, and contributes negligible frequency drift. Present equipments employing this principle maintain a stability of ±6 cycles on the 1 to 6 mc range over an operating period of 6 hours or more.

In actual commercial operation the mark and space frequencies are checked at least once every twenty-four hours by means of a primary or secondary frequency standard. It has been determined by these measurements that the 200 kc oscillator usually requires no frequency readjustment over periods of a week or more.

A-C line fluctuations of ±10% reflect no more than a ±6 cycle change on the output frequency.

Improved temperature over design techniques are now available which will greatly reduce even the present drift due to ambient temperature changes. Small ovens suitable for this type of equipment have been constructed which maintain constant temperature within .3 of 1°C or better with a change in the ambient of from 0° to ±50°C.

In order to achieve the required stability without using temperature control it is necessary to place the reactance tube-oscillator circuit on a frequency lower than 50 kc. This means that two or more frequency conversions must be performed to obtain 1 to 6 mc output frequencies with sufficient attenuation of undesired sidebands. Despite the additional converter stage, this system has considerable merit in that it eliminates costly oven construction.

Whichever method is used it is apparent that the reactance tube principle of producing frequency shift keying has many advantages over all existing methods. Among these advantages are the following:

1. Wave shaping is easily accomplished in the grid circuit, minimizing undesired transients and permitting minimum bandwidth for a given keying speed.
2. An excellent linear characteristic is obtainable which allows the use of the system for photo and facsimile transmission.
3. The system is very flexible. Any value of frequency shift may be set up and divided as required. Standard high frequency crystals may be used in the high frequency oscillator and the characteristics of these have no bearing on the keying or frequency shift.

It is pointed out that direct or indirect phase modulation of crystal oscillators as applied in frequency modulation systems for voice and program frequencies is not applicable to frequency shift telegraph or facsimile keying. This is so because, for the latter operations, the modulation or keying frequency must go down to zero. That is, discrete frequencies representing either the Mark or Space signals, must be able to be maintained for an indefinite period which may be seconds, minutes, or hours.

Phase modulation systems are based on a definite lowest modulation frequency usually 15 to 30 cps and are, therefore, not suitable for this purpose.

The design of frequency shift receiving equipment offers no great problems as far as frequency stability is concerned because the conversion can readily take place at audio frequencies or very low radio frequencies 50 kc or lower.

Attempts made to discriminate directly at standard intermediate frequencies, such as 465 kc, have met with little success due to mechanical and thermal instabilities of the discriminator at these frequencies.

The reduction of frequency-shift

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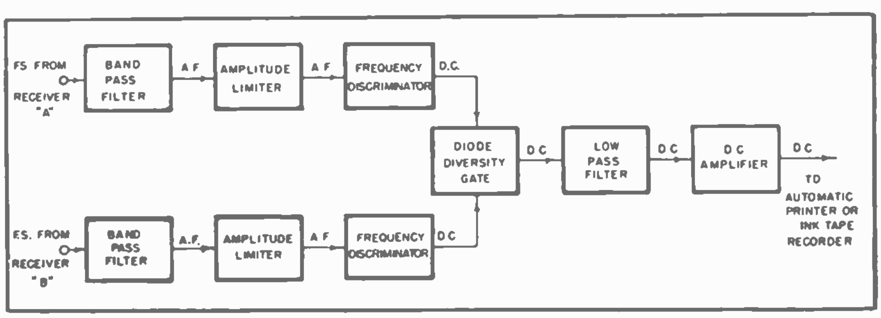


Fig. 6. Block diagram of dual diversity receiving system

NOTES ON

A. C. MATTHEWS

All receiver design engineers need a quiet spot in pleasant home-simulated surroundings in which to listen to their newly developed models. Many far-sighted manufacturers provide such facilities in the form of a field laboratory; others either require or permit the engineers to take the receiver home for these tests. The remainder provide no facilities, but depend upon listening tests made in the laboratory under far from normal operating conditions. Sooner or later customer complaints will convince these manufacturers of the need for special facilities.

The field laboratory is not only an ideal proving ground for a company's product but it can be used for many other purposes if intelligent planning has gone into its layout. Besides the regular listening rooms, which should be furnished as nearly like a regular living room as possible, there should be at least one extra large room suitable for small "get-togethers", where conferences can be held by engineering, sales, or management. But the main objective is to provide a suitable listening post which approximates an average residential home and to provide some laboratory facilities for making comparison measurements of receivers. When possible, a comparison should be made between all new designs and a representative sample of previous designs or perhaps a competitive manufacturer's current production. Listening posts should be made under as nearly normal living room conditions as practicable, particularly if tonal fidelity is being checked. Unusually high electrical or aural background noise masks the program and makes it difficult to listen critically. For this reason approximate home conditions are preferred.

Facilities Required

The laboratory building can be designed on a single floor plan, although the heating facilities could be located in a small basement if desired. The building shown in the sketch (*Fig. 1*) is of cinder block construction with glass brick for decorative effect and privacy. A second floor is not recomended because of the inconvenience of moving apparatus from one floor to another.

The amount of floor space depends upon the size of the particular engineering department and the extent to which it will make use of the field laboratory. There is always a tendency to provide too little floor space, therefore this point should be carefully considered. An extra listening room costs very little additional if included in the original plans but if it must be added later the expense involved is sometimes prohibitive. Past experience has shown that a field laboratory becomes increasingly popular with the design engineer as he discovers the speed with which he can solve certain acoustic problems when a quiet working space is available.

Antennas

If the company is engaged in manufacturing farm receivers, then a typical farm antenna should be erected. Television, FM and other high-frequency receivers of course require adequate dipoles or other forms of high-frequency antennae. An easily erected mast of 20 or 30 feet will also come in handy in case antenna systems are to be studied. This should be well in the clear in order to eliminate reflections from nearby buildings.

Equipment Required

Next, the actual required measuring equipment should be decided upon. This should include AM and FM signal generators for all frequencies ordinarily used, together with a-f oscillators to modulate same. Obviously a separate variable audio oscillator will not be required for each generator but it is advisable to include at least three since in this way audio investigations can be carried on simultaneously by another group without loss of time in waiting for equipment. Several vacuum tube voltmeters and output meters should be provided. At least two oscilloscopes will also be found invaluable. Of course, a supply of small components such as resistors, capacitors and hardware are an absolute must as is a complete range of a-c and d-c meters.

Several types of switches should be provided for switching antennas, receivers and speakers. A few of the more common types are shown schematically in *Fig. 2*. Note that indicating lamps are included to assist untrained personnel in following the switching during demonstrations.

Portable acoustic measuring equipment can be set up in the rear of the building for speaker measurements if the building is located in a quiet neighborhood. Outdoor measurements are superior to those made indoors because of the absence of undesirable reflections.

As for tools, some companies insist that each engineer bring his own from the main laboratory, others supply a fairly complete complement which always remains on the premises. The latter method is to be preferred. Electric bench-type drill presses and similar equipment are not required since major changes should be made at the main plant where more complete facilities are available. A small hand drill, however, will often come in handy if minor changes are necessary.

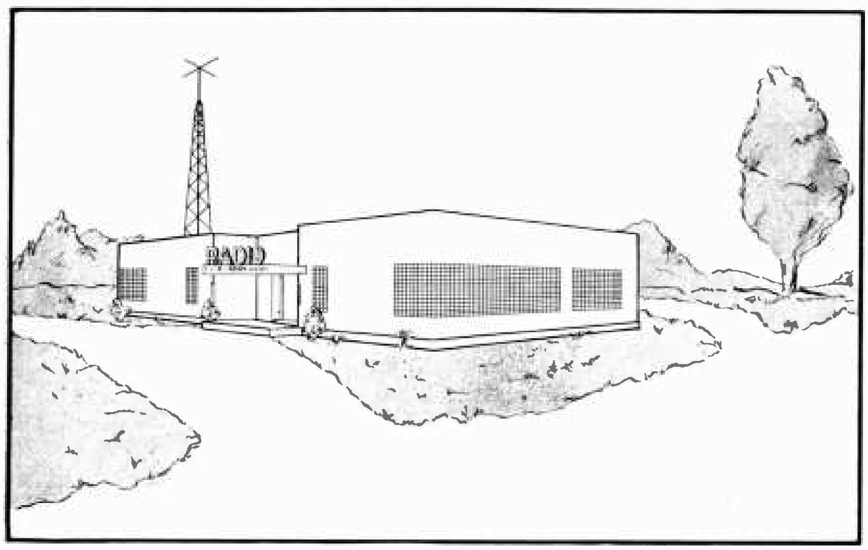


Fig. 1. Perspective view of field laboratory.

FIELD LABORATORY DESIGN

Useful information on the design and construction of a field laboratory

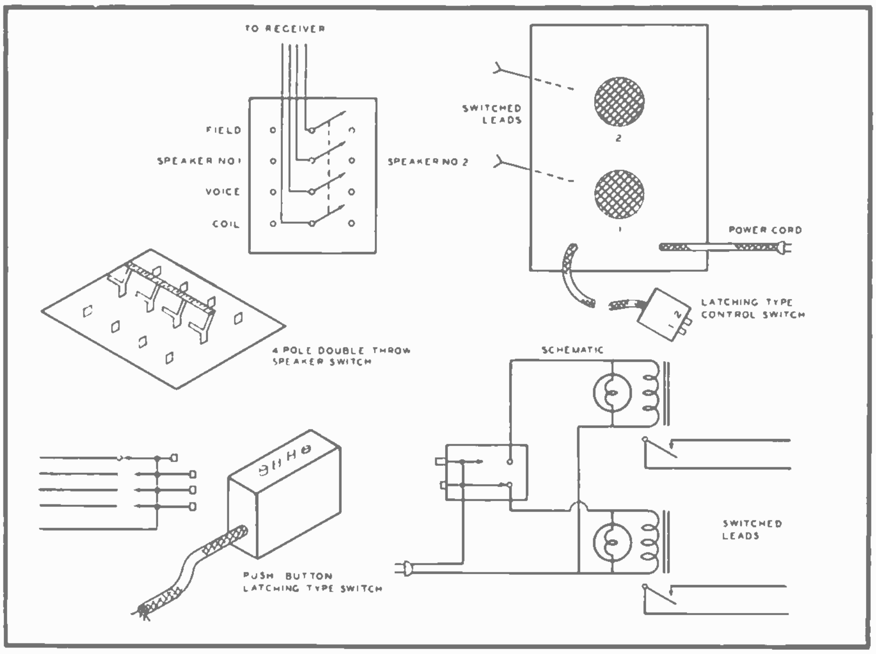


Fig. 2. Details of switching arrangements for comparison tests.

Each listening room should be furnished as a typical living room with rugs, drapes, tables, over-stuffed furniture, floor lamps, etc. One or two "tea wagons" should also be provided for measuring equipment. In addition to the normal living room furniture a supply of folding camp chairs often are useful, especially when a demonstration is to be given. The workroom should be equipped with cupboard space to hold the unused equipment and supplies.

Maintenance

A junior engineer can be assigned to check the supplies, ordering new components as required. He can also check the measuring equipment from time to time to see that it is maintained in good order. Unless an automatic heating system is available a janitor or caretaker will be required daily.

Actual Layout

A typical floor plan is shown in *Fig. 3.* There are actually four listening rooms since the sound-proofed room can be used if necessary. Such a layout should be adequate for even the largest radio receiver manufacturer since the building is to be used only for listening tests and demonstrations. The main room with 1000 square feet of floor space is adequate for demonstrating several receivers to a fairly large audience. Such a room can be used by management and engineering to demonstrate new advances in the line.

Telephone facilities should be located nearby, but not actually in the room, since this can often be a disturbance during demonstrations or talks. At least two doors should be included because of the size of the room. This facilitates the moving of equipment or receivers to the storage space without unduly disturbing the audience. Built-in seating along the front and part of the side of the outer wall will be found very convenient in many instances.

A storage and utility room located close to the main demonstration room provides a convenient place for storing receivers which are not actually being used, but are required for tests from time to time; as for instance, competitive models and samples of the previous year's production. This room should also include heating and air conditioning equipment for the entire building. A cloak closet has been centrally located in the main vestibule and at the rear of the building space has been provided for toilet facilities.

To the left of the ten-foot wide vestibule, when entering the main door, are located two smaller listening rooms. These are approximately the size of an average living room and, like the main demonstration room, should be completely furnished to approximate normal home conditions. Without adequate furniture a room will tend to have too much reverberation and therefore will be misleading to the listener.

At the rear of the building space has been provided for a small laboratory with a connecting sound-proof room. The former can be used for making minor changes and measurements while the latter is ideal for hum or low level distortion tests. Equipment as previously described should be available for these rooms.

Many refinements can be added to these plans such as attractive pilot lights at each door to indicate when the power is turned on, a paging system for the telephone, photo-electric door openers, a high quality line to a local broadcasting station for comparison purposes, etc.

The antenna tower, as shown, is optional and may be located in the rear of the building as will other antennas if required. A driveway should be provided at the rear of the building to facilitate loading and unloading heavy equipment.

The cost of a field laboratory as described should not be prohibitive, especially since it helps insure maintenance of a high-quality product from year to year by permitting comparisons to be made under actual operating conditions.

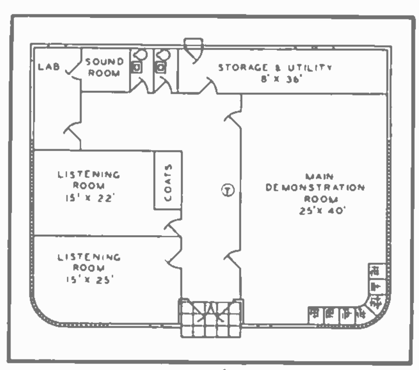


Fig. 3. Floor plan of field laboratory.

RADIO DESIGN WORKSHEET

NO. 51 – GRAPHICAL ANALYSIS OF THE CATHODE – COUPLED AMPLIFIER; SYMMETRICAL T AND H ATTENUATORS

GRAPHICAL ANALYSIS OF THE CATHODE-COUPLED AMPLIFIER

Yielding double-ended output from single-ended input, the two-tube cathode-coupled amplifier circuit shown in *Fig. 1* may be conveniently analyzed on the published plate family. Details of the operation may be thus evaluated to a considerable degree of precision.

V_1 and V_2 are usually the same tube type, and the analysis is made upon this basis. V_2 derives its excitation from the drop across the common cathode resistor R_k, while V_1 is excited by $e_i - e_k$. The output is customarily taken from plate-to-plate.

Guideposts

Various guideposts in the analysis may be observed at the outset. When $e_i = 0$, the grids of V_1 and V_2 must have the same potential, and this potential is $-e_k$. Currents i_1 and i_2 will not necessarily be equal, however, unless R_{L1} and R_{L2} are equal. In general this will not be the case.

When $e_i \neq 0$, the grid of V_1 is at a potential $(e_i - e_k)$, while the grid of V_2 is at a potential $-e_k$. A positive-going voltage on the grid of V_1 leads to a negative-going voltage on the grid of V_2.

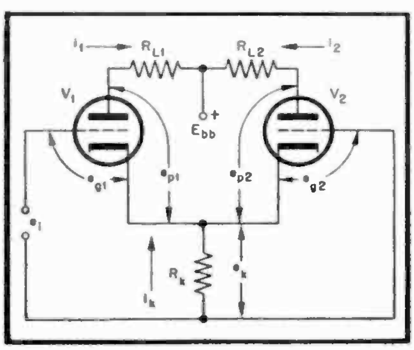


Figure 1

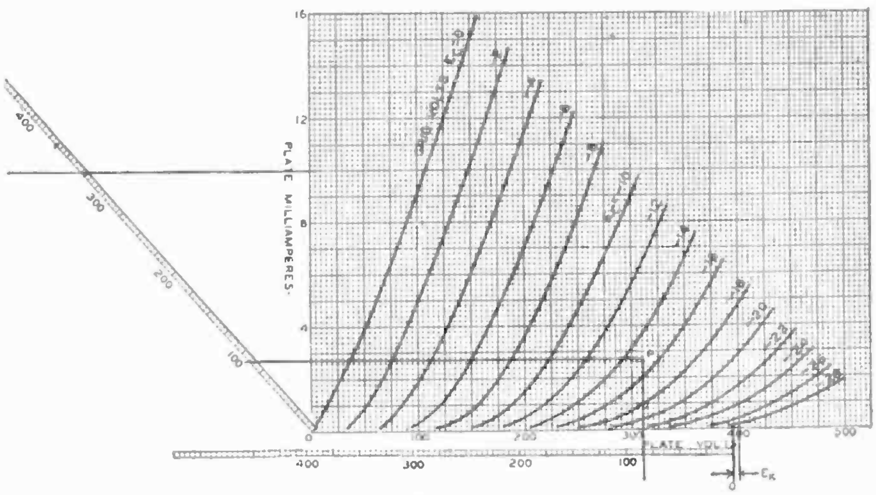


Figure 2

Published plate characteristics present voltages with respect to the cathode, and since the circuit of *Fig. 1* causes the lower end of R_k to be a voltage reference point, it becomes necessary to suitably modify the conventional procedure. The technique is well known for the case of a single-ended amplifier of the current-feedback type.*

The analysis is started with some arbitrarily chosen value of cathode-resistor current I_k, and its resulting drop e_k through the resistance R_k. This drop e_k is evidently the voltage e_{g2}, the grid-cathode voltage impressed upon V_2. Unknown at this point are the components of I_k, i_1 and i_2, their resulting drops through R_{L1} and R_{L2}, and the required input voltage e_i.

The pattern of the analysis is as follows: Having chosen an arbitrary cathode resistance current I_k whose unknown components are i_1 and i_2, i_2 is as yet unknown. But i_2 can be found because e_{g2} is known, and $e_{p2} = E_{bb} - e_k - i_2R_{L2}$, as explained in greater detail below. Having found i_2, $i_1 = I_k - i_2$, and the drop i_1R_{L1} can be computed. Then $e_{p1} = E_{bb} - e_k - i_1R_{L1}$, and e_{g1} is found upon the characteristics at the intersection of e_{p1} and i_1. Knowing $e_{g1} = e_i - e_k$, it is now possible to compute e_i and the problem is completely solved.

The end result of the analysis consists of two paths of operation upon the characteristics, each of which describes the behavior of an individual tube, and which together describe the plate-to-plate behavior when the individual outputs are added. The operating points are at $e_i = 0$ on each path of operation.

Successive Approximations

To explain in greater detail how to proceed with the analysis, a slide rule is useful in making the most involved step: that of finding i_2. Subtract E_{bb} and e_k, and jot down the value. Set the index of the slide rule at the value of R_{L2} so

*RADIO, March, 1946, p. 23

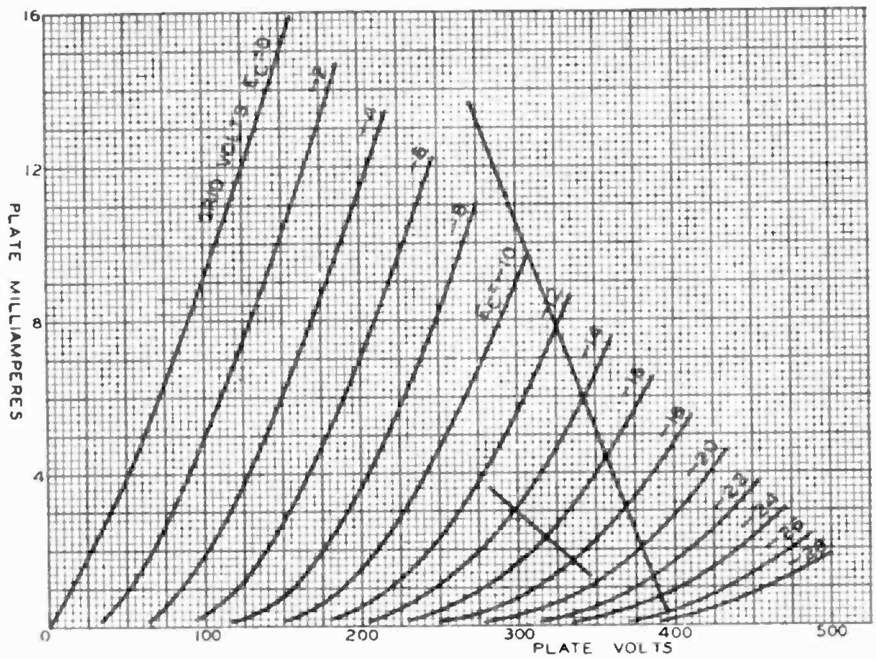


Figure 3

that all the drops of i_2R_{L2} are apparent. Follow down the curve $c_c = c_{g2}$, until a likely looking value of c_{p2} is seen projected below; note the value of i_2 at this point on the c_c curve, and glance at the slide rule, subtracting the slide rule drop from the jotted value. It will be too large or too small, indicating the direction and magnitude of error. Correct the chosen point accordingly, and check again. Three or four trials establish the point very closely, and subsequent points on the path of operation involve much less labor, since their general location follows from points already found.

In practical cathode-coupled grounded-grid amplifiers, a fixed bias is usually superposed upon the grids of V_1 and V_2 in order to control the operating point. This modifies the analysis only to the extent that when computing c_{g2} it is recognized as having a value $c_k - E_c$, where E_c is the fixed bias. Likewise, in computing c_i, it is seen that $c_i = c_{g1} + c_k - E_c$.

Complete Graphical Solution

A complete graphical solution is shown in *Fig. 2*. Here E_{bb} is located, and the R_k drop computed for the assumed value of I_k. This is graphically subtracted from E_{bb} as shown.

Next, an c_k scale is laid off from right to left as shown, so that the value of $E_{bb} - c_k - c_p$ can be read directly. Likewise, another c_k scale is laid off at an angle with respect to the i_p axis, as shown, to allow the i_pR_L drop to be read directly.

In other words, this set of linear scales solves the equation $i_pR_L = E_{bb} - c_p - c_k$, as is seen from *Fig. 2*. To locate a point on the load line of V_2, a right-angled device such as a draftsman's triangle, or even a sheet of paper, is slid along the characteristics, with the corner on the $c_c = c_k$ curve, as shown. Maintaining the right-angled device square with the axes, the slide down the curve is stopped when the same value of voltage is attained on both auxiliary scales. The terminating point on the curve (P) is a point on the load line of V_2. Other points are found in the same manner by choosing other values of I_k. The overall result of an analysis appears as shown in *Fig. 3*.

Since the corresponding points on the V_1 load line are found by usual arithmetic calculations and points of coordinate intersection, the graphical treatment is applied only for the V_2 determinations.

Thus, determining the paths of operation for V_1 and V_2 involves only slightly more labor than does analysis of the transformer-coupled push-pull amplifier. Moreover, the graphical analysis of the cathode-coupled grounded-grid circuit affords the only known method of computing actual performance.

Assuming that mu and R_p are constant, as is done in algebraic solutions, necessarily leads to inexact conclusions. Using large charts of characteristics and making the graphical analysis carefully, it is reasonable to expect highly accurate results.

When the loadlines are drawn upon the plate characteristics, and the various values of input voltage noted at the proper points as explained under *Fig. 2*, an operating point ($c_i = 0$) is determined upon each loadline. Travel along the loadlines for a given increment of input voltage takes place in opposite directions, and the projections of the grid swings upon the c_p axis yields the resulting plate-to-plate swing.

Gain of the circuit is of course found from the ratio of the plate-to-plate swing to the input voltage c_i. In general it will be found that the gain of the circuit is not much greater than that obtained for a single stage operating in the conventional manner. However, the advantage of the cathode-coupled circuit lies in the balanced output obtained as well as its improved performance under conditions of overdrive.

Graphical analysis of the circuit is interesting, and is capable of yielding information not otherwise obtainable with assumed linear parameters.

SYMMETRICAL T AND H ATTENUATORS

Let Z = terminal impedance in ohms, pure resistance

θ = attenuation in decibels multiplied by 0.1151

R_1 = series arm resistance in ohms

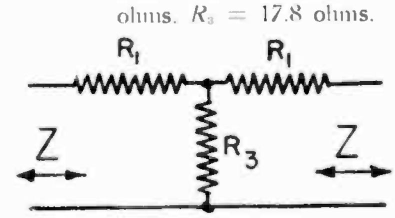
R_3 = shunt arm resistance in ohms

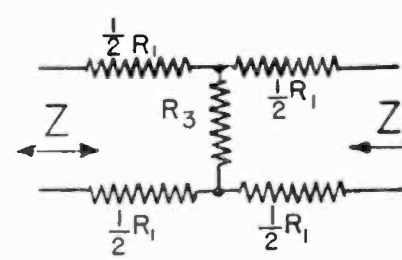
$$\text{Then } R_1 = Z \tanh \frac{\theta}{2}$$

$$R_3 = \frac{Z}{\sinh \theta}$$

Example 1: Z = 500 ohms and attenuation = 5 db. R_1 = 140 ohms, R_3 = 822 ohms.

Example 2: Z = 500 ohms and attenuation = 35 db. R_1 = 483 ohms, R_3 = 17.8 ohms.





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

Thermionic Tube Circuit

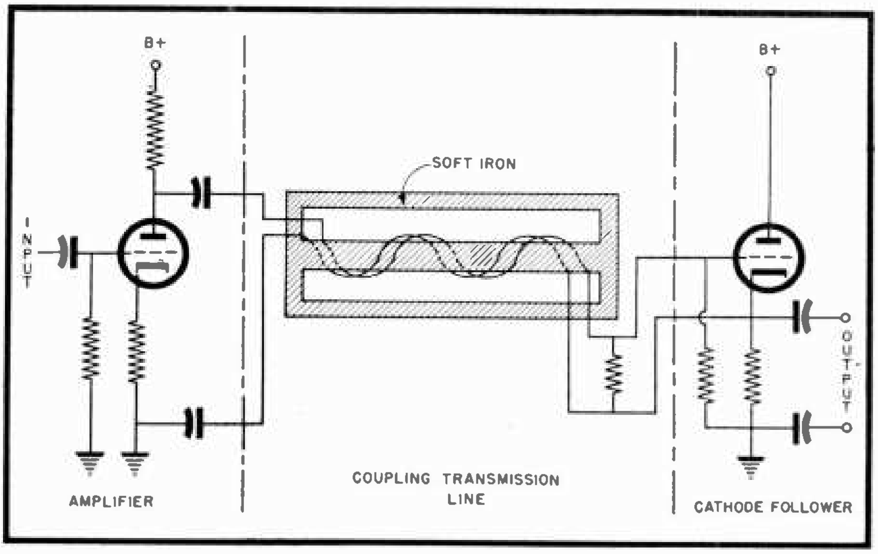
★ A method of coupling to a cathode-follower vacuum tube through an artificial transmission line is described in a patent issued to Cyril E. McClellan recently. A cathode-follower circuit normally comprises a tube having a load impedance in the cathode connection which is common to both the input and output circuits of the tube. It is claimed that the method of the invention is superior to more usual arrangements because much lower voltage can be applied to the cathode-follower tube while yet obtaining voltages from the output connections that are at any desired level consistent only with the characteristics of the cathode-follower tube and the insulation of the artificial transmission line.

Reference to the accompanying diagram will aid in a further explanation of the invention. Suppose that the input signal is such that the plate of the amplifier tube swings over a 200 volt range. In an ordinary cathode-follower connection in which the grid of the cathode-follower tube is connected directly to the plate of the amplifier tube through a condenser alone so that a signal is applied between grid and ground, operation is possible only if the cathode voltage of the cathode-follower tube is not required to swing through a range of more than 200 volts above ground less whatever amount is necessary to keep the cathode-follower tube from being cut off.

The signal applied between the cathode and grid of the cathode-follower tube is that from the plate of the amplifier tube less whatever portion of that voltage is found across the output terminals of the cathode-follower. With the present invention this is not the case. The signal from the amplifier tube is carried through a transmission line and applied directly between the grid and cathode of the cathode-follower stage.

The artificial transmission line used in one form of the invention comprises two coils wound together on the central leg of a soft iron spool. The coils are arranged so that their coupling approaches unity. Because of this coupling and the nature of the transmission line element, the two connections to the cathode-follower tube are divorced from ground and hence can be applied directly between the grid and cathode.

The patent, number 2,379,168, is assigned to Westinghouse.

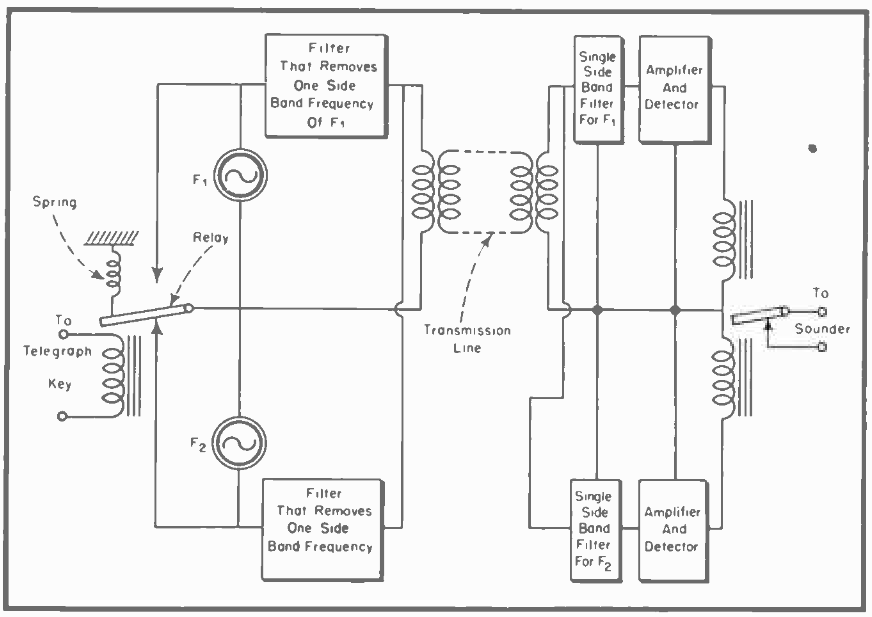


Patent No. 2,379,168

Telegraph Signaling System

★ An improved method of carrier telegraphy is shown in a patent issued to Harry Nyquist recently. This system utilizes a frequency modulation technique to obtain simple and positive keying at high speed, yet maintaining most

[Continued on page 29]

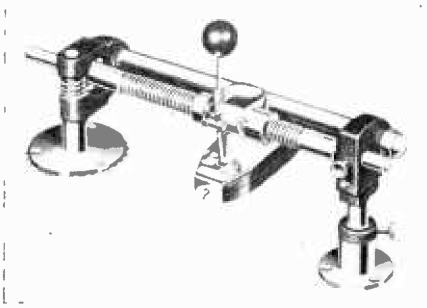


Patent No. 2,386,566

New Products

NEW RECORDER

Techno Machine & Tool Co., 200 Hudson St., New York 13, N. Y., announces a new low-cost instantaneous recording



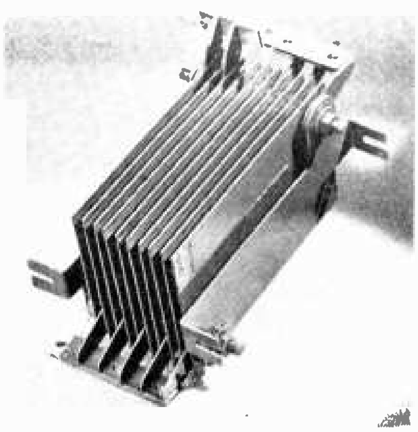
mechanism of the overhead type. This recorder is entirely new in design. Features are: Cutting needle angle adjustment, single lever for engaging feed screw and lowering cutting head and positive drive and gear which cannot be clogged by chips. The Techno-Craft recording mechanisms are adaptable to any height recording turntable. A thumbscrew allows for accurate adjustment of cutting depth. Its cutting pitch is 110 lines per inch, outside-in. The two models available permit recordings up to 16" diameter.

HEAVY DUTY RECTIFIER

The newest of a series of improvements in the design and efficiency of selenium rectifiers have been incorporated in a heavy-duty stack developed by Federal Telephone and Radio Corp., Newark, N. J.

Federal's new selenium rectifier stack has double studs, center contact construction and 26-volt plates. Employing rectangular, square-cornered plates instead of the round type, the new stack is designed to mount either in a vertical position or in a horizontal position, thereby affording improved and unobstructed circulation of air for plate cooling. One of the new rectangular plates more than takes the place of two of the 4⅜" diameter plates.

The advantages of parallel or series or series-parallel connection permits the formation of whatever combination is needed to supply the desired load.

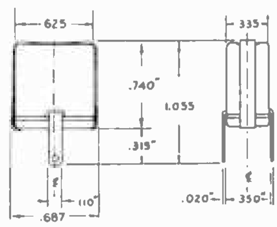


The vibration problem present in all rectifiers has been solved by the double mounts. The mounting of a-c and d-c bus connections also has been simplified. At the same time, better space utilization for heavy-duty current applications has been achieved.

One of the principal advantages of selenium rectifiers has always been the high allowable reverse voltage per plate. The new stack is composed of plates possessing higher reverse voltage than heretofore practicable from a commercial standpoint. These new plates are designed to withstand a rms voltage of 26 volts per plate, compared with the 18-volt plates previously supplied. With the new 26-v plates rectifier users have a tremendously greater factor of safety and allowable reverse voltage.

NEW CRYSTAL UNIT

The Bliley Electric Company, of Erie, Pennsylvania, announces the release of a new crystal unit, type VX2, specifically



designed for use where space is at a premium. Type VX2 features a compact, gasket sealed assembly and solder lug connections replace the usual pin contacts. The unit is supplied at 3105 kc for use in private aircraft transmitters and is available at any specified frequency between 5000 kc and 1000 kc.

MULTIPLE CONTACT CONNECTOR

A self-separating connector, newly developed by The Winchester Co., New York 17, N. Y., eliminates the prying and pulling required to disengage the ordinary multiple connector.

Molded of melamine plastic, the one-piece inserts reduce the danger of flash-over due to moisture and dust accumulations. Not only does this monoblock type construction permit easy removal of contacts, but it also makes the connector more rugged.

This connector can be supplied with a simple self-contained locking device for applications with very close space limitation. The necessity of any external clamping arrangement is thereby eliminated.

Multiple telescoping barriers serve to isolate contacts and increase both surface creepage and air gap between adjacent contacts. The connector is thus capable of being used at high potentials. Minimum air gap of ⅛ inch is maintained between all contacts. Contacts are designed for use with a maximum wire size of #16 AWG.

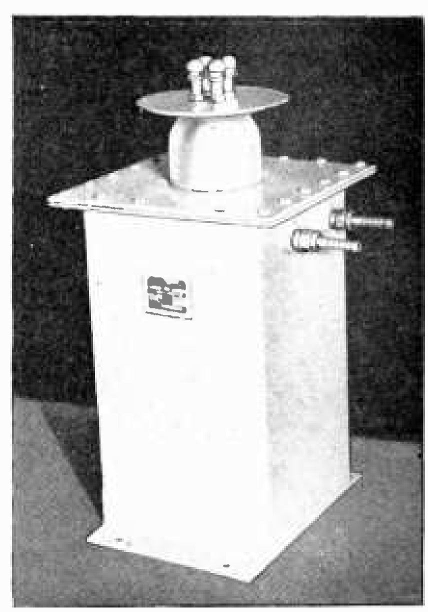
Descriptive bulletin 831-K is available; inquiries should be addressed to The Winchester Co., 6 East 46th St., New York 17, N. Y.

FM ANTENNA

A new high efficiency antenna to meet the FM broadcaster's needs for maximum coverage of a given area has just been announced by the Western Electric Company. The new antenna, called the 54A Antenna, or "Cloverleaf," was designed by the Bell Telephone Laboratories to radiate horizontally polarized waves and to concentrate this radiated energy into a service area surrounding the transmitting station. The new antenna is engineered particularly for use by frequency modulation broadcast stations operating at the new FCC assigned carrier frequencies between 88 and 108 megacycles and at power levels up to and including 50 kilowatts.

WATER-COOLED CAPACITOR

Boosting kva ratings by a factor of five or more, or conversely, reducing the bulk for given ratings, the new Aerovox Series 1780 water-cooled mica capacitor is now available for extra-heavy-duty service such



in high-power transmitters and induction furnaces.

The mica stacks are in an oil bath. Cooling coils in the oil bath provide for the efficient transfer of heat. Available in ratings up to 25,000 volts a.c. test, and in capacitances up to .01 µfd., by Aerovox Corp. of New Bedford, Mass.

RH-10 FREQUENCY CALIBRATOR

The Browning Laboratories has recently developed a new frequency calibrator Model RH-10 which allows full use to be made of the world's finest frequency standards which are transmitted from radio station WWV. The RH-10 is pretuned for 5 and 10 megacycles; either may be selected at will. Provisions are made for coupling secondary standards or other r-f sources and comparing their fundamentals or harmonics with the standard frequencies transmitted by WWV. A cathode ray indicator permits frequency comparisons to be made to at least 1/10 cycle. A dual filter allows the selection of either the 440 or 4000-cycle modulation. This allows these frequencies to be employed as a primary standard.

The sensitivity of the RH-10 is better than ½ microvolt and the image rejection ratio is more than 50 db.

For further data, write Browning Laboratories, Inc., Winchester, Mass.

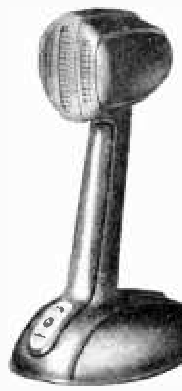
H-F VTVM

The -hp- 410A high frequency vacuum tube voltmeter is a multi-purpose instrument for laboratory, broadcast station, and production-line use. It measures a-c voltage from 20 cps to 700 mc, d-c voltage at 100 megohms input impedance, and resistance from 0.2 ohms to 500 megohms. For making a-c measurements a special low-capacity probe is employed which incorporates a new diode especially developed by Eimac for this instrument.

Input capacity is 1.3 µf; input resistance is 6 megohms below 10 mc, less at higher frequencies due to dielectric losses. On a.c. the 410A reads 1 v. full scale to 300 v. full scale in 6 ranges. D-c measurements may be made from 1 v. full scale to 1000 v. full scale in 7 ranges; input impedance for d-c measurements is 100 megohms for all ranges. For making a-c measurements in low impedance circuits, the probe may be stored in a compartment in the instrument and connections made to binding posts on the front panel. Overloads will not damage the instrument.

NEW E-V MIKE

A unique new combination crystal microphone and desk stand is announced by Electro-Voice, Inc., South Bend, Indiana. Internal construction, together with high capacity crystal, provides smooth, wide-range response and exceptionally high output—gives fine reproduction of voice and music. Frequency response is substantially flat from 70 to 7,000 c.p.s.



Output level is 48 db below 1 volt/dyne/cm², open circuit. Voltage developed by normal speech (10 dynes/cm²) is .0394 volt. Impedance is Hi-Z. Can be used with any standard amplifier employing high impedance input.

The Electro-Voice Comet, Model 902, may be used for group pick-up or for a single person.

For complete information, write to Electro-Voice, Inc., 1239 South Bend Ave., South Bend 24, Indiana.

LEVER SWITCHES

A new line of lever-action switches has been announced by the P. R. Mallory & Co., Inc. These new switches are adapted to intercommunication, centralized radio, sound distribution and public-address equipment.

The lever-action switch offers a total of 26 circuit combinations, 13 each shorting and positive non-shorting, including two, three and four positions, all with positive indexing at 20 degrees between positions.

For complete information write for Engineering Data Folder, "Mallory Lever

Action Switches, Series 5000 and 6000." Address requests to P. R. Mallory & Co., Inc., 3029 Washington St., Indianapolis 6, Ind.

NEW PILOT LIGHT

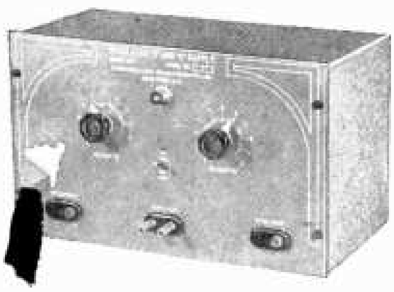
This series of pilot light assemblies is designed on the light-shield principle—to direct a beam of light within a rotation of 360 degrees. A turn of the knurled head directs the light on to any localized spot, at any desired angle.

Complete descriptive literature can be obtained from the manufacturer, Dial Light Co. of America, Inc., 900 Broadway, New York 3, N. Y.

DUAL POWER SUPPLY

Two independent, regulated power sources are combined in the CML 1115 Dual Power Supply.

The "B" supply furnishes a continuously variable d-c voltage from 180 to 300 volts, at 70 ma., with a maximum ripple of less than 25 mv. The negative side of the supply is isolated from the chassis, so that the +B may be grounded if it is desired to use the supply as a source of grid bias for tubes which draw heavy grid current.



A continuously variable d-c voltage from 0 to 75 volts with less than 7 mv ripple is furnished by the "C" supply.

Descriptive bulletin available; inquiries should be directed to Communication Measurements Laboratory, 120 Greenwich St., New York, N. Y.

R-F PROBE

A new r-f probe for functional testing of high frequency power circuits is manufactured by Radio Frequency Laboratories, Inc., Boonton, N. J. When the probe tip is subjected to an r-f field, a proportionate r-f current is capacitively induced, rectified and indicated on Weston 506 meter.

Many uses include the quick detection of standing waves, shielding power leads, r-f choke efficiency, and circuit tracing for r-f in all radio frequency equipment and associated components, without affecting operation of the circuit.

1LG5 NEW PENTODE

A new semi-remote cut-off pentode amplifier, designed for efficient operation in portable battery and a-c/d-c receivers where plate supply may drop as low as 45 volts, has been announced by the radio tube division of Sylvania Electric Products, Inc., 500 Fifth Avenue, New York 18, N. Y. Remote cut-off characteristic of the new type 1LG5 tube makes it better suited to a-v-c circuits than type 1LG5. Efficient operation with 45 volt plate supply makes it complementary to types 1LD5, 1LC6 and 1LB4 for receiver circuit applications, since they also provide good operation under the same low plate voltage condition.

The tube filament is rated at 1.6 volts maximum for battery operation and has

a design center of 1.3 volts for a-c/d-c operation. Maximum direct interelectrode capacitances, when 1 5/16" diameter RMA standard M8-308 shield is connected to the negative side of the filament, are: grid to plate .007 max. mmf; input 3.2 mmf; and output 7.0 mmf.

Typical operating conditions and characteristics with 45 volt plate supply in class A1 amplifier service, with suppressor grid connected to negative filament at socket, are:

Filament voltage, d-c	0.05 ampere
Filament current	1.4 v.
Plate voltage	45 v.
Screen grid voltage	45 v.
Control grid voltage	0 v.
Control grid resistance	2.0 meg.
Plate current	1.5 ma
Screen grid current	.45 ma
Mutual conductance	800 micromhos
Plate resistance, approx.	0.35 megohm

Control grid voltage for a Gm of approximately 10 micromhos is -9 volts. The grid leak is recommended to supply required operating bias in addition to that obtained from the a-v-c circuit.

NEW CHOKES

Two new chokes, the R-100S in the 2 1/2 mh size and the R-300S in the 1 mh size, have been placed on the market by the National Company, Inc. of Malden, Mass.

The R-100S is a continuous universal winding in four sections wound on an isolantite form for 6-32 screw mounting in any position. Each end of the winding terminates at cotter-pins, easily accessible for soldered connections. The overall dimensions are 2" x 11/16," the current rating is 125 ma, and the direct current resistance is 50 ohms.

The R-300S r-f choke has an isolantite form and is wound in a continuous universal winding in three sections. Characteristics include a d-c resistance of 10 ohms, a current rating of 300 ma, and a distributed capacity of 1 mmf. The overall dimensions are 2" x 11/16".

NEW CONCORD BULLETIN

News of interest to the radio field is contained in Concord Radio Corporation's announcement of a brand-new bulletin and supplement to Concord's complete catalog which was issued recently. The new bulletin-supplement features new merchandise available for immediate shipment from warehouses in Chicago and Atlanta. The offerings include hundreds of hard-to-find, long-sought items—and also many standard items at money-saving bargain prices.

A free copy of the new bulletin may be obtained by writing the Concord Radio Corp. at 901 W. Jackson Blvd., Chicago 7, Ill.

FTR REFERENCE BOOK

"Reference Data for Radio Engineers," radio handbook published by Federal Telephone and Radio Corp. has been reissued in revised and enlarged form. This second edition, like its predecessor, has been presented as an aid in the fields of research, development, production and education.

Over 50,000 copies of the first edition of "Reference Data for Radio Engineers" were sold. The second edition retains all the material that proved highly useful and popular in the first edition, with much additional data. The second edition has been expanded to 336 pages and now has over 400 illustrations, more than twice as many as in the original edition. The format is completely new and modern and a complete subject index has been added.

New chapters on transformers and on room acoustics have been added. The room acoustics chapter was specially written for the book by Edward J. Content, well known consulting engineer on numerous important acoustical installations and a recognized authority on the subject. Some of the original chapters have been rearranged and in many instances much new material has been added.

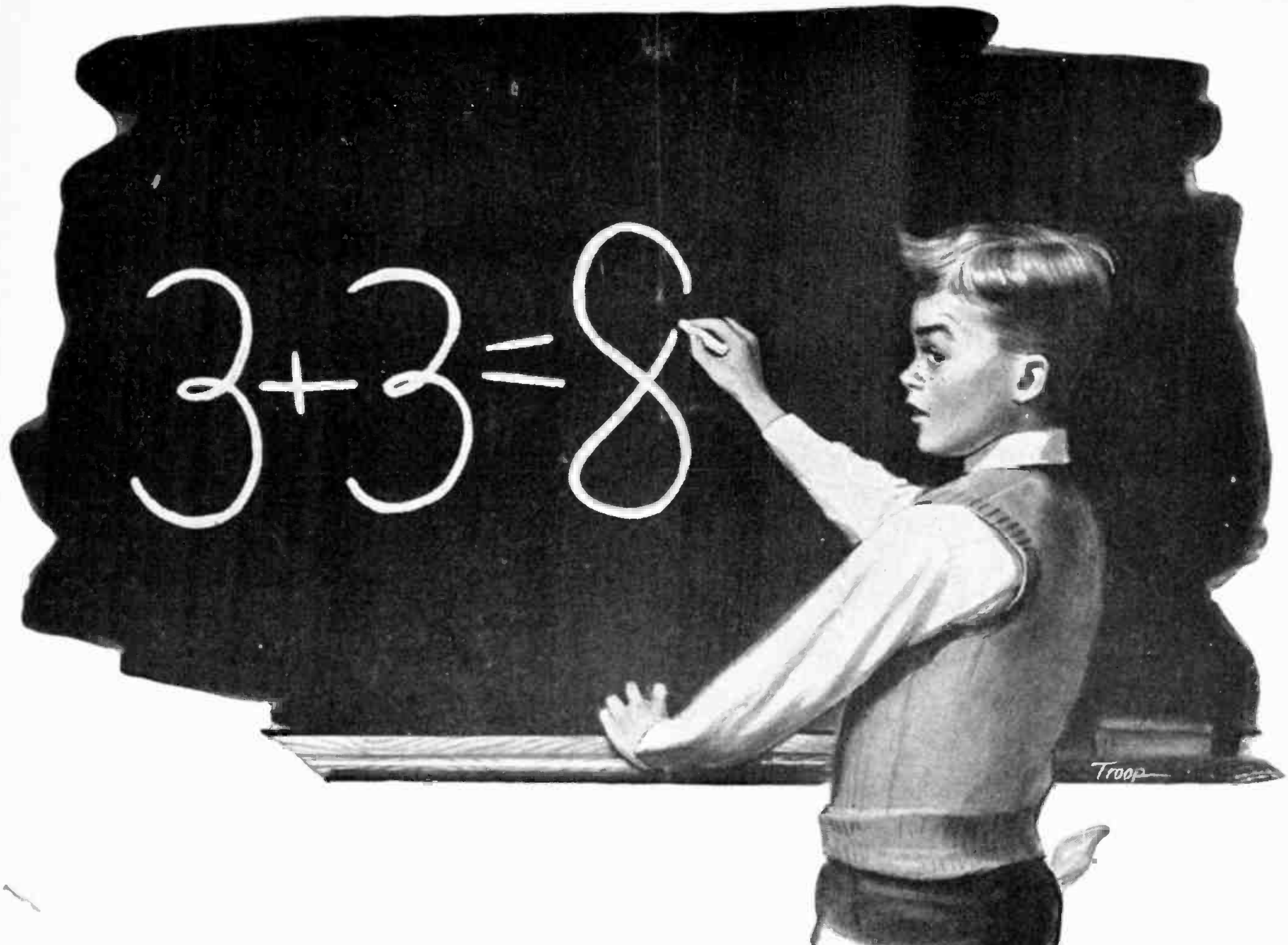
The new book is priced at $2.00 a copy, or $1.00 a copy when ordered for bulk shipment to a single address in quantities of 12 or more. All queries concerning "Reference Data for Radio Engineers" should be addressed to Publication Department, Federal Telephone and Radio Corp., 67 Broad St., New York 4, N. Y.

RECTIFIER TUBES

Technical data on thyratrons, mercury vapor and high-vacuum rectifiers, as well as multi-grid thyratrons, is presented in a two-color 24-page catalog issued by Chatham Electronics, 475 Washington St., Newark 2, N. J. The material is attractively bound and printed.

CARRIER-SHIFT TRANSMITTERS

A wide cross-section of frequency-shift transmitting equipment is described and illustrated in a loose-leaf offset-printed bulletin offered on request by Press Wireless Mfg. Corp., 38-01 35th Ave., Long Island City, N. Y. Units included in the bulletin include a 50-kw 4-21 mc transmitter capable of keying at 400 wpm, 15-kw amplitude modulator, several smaller telephone-telegraph transmitters from 400 watts upward, frequency-shift keyers,



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Contributed by this magazine in cooperation with the Magazine Publishers of America as a public service monitor, keyer coupler, compressor amplifier and preamplifiers for voice transmission, line amplifiers, triple diversity receivers, diversity tone keyers, polar d-c driver, tape scanner, recorder, and a complete line of photo-fax units.

An interesting insert discusses the technical features of r-f carrier shift, which is described in detail in RADIO.

The bulletin is handsomely illustrated and is a valuable addition to any technical library.

MIDGET RELAYS

Coil and contact data, contact arrangement diagrams, and dimension sketches of midget metal-base relays are presented in a new four-page booklet issued by Ward Leonard Electric Co., 31 South St., Mt. Vernon, N. Y.

SPECIAL-PURPOSE SPEAKERS

Loudspeakers for railroad and marine, submergence, industrial, and field applications are described and illustrated in a 24-page two-color catalog offered by University Loudspeakers, Inc., 225 Varick St., New York 14, N. Y. Speakers are listed with ranges up to two miles, explosion-proof designs, and models which will function in live steam at 90-pounds pressure.

INVENTIONS

[from page 22]

of the band width economy obtained with simple side-band transmission.

If it is desired to send simultaneously several telegraph messages over a single transmission link, it may be done by sending each by means of symbols formed by interrupting an alternating current of a characteristic frequency. At the receiving end the various frequencies are separated by filters, then separately rectified and made to operate simultaneously independent sounders with the individual messages. The number of messages which can be handled depends upon the frequency band width required by each channel. This width in turn is determined by the side band frequencies generated at the moment the carrier frequency is interrupted or restored. As in any amplitude modulation, these frequencies must be transmitted in order to reproduce the abrupt on-and-off character desired at the receiver. But it is possible to eliminate half the side bands without harming the intelligence and this is normally done. A filter, placed in the transmitter at a point beyond the keying point, is arranged to pass only the carrier frequency and single side band.

In practice, practical side-band filters introduce a 90° phase shift of a part of the side band energy, and that this phase-shifted component, which is present only during interruption or reconnection of the carrier frequency, tends to affect adversely the response of the receiving sounders. The present invention seeks to avoid this difficulty by using two carrier frequencies for each message channel instead of one. The interruption of one carrier to form a space between the code symbols connects another carrier of a different frequency to the line in its place and the unwanted phase-shifted side-band components are thus caused to compensate for each other.

In the accompanying drawing, the two frequencies F_1 and F_2 are generally close together in frequency so as to use as little spectrum space as possible. Only one transmitting equipment and the corresponding receiving station are shown, although several such pairs would normally be connected in parallel to the same transmission line.

The patent, No. 2,386,566, is assigned to the Bell Telephone Laboratories.

FREQUENCY SHIFT

[*from page 17*]

principles to operating actualities received great impetus during the war. This was due in part to the shortage of trained Morse code operators, which made automatic printing essential to speedy handling of the vast amount of traffic. Frequency-shift techniques proved entirely successful for operating automatic printers on difficult, long range, radio circuits where other methods failed.

Most commercial communications companies are now carrying on frequency-shift development programs. These promise to produce greatly improved techniques in this field which will eventually convert the majority of all radio communications to an automatic printing basis.

TRAVELING WAVE

[*from page 13*]

extend on to the right for many cycles. In the other two drawings, the same situation is shown with the sine waves shifted somewhat to the right as they will be at slightly later times. If one thinks of the first sketch of *Fig. 1* as gradually changing into the second sketch and then into the third he obtains a picture of the motion of the traveling wave.

Now a very important factor in the traveling wave tube generator of r-f energy is that the electrons move somewhat faster than the wave. The tolerance on how much faster is quite broad and is quoted as being one of the important advantages of this type of tube. Nevertheless, the excess speed is important and is the reason that even though electrons are fed into the tube at all phase relations to the traveling wave, there is still a selective action which causes much more energy to be transferred from the beam to the r-f field than vice versa. A qualitative explanation of this may be given in reference to *Fig. 4*.

Consider an electron like the one marked *A* in *Fig. 4*. This electron has happened to enter the tube at a time when it travels along with a portion of the traveling wave that causes acceleration. It is therefore a disadvantageous electron as far as the desired action of the tube is concerned. It gets ahead of the wave, however, for two reasons, because it has a larger initial velocity and, less important, because it is accelerated. Thus as is shown in the successive sketches of *Fig. 4*, it rather quickly catches up to at least a neutral point like the one in the last drawing and then no longer absorbs energy from the r-f field.

On the other hand, an electron like the one marked *B* in *Fig. 4*, which happens to enter the tube with a phase relation that calls for deceleration, will tend to stay in the decelerating region it enters. It may for some time move faster than the traveling wave because of its initial superior velocity. This is shown in the second sketch of *Fig. 4*. It may later have lost so much energy as actually to start to get behind again as is shown in the last sketch.

Electrons may also move from an accelerating region into a decelerating region. Consider for example an electron like the one marked *C* in *Fig. 4*. Starting in an accelerating field, its initial superior velocity may carry it over into a decelerating portion of the wave. There, it gave up energy to the r-f field.

Electron and Wave Velocities

In coaxial line, traveling waves are propagated with the speed of light and there is of course no possibility of getting the electrons to go faster than that. Not only do very high velocities call for inconveniently high voltages under any circumstances, but also the speed of light is known to be greater than any physical body can possibly travel. It would take an infinite amount of energy to make even a particle as small as an electron go that fast. As such a particle is accelerated more and more by a voltage, it is found that it refuses to go much faster but simply gets heavier instead. This, incidentally, is an interesting point in conjunction with electron accelerator tubes because it means that the traveling wave velocity need not change much progressively to keep up with increased electron energy once the speed of light is approached.

In wave guides, unlike coaxial line, the velocity of propagation is slower than the velocity of light. Furthermore it is to some extent controllable by variation in the wave guide size. Unfortunately, however, it is always a large percentage of the velocity of light and there is no possibility of decreasing it enough to allow electrons from convenient electron guns to have greater velocity. Only by the use of a special arrangement can the desired propagation velocity be obtained.

Figure 5 illustrates a way in which a traveling wave may be made to have a suitable form and yet travel with a speed as small as a tenth to a twentieth

ADVERTISING INDEX

ADDRESS CHANGES—

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of the velocity of light The instantaneous picture of the electric field is very similar to that of the circular wave guide shown in *Fig. 3*. There is, however, one important difference. The tube-like arrangement down which the wave travels is actually a helix rather than a solid metallic cylinder. This means that the charge flowing in the walls cannot move from left to right in a straight line as it does in a wave guide but must travel around the helix in order to move down the length of the tube. This greatly reduces the propagation velocity and makes it conveniently possible to project an electron beam down the axis of the tube with a superior velocity. The situation is very similar to that of a circular wave guide in other respects, and in fact the formulas of circular wave guides need only to be specialized to require circular currents in order to furnish criteria for design of the helix.

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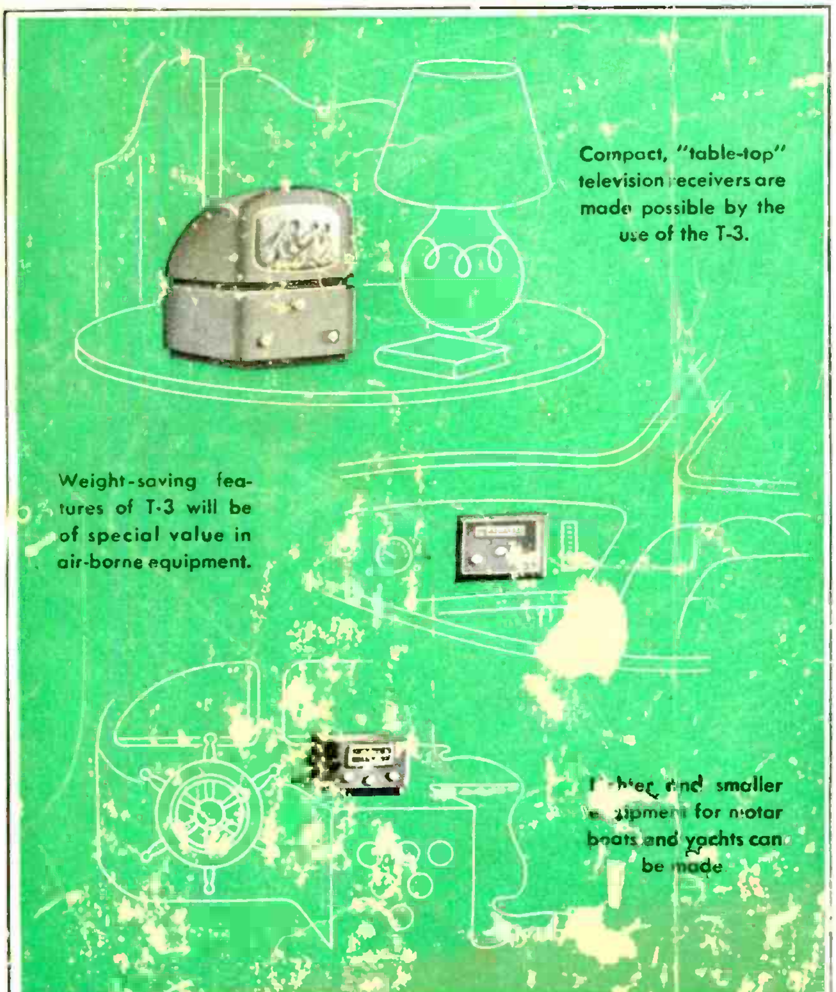
SYLVANIA NEWS

CIRCUIT ENGINEERING EDITION

AUG. *Prepared by* SYLVANIA ELECTRIC PRODUCTS INC., Emporium, Pa. 1946

MODERN SET DESIGN SEEN GREATLY INFLUENCED BY NEW SYLVANIA ELECTRIC T-3 TUBE

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



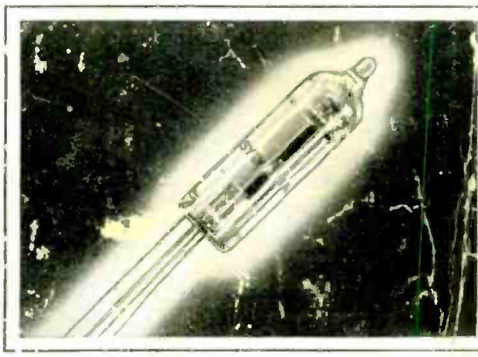
Radio equipment manufacturers are viewing with marked interest the radical reductions in size and weight now made possible in many types of electronic equipment through the use of the sensationally small Sylvania vacuum tube, T-3.

The commercial version of the former proximity fuze transceiver tube is noted for exceptional ruggedness . . . long life . . . ideal suitability for high frequency operation.

Some of the design possibilities opened by the T-3 are shown here. Of course, its potentialities are not limited to these fields.

Write Sylvania Electric Products Inc., Emporium, Pa.

SHARE A MEAL EVERY DAY



The T-3 tube is shown here in its actual size.

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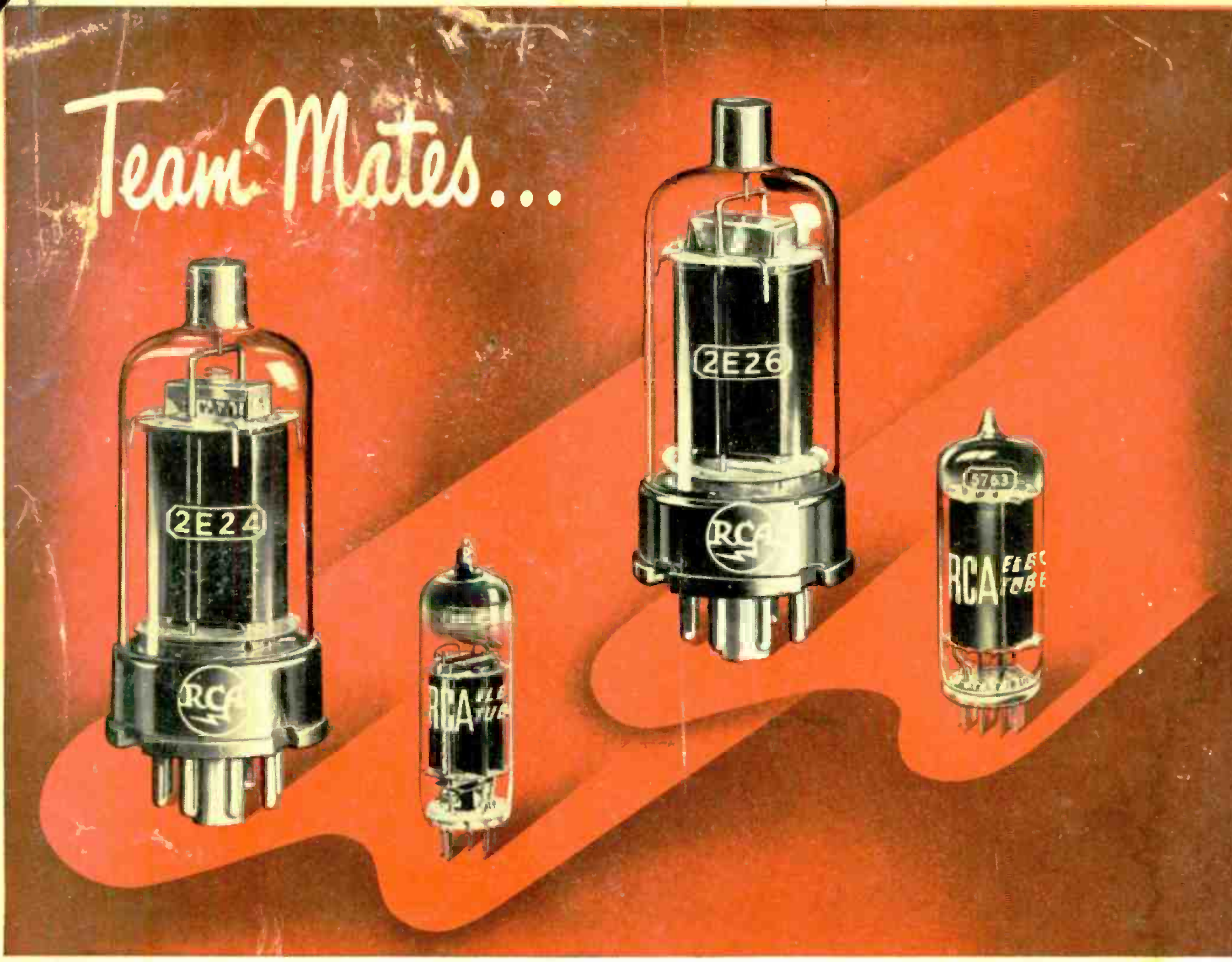

...for mobile communications

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The RCA-5763 miniature type beam power tube is very suitable as an output stage of low-power mobile transmitters and as a doubler or tripler in higher-power units. It can be operated with full input up to 175 Mc. The RCA-2E26 is intended primarily for use in the driver stages or the output stage of emergency mobile or FM transmitters. It can be operated with full input up to 125 Mc. and will provide an output of about 13 watts at 160 Mc.

The RCA-5618 power pentode and the RCA-2E24 beam power tube are quick-heating types with low filament drain, and are particularly suitable for mobile and emergency-communications transmitters where the operating power supply must be kept small. Both types are designed for intermittent operation. The RCA-5618 is superior as a doubler or tripler; the RCA-2E24, as the final amplifier in low-power FM transmitters.

Already proved in thousands of installations, these RCA tubes can be depended upon for their quality, ruggedness, and superior performance.

RCA Application Engineers are ready to work with you in applying any of these or other RCA tube types to your specific designs. For further information write RCA, Commercial Engineering, Section H42R, Harrison, New Jersey.

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