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—*Bell System Technical Journal*

The Transitron Oscillator
—*I.R.E. Proceedings*

Transmitter Safety Technique
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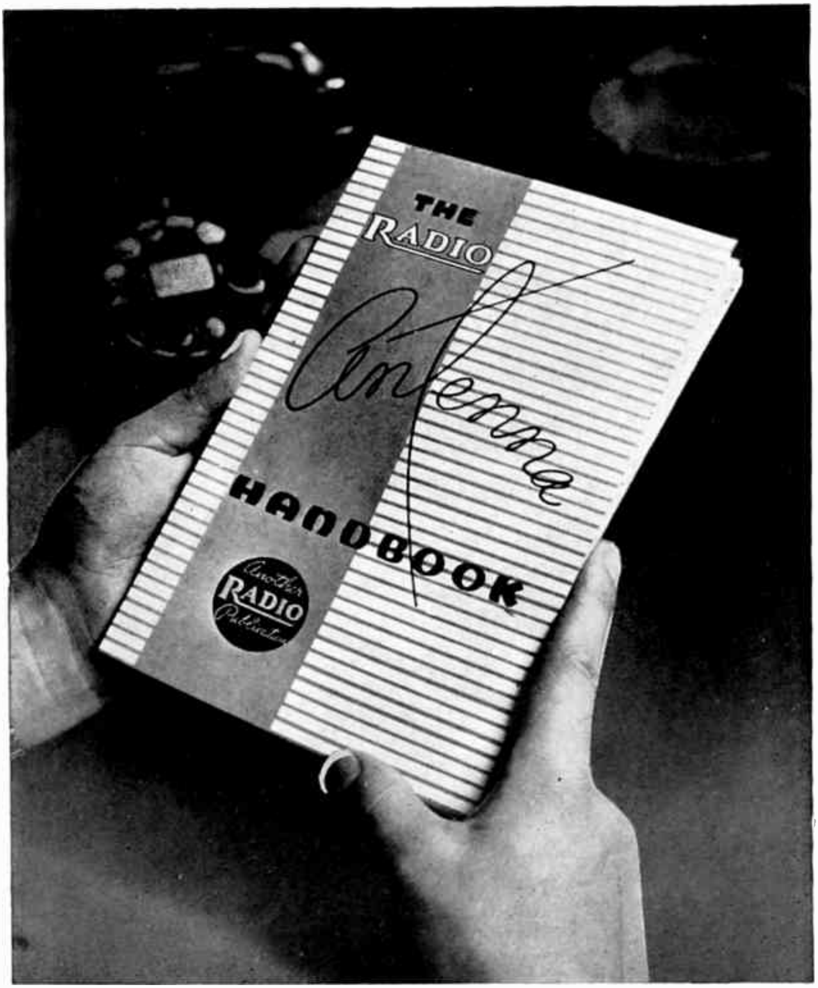
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RADIO Technical Digest

● MAY - JUNE, 1939 NUMBER 11 ●

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RADIO TECHNICAL DIGEST • **A. McMullen**, Managing Editor

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25c per copy. By subscription: 12 issues, $2.50 in U.S.A., Canada, Newfoundland, Spain, and all Pan-American countries; elsewhere, $3.00 or 12s. 6d. (British postal orders accepted.)

Published every two months by Radio, Ltd., 7460 Beverly Blvd., Los Angeles, Calif. Entered as second-class matter January 25, 1939, at the post office at Los Angeles, California, under the Act of March 3, 1879.

PRINTED IN U.S.A.

continuously a visual indication of the altitude.

At that time, however, a really practical terrain clearance indicator could not be built due in large part to the lack of suitable radio instrumentalities. Vacuum tubes capable of operating on frequencies approximately fifty times higher than those generally available were indicated as necessary before a satisfactory system could be built.

A long-range program, however, of vacuum tube development for high frequencies was under way in Bell Telephone Laboratories. This resulted in the production of suitable tubes, and they were described by A. L. Samuel to the Institute of Radio Engineers in October, 1937. One of these was capable of providing a stable output of between five and ten watts at a frequency of approximately 500 megacycles, so it became feasible to undertake the development of a practical terrain clearance meter.

The Japanese have been experimenting recently with apparatus operating upon the same basic theory and a paper was published in Japanese in 1936. A later paper was published in English in 1938 by the same author, which describes the apparatus and the results of tests made on the ground over short distances with the equipment at rest.

• Technical Problems

At the time this development was undertaken a number of questions presented themselves as to what the earth's surface would do to the incident wave in reflecting it. It seemed possible that the signal might be so scattered and broken in reflection by small irregularities that the echo would be more like static than a useful signal.

Even if the reflected signal proved satisfactory over the smoother surfaces, it was hard to predict what would happen when flying over timber land or over very irregular mountainous terrain. There was also the question of what would happen when the surface happened to be that of a city where an airplane flying at 250 to 300 feet per second passes over several buildings and streets with abrupt altitude changes of possibly hundreds of feet several times in the course of one second. Even with the most directive systems that can be devised, the beam radiated from the airplane is so spread that echoes can be expected to arrive simultaneously from several surfaces, for instance from both the leaves on the trees and the ground between the trees, or from the top of a building and from the adjacent street.

Several problems were anticipated in the apparatus itself. The theory is based upon a frequency-modulated signal free from any amplitude modulation, and it was questioned whether a transmitter could be built to operate on ultra-high frequencies which would be sufficiently free from amplitude modulation, when subjected to the vibration of the airplane, to be satisfactory. Since the receiver utilizes both the direct and reflected signals in making the altitude measurement, it is necessary that some signal be picked up directly from the transmitting antenna but not enough to overload the receiver and thus prevent reception of the echo. It was expected that difficulty would be encountered in sufficiently reducing the direct signal.

After considering all these problems, it was decided that the cheapest and easiest way of determining the answers was to build the apparatus and try it out to see if correct operation could be obtained, first, under the more or less ideal conditions of flying over smooth water and, then, over less favorable surfaces.

Most of the measuring equipment available for radio frequency test work is useless at ultra-high frequencies. Hence, it was necessary to get the system functioning as a whole before any means were available for determining the best adjustment of the radio-frequency parts of the system. Because of the difficulty of providing, while on the ground, an adequate reflector at distances of from a few feet to thousands of feet from the apparatus, it was necessary to install the equipment in an airplane very early in the development and make most of the tests during flights. Nearly a hundred airplane flights were made in one of the Bell Telephone Laboratories' airplanes during the development period of seven months which preceded the public demonstrations made in the United Air Lines Flight Research Airplane.

• Operation and Theory

The fundamental parts of the altimeter in relation to their application are shown in figure 1. An ultra-high frequency oscillator is provided, whose frequency is varied up and down by a modulator which consists of a small rotating variable condenser driven by a motor. The oscillator is connected through a coaxial transmission line to a transmitting antenna which is located on one of the lower surfaces of the airplane. The signal is radiated downward by this antenna. A radio receiver is connected through a similar coaxial line to a second antenna similarly located but arranged in such a way that a minimum of direct signal is received from the transmitting antenna and as much echo as possible from the ground. The direct and reflected signals are applied to a detector circuit in the receiver. The output of this detector is a signal of a frequency equal to the instantaneous difference existing between the direct and the reflected signals and is proportional to the height of the plane above the terrain. This signal is amplified by the receiver and applied to a frequency meter or counter circuit which is so designed that a current proportional to the frequency and, hence, to the height flows through a meter calibrated in feet and located on the airplane's instrument panel. A number of types of indicating frequency meter circuits of the condenser charge and discharge variety have been described in the technical literature.

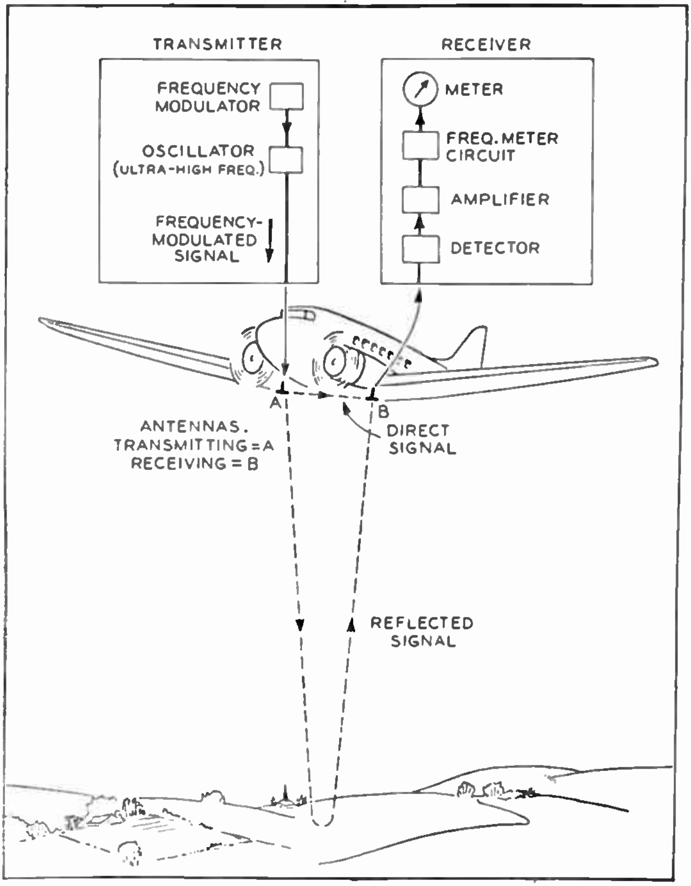

Figure 1. Overall system.

The operation of the system can be understood more easily by reference to figure 2. The variation of the transmitter frequency with time is indicated by the solid sawtooth line.* The value of the ordinate of this curve at any point is the transmitter frequency for the corresponding time. The frequency is

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*A simple harmonic wave that changes in frequency from instant to instant is no longer a single frequency but a series of discrete frequency components. In the present instance, the number of cycles of frequency modulation per second is small compared to the transmitter frequency swing, so the spectrum occupied by the signal is substantially that of the swing itself.

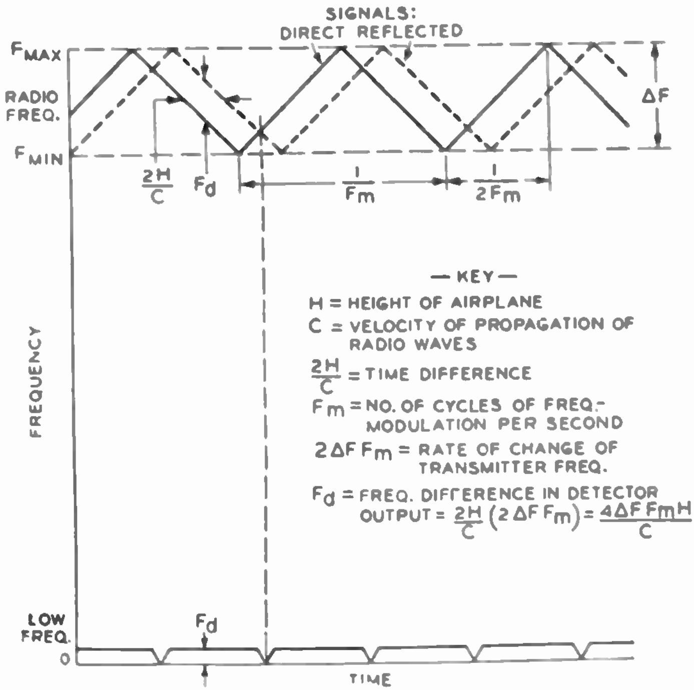
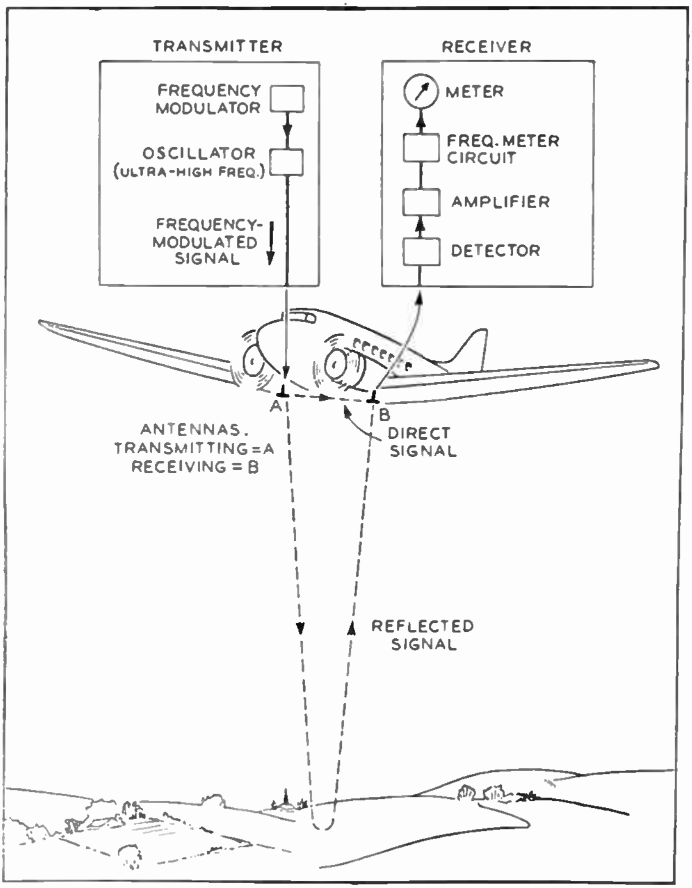


Figure 2. Operating theory.

varied from $F_{MIN.}$ up to $F_{MAX.}$ and back F_m times per second, so the rate of change of frequency is $2\Delta F\ F_m$ when ΔF is substituted for $F_{MAX.} - F_{MIN.}$ The linear frequency variation shown, while ideal, is not essential for the successful functioning of the apparatus. The dashed sawtooth line represents the variation with time of the frequency of the echo signal from the earth's surface. This curve is displaced to the right by a time equal to twice the height divided by the velocity of propagation, or, in other words, the time it took the radio signal to go down to the earth and return. This results in a frequency difference between the direct and reflected signals which is equal to the product of the time delay $2H/C$ and the rate of change of frequency, and is given by the equation,

$$F_d = 4\Delta F\ F_m H/C \text{ cycles per second.}$$

The difference is plotted again at the bottom of the diagram and appears as a series of trapezoids of height F_d. The time delay, $2H/C$, has been greatly exaggerated in comparison with $1/F_m$, the time



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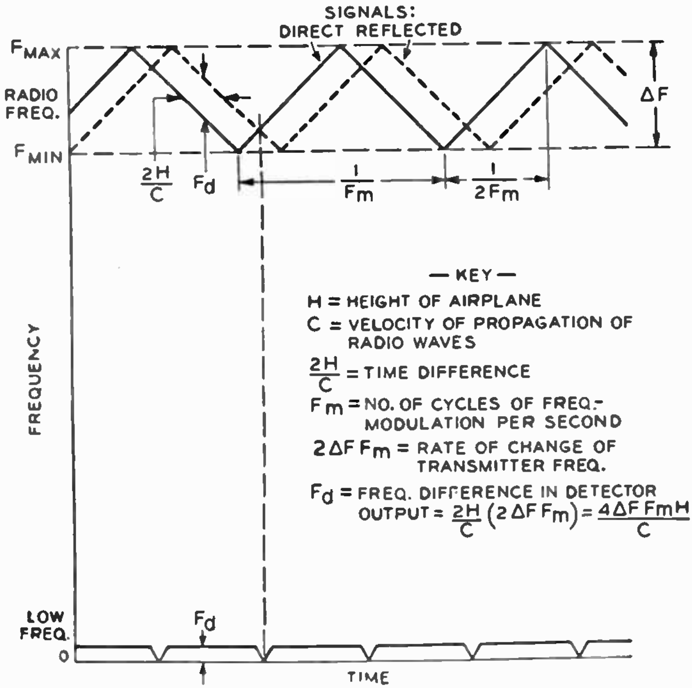

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The difference is plotted again at the bottom of the diagram and appears as a series of trapezoids of height F_d. The time delay, 2H/C, has been greatly exaggerated in comparison with $1/F_m$, the time interval corresponding to one cycle of frequency modulation, in order to make the difference, F_d, large enough to show on the diagram. F_d is actually only a few cycles in hundreds of millions. It will be noted that F_d drops momentarily to zero twice for each complete sawtooth variation of the transmitter frequency. This is due to the necessity of varying the transmitter frequency first up and then down, instead of forever in one direction. Hence the theory must be considered from the standpoint that one altitude measurement is made for each upward and another for each downward sweep, ΔF, of transmitter frequency so that a total of $2F_m$ measurements are made per second. The number of cycles of frequency F_d, occurring during one frequency sweep, is

$$F_s = F_d \times \frac{1}{2F_m} = 2\Delta F \ H/C,$$

since $\frac{1}{2F_m}$ is the time of one sweep, ΔF. F_s is directly proportional to both the height and to the amount of transmitter frequency change, ΔF.

The fact that $2F_m$ separate measurements are made per second is important only when considering small altitudes. The height which gives a value of unity for F_s corresponding to a frequency meter signal of $2F_m$ cycles per second is the minimum height which can be indicated since lower altitudes give the same reading. Lower altitudes cause only a fraction of a cycle of frequency, F_d, to be generated per sweep but since this fraction is repeated $2F_m$ times per second, it constitutes a signal of the same frequency $2F_m$ and is so counted by the frequency meter. In order to make this minimum altitude small, it is necessary that ΔF be large, since they are inversely proportional to each other. A frequency sweep of aproximately 25 megacycles is required to provide measurements down to the present minimum of about twenty feet. If a high antenna efficiency is to be obtained over a band 25 megacycles wide, it is necessary that the percentage variation from the average frequency during the modulation cycle be small. This percentage variation is made small by the use of an average frequency of approximately 450 megacycles. The use of this ultra-high frequency has the additional advantage that the antennas can be both small and efficient and cause little drag upon the airplane.

The indicating meter has two scales, the upper extending from 0 to 5000 feet and the lower 0 to 1000 feet. The position of the range switch determines the scale to be used in reading the meter.

The transmitter, power unit, receiver and a junction box are installed in the baggage compartment just aft of the cockpit with cable connections to the airplane battery and to the meter and range switch on the instrument panel. The transmitting antenna is below the wing to the left of the engine nacelle and the receiving antenna to the right of the other engine nacelle. Coaxial transmission lines connect the antennas to the transmitter and receiver.

The installation with apparatus as described weighs complete with all cables and connections about seventy pounds. Since this equipment represents a working model built with the idea of attaining performance rather than minimum weight, undoubtedly some reduction in weight will be obtained in future models.

The antenna installation shown in figure 1 when utilizing half-wave dipole type antennas approximately a quarter wavelength below the reflecting surface of the wing is not particularly directional. The signal is radiated over approximately the whole hemisphere below the wing centered on the transmitting antenna. The strength of the signal is greatest in the downward direction but does not fall off rapidly in other directions. The advantage of this antenna arrangement is that the distance to the nearest reflecting surface is measured regardless of whether it is directly beneath, or to the front or side. As a result very little change in reading occurs when the airplane banks steeply. Some advance indication also is given when the airplane in level flight approaches higher terrain.

- Performance

The terrain clearance indicator in its present experimental form indicates altitudes between approximately twenty and five thousand feet. When over smooth water or land, it is subject to errors as indicated by a consideration of the fundamental equation upon which the altimeter is based,

$$F_d = 4 \Delta F F_m H/C.$$

Since F_d is directly proportional to both ΔF and F_m, any variation of a given percentage in either will result in a corresponding percentage error in the reading of the meter. It is believed from the data available that the errors due to variation of either ΔF or F_m do not exceed ± 1 per cent.

Additional errors can also occur in the frequency meter circuit. These errors are believed to be less than ± 7 per cent, so that a total error of ± 9 per cent might occcur if all the errors were simultaneously in the same direction. Fortunately, all these are of a percentage nature, so that the error in feet becomes smaller as the ground is approached. An absolute error in the indication is still possible because of the limitations of the milliammeter used on the instrument panel. The Weston aircraft meter used is guaranteed to be correct to within one per cent of its full scale reading at any point on its scale, which permits maximum errors of ten feet on the 1000-foot scale and fifty feet on the 5000-foot scale.

When flying over rough water, wooded terrain or cities, reflected signal is received from surfaces at different distances simultaneously, resulting in addition and subtraction interference effects, thus sometimes momentarily reducing the echo signal below the minimum required for accurate indication. In such a case, the meter hand may swing down momentarily as much as 10 per cent. For the present limited transmitter power and receiver sensitivity, at altitudes above 2500 feet, these momentary signal reduction effects become progressively more serious when flying over irregular surfaces so that for a substantial part of the total time the echo signal may be below the minimum required for correct meter reading. This is indicated by a reading fluctuating between 3000 and 5000 feet when flying at 5000 feet over a surface dotted by buildings, timber, etc. The meter swings up to the correct reading every time the airplane passes over a smooth field or body of water of any size. Up to 2500 feet the echo signal has proved to be sufficient for steady operation over all kinds of terrain.

Tests have been made over New York, Raritan, Newark and San Francisco Bays, Great Salt Lake, Lakes Erie and Michigan, the timbered mountains of Washington and Oregon, the deserts and mountains of the southwest and the cultivated areas of the midwest during the period of the recent demonstration flights made with the equipment installed in the United Air Lines Flight Research Airplane.

An indication of the character of the surface over which the airplane is flying is given by the variations in the meter reading. A city usually causes rapid fluctuations of the order of fifty feet, depending, of course, upon the height and the spacing of the buildings. Cultivated farmland causes fluctuations of lower frequency and amplitude. An isolated high object such as a skyscraper or a chimney is indicated only by a slight meter kick as the airplane passes over it, which may not be noticed by the observer. If the airplane passes over only a few feet above the object and the top is large enough to contribute momentarily most of the echo signal received by the airplane, the indication is unmistakable and the correct distance to the object is indicated by the meter. For instance, the gas storage tank near the Chicago airport is an excellent object upon which to demonstrate the altimeter performance. The instrument is useful as a position indicator when approaching an airport on a course which crosses an obstruction of appreciable height and size since the moment of passage over the obstruction is clearly indicated. In fact, use as a position indicator may be one of the altimeter's most valuable applications.

A study of the circumstances in connection with a number of crashes in the west during recent years has revealed that in most of the cases the airplanes crashed after having been within a few feet of the ground without the pilot knowing it for several minutes before they struck. In such a situation the terrain clearance indicator should be capable of warning the pilot in ample time to avert a crash.

From Radio
March, 1939

THE SQUARE-CORNER REFLECTOR

BY JOHN D. KRAUS, W8JK

THE use of parabolic reflectors in directional antenna systems is well known. The antenna is placed at the focus, and it has been customary to construct the parabolic reflector so that the distance from the focus to the vertex is about one-quarter wavelength. This is indicated in figure 1-A, which is an end view of a long sheet reflector of parabolic cross section with a half-wave antenna at the focus. The reflector of figure 1-A has an aperture of one wavelength. The gain of a perfectly conducting parabolic sheet of this aperture is approximately 9 db over a single half-wave antenna. Improvements of this order can also be obtained readily by rather simple configurations of half-wave elements. These are more practical on the lower frequencies but on the ultra-high frequencies the dimensions of a parabolic reflector become small enough to make it practical also.

Other types of sheet reflectors are likewise possible. For example, figure 1-B shows a half-wave antenna in end view located at a distance, D, from a large flat perfectly conducting sheet. This arrangement has been treated by Brown[1] and was shown to be capable of a gain of about 7 db when the sheet is considered to be infinite in extent.

• The Corner Reflector

Another possible configuration, which has not been previously discussed, consists of two flat perfectly conducting sheets which intersect at some angle, forming a corner. Let us first consider the case when the corner angle is 90°. The antenna is located parallel to the corner and at a distance, S, from it. This arrangement is illustrated in figure 2. The antenna is equi-distant from both

[1]G. H. Brown, "Directional Antennas," *Proc. I.R.E.*, Jan., 1937, p. 122.

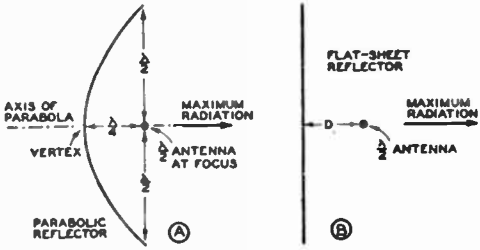


Figure 1. Cylindrical parabolic and flat sheet reflectors.

planes or sheets. The maximum radiation is in the direction of a line bisecting the angle between the planes as indicated. This is taken as the direction for which $\phi = 0^\circ$.

When the two planes are considered to be infinite in extent the gain of the system over a single half-wave antenna for various values of S is given by figure 3. The analysis and equations for obtaining these gain-spacing curves are treated in the appendix. The upper curve of figure 3 shows the gain of the beam system when zero loss resistance is assumed. This case is of theoretical interest only, since in all practical cases some loss resistance is present. The lower curve gives the gain when a loss resistance of 1 ohm is assumed for the half-wave radiator. It is apparent in this case that the gain decreases rapidly for antenna-to-corner spacings of less than about 0.15 wavelength. A suitable range of spacings is from about 0.15 to 0.30 wavelength. The gain over this range is about 10 db. Larger spacings can be used but to no particular advantage.

Flat sheets which are infinite in extent are a fiction which is helpful in the analysis. In practice it is desirable to make the planes as small as possible without involving much sacrifice in gain. Thus, the width and length of the sides should be such that the performance approaches as nearly as is practical to that with infinite planes. As a first trial, it was decided to use a side width of about 0.35 and a corner or side length of about 0.6 wavelength, and a spacing, S, of 0.15 wavelength.

• Five-Meter Square-Corner Reflector

To test this type of antenna, construction of a 56-Mc. square-corner reflector with these dimensions was undertaken. The problem of the material for the reflector at once presented itself. The ideal material is, of course, a perfect conductor. Copper sheets approach closely to this ideal. Such sheets are economical to use with microwaves. However, a 56-Mc. reflector requires about 12 square yards of sheet and

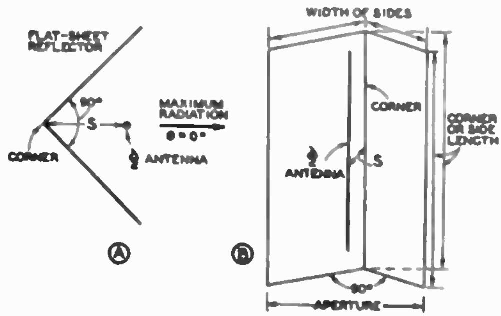
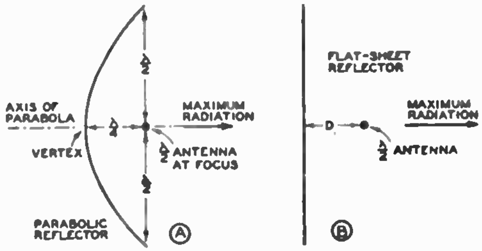


Figure 2. Square-corner reflector.

the cost of this amount is very high. Copper screen is a possibility but this is also quite expensive. A practical and economical solution to the reflector problem for a 56-Mc. antenna appears to be a curtain consisting of a large number of parallel copper wires. This construction is light, of moderate cost, and has very little wind resistance. Accordingly, this type of reflector was built.

The dimensions used are given in figures 4-A and 4-B. The corner length is 10 feet 6 inches and the side width is 6 feet. The wires are supported on a light framework of white pine (1" x 1"). Coating the frame with spar varnish or lacquer is desirable. The reflector is made from a continuous piece of copper wire woven back and forth over the frame. The wire is hooked over small nails on the top and bottom side members. Wire jumpers connect the parallel reflector wires together at the top and bottom. A jumper at the center of the reflector is also used. This is especially helpful in keeping the reflector wires lined up. The "wiring diagram" for the reflector is given in figure 4-A. A spacing of 6 inches between the wires can be employed. On this basis a total of 24 reflector wires is required, 12 on each side. The reflector at W8JK was designed to use an antenna-to-corner spacing of 0.15 wavelength and the reflector wires were spaced 3 inches apart for a distance of 3 feet out either side and 6 inches for the remaining distance. See figure 4-B. This closer spacing is probably not essential, especially if larger values of S are used. No. 12 wire or larger should be satisfactory for the reflector and antenna. It is an advantage to use bare or tinned copper wire in the reflector. With enameled wire much effort must be expended in removing the insulation for the large number of connections necessary along the top, bottom and middle of the reflector.

The antenna at W8JK is fed from the lower end, the transmitter being supported on the bottom cross members of the reflector structure. Other feed arrangements are shown



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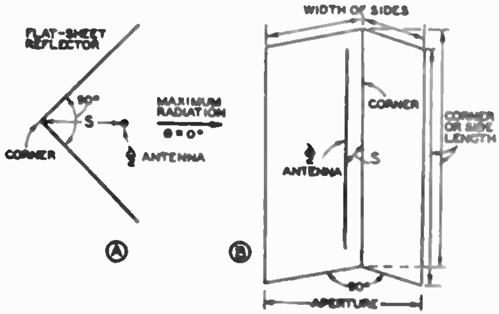

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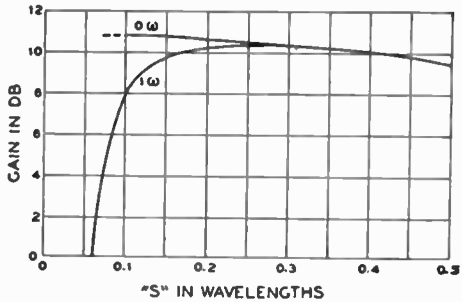

Figure 3. Variation of gain with a square-corner reflector as a function of the antenna-to-corner spacing, S.

in figures 5-A and 5-B. In figure 5-A the antenna is series tuned at the middle and coupled to the transmitter situated at this point. Probably the most practical arrangement is shown in figure 5-B, the antenna being fed by means of a half-wave stub and 600-ohm transmission line. Zepp feeders could also be used. In adjusting this arrangement, the antenna is shock excited and the shorting wire located for maximum current or antenna resonance. The 600-ohm line is then connected at the point which gives minimum standing waves on the transmission line.

Tuning up the antenna with square-corner reflector consists only in making feeder and transmitter adjustments to get maximum power in the driven half-wave radiator. No adjustments are made on the reflector. During the tune-up, a current indicating device at the center of the half-wave antenna is useful in determining when the antenna current is maximum. The length of the half-wave radiator can be determined from the usual antenna formulas. A length of about 8 feet was used for the antenna at W8JK.

Nothing in the antenna appears to be critical. The dimensions of the reflector, spacing of the wires, and the value of S all can be varied slightly with little change in performance. The angle of the corner

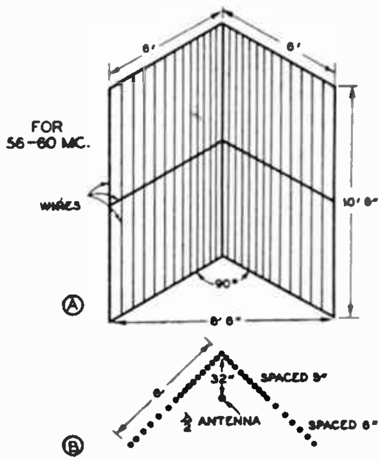

Figure 4. Dimensions and wiring of the 56-Mc. square-corner reflector.

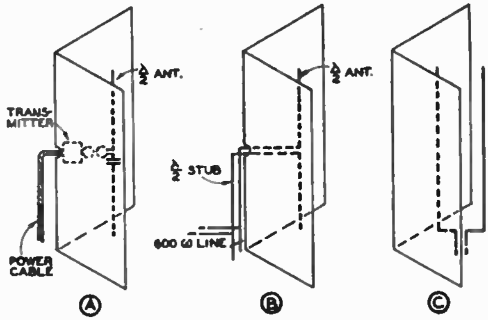

Figure 5. Methods of feeding the driven radiator. The arrangement at C is a single-section flat-top beam with square-corner reflector.

is also not at all critical. It is not known if the corner length of 10 feet 6 inches, used in the tests, is the optimum value. However, satisfactory results were obtained with this length.

Figure 5-C shows a single-section flat-top beam[2] with square-corner reflector. Although such an arrangement might appear promising, each element of the flat top must be tuned individually. This results from the fact that the inner flat-top element is closer to the reflector and has a considerably lower radiation resistance and a different reactance than the outer element. By spacing both flat-top elements sufficiently far from the corner this differential can be reduced, but a reflector with wider sides is then necessary.

- **Field Tests**

The results of a field test on the antenna at W8JK are shown by the solid curve in figure 6. The dashed curve is computed for the case of a square-corner reflector with infinite sides. Both curves are adjusted to the same maximum. A calibrated field intensity meter was used and was located about 4 wavelengths from the antenna. The antenna was then rotated through 180°.

The beam has a measured front-to-back power ratio of about 60 to 1 or about 18 db. The measured pattern is not as sharp as the computed one. This is due to a number of causes. First, the sides of the antenna are not infinitely large; second, the reflector is not a solid perfectly conducting sheet so that some radiation may "filter" through; and third, some of the radiation picked up with the beam turned in the 180° position may have come from the leads to the power supply. The gain of the actual reflector is probably a couple of db less than the value computed for infinite sides.

A spacing, S, of 0.15 wavelength was used in this test. With this spacing, the radiation resistance of

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[2] J. D. Kraus, "New Design Data on the Flat-Top Beam," RADIO, June 1938, p. 15.

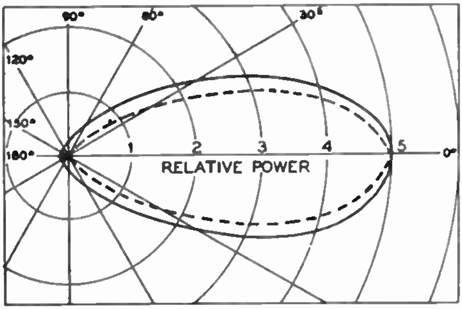


Figure 6. Measured radiation pattern of the 56-Mc. square-corner reflector (solid curve). The antenna-to-corner spacing is 0.15 wavelength. The dashed curve is computed for a square-corner reflector with infinitely large sides.

the half-wave radiator is quite small, and any loss resistance present tends to have a marked effect on the gain (see figure 3). More spacing is therefore desirable if it can be used conveniently. Spacings of 0.2 to 0.3 are recommended. Table 1 gives dimensions for the reflector according to the value of S chosen. In each case, a range of side widths is given. The largest value which is convenient should be employed. The smallest values of side width listed result in a slight sacrifice in gain. If directivity and not gain is desired, as with the antenna used exclusively for receiving, a value of S of 0.15 wavelength or somewhat less could be employed to advantage.

In another test with the reflector at W8JK an antenna-to-corner spacing of 0.3 wavelength was tried. This arrangement gave a measured gain of about 7.5 db over a single half-wave antenna. This gain was somewhat more than when S was 0.15 wavelength.

TABLE I
Dimensions of Square-Corner Reflector For 56 to 60 Mc.

"S" in wavelengths	"S" in feet	Width of sides
0.15	2' 7"	4' to 6'
0.20	3' 5"	5' to 8'
0.25	4' 3"	6' to 10'
0.30	5' 1"	7' to 12'

Corner or side length = 10' 6"
Aperture = Width of side x 1.41
Reflector wire spacing = 6"
For 112 Mc. (2½ meters) divide the above dimensions by 2.

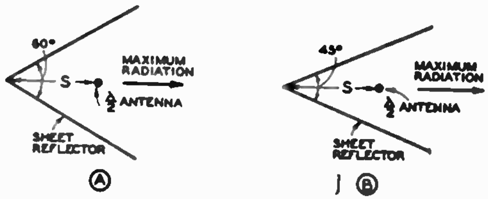
The square-corner reflector described is used with the corner and half-wave antenna oriented vertically, giving vertically polarized radiation. If desired, the corner and antenna can, of course, be turned horizontal to produce horizontally polarized radiation.

Another possibility is to make the reflector twice as long and use a double zepp antenna as the radiator. This would give slightly more gain.

- Corners of Less Than 90°

Two flat sheets intersecting at angles of less than 90° are also possible. Figure 7-A shows a re-

Figure 7. Reflectors with 60° and 45° corners.



flector with an angle of 60° and 7-B shows one with an angle of 45°. Assuming infinite planes, the gain of the 60° corner reflector is over 12 db and the gain of the 45° corner even more. Intermediate angles can also be used but these are not as simple to analyze by means of the method used in the appendix. As the angle between the planes is decreased, the gain of the system can theoretically be increased to any desired amount. There is, however, a real objection to the use of corners of less than 90° unless the value of S is at least about 0.5 wavelength. This is so because the radiation resistance of the half-wave radiator becomes very small as the angle between the planes is decreased, when small values of S are employed. If the value of S is about 0.5 wavelength, corners of less than 90° can be used advantageously. For example, a 60° corner reflector with S equal to 0.5 wavelength gives a computed gain of about 12.5 db even with considerable loss-resistance present. This is for infinite sides. If the sides are of such width that the aperture of the 60° corner reflector is about one wavelength, the gain should still approach 12 db.

Corners of more than 90° can also be used if desired. The limiting case would be a 180° "corner" or flat sheet.

- Conclusion

The corner reflector is a type which appears to have excellent possibilities. The simplicity of its construction when compared with a parabolic reflector is of considerable advantage. The corner reflector pro-

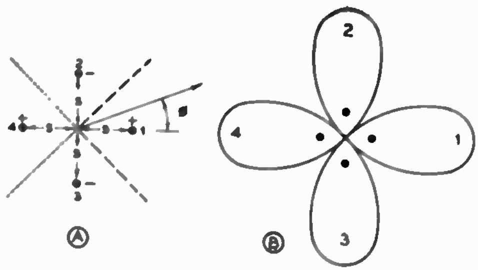


Figure 8. Image antenna configuration and pattern for analysis of the square-corner reflector.

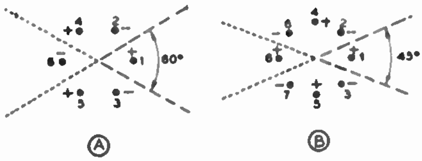


Figure 9. Arrangement of images for analysis of 60° and 45° corners.

duces a highly directional beam system with a relatively small structure. The gain is substantial. For example, a square-corner reflector with an aperture of one-half wavelength can give a gain of about 8 db. An aperture of twice this value, or one wavelength, is necessary with a conventional parabolic reflector to obtain a gain of this order. This applies to parabolas with a focus-to-vertex spacing of about one-quarter wavelength. Smaller spacings with correspondingly smaller apertures could be used with the parabola, but for a given size of aperture the corner reflector would still compare very favorably in performance.

APPENDIX

The method of images is used in the analysis of the corner reflector. This method can be applied in all cases where the angle between the planes is 180°/n, where n is any positive integer. Thus, corners of 180° (flat sheet), 90°, 60°, 45°, and so forth, can be treated. This fact is well known in electrostatics.[8] It is assumed that the planes are infinite in extent.

[8] Sir James Jeans, "Mathematical Theory of Electricity and Magnetism," 5th edition, Cambridge University Press (London), p. 188.

In the case of the square-corner reflector, there are three images, 2, 3, and 4, as indicated in figure 8-A. At first glance, only two images, 2 and 3, would seem to be required, but actually the planes forming the corner must be extended as indicated by the dotted lines. Element 4 is then the image of 2 and 3. The plus and minus signs show the relative phases of the currents in the elements. The currents in the four elements are equal in magnitude.

The gain of the beam over a half-wave antenna at a distant point is the product of the vector sum of the fields from the four elements and the current in each element expressed in terms of the current in a half-wave antenna having the same power input.

The voltage V_1, at the terminals of element 1 is by Kirchhoff's law,

$$V_1 = I_1 Z_{11} + I_1 Z_{1L} + I_1 Z_{14} - 2 I_1 Z_{12},$$

where,

Z_{11} = the self-impedence of element 1,
Z_{1L} = the loss impedance of element 1,
Z_{14} = the mutual impedance of elements 1 and 4, etc.

There are three similar expressions for the image elements. The power in each element is the product of the square of the current in the element and the resistive part of its impedance. Then, due to symmetry, we may write for the total power in the four elements,

$$4P = I_1^2\, 4\, [R_{11} + R_{1L} + R_{14} - 2R_{12}],$$

where,

R_{11} = the self-resistance of element 1,
R_{1L} = the loss resistance of element 1,
R_{14} = the mutual resistance of elements 1 and 4, etc.

The current in element 1 is then,

$$I_1 = \sqrt{\frac{P}{R_{11} + R_{1L} + R_{14} - 2R_{12}}}.$$

The current in a half-wave antenna with the same power input, P, is

$$I_O = \sqrt{\frac{P}{R_{OO} + R_{OL}}},$$ where,

R_{OO} = the self-resistance of the half-wave antenna and
R_{OL} = the loss resistance of the half-wave antenna.

The current factor thus becomes,

$$\frac{I_1}{I_0} = \sqrt{\frac{R_{OO} + R_{OL}}{R_{11} + R_{1L} + R_{14} - 2R_{12}}}$$

The expression for the gain in field intensity of the square-corner reflector over a single half-wave antenna is then,

$$\text{Gain} = \sqrt{\frac{R_{OO} + R_{OL}}{R_{11} + R_{1L} + R_{14} - 2R_{12}}}$$

$$\left| \left[1 + 1 \angle 2S^\circ \cos\phi - 1 \angle S^\circ (\cos\phi + \sin\phi) - 1 \angle S^\circ (\cos\phi - \sin\phi) \right] \right|,$$

where,

S° = antenna-to-corner spacing in electrical degrees or
S° = 360° × antenna-to-corner spacing in wavelengths.

The factor in the brackets is the vector sum of the fields of the four elements at a distant point in a direction making an angle, ϕ, with an axis through elements 1 and 4. The distant point is in a plane which is perpendicular to the elements. This equation was evaluated for various values of S to obtain the curves of figure 3 and for various values of ϕ to obtain the dashed pattern of figure 6.

The four-element system used in the analysis has four lobes of radiation as shown in figure 9-B. When the corner is present, however, lobes 2, 3, and 4 are absent and all of the power is concentrated in lobe 1.

A corner reflector with a 60° angle can be replaced for analysis by five images, 2, 3, 4, 5, and 6, as illustrataed in figure 9-A. Likewise, a 45° corner can be replaced by seven images as in figure 9-B. The gain expressions for these reflectors can then be developed by the method outlined above for the square-corner reflector.

From Bell Laboratories Record
February, 1939

PEDRO THE VODER

A Machine That Talks

WHEN the Emperor of Brazil after listening to Bell's telephone at the Philadelphia Centennial Exposition exclaimed, "My God, it talks!" he somewhat overstated the facts; for the telephone didn't talk, it carried talk. But there is a machine that does talk which will be exhibited by the Bell System at the San Francisco Exposition and at the World's Fair in New York. It creates speech. It is the first machine in the world to do this. It looks like a little old-fashioned organ with a small keyboard and a pedal. It is played by a girl operator. It takes a good deal of practice and some time to learn—not as much time as it takes the human to learn the mechanisms he is born with, but still quite a while. And it talks with what might be called a slight electrical accent. Nevertheless a skilled operator can make it say what she wants.

The device is an electrical arrangement which corresponds to the mechanism of human speech in all the essentials of kinds of sound and of the completeness of their control. It was designed in Bell Telephone Laboratories as a scientific novelty to make an interesting educational exhibit, and it is built entirely, except for its keys, of apparatus used in everyday telephone service.

The last part of the name, Pedro the Voder, comes from the key letters of the words, "*V*oice *O*peration *DE*monstrato*R*," because it is a device which shows electrically the operation of the human voice. The first part is taken from the name of Dom Pedro, the emperor who so promptly recognized the marvels of Bell's "speaking telephone."

In human speech there are two kinds of sound and the Voder has electrical equipment corresponding to each of these. One kind of sound is made by forcing the breath through the mouth, past tongue and teeth and lips, while shaping the mouth cavity. That is the way in which are made consonant sounds like "s," "th" and "f." And that is the way in which are made all the sounds of speech when one whispers. In the Voder there is an electrical source which contains all the sounds which enter into whispered speech. By choosing the proper combination of keys the operator can let through to the loud-speaker an electrical current to make any of them.

The other kind of sound which enters into human speech comes from the vocal cords. The most important of these sounds are those of the vowels like "a," "o" and "u." The human vocal cords give off a very complex and somewhat musical sound. When one talks one shapes his mouth cavity so that some particular parts of this complex sound come through clearly, while other parts are suppressed and unheard. In the Voder, therefore, there is an electrical source of sound corresponding to the vocal cords; this is a "relaxation oscillator" which gives a saw-tooth wave of definite pitch. There is a pedal for changing this pitch and for giving to speech a rising or falling inflection as desired. When the operator wants the sounds made by the vocal cords, instead of whispered sounds or consonants, a switch is depressed by her wrist to bring this oscillator into play. Then the particular parts of the sound which are wanted are selected by playing the proper keys. Each key operates a variable attenuator to control the current in a definite frequency range. The source of current for each attenuator is an electrical filter which picks from the saw-tooth wave one particular group of its overtones.

The Voder, an outgrowth of fundamental researches, is based on a development by Homer W. Dudley of a speech synthesizer which is controlled electrically by a speech analyzer. (This was described in the *Record* for December, 1936.) It is an adaptation of that synthesizer with manual instead of automatic electrical controls. The first model was built in the Research Department by Messrs. Dudley, R. R. Riesz, R. L. Miller, and C. W. Vaderson. Its further development was carried out by F. A. Coles and E. H. Jones of the Apparatus Development Department. Meanwhile the difficult task of working out its linguistic possibilities and its technique of operation was undertaken by S. S. A. Watkins, who also developed a course of training for its operators.

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A PORTABLE transmitter, with an induction heating coil attached in place of the antenna, was used to heat the last rivet in the steel work of the RCA Exhibit Building at the New York World's Fair Grounds. The rivet, suspended in the induction coil, became white hot in less than a minute. —Electronics.

From Electronics
March, 1939

Demonstration of FREQUENCY MODULATION

ON FEBRUARY 9, the editors of *Electronics* were given a convincing demonstration of the wide-band frequency modulation system invented by Major E. H. Armstrong. The demonstration was made over a fifty-mile path from transmitter to receiver, on each of two frequencies, on 42.8 Mc. and also on 110 Mc. The program material consisted for most part of high-fidelity vertical-cut recordings, together with a few studio presentations, involving piano music and hard-to-reproduce noise effects. The quality of the reproduction was of the highest excellence. Measurements indicate that the system is "flat" within one db from 40 to 15,000 c.p.s. and there was nothing to gainsay the measurements so far as the ear could detect. The absence of noise in the circuit, even over the 50-mile path with the low power transmitter, was the most startling aspect of the demonstration. The background needle-hiss of the records was definitely audible, of course, but between records the circuit displayed virtually no noise at all. The effect was, in fact, as if the set had been turned off altogether. The only interfering noise was an occasional flash of ignition interference, arising from motor cars on the street directly in front of the receiver antenna. The level of this interference was low and it could not be heard except when the circuit was not modulated (in the absence of music or speech).

Behind this demonstration lies a long period of development. Previous articles in *Electronics*[1,2,3,4] have

[1]Frequency Modulation Advances, *Electronics*, June 1935, page 188.

[2]Phase-Frequency Modulation, *Electronics*, November 1935, page 17.

[3]High-Power Frequency Modulation, *Electronics*, May 1936, page 25.

[4]Noise in Frequency Modulation, *Electronics*, May 1937, page 22.

See also the brief comment in Tubes At Work, *Electronics*, February 1939, page 36.

covered in detail the development of the system. Frequency modulation was considered, prior to 1935, to have little virtue and in fact was thought to have inherent distorting qualities. In 1935 Major Armstrong announced before the New York Section of the I.R.E. that he had developed a method of frequency modulation which was not only free from distortion but which possessed marked advantages in respect to the signal-to-noise ratio. The success of the system resides in the discovery that by introducing into the transmitted wave a swing greater than can exist in natural disturbances and by designing a receiver which is substantially not responsive to amplitude changes or small frequency changes, but only to the wide frequency changes of the signal, noise can be discriminated against. A high signal-to-noise ratio results. Furthermore, the wider the frequency swing used, the higher the signal relative to the noise, contrary to previous theory. In practice, the signal-to-noise ratio may be improved by a factor of 1000-to-1, relative to conventional amplitude-modulated transmission, when the noise is of the "fluctuation" type which arises in tubes and circuits. The available improvement is not so great when the noise is of the impulse variety associated with ignition systems, but the ratio is substantially bettered even in this case. Direct comparisons between amplitude-modulation and frequency-modulation transmissions on the same wavelength, cited in a previous article[3], show that an improvement of 50-to-1 (35 db) in the signal-to-noise voltage ratio occurs in the absence of impulse noise, and an improvement of 20-to-1 or higher in the presence of impulse noise. Comparisons with amplitude modulation on broadcast frequencies show an even greater advantage in favor of frequency modulation since the frequencies from 2000 kc. to 500 kc. are much more infested with atmospheric static, especially in summer.

- The High-Power Installation in Alpine, N. Y.

To show conclusively the advantage of his system over that of conventional broadcasting, Major Armstrong in 1936 began the construction of a frequency modulation station of a power commensurate with that of existing broadcasting stations. A permit was issued by the FCC to allow the construction of a transmitter of 40 kw. output power, under the call letters W2XMN, at a site on the Palisades, in Alpine, N. J., about 10 miles north of the upper tip of Manhattan Island, New York. The construction was completed in all essentials in the summer of 1938, but the high power was not used until near the end of the year. Since then demonstrations have been given to various groups, notably to an I.R.E. section meeting at Bridgeport, Conn., some 40 miles distant. Tests were also conducted in the house of George Burghard at Westhampton, Long Island, about 70 miles distant, until this house was destroyed by the 1938 hurricane. Since then the receiving headquarters have been located at Sayville, Long Island, some 50 miles airline from the transmitter. The signals are heard at this point with substantially perfect performance, i.e. very low (actually inaudible) noise level and no fading. The transmitter has been heard consistently on a receiver located at the top of Mount Washington in New Hampshire, at an airline distance of 275 miles. At this distance, fading is experienced, but without distortion so that a.v.c. action can be employed profitably.

The transmitter is remarkable in that it produces by far the highest power ever developed for any purpose on the ultra-high frequencies, whether for frequency modulation or otherwise. At present the output power of the final stage is limited to 20 kilowatts, since at higher levels the grid seals of the amplifier tubes become hotter than is permissible. However, the full 40 kilowatts output (85 kilowatts input) has been developed for periods of a few minutes. At present special air blowers are being installed for cooling the grid seals, after which the full power of 40 kilowatts will be employed regularly. The effective signal level along the ground is increased by the use of a turnstile antenna system which has a power gain, in all directions, of at least two.

The transmitter building is located on cliffs which are approximately 500 feet above sea level. The antenna is supported on a massive 400-foot steel tower. The antenna proper is mounted on a vertical mast supported at the ends of two side arms on the tower. The turnstile antenna is based on the design given by G. H. Brown[5]. Unfortunately the theoretical design does not coincide exactly with the actual design, aparently due to the effect of the metal support mast. As a result it was necessary for Major Armstrong to spend many hours daily for a period of over two months suspended on a boatswain's chair while adjusting the position of the dipoles and feeder wires. At present the turnstile consists of two sets of four horizontal dipoles each, the two groups being supported from a single mast but fed separately from each end of the mast. The power gain of this arrangement, compared to a single dipole of the same dimensions, is roughly 4 times. Further adjustments are expected to raise the ratio to 5 times. The height of the cliffs plus the tower puts the antenna about 900 feet above sea level; consequently the antenna commands within its horizon virtually the entire metropolitan area for some 35 miles in all directions. However, the limit of the station's primary service area is definitely not the horizon distance. Acceptably high field strengths are obtained in almost any location within 100 miles of the transmitter.

The operation of the transmitter itself is essentially as follows: The

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[5]The "Turnstile" Antenna, by G. H. Brown, *Electronics*, April 1936, page 14.

program starts in a conventional high quality telephone amplifier, and is given to a predistorter which accentuates all frequencies above 1000 cycles. The signal is then passed through a correction amplifier which introduces an amplification inversely proportional to frequency. The output of this amplifier is then used to control the phase angle of the output of a low frequency (200 kc.) crystal-controlled oscillator. Subsequent frequency multiplier stages multiply the oscillator frequency, and its attendant variable phase shift, by several thousand times. The multiplied phase shift, with the amplitude inversely proportional to frequency, is equivalent to a frequency modulation, i.e. the amount of frequency deviation corresponds to the amplitude of the original program. The frequency-modulated signal is then heterodyned to a submultiple of the carrier (middle-value) frequency. Thereafter the signal is frequency-multiplied to the carrier frequency of 42.8 Mc. All this signal manipulation consumes a great number of tubes (about 50 in all) but the tubes are of small size. When the central frequency and its deviations appear at the carrier values they are at low level. Thereafter three class-C amplifier stages increase the power level to the final value of 40 kw.

The input to the first of these stages uses conventional coil-and-condenser tuned circuits, but the plate circuits and all the circuits in the last two employ resonant-line circuits. The intermediate power amplifier (driver of the final stage) employs two type 858 tubes in push-pull, with four coaxial-line tuned circuits, two in the grid circuits and two in the plate circuits. The final stage employs two type AW-200 tubes, with coaxial lines in the grids and an open-wire circuit in the plate. Neutralization of the final stage is accomplished in the plate circuits. The total length of the tuned circuit in the final output is roughly 24 inches. From the output tank, an open wire balanced feeder line is used to convey the energy to the tower and thence to the two sets of dipoles in the turnstile antenna.

The efficiency of the final stage is between 45 and 50 per cent. This is remarkable performance at 42 Mc., but the explanation lies in the fact the stage acts as a class-C (telegraph) amplifier. It is a characteristic of frequency modulation transmission that no variation in amplitude occurs, and consequently the class of amplifier operation is of little moment, so far as distortion is concerned. Class C is used because it is the most efficient. Furthermore the power input and output remain constant, regardless of modulation level or frequency. The result is that the carrier level of the transmitter corresponds to the peak level, rather than to one-fourth the peak level as in amplitude modulation. An antenna meter in the feeder line showed no movement whatever when the transmitter modulation was increased from zero to full level (the latter point corresponding to a frequency swing of roughly 120 kc., or 60 kc. each side of the center frequency).

The three class-C amplifiers are required, of course, to pass a frequency bandwith of at least 120,000 kc. (actually the sidebands extend somewhat beyond the region of frequency swing). This bandwidth constitutes a very small fraction of the carrier frequency, and for this reason no loading is required in the tuned circuits of the last three stages, since the tubes themselves introduce the necessary damping.

The station itself is arranged with the low level modulating stages inclosed in a doubly shielded room, containing a high quality phonograph turntable for both vertically- and laterally-cut recordings. The last two or three frequency-multiplying stages are outside this room, and feed the first class-C amplifier. The last two amplifiers, which employ the resonant lines, are mounted on a table and completely surrounded with a wire shield. The high voltage power supply is located across the room from the final amplifier. The station, despite the large number of small tubes used, is extremely stable and simple to operate. "Cranking up" the transmitter consists simply in lighting the filaments, starting the air blowers, and bringing up the high voltage power to the desired level. Virtually no supervision is required after the station is on the air, since there are no peaks of power. As a result rectifier arc backs are extremely rare, and the station has thus far never been forced off the air for any reason other than a momentary loss of power from the incoming 60-cycle lines. The operators do not "ride gain" in any sense, since overmodulation cannot occur, in the usual meaning, and since the peak frequency swing (corresponding to maximum audio level) can be readily adjusted to the limits allowed by the channel.

- The 110-Mc. Transmitter at Yonkers, N. Y.

The other transmitter used in the tests was W2XCR, at the home of C. R. Runyon of Yonkers, N. Y., who has been associated with Major Armstrong throughout the development of the system. The modulating equipment is essentially the same as that used at Alpine, but the carrier frequency is 110 Mc., and the output of the final linear amplifier is only 600 watts. This station was originally an amateur station (call W2AG) operating above 110 Mc. However, in order to transmit music after the December 1 amateur regulations went into effect, an experimental license was obtained. The antenna is a 7-element turnstile array supported on the top of a 100-foot steel tower. This tower is 700 or 800 feet below the line of sight to the receiving location at Sayville, but this circumstance appears to have little effect on the strength and quality of the reception. The antenna power gain (non-directional) is five, making an effective power of three kw.

The receivers employed (except the 110-Mc. receiver) were constructed by the General Electric Company to specifications laid down by Major Armstrong. These receivers contain 15 tubes (1 rectifier, 4 audio, 10 r.f.), and will deliver a recognizable program with but 1 microvolt input. However, proper limiter action is obtained only with a signal of perhaps 2 to 5 microvolts, which can be obtained well beyond the horizon distance, up to 100 miles if the effective transmitter power is of the order of three kilowatts or greater, at reasonable antenna heights.

• Details of the Test Demonstration

The following brief resume of the impressions gained during the demonstration indicate the quality of the system as a whole. The first demonstration was at the apartment of Major Armstrong, on the east side of Manhattan Island, roughly 14 miles air line from the transmitter. The receiver was mounted in a conventional but massive console located in a room on the south side of the building and had but three controls, tuning, volume and tone. When the Alpine station came on the air, exact tuning was accomplished by listening to the noise level, since no tuning meter was provided on the set. Tuning was not at all critical, and required no readjustment, once set. The quality of the system, as previously stated, leaves nothing whatever to be desired. The background noise was, so far as the ear could detect even within a foot of the speaker, completely inaudible. The antenna used was a 6-foot length of twisted lamp cord, with the outer ends unraveled for a few feet to produce a dipole. Moving the antenna about in the room had no noticeable effect. One noticeable fact was the high audio level at which the receiver could be operated without any apparent distress to the ear. The lack of distortion and of background noise probably accounts for this.

One interesting comparison was made at the alpine station, to which the editors traveled before going to Sayville. At the station, a loudspeaker was so connected that it could be switched rapidly from the ingoing audio line (from the turntable pickup amplifier) to the output of a monitor receiver which picked up the frequency-modulated signals from the output of the station. Thus a direct side-by-side comparison of the distortion and noise introduced by the frequency-modulation system could be made, relative to the original audio-frequency signal. It was literally impossible to tell the difference between the two switch positions. In response to a request for a demonstration of "over-modulation", Major Armstrong increased the audio level gradually to 15 db above normal, thus increasing the frequency swing greatly beyond its normal limits. No distortion could be noticed in the monitor receiver until roughly 10 db above normal range was reached.

At Sayville, the results were substantially the same as in New York City, although the receiver was approximately 40 miles farther from the transmitting station. As previously mentioned, the only sources of noise were needle-hiss on the records, and very occasional ignition interference, the latter being of such low level that it could not be heard when music was being received. After several recordings were received from the Alpine station a relay was arranged whereby the 110-Mc. station at Yonkers was picked up at Alpine (about one mile from Yonkers) and rebroadcast on 42.8 Mc. to Sayville. As was to be expected, the results in this case were the same as when recordings originated at Alpine. However, Mr. Runyon's home at Yonkers provided a studio (actually a living room) for some piano music, and for several sound effects. The piano music was extremely good, since there was no background noise whatever. The sound effects consisted of tearing a piece of paper, lighting a match and a cigarette, pouring water from a bottle into a glass, and similar noises in which high frequencies predominate. This was the most perfect example of sound reproduction the writer has ever witnessed, no doubt due to the fact that 15,000 c.p.s. was actually reproduced. But if the slightest background noise had existed the crispness of the reproduction would have suffered. The absence of distortion was shown by the ringing of a bell and of a set of chimes. The disonant upper partials in the bell tone were correctly reproduced without "overhang" or blurring. This was a most effective demonstration of what truly high fidelity, coupled with low background noise, can mean to a sound reproduction system. The antenna used was a 6-foot partially unraveled lamp cord, tied to the curtain rods near the set.

As a final test, a 110-Mc. receiver was used to receive the signals from the Yonkers location directly over the 50-mile path. A dipole and single reflector were mounted on the roof as a semi-directional receiving antenna. Despite the fact that the effective power of the 110-Mc. station was 3000 watts, or roughly 1/30th of the Alpine transmitter, and that the frequency was 2½ times as high, the 110-Mc. reception was virtually the equal of the 42.8-Mc. case. The only difference was that a slight background hiss could be heard, but only if the audio output level of the receiver was raised to its highest point. A switch was arranged for transferring from 42.8- to 110-Mc. reception, on the same program, and no difference whatever could be detected, except the almost imperceptible increase in background noise in the 110-Mc. case. The test showed that a frequency modulated transmitter of moderate power (600 watts output at the final amplifier) and a simple antenna can cover a radius of 45 or 50 miles with a completely satisfactory signal. Other tests not witnessed by the editors indicate that the useful range of the low power transmitter is nearer 100 miles.

Plans are now underway to provide demonstrations of the system to interested persons, such as owners and operators of conventional broadcasting stations, during the coming summer. Studio as well as recorded programs will be made available from station WQXR, local high fidelity station in New York, as soon as telephone repeaters having a low enough noise level are installed in the line from the WQXR studio.

(See poges 51, 52 ond 53 for photogrophs.)

Broadcasting Business Expands

THE gross volume of "time sales" by broadcasting stations and networks in the United States during 1938 omounted to $150,118,400, as compared to $144,142,482 during the preceding year, according to the 1939 Yearbook published by Broadcasting Magazine, trade journal of the industry.

The Yearbook, listing all United States and Canadian broadcasting stations by stotes, call letters and wavelengths, and showing the executive personnel, equipment, etc. of each station, discloses that there were exactly 764 stations in operation or authorized for construction as of Jan. 1, 1939. Of these, 52 had been authorized during 1938 by the Federal Communications Commission; 29 of these remain to be built.

In addition to the national networks, the Yearbook lists 35 state and regional networks or group-operated stations in the United States.

Among the 764 stations, the Yearbook discloses that 238 are owned in whole or part by newspaper or other publishing interests, this number comparing with 211 the yeor before. Twenty-five stations in Conada are newspaper owned. That the trend toward newspaper acquisition of stations noted in recent years is continuing, is evidenced not only by the increase during 1938 but by the fact that at least 10 applications are pending before the FCC for approval of purchases or transfers of that many stations to newspaper interests. All but 56 of the country's stations are privately owned ond all but 36 derive their revenue from the sale of advertising time.

As of Jan. 1, 1938, the Yearbook discloses, there were 26,666,500 homes in the United States equipped with one or more radios, or 82% of all homes in the country. Urban homes with radios numbered 17,195,600, representing 91% of all such homes, while 9,470,900 rural homes, or 69%, had radios. These figures are given in the 1938 survey of the Joint Committee on Radio Research of the American Association of Advertising Agencies, Association of National Advertisers and National Association of Broadcasters. Later estimates, however, indicate that 6,000,000 additional home radios and 800,000 auto radios were sold during 1938, which would substantially increase the Joint Committee's count.

F. C. C. WATCHES SUNSPOTS

As the radio services grow and congestion increases, due to the limited frequencies available, studies of the sunspot cycle offer great hope for the improvement of all radio service in the near future. This view was expressed recently by engineers of the Federal Communications Commission in reporting upon "sunspots" and their effect on radio wave transmission.

Sunspot activity constitutes one of the most interesting and at the same time troublesome phases of radio today. The National Bureau of Standards, the Army, the Navy, and the Coast Guard are cooperating with the Commission in a continuous study on land and sea of the effect of the solar sunspot cycle on radio.

Sunspots are no more than the name implies — dark spots on the surface of the sun which come and go. The number of these spots has been found to vary periodically over a period of 11 years. It is believed that these spots are the centers of violent electromagnetic eruptions or disturbances on the sun's surface. With the coming of radio, it was found that these periods within which violent outbreaks of sunspots occurred on the sun — often called magnetic storms—had a pronounced effect on radio transmission. In addition it was also determined that a certain correlation could be made between the general trend of radio transmission and the number of sunspots occurring throughout the 11-year period. It is this period which is called the solar sunspot cycle.

High-frequency waves such as those used for international broadcasting are always weakened, and sometimes blotted out completely for many hours or even days during the course of one of these magnetic storms. Radio engineers and the managers of radio stations are thus able, with the knowledge of the cycle or period of activity of magnetic storms, to choose their program time in advance in the case of international broadcasts, in such manner as to avoid, whenever possible, those times when interruptions to their service appear to be most likely.

As the average number of sunspots varies in a regular manner over this period of 11 years and since there is a definite relationship between them and the transmission of radio waves, the importance and necessity of continuous experimental observations is readily understandable.

The magnitude of the work involved is not so generally appreciated, however. In a survey made for broadcasting by the Federal

Communications Commission in 1935, in which the radio industry cooperated, 58 field intensity meters were operated at 11 different locations in the United States for a period of six months. Over 4000 continuous 24-hour records of the field intensity of clear channel stations in the United States were obtained over some 500 different paths, varying in distance from 60 to 2700 miles. It took a staff of the Commission's engineering department over six months to make a statistical analysis of the most important part of this data. In a more recent survey, made by the Commission for the marine service, data were secured on somewhat more than 100 vessels, and measurements of field intensity and noise covering another period of six months were made on a number of vessels on voyages throughout the world.

The information obtained in this way is used by the Commission in assigning the frequencies and powers of broadcast stations and in fixing the minimum distances between stations operating on the same or adjacent frequencies. It is also used in prescribing the power of stations in the marine service in order that the statutes of law, enacted by Congress with respect to safety of life and property, will be observed by American vessels.

This information is essential in formulating the standards of good engineering practice for all radio services and is of particular importance in the regulation of broadcasting and the safety services, such as marine, aviation, and police, where the interest and safety of the public are the Commission's chief concern.

●

A LITTLE girl in the Bronx, New York, who is studying "Georgraphy," confronted the biggest electrical company in the world with a new problem today. She wants "a little sample of electricity."

It was the first request of its kind within the memory of officials of the General Electric Company, which for 60 years has been applying electricity to everything from a miniature light bulb slightly larger than a pinhead to a 208,000-kilowatt turbine.

The request came on a postcard which read:

"Dear Sirs:

Will you kindly send me some booklets and a little sample of electricity, if you can spare it. We are studying about it in Georgraphy.

Yours truly. . . . "

Officials of the company promised to find a means to "spare" something—just as soon as they can figure out what it will be.

From I.R.E. Proceedings
February, 1939

THE TRANSITRON OSCILLATOR

BY CLEDO BRUNETTI

INVESTIGATORS have agreed that the negative-resistance oscillator possesses good frequency stability, excellent wave form, and other advantages that make it superior to other types of oscillators. The dynatron has been the most popular of the types displaying these advantages. It has not been made use of fully, owing to the fact that the dynatron depends for its operation on the phenomenon of secondary emission, a property much too variable with age. The solution to this difficulty was supplied with the introduction of the double-grid tube employing negative transconductance [1,2] but it appears that not all are aware of this. It is the logical tube to replace the dynatron since it has all the advantages of the latter without the disadvantages. It possesses essentially the same type of negative-resistance characteristic as the dynatron but has the advantage in that its characteristic is independent of secondary emission and remains practically constant throughout the life of the tube. To this similarity may be added the convenience that with only a slight modification of the circuit any double-grid tube if originally employed as a dynatron may be converted to one displaying negative transconductance. All theory and results deduced with the dynatron may also be carried over.

For the sake of brevity it has been found desirable to provide a name for the retarding-field negative-transconductance device. As one which offers a simple means of identification, the name "Transitron" is suggested. The theory and mechanism of operation of the transitron oscillator has been treated

[1] E. W. Herold, "Negative Resistance and Devices for Obtaining It." *Proc. I.R.E.*, vol. 23, pp. 1201-1223; October, (1935).

[2] K. C. Van Ryn, "The Numan's Oscillator," *Wireless Eng.*, vol. 2, pp.134-136; December, (1924).

by the author in a previous article.[3] It is the purpose of this paper to present a discussion of the oscillator from a more practical standpoint setting forth some of the applications and discussing its limitations. By so doing it is hoped that the advantages of this oscillator will be made avaliable to those who desire

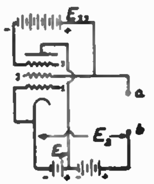

Figure 1. Transitron circuit.

an extremely simple and flexible piece of laboratory or even commercial apparatus.

- Transitron Action

A type 58 tube connected as a transitron is shown in figure 1. The voltage E_{32} is chosen so as to make grid no. 3 negative with respect to the cathode. Electrons attracted by the high positive potential of grid no. 2 (anode) are repelled by the negative potential of grid no. 3. Thus grid no. 3 with its retarding field acts as a virtual cathode. A slight negative increment in voltage across ab is transmitted simultaneously to both the anode and grid no. 3 causing the latter to repel more electrons and the net current to the anode to increase. The transconductance between grid no. 3 and the anode is, therefore, negative. A static current-voltage characteristic for the circuit of figure 1 is shown in figure 2. If the direct voltage E_2 is set at 86.5 volts a direct current of 5 milliamperes will flow. This is illustrated by point 0, which is called an "operating point." About this point the slope of the characteristic is fairly constant and negative. A small alternating voltage impressed across ab (thus applied at point 0 in figure 2) will cause an alternating current to flow 180 degrees out of phase with the voltage. This indicates that the voltage is working into a negative variational resistance.[3] The magnitude of this resistance is equal to the reciprocal of the slope of the curve at the point 0. In figure 2 it is approximately –3800

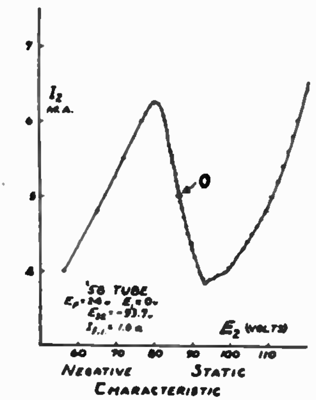

Figure 2. Negative static characteristic showing operating point 0.

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[3] C. Brunetti, "The Clarification of Average Negative Resistance with Extensions of Its Use," *Proc. I.R.E.*, vol. 25, pp. 1595-1616; December, (1937).

ohms. If the alternating voltage is increased so as to swing past the bends of the characteristic the average negative variational resistance will change. The average (negative) resistance corresponding to any amplitude of the alternating voltage across terminals ab may be found either by calculation from the equation of the characteristics or experimentally. This has been treated rather extensively[3] and results have been obtained both theoretically and experimentally showing the relation between R_n and V. (V is the effective value of the impressed voltage. R_n is the average negative resistance.) The R_n, V curve applicable to the conditions of figure 2 is shown in figure 3. The quantity $-R_n$ is positive. As the voltage V is increased the average negative resistance increases accordingly.

By applying a small negative bias to grid no. 1 the total current flowing to the anode may be controlled and the negative slope of the current-voltage characteristic may be varied. An increase in negative bias will cause a decrease in the slope. This offers a flexible means of varying the magnitude of the negative resistance across terminals ab. A more practical circuit than that shown in figure 1 may be had by replacing the bias between grids nos. 2 and 3 with a large condenser as in figure 4. The bias for grid no. 3 is then applied directly

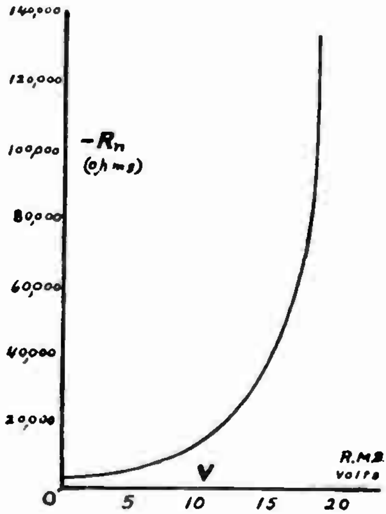

Figure 3. Transitron R_n, V curve. Type 58 tube. $E_p = 24$ volts, $E_1 = 0$, $E_{32} = -93.7$ volts, $E_2 = 86.5$ volts.

from the cathode through the high resistance R_3.

- The Transitron Oscillator

If a condenser C in parallel with an inductance L and its associated resistance R is connected across terminals ab of figure 1 the circuit will oscillate (figure 4). Oscillations in the parallel "tank" circuit will begin when the quantity L/RC is just equal to the reciprocal of the slope of the current-voltage characteristic at the operating point. The latter is usually chosen near the center of the characteristic, as point 0 in figure 2. If L/RC is increased, the amplitude of oscillation increases. L/RC is approximately the parallel impedance of the "tank" or tuned circuit at the frequency of oscillation. This quantity is a pure resistance.

The condition for oscillation[3] is

$$-R_n = L/RC. \qquad (1)$$

As L/RC is increased, $-R_n$ must also increase. Accordingly the amplitude of oscillation increases (figure 3) to maintain this condition. For large values of L/RC the oscillation may swing way over the bends of the current-voltage characteristic in order to obtain a sufficiently large R_n to satisfy (1). This is illustrated in figure 5 which shows photographs of the characteristics (traced out on a cathode-ray oscillograph) for four different values of L/RC.

If the resistance R is small the swinging of the oscillation voltage over the bends of the characteristic will affect the wave form and frequency stability only slightly. For large swings over the bends of the characteristic the tube current will experience considerable distortion but the voltage maintained across the tuned circuit may still be very pure. The harmonic components of the latter will not in general be more than two or three per cent under these adverse conditions provided the ratio L/C is kept small.

Good wave form is accompanied by good frequency stability. The latter is important since when once the tuned circuit parameters are adjusted it is desirable that the frequency remain constant. Notable

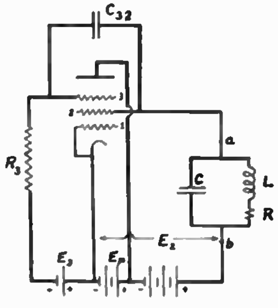

Figure 4. Transitron oscillator. Type 58 tube.

E_3 = — 10 volts
E_p = 11 volts
E_2 = 100 volts
C_{32} = 0.1 microfarad
R_3 = 10^5 ohms
C = 0.02 microfarad
L = 0.506 henry
R = 30 ohms
f = 1580 cycles per second

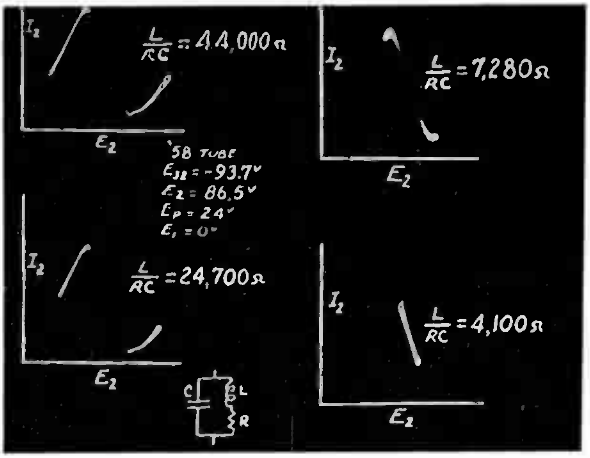

Figure 5. Cathode-ray oscillograms showing oscillation over the tube characteristic as a function of the quantity L/RC.

work on the frequency stability of dynatron oscillators has been carried on by Groszkowski,[4] Moullin,[5] van der Pol,[6] and others. Their results apply equally well to the transitron oscillator. It has been shown that variations in frequency depend directly on the amount of harmonics present in the oscillation voltage. If the voltage contains no harmonics or if the amount of harmonics remains constant the frequency of the system will also remain constant irrespective of any changes in the operating conditions such as changes in the supply voltage. Under normal conditions the transitron oscillator will not experience changes in frequency of more than a few hundredths of one per cent for relatively large variations in the direct anode voltage if the change in tube capacitance is negligible. In these respects it may be compared to a crystal oscillator without temperature control. It may be safely stated that in general the wave form and frequency stability of the oscillations are much better than those of the ordinary back-coupled triode oscillator operating under similar circumstances. The same may also be said for the amplitude of the oscillations. It will be shown later

[4] J. Groszkowski, "The Interdependence of Frequency Variation and Harmonic Content, and the Problem of Constant-Frequency Oscillators," *Proc. I.R.E.*, vol. 21, pp. 958-981; July (1933).

[5] E. B. Moullin, "The Effect of Curvature of the Characteristic on the Frequency of the Dynatron Generator," *Jour, I.E.E.* (London), vol. 73, no. 440, pp. 186-195; August, (1933).

[6] B. van der Pol, "The Nonlinear Theory of Electric Oscillations," *Proc. I.R.E.*, vol. 22, pp. 1051-1086; September (1934).

that as the frequency is changed, for example by varying the capacitance C, the amplitude of oscillations will not vary greatly over a wide range of frequency.

• Frequency of Oscillotion

For general use it is not necessary to calibrate the oscillator, since the frequency may be predicted fairly accurately from the formula

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}. \quad (2)$$

This expression, easily derived, [5,7] is based on the assumption that the tuned circuit is connected to a constant negative resistance satisfying (1). Because of the excellent wave form of the transitron oscillator, equation (2) has been found to hold closely even when operating well over the bends of the tube characteristic. The effect of the curvature of the characteristic on the frequency has been carefully studied and reported in the literature. [4,5,6] As mentioned previously, the change in frequency is caused by the introduction of slight harmonics as the bends of the characteristic are traversed. The presence of the harmonics causes the frequency to be lower than that given by (2). In extreme cases this correction may amount to fifty cycles in one million. In the audio-frequency range the correction is negligible. For best results the coil resistance R should be as low as possible. The quantity R^2/L^2 is then small in comparison with $1/LC$ and (2) reduces to

$$f \cong \frac{1}{2\pi\sqrt{LC}}. \quad (3)$$

Additional factors which influence the frequency may well be noted here. Thus if the coil L consists of an iron-cored choke, changes in the direct anode current flowing through it may change the inductance of the coil two or three per cent. This may be corrected by employing parallel feed for the direct anode voltage or by using air-core coils. The latter is to be preferred if space and weight are not important since the choke required for the parallel feed will still influence the oscillation frequency to some extent. If a variable inductance is to be used to extend the frequency range, short-circuiting out the unused portion of the inductance will serve to cut down harmonics.[8] Any variation in R, L, and C with temperature will affect the frequency. The tuned circuit should therefore not be placed near other pieces of apparatus which radiate heat such as tubes and resistors. Proper shielding is advisable at high frequencies in order to maintain good frequency stability. At extremely high frequencies the tube capac-

[7] A. W. Hull, "The Dynatron, a Vacuum Tube Possessing Negative Resistance," *Proc. I.R.E.*, vol. 6, pp. 5-37; February, (1918).

[8] H. J. Reich, "A Low Distortion Audio-Frequency Oscillator," *Proc. I.R.E.*, vol. 25, pp. 1387-1398; November, (1937).

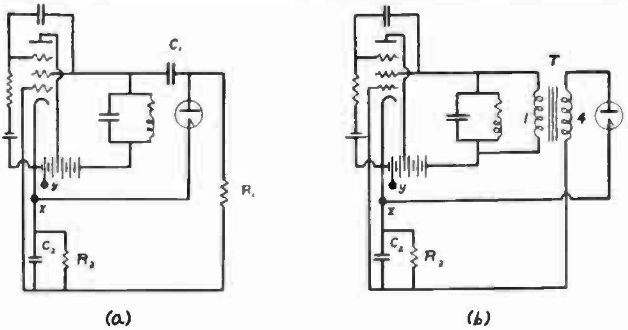

Figure 6. Two methods of applying automatic amplitude control to a transition oscillator.

$C_1 = 0.2$ microfarad
$C_2 = 1.0$ microfarad
T = 1-4 ratio audio-frequency transformer
f = 1200 cycles per second
$R_1 = 0.5$ megohm
$R_2 = 1.0$ megohm

itance may not be neglected. In addition the dependence of the latter on space charge may require consideration.[9]

• Automatic Control of Amplitude

Additional amplitude control may be had by allowing the oscillation voltage to regulate the bias on grid no. 1. Circuits for accomplishing this are given in figure 6.

Any 3-grid tube may be used as the diode rectifier by tying the grid and plate together. The operation is as follows: The diode fed from the oscillating circuit produces a direct voltage across the R_2, C_2 combination which is proportional to the amplitude of the oscillation voltage. This negative bias is fed to grid no. 1. If the oscillation amplitude tends to increase following an increase in the quantity L/RC the negative bias will increase. The latter will produce the required increase in $-R_n$ to satisfy (1) and the necessity for swinging over the bends of the tube characteristic is eliminated. Thus as the frequency of oscillation is changed the amplitude may be restricted to oscillation over the linear portion of the tube characteristic and very nearly ideal conditions will obtain. The automatic-amplitude-control circuit starts to function as soon as any oscillation voltage appears. Better results may be had if the control action is delayed[10] until the oscillations reach a certain minimum am-

[9] G. B. Baker, "The Inter-Electrode Capacitance of the Dynatron, with Special Reference to the Frequency Stability of the Dynatron Generator," *Jour. I.E.E.* (London), vol. 73, no. 440, pp. 196-203; August, (1933).

[10] F. E. Terman, "Measurements in Radio Engineering," McGraw Hill Book Company, p. 289, (1935).

plitude. This is accomplished by moving the diode cathode connection from x to y in figure 6. In this manner a negative direct voltage is applied to the diode plate and diode current will not flow until the oscillation voltage exceeds the negative direct voltage, usually 5 or more volts. Delay action will aid considerably in keeping the output level constant and will allow much better control.

By restricting the oscillations to the linear portion of the characteristic a practically sinusoidal wave form will be maintained and the frequency stability improved materially. Changes in the audio-frequency range resulting from a 33 per cent change in direct anode voltage may be kept to within ten parts in a million in this manner. Additional frequency stability may be provided if desired by connecting special series filter circuits across the tuned circuit and by other slight circuit modifications.[4,5]

- Determination of Frequency Range

The circuit of figure 4 shows the oscillator in its simple form. The frequency of oscillation may be calculated for any setting of the parameters R, L, and C using (2). In order to determine the frequency range for satisfactory operation it is necessary to know first the minimum value of L/RC permissible and, second, the amount of harmonic distortion that may be tolerated. The former is equal to the reciprocal of the slope of the current-voltage characteristic at the operating point or the lowest value of $-R_n$ obtainable (equation (1)) with a given characteristic. It may be found from a plot of the characteristic. In figure 2 at point 0 the minimum value is 3800 ohms. A simple experimental method of obtaining it is to have the circuit oscillating. The capacitance C is gradually increased until the oscillations are on the point of being extinguished. At this setting the minimum value of L/RC consistent with oscillation will obtain.[3] As long as the operating point is not changed this minimum value will hold regardless of which of the quantities R, L and C is varied. If L and R are fixed and tuning is accomplished by varying C, the minimum value of L/RC fixes the maximum value of C and therefore the lowest frequency obtainable. Since the transitron will give much lower values of $-R_n$ than the dynatron it will have a much larger frequency range for any given value of L and R than the latter.

The maximum frequency when L and R are fixed will be set by the harmonic distortion permissible. This distortion is proportional to the ratio of inductance to capacitance in the tuned circuit. [11,12] If L/C is small the wave form will be very nearly sinusoidal, especially if the resistance R is not unreasonably large. Values of L/C less than 10^6 will yield excellent wave form. If

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[11] M. G. Scroggie, "Applications of the Dynatron," *Wireless Eng.* vol. 10, pp. 527-540; October, (1933).

[12] J. E. Houldin, "The Dynatron Oscillator," *Wireless Eng.*, vol. 14, pp. 422-426; August, (1937).

oscillation is confined to the linear part of the tube characteristic this ratio may be as high as 150×10^6 without any great distortion being noticed. For general purposes using low resistance coils very satisfactory wave form will be had if L/C is kept below 30×10^6. It is evident that if L is fixed the minimum value of C, and hence the upper frequency limit, depends on how great a ratio L/C may be tolerated. If we let D represent this ratio then C_{min} is equal to L/D.

A typical set of experimental data showing the operation of the transitron oscillator is given in Table I. These data are obtained using a type 58 tube with $E_s = 11$ volts, $E_a = 100$ volts, $E_c = -10$ volts, $C_{sa} = 0.1$ microfarad, and $R_s = 10^6$ ohms (as in figure 4). E_c is chosen so that the operating point falls near the center of the characteristic. The no. 1 grid is tied to the cathode. The anode and plate direct currents do not exceed 3 milliamperes. The minimum value of $-R_n$ is 2800 ohms. The agreement between this value and L/RC_{max} is very good.

The upper frequency limit shown in Table I does not represent the highest frequency attainable. It represents the highest frequency at which good wave form still obtains as shown by inspection on a cathode-ray oscillograph. In all cases the ratio D = L/C is less than 30×10^6. If good wave form were not a prerequisite the upper frequency limit could be extended with the coils of Table I by additional reduction of C. If good wave form is desired at still higher frequencies it is necessary only to decrease L with C to keep the ratio L/C from becoming too large. With ordinary tubes the transitron oscillator will produce oscillations throughout the frequency spectrum from the lowest audio frequency up to about 20 megacycles. With the type 954 acorn pentode this range may be extended at least two or three times.

Transitron action may be obtained with any ordinary 2-grid tube although a pentode will also allow automatic amplitude control. Some suitable pentodes are the types 57, 58, 59, 89, 6C6, 6J7, and 6K7. The magnitude of the condenser C_{sa}

TABLE I

OSCILLATOR DATA

Coil	L (Henrys)	R (Ohms at Low Frequency)	Range of C (μfd.)		Corresponding Frequency Range (cycles per second)		$\frac{L}{RC_{max}}$	$\frac{L}{C_{min}}$ ($\times 10^{-6}$)
			C_{max}	C_{min}	Low	High		
1	5.00	200	9.00	0.200	23	159	2780	25.0
2	0.506	30	6.00	0.020	91	1580	2810	25.3
3	0.301	120	0.90	0.016	300	2,293	2790	18.8
4	0.0285	18	0.56	0.001	1270	29,800	2830	28.5

Coils 1 and 2, iron core. Coils 3 and 4, air core.

is governed only by the requirement that its reactance at the lowest frequency be small in comparison with R_3. R_3 may be anything from 10^5 ohms upward although very good results may be had if it is kept less than 10^6 ohms. C_{32} may also have any value from 1.0 to 0.0001 microfarad depending on the frequency range of operation. The circuit for which the data of Table I were obtained will work satisfactorily at any frequency up to 20 megacycles with no change in either C_{32}, R_3, or the direct voltages necessary.

• Additional Facts on Performance

In predicting the performance of the oscillator one may be interested in knowing the variation of amplitude with frequency. If automatic control is used the amplitude can be adjusted to a good degree of constancy over the tuning range. The variation of amplitude without automatic control may be found from an R_n,V curve (figure 3). This curve which shows the relation between amplitude V and $-R_n$ may also be taken as the curve for V as a function of L/RC (see (1)). If L and R are fixed the quantity L/RC is proportional to the frequency squared (very nearly). Thus the R_n,V curve may also be used to show the variation of amplitude with frequency squared. From figure 3 one may conclude that even without automatic control the amplitude remains fairly constant over the greater portion of the frequency range.

The direct voltages E_p, E_2 and E_3 are not critical. Small variations from specified values will cause little apparent change in the operation. In fact with a given setting of L, R, and C and with $E_2 = 100$ volts, $E_3 = -10$ volts, the plate voltage E_p may be varied from 2 volts to past 50 volts without quenching the oscillations. With the same tuned circuit and $E_2 = 100$ volts, $E_p = 11$ volts, the voltage E_3 may be varied from 0 to -20 volts with the oscillations continuing throughout. If E_3 is made zero, $E_p = 4$ volts, it is possible to vary E_2 from 2 volts to past 200 volts without stopping the oscillations. Because of this versatility the oscillator will function with a great variety of direct voltages on the tube elements. Thus any voltage from 2 volts to 50 volts may be chosen for E_p. E_2 should be made larger than E_p and may be any value from a few volts to 250 volts. Having selected E_p and E_2 using a tuned circuit having a sufficiently large value of L/RC one may immediately start the oscillations by adjusting E_3. If the oscillations should stop for any reason, other than making L/RC too small, a slight manipulation of E_3 will generally start them again. E_3 may well serve as an oscillation control.

The length of the negative slope portion of the current-voltage characteristic increases with both E_p and E_2. An increase in these voltages will therefore increase the amplitude of the oscillation voltage. A high value of E_2 may be accompanied by a direct current to grid no. 2 as high as 8 milliamperes. While this may be considered excessive the author has operated a 57 tube at this value for well over a year without any noticeable effect on the tube. Oscillation voltages across the tuned circuit may be obtained from a fraction of a volt to over 20 volts (root-mean-square) using a single tube.

A suitable set of direct voltages that will give fairly strong oscillations is $E_p = 11$ volts, $E_2 = 100$ volts, and $E_3 = 0$. The advantage of having $E_3 = 0$ is immediately apparent. The required voltages may be obtained from an ordinary rectifier and voltage-divider combination if desired.

Since the problem of amplification presents no difficulties one may prefer to work the oscillator with much smaller direct voltages. In this connection it should be mentioned that a very satisfactory oscillator may be had with $E_2 = 4$ volts, $E_p = 2$ volts, and $E_3 = 0$. With a suitable tuned circuit these diminutive voltages will yield an oscillator of very good wave form and fairly constant amplitude over the whole frequency range of the tuned circuit. The quantity $-R_n$ is higher at these low direct voltages and the only requisite is that a tuned circuit having a sufficiently high value of L/RC be used. This again presents no difficulty. The fact that the oscillator will function with such low voltages and deliver an almost sinusoidal voltage over a large range of frequencies should appeal to many an investigator.

The negative slope of the characteristic may be varied by introducing a small bias on grid no. 1 as described earlier. It is possible to obtain tubes with the negative slope part of the characteristic almost a straight line. This highly desired trait is found in the types 57 and 58 tubes. These tubes may display negative resistances of as low as 1300 ohms. This feature is valuable in extending the frequency range of oscillation as was pointed out previously.

An artificial means may be had for extending the tuning range. It may be used when the tuning condenser C is made so large that L/RC becomes smaller than the minimum tube negative resistance. This practice is to insert a resistance r in series with the tube and tuned circuit. If R_{no} is the minimum tube negative resistance the effect of introducing r is to change the minimum effective resistance into which the tuned circuit is working from R_{no} to $R_{no} + r$. Since R_{no} is negative and r is positive a lower value of L/RC may then be used (equation (1)). This will work satisfactorily provided r is small in comparison with $-R_{no}$.

If r is made too large harmonics will creep into the voltage causing distortion and decreasing the frequency stability. The resistance r may be increased to the point where relaxation oscillations take place. These oscillations will also occur if the tuned-circuit resistance R is made too large or the tuning capacitance C is made very small.[6,12] Thus if an oscillator is desired having a sharply peaked voltage wave form it may be had by a suitable variation of either r, C, or R, or all three. As the quantity r is increased there is a gradual transition from a sine wave to an extremely distorted wave. By introducing a small external electromotive force of frequency f in series with the tube and tuned circuit, relaxation oscillations of exactly f, or f/2, . . . , f/n may be obtained with precision. This process of frequency demultiplication has been treated theoretically by van der Pol[6] and others. The sharply peaked wave forms may be very valuable in precision measurements of frequency.[13] They may also be applied to the stroboscope, to timing devices, and other physical uses. The oscillator will also act as a frequency multiplier. Frequency multiplication and demultiplication may be obtained with sinusoidal as well as relaxation oscillations.

• Other Circuit Combinations

At large amplitudes of oscillation it is possible for grid no. 3 (figure 4) to draw a small direct current during a portion of the cycle. This direct current flowing through the high resistance R_3 will produce a voltage drop which will change the bias on grid no. 3. This may be avoided, if desired, by replacing R_3 with a low resistance choke. If the reactance of the choke is large the oscillator will function as well with the choke in the circuit as with R_3. In addition a fairly constant bias may be maintained on grid no. 3 at all amplitudes of oscillation with a consequent improvement in wave form and frequency stability.

The configuration of the circuit may be changed without affecting the mechanism of operation by transferring the tuned parallel circuit to the no. 3 grid circuit in place of the resistor R_3 (figure 4) or the choke mentioned above. The choke is then connected in the no. 2 grid circuit replacing the tuned circuit. Since the purpose of the condenser C_{32} is to keep the grids nos. 2 and 3 at the same alternating-current potential in respect to the cathode, it is seen that it is immaterial whether the tuned circuit is located in one grid circuit or the other. The no. 2 grid circuit is still the negative-resistance circuit. Thus assume that grid no. 3 is biased negatively and draws no current. The alternating current then flows from grid no. 2 through C_{32} to the tuned circuit and back to the cathode. This current is forced through the tuned circuit by way of C_{32} because the choke prevents it from going the other way. The same direct voltages may be used with this arrangement as with the original.

If one desires one may replace the choke by another tuned circuit, thus having two tuned circuits oscillating simultaneously.[14]

If a tuned circuit is placed in

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[13] L. M. Hull and J. K. Clapp, "A Convenient Method for Referring Secondary Frequency Standards to a Standard Time Interval," *Proc. I.R.E.*, vol. 17, pp. 252-271; February, (1929).

[14] T. Hayasi, "The Inner-Grid Dynatron and the Duodynatron," *Proc. I.R.E.*, vol. 22, pp. 751-770; June, (1934).

series with the plate, (figure 4) and properly adjusted, it will oscillate. The same holds for a tuned circuit connected in series with the cathode. Finally if a second tuned parallel circuit is connected in series with the tuned parallel circuit of figure 4 they can both be made to oscillate.[15] If one is tuned to a low audio frequency and the other to a radio frequency it is possible to obtain satisfactory modulation of the high frequency by the low.

[15]N. W. McLachlan, "On the Frequencies of Double Circuit Screen Grid Valve Oscillators, *Wireless Eng.*, vol. 9, pp. 439-444; August, (1932).

In its simplest form the transitron oscillator will provide a much-needed piece of laboratory apparatus. It should appeal to the many investigators who are not versed in radio engineering but find themselves confronted with the task of providing an oscillator for a bridge circuit or other use. The simplicity of construction and operation and the ease with which it can be made to oscillate are much-desired features. These factors coupled with the added assurance of good wave form, good frequency stability, and consistent performance should make it unusually attractive.

•

A PHILCO television caravan is making a cross-country tour of the United States in what is believed to be the first attempt to acquaint the country at large with both television receiving and broadcasting at first-hand. The caravan will carry a portable television transmitter that is completely mobile and requires only a plug-in to a nearby electric outlet for its operation either indoors or outdoors. A number of television receivers are also being transported on the itinerary so that the broadcasts picked up from the transmitter may be shown in the cities visited.

Within the six weeks of this tour ten of the country's largest cities will be visited. The schedule from April 18 to May 9 includes Detroit, Chicago, Milwaukee, Minneapolis, and St. Louis in the order named. Following this series, an itinerary is being contemplated which would take the television caravan through the Western and Southern areas of the U. S. with journey's end at the Pacific Coast.

From Service
March, 1939

MICROPHONE RATINGS

BY JOHN H. POTTS

IF YOU talk into a microphone, a minute voltage results across its terminals, which must be amplified to actuate a speaker. If the voltage is known, under specified conditions, it is possible to determine not only the amplifier gain required to produce a given electrical power output, but also the equivalent sound level which actuates the microphone. In order to do this, it is necessary to correlate microphone ratings with both amplifier and acoustical level ratings, all of which are expressed in different terms. It is the purpose of this article to show just how this may be done.

• Microphone Rotings

Microphones are rated on the basis of their electrical output for a given sound input. When you talk into the microphone in an average conversational tone at a distance of approximately 10 in., a sound pressure of one bar (or one dyne per sq. cm.) is exerted upon the microphone. This standard level of sound pressure causes the microphone to produce a small voltage of an amount depending upon its sensitivity. This sensitivity rating is expressed in db below a reference level of one volt per bar. This rating is therefore a voltage ratio as follows:

$$\text{Microphone sensitivity in db (per bar)} = 20 \log E_0/1$$

in which E_0 is the output voltage and 1 is the reference level of one volt. If the output voltage for a sound pressure of one bar is 10^{-3} volt (1 millivolt,) the microphone rating is —60 db. Both sound pressure and voltage output are expressed in r.m.s. values. Most microphones are rated from about —60 db to —100 db corresponding to voltage outputs of 10^{-3} and 10^{-5} respectively. These are generally open-circuit output voltages, wheth-

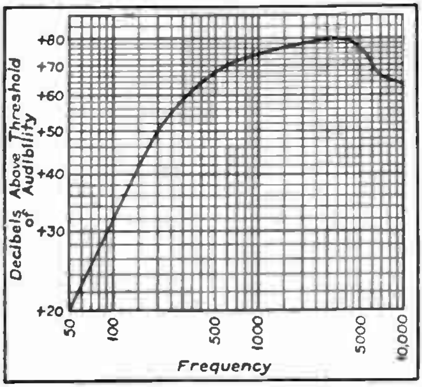


Figure 1. One bar tones of different frequencies have different loudness levels.

er or not the microphone is designed to work into a low-impedance line. A microphone with a built-in transformer designed to work into a 250-ohm line, for example, will give only half this rated output when the line is terminated with a 250-ohm load, corresponding to that of a suitable matching transformer. This reduces the level by 6 db.

Some microphones are rated on a basis of a sound pressure of 10 bars. To convert such a rating to a one-volt-per-bar rating, simply add 20 db to the latter. Thus a microphone which delivers 1-millivolt output for a sound pressure of 10 bars will produce 0.1 millivolt at a 1-bar level and its rating at the lower level would be —80 db instead of —60 db. The 10-bar level corresponds to about four times the sound pressure produced by the average speaker before an average audience.

- Amplifier Gain

In order to find the amplifier gain required to produce a given electrical power output, it is usually necessary to convert the microphone voltage output to a power output level, since all amplifiers are rated by the ratio output power delivered to the speaker to the input power required to produce this output. The input power is that which is dissipated in the input resistance of the amplifier. When this resistance is low, and matches that of the microphone, no difficulty arises. But when the microphone works directly into a high resistance, representing the grid load of the input tube misleading results occur. For example, a microphone of a high-impedance type, designed to work into a 2000-ohm line, would deliver substantially the same voltage to an amplifier with an input resistance of 1-meg as it would to 10-meg. There would, however, be a 10-db variation in *input power* while the *output power* of the amplifier would remain constant. Often, too, the impedance of the cable connecting the microphone to the amplifier will be lower than that of the input resistance of the amplifier.

For practical purposes, it is customary to assume that the input resistance of the amplifier is from 80,000 to 150,000 ohms for the purpose of calculating gain. The actual figure used is, or should be, given by the amplifier manufacturer. Even this artifice causes misleading results when there is a wide discrepancy between the microphone internal resistance and the figure used for computing amplifier gain.

To avoid these complications, the amplifier gain ratings should be expressed in terms of its voltage sensitivity, i.e., the voltage input required to produce a given power output. This can be done in the following manner. Taking the usual expression for amplifier gain in db:

$$= 10 \log \frac{\text{output power}}{\text{input power}} = 10 \log \frac{(\text{output voltage})^2/\text{output load}}{(\text{input voltage})^2/\text{input load}}$$

$$= 20 \log \frac{\text{output voltage}}{\text{input voltage}} \text{ plus } 10 \log \frac{\text{input load}}{\text{output load}}$$

From this it is seen that the voltage gain in db

$$= 20 \log \frac{\text{output voltage}}{\text{input voltage}} = \text{rated power gain in db} - 10 \log \frac{\text{input load}}{\text{Output load}}$$

For an amplifier to give its rated output it is necessary that its voltage gain in db be equal to the microphone output voltage rating in db across the amplifier input load. When this load is very high in comparison to the internal resistance of the microphone, the open-circuit voltage delivered by the microphone, expressed in db, gives the required information.

In a typical amplifier, for example, the manufacturers rating is 120 db with an input resistance of 100,000 ohms. The output power is developed across a 10-ohm load.

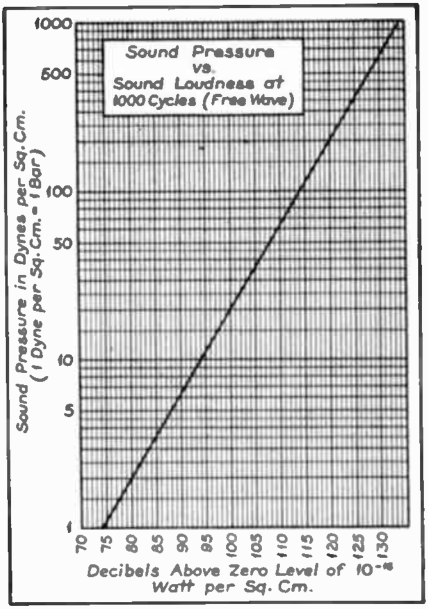


Figure 2. A sound pressure of 1 bar (1000 cycles) is equivalent to 74 db above 10^{-16} watts per sq. cm.

Its voltage in db becomes:

$$120 - 10 \log 100{,}000/10 = 120 - 40 = 80 \text{ db.}$$

A voltage input of —80 (reference level 1 volt) will thus cause the amplifier to deliver its rated output. Since microphones are rated on this basis, this formula and method is most convenient. A further advantage is its independence of the reference level used in amplifier ratings.

When the input and output resistances of the amplifier are the same, the voltage gain and the power gain, in db, are the same. When the input resistance of the amplifier equals the internal resistance of the microphone, only half the microphone output voltage appears across the input of the amplifier. In such cases, the amplifier gain should be 6 db greater.

- Loudness

An amplifier and microphone may be combined to indicate sound pressure levels as picked up by the microphone when the rating of each is accurately known. Often it is desired to know the loudness of the sound in so far as it affects the human ear. Loudness is a psychological effect which varies with frequency and is expressed in db above a reference level of 10^{-16} watts per sq. cm.

Since microphones are rated on a sound pressure basis representing average conversational speech while sound loudness is based on a reference level corresponding to the least audible intensity of a given frequency, to correlate the two we must express the microphone sound pressure level of one bar in terms of the acoustical reference level of 10^{-18} watts per sq. cm. By reference to the chart (figure 1) it is seen that a sound pressure of 1 bar corresponds to plus 74 db in terms of the relative loudness of a 1000-cycle note in free air above the threshold of audibility, 10^{-16} watts per sq. cm. If the microphone rating is —60 db at a reference level of 1 volt/bar its output for one bar sound pressure is 10^{-3} volt (1 millivolt). In terms of the acoustical level of 10^{-16} watts, its output is 10^{-3} volt for a 1000-cycle free wave 74 db above the threshold of audibility. Assuming that the microphone calibration curve is flat, the microphone output would be the same for a 50-cycle tone only 20 db above the threshold of audibility because the sensitivity of the ear is far less at very low frequencies. Figure 1 shows the relative loudness of tones of different frequencies at a sound pressure of one bar.

648 Tubes for Television Broadcasting

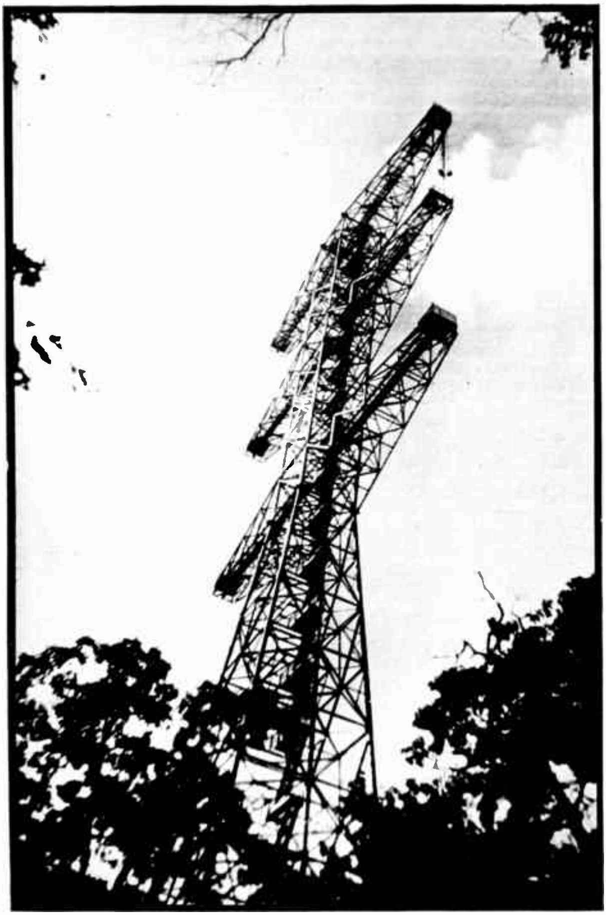
PITY the poor television studio technician if one of the tubes in his transmitting equipment goes bad. General Electric's television station scheduled to go into operation this year will have a total of 648 vacuum tubes—all essential to putting a broadcast on the air!

The 648 tubes are almost seven times the number used in transmitters of most radio broadcasting stations today. Station WGY at Schenectady, for instance, only requires the comparatively small number of 94 tubes.

Demonstrating

FREQUENCY MODULATION

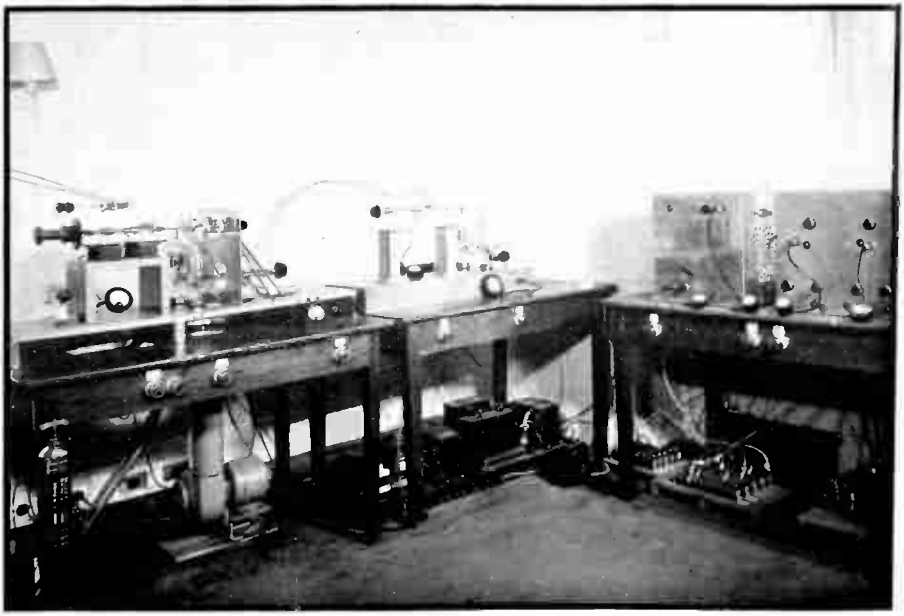
(See article on page 24)



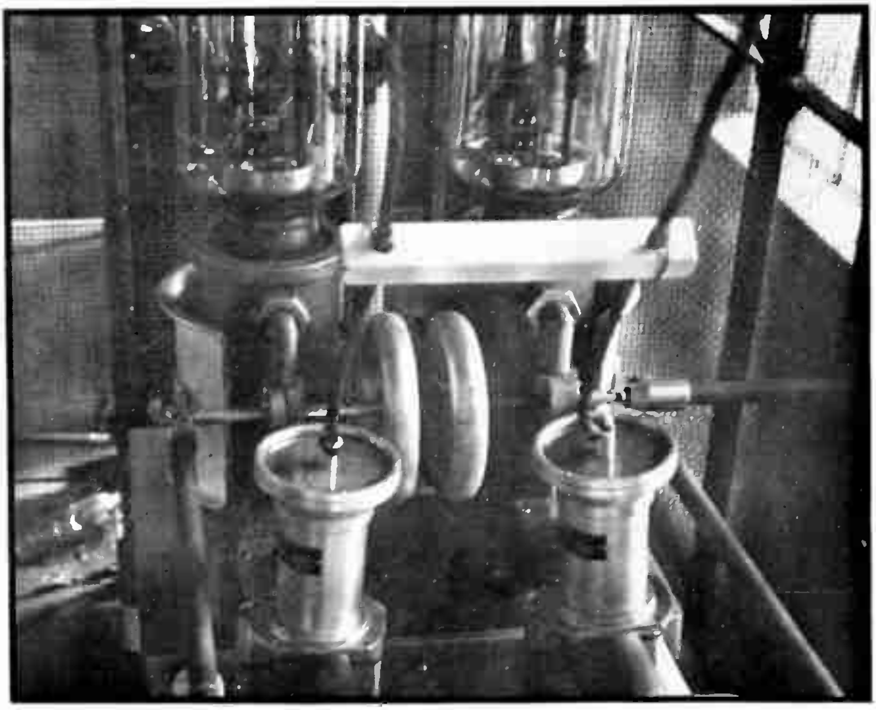
Four-hundred-foot steel tower atop Palisades supports turnstile antenna 900 feet above sea level.

Radiating structure is supported between the two arms at the upper right of the tower.

The transmitter building at Alpine, which houses the 40-kilowatt station and experimental facilities.



W2XCR, the 110-Mc. 600-watt frequency modulation station of C. R. Runyon at Yonkers, N. Y., which participated in the tests.



The final power stage, showing plate seals of AW-200 tubes, tank condenser and transmission line (foreground).

(Cuts used on pages 51, 52, 53, courtesy "Electronics.")

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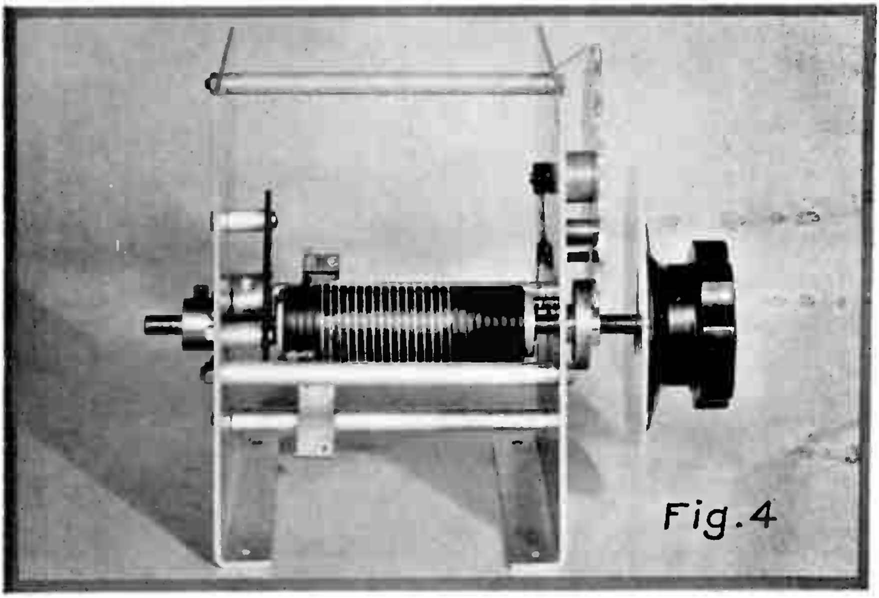
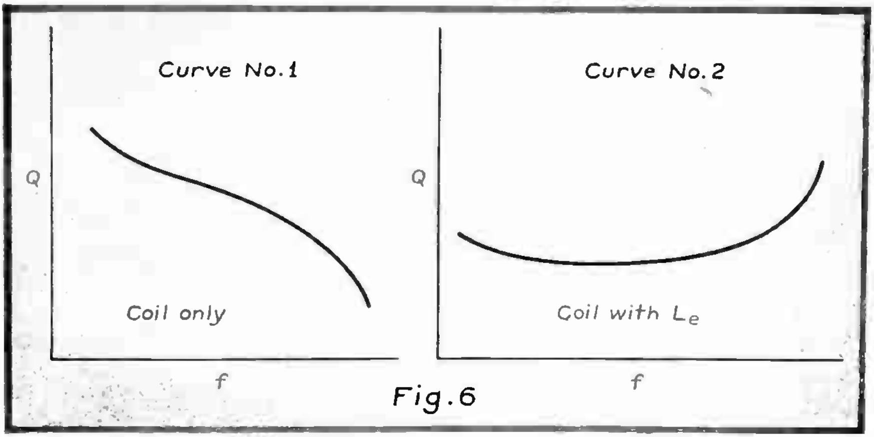
INDUCTIVE TUNING

(Cuts courtesy "Communications")



A continuously variable inductance tuning unit.



Showing Q of coil with and without L_e.

From Communications
February, 1939

INDUCTIVE TUNING

Theory and Application

BY O. J. MORELOCK

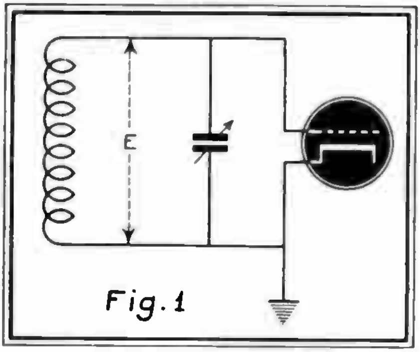
THE method of tuning radio-frequency circuits by variations in inductance is far from new. In fact, the earliest tuning device for commercial receivers was an adjustable inductance consisting of a cylindrical coil and a contactor sliding along the coil parallel to its axis. The contactor jumped from one turn to another and picked up the required inductance for the tuned circuit. Progressively, the so-called variocoupler was an elaboration of the earlier arrangement and included a tapped secondary winding along with the mutual coupling between the two coils. The variometer then appeared and following this came the double roller type of tuner involving a bare wire wound from an insulated roller onto a bare metallic roller for varying the inductance of the insulated coil.

Since then the variable condenser has taken the primary position in the field of tuned circuits. Although years of skillful development of the variable condenser as a tuned circuit component have brought many improvements in this device, there is still room for considerable improvement and economy in meeting stricter requirements for resonant circuits, especially in the high-frequency field. A new basic method of inductive tuning was described last year in the *I.R.E. Proceedings* for March, 1938, under the heading "A New System of Inductive Tuning". Since that time considerable development work has been undertaken* in adapting this principle to actual production devices, especially in the high-frequency tuning bands.

There are two basic advantages of the inductive tuning system over the condenser tuning system:

(1) Much broader frequency coverage is possible with the inductive tuning system. Frequency ratios of 7 or 8-to-1 can be obtained as

*This work has been undertaken by the Western Electrical Instrument Corp. under its licenses.



Circuit for coupling to input of vacuum tube.

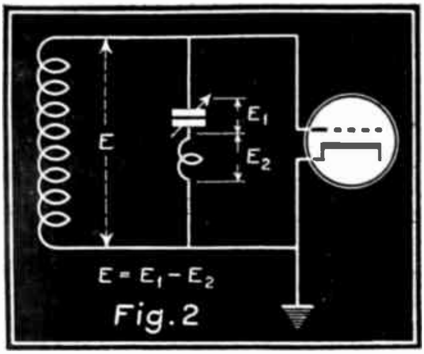
against ratios of 3 or 3½-to-1 for condenser tuning systems. This has been verified in actual production devices.

(2) Increased amplification and higher resonant-circuit voltages are available with the inductive system.

If a simple resonant circuit for coupling to the input of a vacuum tube is observed, theoretically the voltage across such a circuit would be equal to the induced voltage across the coil itself, or E in figure 1. This, however, will be the case only if the circuit components are lumped in each section of the parallel circuit, i.e., L and C are pure inductors and capacitors respectively. In high-frequency work it is well known that there is very appreciable inductance in a variable condenser and its connecting leads. The actual voltage E available at the input of the vacuum tube will, therefore, be reduced considerably by E_2, the inductive drop across the variable condenser and leads, as shown in figure 2. If, on the other hand, a variable-inductance device is used to resonate with a small highly stable fixed condenser designed for minimum inductance, considerably higher voltages would be available in a tuned circuit of this type. At the high-frequency end of the tuning range, the ratio of desired to undesired reactance is considerably increased. The input voltage to the vacuum tube would be available across the points shown in figure 3 wherein the inductance of the capacitive leg of the parallel circuit would be kept at an absolute minimum. An inductance-tuning device involving principles wherein high-gain circuits of this type are entirely practical at relatively high frequencies, is described in the following paragraphs.

- Mechanical Design

The continuously variable inductance (CVI) system makes use of a rigid coil which rotates on its own axis driven by a direct or geared shaft. A contactor is constrained to slide directly along the length of the coil wire whenever the coil is rotated. This contactor is mounted in a small carriage which is allowed to slide along the axis of the coil and is moved in this direction by a small insulated pulley, grooved to follow the convolutions of the wire. When the coil is rotated for tuning, the carriage and likewise the contactor, is moved in a direction parallel to the coil axis, depending upon the direction of rotation. A rod, likewise parallel to the coil

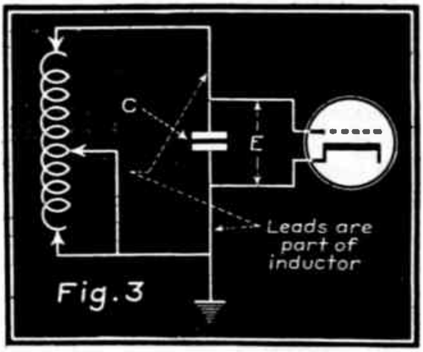


Illustrating inductive drop across condenser.

axis, acts as the guide for the motion of the carriage. The carriage assembly itself is compressed between the guide rod and the coil form, maintaining a light pressure between the contactor and the wire on the coil.

The contactor itself takes the form of a small bifurcated phosphor bronze spring having two parallel nibs which ride on the outside diameter of the coil conductor. The contactor spring itself is not called upon to perform any mechanical function other than that of supplying the continuous contact at all times. The bifurcated contact spring greatly improves the contact reliability of this device and hence enables reduction in required pressure due to the double contacting arrangement. Any minute obstruction on the outside surface of the wire under conditions of single contact, might cause a break in the direct continuity but with the double contact arrangement such irregularities have little or no effect.

Grid and ground contacts are picked up at the opposite ends of the coil. The contactor itself operates at ground potential and determines by its position the grounded or low-potential end of the tuned circuit. The unused portion of the coil is grounded at all times and the upper limit of tuning range is determined by the natural period of the unused portion of the coil when the contactor aproaches the grid end. Voltage is picked up at the high potential or grid end of the inductor through a contactor mounted on a small insulating strip suitably spaced from the grounded end plate. This connects to an "end" or minimum inductance which, in turn, is connected into the resonant circuit in the regular manner. This end inductance takes the form of a coil of heavy wire having a diameter of approximately ½" and from 1 to 7 turns depending

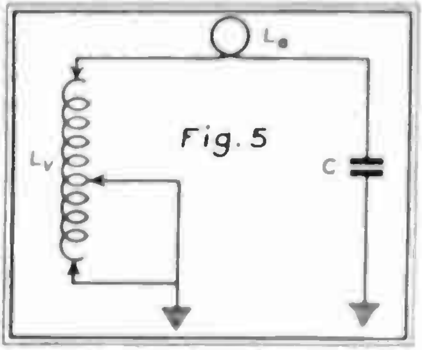


Illustrating inductive tuning.

upon the tuning range required. This coil is adjustable and is somewhat analogous to the trimming condenser used for the minimum capacity adjustment on a variable condenser. The end inductance is adjusted correctly for the high-frequency tracking and determines the high-frequency limit of the coil resonated with a fixed condenser.

The coil rotates on a copper shaft which connects to the coil end ring and to the ground contactor, and is maintained at ground potential. This shaft rotates in suitable insulated bearings so as to maintain a low noise level for high-frequency operation in receivers.

In multiple-section units, the shaft is cut to length depending upon the number of units required and each inductance section mounts between end plates directly on the shaft. With a single knob, a direct-drive mechanism is thus obtained with a multiplicity of full revolutions, depending upon the required coverage of the tuning unit. The units are adaptable to several types of dial mechanisms with a spiral dial calibration and with this arrangement a calibrated dial with markings extending over 5 or 6 feet of spiral length, may be used with the continuously variable inductance units. A stop mechanism mounted either on the back or front end plate is designed to allow free movement of the coils through a predetermined number of revolutions and in turn, this mechanism stops the coil rotation near the end of the winding.



Circuit of tuning system.

• Electrical Characteristics

A typical circuit representing a variable-inductance fixed capacitance arrangement is shown in figure 5. In this case the end or fixed inductance is represented by L_e in the figure and connects directly in series with the fixed tuning capacitor. A sliding contactor is represented by the arrow and this in turn maintains ground potential at the point indicated on the coil periphery. The use of the end inductance provides superior performance to an equivalent mechanically stopped off variable inductor. With the end inductance an increase in Q of the circuit is available with increase in frequency. Without this end inductance, the curve of Q versus frequency drops off at the high frequency end. The improved performance with the end inductance will be noted by comparing curves 1 and 2 figure 6 (page 54).

The maximum frequency limit for any inductively-tuned circuit is determined by the natural period of the unused part of the variable coil. Absorption will take place if the circuit is tuned past this natural frequency, this being due to the mutual coupling between the used and unused parts of the variable coil; the natural frequency, of course, decreasing as the contactor approaches the high-frequency end of the tuning range. It is therefore considered essential to ground the unused end of the coil as this in turn raises quite considerably the natural frequency of the unused portion. This is automatically taken care of by the ground contactor at the low-potential end of the coil.

There are two factors that account for the increased frequency coverage of the inductive tuner over that of the variable condenser.

(1) The LC product of the inductively-tuned circuit may be reduced to a much smaller magnitude than in the case of the variable-condenser circuit, where the LC product minimum is limited by the minimum capacity of the variable condenser plus the capacity of the external circuit. This is especially true in high-frequency circuits where the minimum capacity of the variable condenser and leads is a large percentage of the total.

(2) By increasing the number of turns in the variable-inductance coil, the low-frequency end of the tuned circuit may be extended so long as the natural frequency of the unused part of the coil is above the operating range. Actual production devices have been manufactured with tuning ratios of 7 or 8-to-1 in the ultra-high-frequency bands. The continuously variable inductance unit shown in figure 4 (page 54) actually consists of a coil and fixed capacitor covering a frequency spread from 22.5 to 150 megacycles in a single range with no band-switching. This involves 16 complete dial rotations in a continuous band. There are already 2 or 3 applications of this system in actual equipment, which will appear shortly on the market.

IT is estimated that more than 72,000,000 persons in the United States listen to programs from approximately 700 radio broadcasting stations every day. This means that after excluding the very young, the very aged and various other special classifications the overwhelming majority of all U. S. citizens are reached by radio daily.—Ohmite News.

From QST*
March, 1939

TRANSMITTER SAFETY TECHNIQUE

BY GEORGE GRAMMER, W1DF

Every radio amateur should make it a point to read this article thoroughly. It summarizes the results of much individual thinking and many intensive group conferences into simply-applied safety codes, one covering precautions that should be taken when working around transmitters, and the other, methods of making the transmitter itself less dangerous in ordinary operation.

WE'VE been told that the American pioneers once had a saying, "The only good Indian is a dead Indian." We'd like to paraphrase that slogan and shift the phase by 180 degrees: "The only good amateur is a *live* amateur." And then never forget it when we're working around radio equipment.

Far more amateurs die from natural causes, or from accidents not connected with radio, than are killed by electrocution in the course of ham operating or experimenting. That is fortunate. "Fortunate" is exactly the right word, too, because nearly every amateur can tell of a narrow escape from death or serious injury by electrical shock — we know, because we've heard of innumerable cases since the untimely deaths of Ross Hull and Phil Murray. And most hams, having come through such an experience without serious damage, never realize by what an exceedingly small margin they made good their escape. With a small change in atmospheric or bodily conditions, or a slight difference in the layout of equipment or bodily position at the time of contact, there might have been an

* *Journal of the American Radio Relay League, Inc., West Hartford, Conn.*

entirely different story to tell—with someone else doing the telling.

What can be done to make amateurs safety-conscious, to instill in them a healthy respect for electrical circuits? What should be done to transmitters to make them safer to operate and adjust? We came to the conclusion that much could be done to make equipment, particularly transmitting equipment, safer, but that, at least at the present stage of the game, no transmitting equipment could be built that would permit the operator to blindfold himself, stick his hands in the works with all the power on, and be perfectly safe while doing it. We realize, too, that a lot of inertia had to be overcome—no one is going to get involved in constructing safety devices when, after all, *he's* not going to be guilty of carelessness in handling dangerous voltages. And so we found that the subject of safety naturally divided itself into three sections: First, a set of rules for personal conduct in the handling of transmitters; brief, easily memorized, designed to prevent shock when operating or adjusting *any* transmitter. Second, a set of constructional precepts which, although involving no special hardships or expense, would minimize danger of shock in normal operating or adjustment; really, a code of good practice in transmitter construction. Third, special devices such as interlocks, warning signals and the like, whose purpose is to protect the operator from the disastrous consequences of a moment of forgetfulness.

With so much that can be said and done about safety, we must confine ourselves to the first two classifications for the present.

The "personal" code is most important. Its seven simple points should be remembered as automatically as the characters of the international telegraphic code, and applied as instinctively.

(A) Kill all transmitter circuits completely before touching anything behind the panel.

If we could be sure this rule would be followed unfailingly by everyone, we could almost end the discussion right here. After all, no one is ever hurt by a "dead" circuit. But far-reaching though it is, this rule is not quite enough. Phil Murray, remember, was handling only a microphone, supposedly as safe a piece of equipment to touch as anything about a transmitter. When changing coils, making internal adjustments, or shooting trouble inside the transmitter, kill *all* the power circuits before handling anything. If you have to see what happens with the power on, don't close the switch until you're clear. Does the risk seem worth the few minutes saved by disregarding this rule?

(B) Never wear phones while working on the transmitter.

Headphone circuits usually work back to ground, and the cord insulation isn't intended to stand high voltages. When you get a shock, your hand is nearly always at one end of the circuit; your chances are pretty slim if your head is at the other end.

(C) Never pull test arcs from transmitter tank circuits.

R.f. may not shock you, but it can cause bad burns. And it can readily travel through a pencil or screwdriver—possibly to be followed by high-voltage d.c. Like s.w.l. cards, the arcs may impress the visitors but they don't mean much.

(D) Don't shoot trouble in a transmitter when tired or sleepy.

And, we might add, after a convivial evening. Your reactions are slow, you're more likely to forget to take normal precautions. Get some rest first.

(E) When working on the transmitter, avoid bodily contact with metal racks or frames, radiators, damp floors or other grounded objects.

One side of the high-voltage circuit is, or should be, grounded. You don't want to contact ground with any part of your body while working on some part which may be at high potential. This is a precaution which, if made a habit, may save you should you forget "A".

(F) Keep one hand in your pocket.

This can also be made a habit. Its purpose, of course, is to prevent the two hands from being the opposite terminals of a circuit through the vital parts of the body.

(G) Develop your own safety technique. Take time to be careful.

We all develop operating habits which become practically automatic. Make it a point to develop *safety* habits, too. You can, for instance, train yourself to open the main switch without conscious thought every time you push back your chair to get up from the operating table. Work out a routine for safe operation, practice it, make it a part of your second nature.

• Code for Transmitter Construction

We've conceded that no transmitter can be made completely shock-proof under any and all conditions. But *all* transmitters can be constructed so that all operations such as tuning and switching normally carried on from in front of the panel are perfectly safe. And much can be done to "safetyize" the inside of the set.

In formulating the construction rules to follow we had a dual idea in mind: First, to eliminate danger from sources where it should not normally be expected, such as at front-panel controls. Known "hot" spots in the transmitter are still to be treated with utmost respect; still, it is possible to make some of them innocuous. Second, to minimize the danger to life should there be a breakdown somewhere in the equipment. This seldom-considered point is highly important. Altogether there are eighteen rules, most of them already in common use by the more thoughtful constructors, at least. The majority deal with methods rather than specific equipment, and none of them appreciably raises costs. Those not already observed in existing transmitters can be applied quite readily, often with but little inconvenience. The reason for each one should be obvious, but we'll devote a few words of explanation to each. Here they are:

(1) Grounds—With chassis construction, all negative terminals of plate-voltage supplies and positive terminals of bias supplies should be connected to chassis and to a good ground. Chassis should be connected together and to the rack, frame or cabinet, if of metal.

With breadboard construction, negative terminals of plate-voltage supplies and positive terminals of bias supplies should be connected together and to a good ground.

The important thing here is that everything supposed to be at ground potential actually *should be grounded*. Then if a transformer or other component breaks down, no harm can come to the operator from touching a normally "dead" component or structure. Fuses may blow, and some equipment may be damaged, but such things can be replaced. Phil Murray would be alive today if there had been an actual ground on the speech amplifier.

It has been suggested that both sides of power-supply circuits should be insulated from all metal chassis, the r.f. returns being made to chassis through by-pass condensers. Thus the chassis and either side of the circuit could be touched simultaneously without danger of a greater jolt than the discharge from a small by-pass condenser. But this system gives no protection from defective equipment, and we believe it better to conform to the standard practice of connecting one side of each supply circuit (negative in the case of plate supplies and positive in the case of bias supplies) to the chassis, and *then grounding the chassis*. Of course, there is no large metal surface in the usual type of breadboard construction, but the general principle should be followed just as faithfully.

(2) Control Shafts—All shafts, jack frames and other metal parts protruding through panels should be grounded, regardless of whether the panel is metal or insulating material.

For safety in tuning, this rule is extremely important. Obviously, there should be no possibility of getting "bitten" from a control which one *has* to handle. Condenser shafts, in particular, only too often are at the full plate voltage above ground, and only such insulation as the tuning knob may have protects the operator. Even though the knob may be good bakelite, there is still a set screw coming too close to the fingers for comfort. The only safe way is to make the shaft dead, either by using a circuit which permits grounding the condenser rotor, or by using an extension shaft to drive the condenser through an insulating coupling. In the latter case the extension shaft alone is not enough; it should be *grounded* to the panel, if metal (the panel in turn being grounded), or directly connected to ground by wire. Then if the coupling breaks down the only damage is to the plate supply. Extension shafts and panel bushings are readily obtainable and inexpensive.

(3) Plugs, Jacks and Cords—When plugs and jacks are used for meter switching, the circuit should be arranged so that the jack frames can be grounded. The plug cord should be heavily-insulated flexible cable, or shield cable with the shield connected to the plug sleeve.

This rule is very commonly disregarded—mostly, it must be admitted, in connection with supposedly non-dangerous low-voltage circuits. Certainly no jack on the front panel of a transmitter should be at anything except ground potential; it is only too easy to touch it accidentally. Practically, this means that the meter jack must be connected in the negative plate-supply lead or positive bias-supply lead; if it cannot be connected in this way because a common supply is used for two or more stages, then some other method of meter switching should be used.

Note that additional precautions should be taken with respect to the cord. This is not just one of those things to "make assurance doubly sure" but is an essential part of the rule. Should the meter develop an open circuit, a considerable difference of potential—possibly, depending upon the circumstances, the full plate voltage—will appear across the wires of the cord. There should be no possibility of insulation breakdown which might result in a serious shock. The safer of the two alternatives is to use a shielded cord, with the shield connected to the plug sleeve and thus automatically to ground, through the jack frame, before the meter circuit is made.

(4) Cases and Cores—Transformer and choke cores, cases and other metal work not normally a part of the electrical circuit should be grounded.

This is a measure against equipment failure. Breakdown of a winding to the core is probably the commonest of transformer and choke failures. Since the core and case are normally dead such a breakdown can be doubly dangerous, because the appearance of voltage on them is totally unexpected. Don't take it for granted that the bolts holding the units to the chassis make a ground connection; test holding the units to the chassis with an ohmmeter and make sure of both core and case. Units with the core enclosed are best, since the laminations of the core are usually insulated to some extent to prevent eddy-current loss.

(5) Master Switch—There should be one powerline switch, in a conspicuous and easily-accessible location on or near the transmitter, which controls all power to the transmitter.

Without such a switch, the habit of turning off all power before going behind the panel may be difficult to form. Make it *easy* to kill the transmitter—you're more likely to follow the cardinal "A" of the "ABC's."

(6) Power Supply Enclosures—Power supplies should be so enclosed or constructed, or so located, that accidental bodily contact with power circuits is impossible when adjustments are being made to r.f. or audio units.

A grounded cover over a power supply is the safest type of construction. With relay racks, the power supplies are usually at the bottom where a leg or knee may come in contact with exposed wiring when adjustments are being made. Lacking a cover, the next best thing is to use construction without exposed high-voltage points; this is covered in some of the following rules. Alternatively, the power supply may be located well out of reach when work is being done on the transmitter; this means, however, that it cannot be on the same rack or frame with the transmitter proper.

(7) Bleeders—A bleeder resistor should be connected across the d.c. output terminals of each rectified a.c. power supply.

ALWAYS BE CAREFUL

(A) Kill all transmitter circuits completely before touching anything behind the panel.

(B) Never wear phones while working on the transmitter.

(C) Never pull test arcs from transmitter tank circuits.

(D) Don't shoot trouble in a transmitter when tired or sleepy.

(E) When working on the transmitter, avoid bodily contact with metal racks or frames, radiators, damp floors or other grounded objects.

(F) Keep one hand in your pocket.

(G) Develop your own safety technique. Take time to be careful.

Death Is Permanent!

From the electrical design standpoint, every power supply of this type ought to have a bleeder anyway. As a safety precaution, to discharge filter condensers, the bleeder is absolutely essential. Filter condensers can store up quite a charge, particularly on circuits over 1000 volts, and even though the discharge may not last very long it is not to be dismissed lightly—there may be enough energy available to be as dangerous as a continuous contact. And a lot of things can happen in the reaction; the uncontrollable jump you give may result in damage both to yourself and the apparatus.

Even with a bleeder on the supply, it doesn't pay to take it for granted that the condensers are discharged when the power goes off. Bleeders can open up with no warning.

(8) Resistors—Resistors should be so located or protected that accidental bodily contact is impossible. When one side of the resistor is open for adjustment, the resistor should be mounted with the exposed side in such a position that it cannot be touched. Sliders, when used, should be insulated or protected by barriers.

Tubular resistors, unfortunately, are made with exposed terminals. This is also true of the slider on the semi-variable type. Equally unfortunate, a resistor usually has to be mounted in a rather exposed location if it is to dissipate the power it is rated to carry; for the same reason, it cannot ordinarily be mounted inside a box. A lattice or can cover, which would give the necessary protection and still allow plenty of air circulation, would be a good thing to have. Without it, install the resistor where it can't be touched unintentionally, or put a grounded metal barrier, large enough to prevent accidental contact, in front of it.

Don't depend on the coating for insulation—it's there to protect the resistance wire, not you.

(9) Plate Milliammeters—Plate milliammeters preferably should be connected in the negative plate-supply lead so that one side of the meter can be grounded. If this is not possible, the meters should be mounted behind the panel (behind glass if possible) so that accidental contact is impossible.

This practice will protect the meter as well as the operator. Even bakelite-cased meters are rated for only 500 volts or so when mounted on a grounded panel. The danger point on a meter is the reset screw, which is responsible for more than one shock, and the screw therefore should be kept at ground potential. If the meters *have* to be connected in the positive leads, by all means put them where they can't be touched. An insulating mounting behind a relay-rack panel with a slot for viewing is not hard to rig up, and should always be used when the meters are above ground.

(10) H. V. Leads—High-voltage leads should be a good grade of high-tension wire insulated for at least two or three times the peak operating voltage.

Insulation should be good enough so that a high-voltage lead can be run along a grounded chassis or frame without danger of breakdown. Then there will be no danger to the operator should the wire be accidentally touched. Note that peak operating voltage is specified —this is at least twice the steady d.c. plate voltage when the stage is plate-modulated. Automobile high-tension wire, in the better grades, is inexpensive and amply rated for most amateur plate supplies.

(11) Terminals—Exposed termi-

nals and tube caps should be protected by insulating coverings. Barriers should be placed over exposed transformer terminal boards.

High-voltage terminals, tube caps and the like are highly dangerous points and, usually, only too easy to touch unless deliberate care is taken to avoid them. Insulated caps for tubes have been obtainable for a long time, although not generally used by amateurs. They cost little and are not troublesome to install.

We need a new type of high-voltage terminal to replace the feed-through insulator generally used for the purpose. It could be built much along the same lines, but should have a ceramic cap which screws or otherwise fastens to the body of the insulator and which covers the actual connection after it is in place. There's an opportunity here for some manufacturer to bring out a really useful gadget. In the meantime, a rubber sleeve of the type used with test clips could be slipped on the wire before fastening, and afterward pulled over the terminal to cover all the metal normally exposed. It would afford considerable protection.

Likewise, there's room for improvement in transformer terminal boards in the field of protection from accidental contact. When the transformer is mounted so that the present type of terminal board is within reach in the normal course of operating or routine adjustment, it ought to be covered up. This can be done quite easily by running all the wires through a piece of bakelite the same size as the terminal board and shoving the bakelite piece up quite close to the terminals. It will be rather hard to get your fingers in, and you'll probably be reminded to turn off the power before changing connections.

(12) Layout—In construction of r.f. units, components should be located so that danger of touching high-voltage circuits during adjustments or coil changing is minimized.

In other words, don't lay out a circuit so that you practically have to put your hand against the tank condenser or the plate of the tube when you change coils. Coils which have to be changed always should be on the most accessible part of the chassis.

(13) Parallel Feed—When design considerations permit its use, parallel feed to transmitting tubes is recommended for circuits in which coils must be changed manually.

The dangerous thing about a tank coil is the d.c. voltage—r.f. may cause a bad burn but is not likely to be fatal. So, if there's no d.c. on the coil your chances are much better should you forget "A" of the "ABC's." As a matter of fact, there's a lot of unfounded superstition about parallel feed, dating back to the days when it was hard to get a good choke. But at the present time suitable chokes are certainly available for low- and medium-power transmitters, at least when the set is not intended to cover the whole spectrum. Admittedly, it is asking a lot of a choke to work on all bands from 5 or 10 to 160. We don't say categorically that parallel feed must be used; rather, we say that if it *can* be used in your particular transmitter, it *should* be, and the set will be just that much safer to operate.

(14) Series Feed—With series plate feed in the final stage, coupling to the antenna preferably should be inductive; if direct coupling is used, blocking condensers amply rated to withstand the peak plate voltage should be installed between the plate tank circuit and the antenna system.

This hardly needs comment. We certainly don't want the plate voltage to appear without warning at the feeders or on the antenna. Use *good* blocking condensers, not only rated for the peak plate voltage (including modulation) but also to carry the r.f. current that will have to flow through them.

(15) Breadboards—Breadboard type transmitters should be provided with panels to prevent accidental contact with live components when controls are operated. Items (2) and (3) should be observed with respect to apparatus mounted on or projecting through the panel.

It is obviously desirable to have a breadboard transmitter arranged so that no danger spots are waiting for unwary fingers when only normal tuning operations are being carried on. If you have a breadboard layout, by all means put a panel in front (wood, presdwood or similar materials will do) and then treat the panel just as though the set were in a rack. Meters can be mounted conveniently at the back of the breadboard where they are easily visible but well out of reach.

(16) Clips—Adjusting clips on tank coils should be provided with insulating sleeves.

Rubber sleeves over clips used to vary antenna coupling in direct- or capacity-coupled circuits may prevent a burn or shock should the operator forget to turn off the power while making adjustments. They're worthwhile protection, inexpensive and can be installed in a few seconds.

(17) Keys—The arm of the telegraph key should be grounded in every case. In keying circuits which do not permit a direct ground on the key, a suitably-insulated relay should always be used. Live parts of the key should be protected from accidental bodily contact by suitable covers or barriers.

Lots of fellows have had jolts from keys, especially those using center-tap keying. *Always* arrange the circuit so that the arm of the key can be connected to an actual ground. This automatically safety-izes most of the exposed metal parts; the remaining hot points should be covered over so they can't be touched. It would not be hard to make a small box of wood or metal to fit over most of the key, leaving only the operating lever in the open. Manufacturers could help out here, too.

Incidentally, the key symbol in diagrams is not to be taken as a literal representation of the method of connecting the respective sides of the key. Convenience usually dictates which way the key is drawn. Always remember that in doing the actual wiring the key arm *should go to ground,* no matter how it is represented in the diagram.

(18) Relays—Relays should be provided with covers, or installed in such fashion that accidental closing by mechanical means cannot occur.

A relay is a useful and often indispensable device, but is not always to be trusted. A power or keying relay mounted in the transmitter often can be turned on unintentionally if something (a tool, for instance) should drop on it and close the contacts. Therefore the relay should be so placed in the set that such a contingency cannot occur, or a cover should be installed for the same purpose.

• Conclusion

There they are. As we said before, none of them represents any particular hardship, either constructionally or on the basis of cost. All have the weight of logic behind them.

Accidents still can happen, of course, even though all these constructional precautions are taken; that is why we put primary emphasis on the "ABC's." But following them will do much to reduce the chances of accident; for safety's sake, put them into practice *at once.*

"HARDWARE cloth makes good side, top, and back panels for transmitters," suggests W9SDG. "Much cheaper than perforated metal, it also provides more ventilation and visibility. It is a good shield because all crossings of the wires are bounded. It resembles over-size window screen, and is available in ¼-, ⅓-, ½-, ⅝-, ¾-, and 1-inch mesh, with no. 23 or no. 14 iron wire."—QST.

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From Electronics
March, 1939

London Exhibit of SCIENTIFIC APPARATUS

THE annual exhibition of the Physical Society, held in London recently, introduced many new and interesting instrument features.

Electron tubes were prominent and the double beam oscilloscope, shown for the first time last year, was offered in a low priced, revised form as a mains operated unit, capable of showing practically any two cathode ray tube phenomena simultaneously. Another exhibit showed a standard oscilloscope arranged to show four separate traces at once. This was accomplished by switching each of four circuits on to the cathode ray tube in turn and fast enough to allow the persistence of vision to cause the illusion of simultaneous presentation.

Few new photocell uses were exhibited but an ingenious set-up for rectifier type cells was shown. The object was to use these cells in conjunction with robust relays but without the necessity of tube amplification. A saturable reactor has two windings on its core and one is connected in series with supply mains and a heavy current contactor. The other is connected to the cell. When the cell is illuminated the resultant current flowing in the winding is sufficient to change the core flux, alter the impedance of the contactor winding and so allow it to operaate. Control of a 15-amp. 240-volt, non-inductive load is possible.

Almost limitless scope in industrial electronics has been opened in another direction by the introduction of commercial apparatus for determining various chemical and physical changes in terms of electrical capacitance.

The principle of operation depends on the heterodyning of a quartz crystal stabilized circuit with a test circuit, in which are two variable condensers in parallel with a measuring cell. Adjustment or calibration is carried out by means of standard condensers of known capacitance or with chemicals that have definite dielectric constants. If absolute measurements are not required, the instrument can be calibrated in other qualities such as moisture content, polymerization stages, etc.

A new thermo-couple instrument was shown, in which ranges are changed by plugging in different couples, exactly as radio tubes are plugged into sockets.

Every year new radio- and audio-frequency instruments are being produced and this exhibition introduced some good ones. One of these is a commercial model of a noise meter calibrated in phons. Particular care has been taken that intermittent and impulsive sounds are assessed correctly, as these form a large percentage of the man-made noises. A piezo-electric, non-directional microphone is used.

Wave analysis has been made easier by the introduction of a portable instrument capable of dealing with either complex audio frequency waves or the modulation components of radio frequency ones. This instrument can also be used as a direct reading voltmeter, responding to only a narrow band of frequencies. Range: 100 μv to 300 v. Input impedance at audio frequencies, 1 megohm.

Although not electrical, a typewriter was on show, that has been specially made in Germany for scientific work and is the only one of its kind in England. It has 135 characters but only the normal number (45) of keys. This is done by using two shifts and the particular machine is fitted with an assortment of Greek letters and mathematical symbols.

Numerous bridges and test sets were shown for the first time and the following is a typical example.

A precision universal inductance bridge has a range of 1μh to 100 h and is accurate to ± 0.1%, and 10 μμfd. to 1μfd. with accuracy of ± 0.2%.

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THE Don Lee Broadcasting System has made application for a license to construct a one-kilowatt television transmitter in San Francisco, Calif. The Don Lee System has had a transmitter in operation in Los Angeles since about 1931 and, if the application is granted, the television service will be extended to San Francisco to make this the second Pacific coast city to enjoy television. The Crosley Corporation has also made application for a one-kilowatt transmitter to serve the Cincinnati area.

From Radio
April, 1939

TRANSMISSION LINES

As Circuit Elements

BY E. H. CONKLIN, W9BNX

DURING the past two years there has been a growing appreciation of the value of transmission lines as circuit elements at ultra-high frequencies where the usual coil-and-condenser circuits are not very effective.[1,2,3] Up to the present time, however, relatively little has been published on the subject,[4] especially in sources regularly available to amateurs. There is a need for data on the design for best Q and impedance, as well as on the necessary capacity to resonate a short line or to provide a convenient means of varying the resonant frequency. Formulas alone are not sufficient; there should also be charts or tables giving the necessary data for frequencies of interest to amateurs.

Where the object of a tuned circuit is frequency control, a high Q is desirable and the circuit should be loaded as little as possible by the tube. At ultra-high frequencies, the input conductance and capacitance of tubes are such that they load a circuit heavily unless the tube is tapped down on the line. For selectivity, which is not generally a prime requirement of r.f. stages at very high frequencies, a high Q is necessary. But for stage gain a high impedance is desirable, requiring a somewhat different design for optimum performance.

[1] "Aircraft Radio, 1939," *Electronics*, January, 1939, p. 14, referring to u.h.f. receiver of the Civil Aeronautics Authority.

[2] "High Frequency Receivers—Improving Their Perfomance," Reber and Conklin, RADIO, January, 1938, p. 112.

[3] "An Improved U.H.F. Receiver," Reber and Conklin, RADIO, January, 1939, p. 17.

[4] "Transmission Lines at Very High Radio Frequencies," Lester E. Reukema, *Electrical Engineering*, August, 1937, p. 1002. See also discussion in February, 1938, issue.

Table I

Optimum Design for Quarter-Wave Shorted Parallel-Wire Lines for Maximum Selectivity (max. Q)

Freq. Mc.	D/r	D Spacing between centers (inches)	2r Conductor diameter (inches)	Q
30	6.186	2.14	0.69	1660
60	6.186	1.20	0.39	1317
120	6.186	0.66	0.21	1046
240	6.186	0.38	0.12	830

In general, parallel-wire lines are convenient where a push-pull arrangement is used. The ordinary concentric line is most easily adapted to single-ended stages but it can be constructed for use in balanced circuits. The concentric line has the lower attenuation of the two types, giving a higher Q and impedance when used as an anti-resonant circuit. This lower attenuation is due to the relatively low resistance of the outer conductor and the negligible radiation resistance.[4,5,6]

- Parallel Wire Lines

In spite of the radiation that takes place from the shorted quarter-wavelength parallel-wire line—obvious from the fact that there is an external field since transmitter power can be coupled out with a "hairpin" coil—this type is widely used. It has generally been supposed that large pipes and a 3.6 to 1 ratio of spacing to radius give the best results. This assumption, however, neglected some rather important factors.[4] Considering radiation resistance and the proximity effect, the ratio of center-to-center spacing to conductor *radius*, *D/r*, has the optimum values of 6.186 to give maximum Q and 20.96 for maximum sending-end impedance, for a quarter-wave-length shorted line. These compare with 2.72 and 8.0 neglecting radiation resistance and proximity effect. The best spacings are thus surprisingly large, especially for maximum impedance.

The optimum spacing between conductor centers, *D*, for a quarter-wave shorted line designed for maximum Q is $0.0172\lambda^{5/6}$ where the wavelength λ and the spacing *D* are in centimeters. The formula becomes $0.00677\lambda^{5/6}$ if the spacing is to be expressed in inches. The Q is then $166\lambda^{1/2}$. For amateur bands, therefore, the design in table I should be followed if the line is to be used for oscillator frequency control or, occasionally, for selectivity; in either case the tube grid and plate should be tapped down from

[5] Some controversy exists as to whether there is any radiation at all from a concentric line.

[6] "A Survey of U.H.F. Measurements," L. S. Nergaard, RCA *Review*, October, 1938, p. 165.

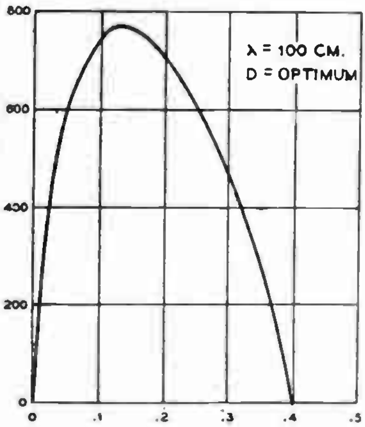


Figure 1.
Variation in Q with conductor radius, at 300 Mc., maintaining optimum spacing.

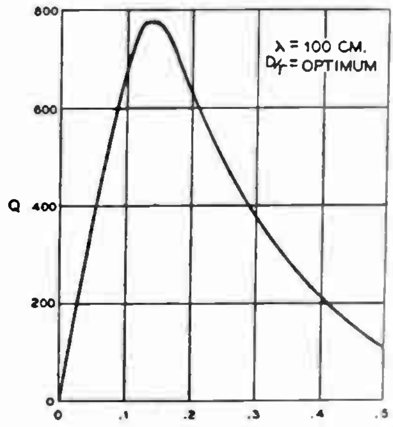


Figure 2.
Variation in Q with conductor radius, at 300 Mc., maintaining the optimum D/r ratio of 6.186.

the open end as far as oscillation, or gain, respectively, will permit.

Thus it is seen that the best Q is obtained with sizes that are entirely practical. For five-meter operation, the optimum conductor diameter is only 0.39 inch—just a little larger than 3/8 inch. Several experimenters have increased the pipe size without obtaining any improvement in the frequency stability of a modulated oscillator. The reason for this is now apparent in that the best size is not the largest possible, but a definite one for each frequency.[4]

The Q falls at higher frequencies. Also, if optimum design is not followed, the Q decreases. If the conductor radius is changed from the best value but the spacing recommended for the wavelength is maintained, the Q varies as shown in figure 1. If the spacing is also changed so that the recommended *D/r* ratio is maintained, figure 2 applies. It is seen that it is much better to maintain the recommended spacing, and for a given deviation in conductor radius, it is a little better to have it too large than too small.

Since for optimum design 71.8 per cent of the radiation resistance is due to the shorting bar, Professor Reukema points out[4] that the Q can be increased by almost 50 per cent if the wires are brought together gradually, thus eliminating the shorting bar. This will slightly alter the characteristic impedance to be used in calculating Q, and increases by 50 per cent the optimum spacing to be used.

- Design for Maximum Impedance

If the grid circuit of an oscillator is tuned with a high-Q line, the plate circuit should be a high impedance. Likewise, for high stage gain rather than maximum selectivity, lines used as interstage couplers should be designed for maximum open-end impedance and the grid and plate leads can be tapped to the points giving the highest stage gain.

In this case the best spacing between conductor centers is $0.0259\lambda^{5/6}$ where wavelength and spacing are expressed in centimeters, or $0.102\lambda^{5/6}$ where the spacing is in inches. The open-end impedance Z_s is $60{,}150\lambda^{1/3}$. As already mentioned, the proper ratio of spacing to conductor radius *D/r* is 20.96. Design data are given in table II.

A surprising thing about these data is that the best conductor size for 60 Mc. is just slightly under 3/16 inch, a very inexpensive size compared with the one-inch pipes, and the like, often used.

Here again, for the highest possible impedance, the quarter-wave line can be drawn together gradually at the shorted end to eliminate the shorting bar. This will increase the open-end impedance about one-third, requiring a 50 per cent increase in both the spacing and conductor radius, maintaining the same ratio between the two.

- Capacity Loading

For a circuit in which the tubes are tapped down substantiallly from the open end of a line, such as in the grid circuit of an oscillator, the values given above are applicable. If a capacity is hung across the open end, a shorter line will be needed to obtain resonance, but the Q, Z_s and even the optimum dimensions may be altered. Nevertheless, knowledge of the results of capacity loading is important because tubes hung across the line alter its length, also because of the convenience of using a small variable condenser to provide tuning and in some cases to shorten the necessary line legth.

We have calculated the effects of such capacity upon line lengths expressed in per cent of a quarter wavelength. These are shown in figures 3 and 4. Figure 3 is based

Table II

Optimum Design for Quarter-Wave Shorted Parallel-Wire Lines for Maximum Impedance

Freq. Mc.	D/r	D Spacing between centers (inches)	2r Conductor diameter (inches)	Input Impedance Z_s
30	20.96	3.22	0.307	601,500
60	20.96	1.81	0.173	477,420
120	20.96	0.99	0.085	378,925
240	20.96	0.57	0.054	300,753

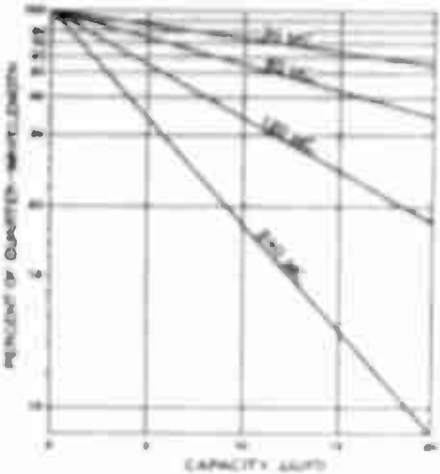


Figure 3. Capacity required to resonate lines less than ¼ wavelength long, for line of 116.7-ohm surge impedance (6.186 D/r ratio).

upon a 6.186 ratio and figure 4 on a 20.96 ratio. It is seen that the loading effect of a given capacity is much less for a line of low characteristic impedance (that is, small ratios of spacing to conductor radius). There may be some reason, then, to deviate from optimum design by using closer spacing or larger conductors to avoid too much shortening, if a large capacity must be hung across the end. For a given line length, though, the D/r ratio should be maintained but the conductor size and spacing, for the maximum impedance design, should be increased slightly. For a ⅛ wavelength (50%) line, the Z_o design figures must be increased 16 per cent.

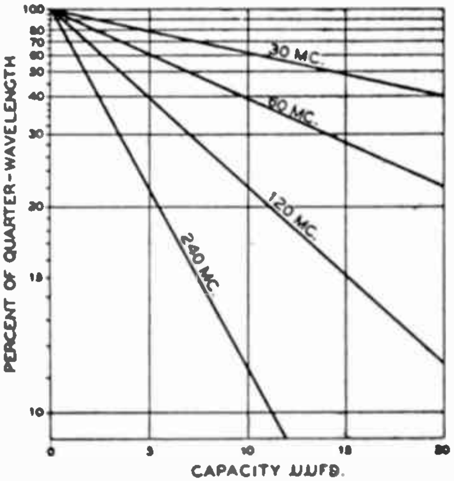
The charts are drawn so that the curves are plotted as straight lines. To obtain data for larger capacitors on the longer wavelengths, it is necessary only to extend the lines and the horizontal scale. For other frequencies, it is apparent that the capacity varies directly with wavelength, provided that the line length is expressed in per cent of a quarter wave.

Actual quarter wavelengths for the edges of several bands have the values given in table III.

There is some inductance in the shorting bar which slightly reduces

Table III	
Quarter Wavelengths	
Megacycles	Length
28	8′ 9.4″
30	8′ 2.4″
56	4′ 4.7″
60	4′ 1.2″
112	2′ 2.3″
224	1′ 1.1″

Figure 4. Capacity required to resonate lines less than ¼ wavelength long, for line of 365.1-ohm surge impedance (20.96 D/r ratio).



the length of an unloaded quarter-wave shorted parallel-wire line. This has not been included in the table, nor in the line lengths given by figures 3 and 4. A small amount of adjustment by moving the shorting bar or the tuning condenser, if used, will compensaate for this.

• Transmission Line Constants

We give below the equations for calculating the constants for parallel-wire transmission lines, at commercial power frequencies, with wide spacing and nonmagnetic material:

$$L_o = 4 \log_e \frac{D}{r} \times 10^{-9} \text{ henries per cm. of 2-wire line,}$$

$$C_o = \frac{1.111 \times 10^{-12}}{4 \log_e \frac{D}{r}} \text{ farads per cm. line to line.}$$

In the above, the logarithm to the base *e* can be obtained by multiplying the common logarithm (to the base 10) by 2.30258. To take into consideration the proximity and skin effects,[4] the above are changed as follows:

$$L_o = 10^{-9} \times 4 \log_e \left[\frac{D}{2r} + \sqrt{\left(\frac{D}{2r}\right)^2 - 1}\right]$$

$$C_o = \frac{1.111 \times 10^{-12}}{4 \log_e \left[\frac{D}{2r} + \sqrt{\left(\frac{D}{2r}\right)^2 - 1}\right]}$$

The characteristic impedance Z_0 is generally taken as $\sqrt{L/C}$, neglecting the quadrature term which on very short lines may result in an error on the order of 50 per cent.[6]. For power frequencies:

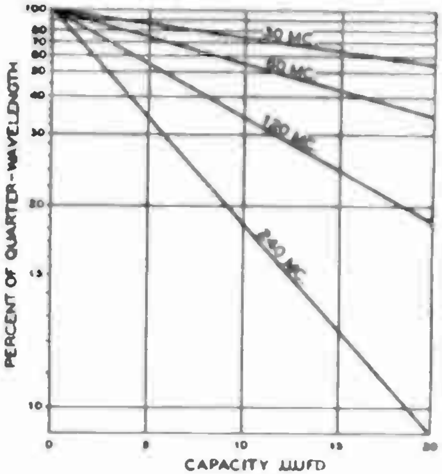


Figure 3. Capacity required to resonate lines less than ½ wavelength long, for line of 218.7-ohm surge impedance (6.186 D/r ratio).

upon a 6.186 ratio and figure 4 on a 20.96 ratio. It is seen that the loading effect of a given capacity is much less for a line of low characteristic impedance (that is, small ratios of spacing to conductor radius). There may be some reason, then, to deviate from optimum design by using closer spacing or larger conductors to avoid too much shortening, if a large capacity must be hung across the end. For a given line length, though, the D/r ratio should be maintained but the conductor size and spacing, for the maximum impedance design, should be increased slightly. For a ⅛ wavelength (50%) line, the Z_0 design figures must be increased 16 per cent.

The charts are drawn so that the curves are plotted as straight lines. To obtain data for larger capacities on the longer wavelengths, it is necessary only to extend the lines and the horizontal scale. For other frequencies, it is apparent that the capacity varies directly with wavelength, provided that the line length is expressed in per cent of a quarter wave.

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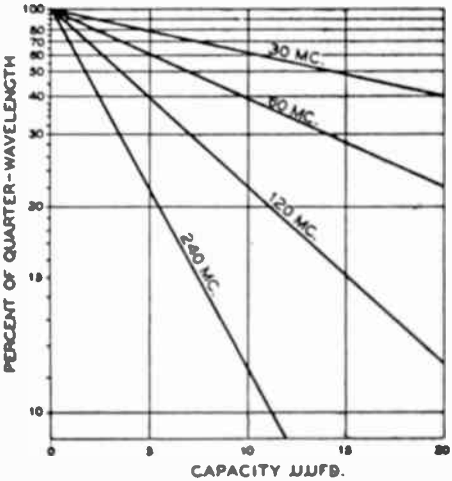

Figure 4. Capacity required to resonate lines less than ¼ wavelength long, for line of 365.1-ohm surge impedance (20.96 D/r ratio).

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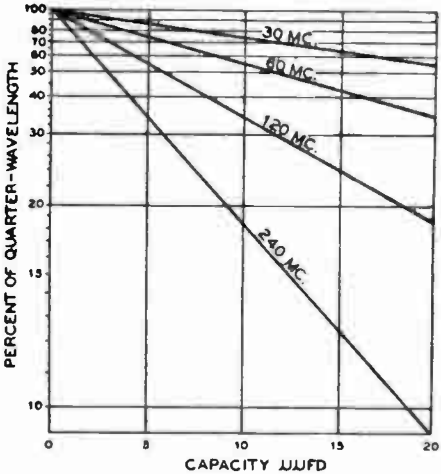

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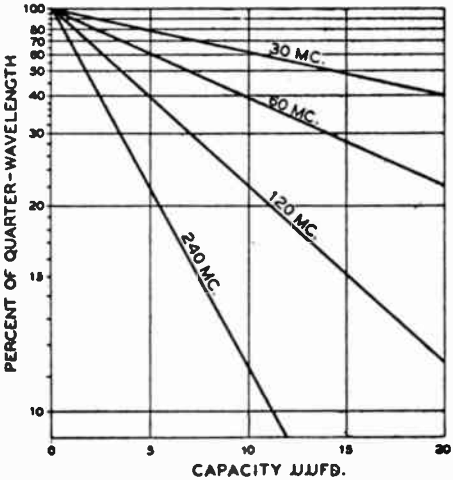

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The characteristic impedance Z_0 is generally taken as $\sqrt{L/C}$, neglecting the quadrature term which on very short lines may result in an error on the order of 50 per cent.[6]. For power frequencies:

$$Z_o = 120 \log_e \frac{D}{r} = 276.3 \log_{10} \frac{D}{r} \text{ ohms.}$$

For high radio frequencies, but still neglecting the quadrature term, the equation takes this form:

$$Z_o = 120 \log_e \left[\frac{D}{2r} + \sqrt{\left(\frac{D}{2r}\right)^2 - 1} \right] \text{ ohms.}$$

The two equations for Z_0 give 218.7 ohms for the simpler, and 211.35 for the latter form, using a 6.186 ratio of spacing to radius. The difference will be greater for a smaller spacing ratio and, consequently, for a lower Z_0.

In order to calculate the shortening effect of capacity at the open end, it is first necessary to calculate the reactance of the condenser which is $1/(2\pi f c)$. This must be equaled by the inductive reactance of a shortened line, as follows:

$$\frac{1}{2\pi fc} = \sqrt{\frac{L_o}{C_o}} \tan \frac{360 l}{\lambda}$$

$$= Z_o \tan \frac{360 l}{\lambda}, \text{ where}$$

$$\tan \frac{360 l}{\lambda} = \frac{1}{2\pi fc \times 120 \log_e \frac{D}{r}}$$

This expression gives the line length l in electrical degrees which, multiplied by 1.111 gives the length in per cent of a quarter wavelength.

Static Suppressor

CULMINATING five years of laboratory and flight research for a device to eliminate aircraft radio static interference, United Air Lines recently announced the successful development of a static suppressor insuring normal reception of both the directive beam and voice radio signals irrespective of the intensity of static conditions.

The device, installed in the tail of the airplane, is electrically released from the pilot's cockpit. With this device the pilot, when he encounters a radio static condition, presses a button which electrically releases a wire in the slip-stream which extends to its full length trailing behind the plane. Static electricity which formerly leaked off various parts of the plane now discharges harmlessly through a special suppressor and off the end of the trailing wire, some distance from the receiving antenna. Each plane carries a reserve wire.

The combination of the anti-static loop antenna, now installed on all transport planes, and the new static suppressor, eliminates all but a negligible per cent of static interference. The device is now available for all planes.

From T & R Bulletin
December, 1938

PHOTOGRAPHING RADIO APPARATUS

BY PERCY MURDEN, F.C.S., F.R.A.S., F.R.G.S.

ANY subject to be photographed, such as a piece of radio apparatus, is really furniture, and is known to the professional photographer as "a subject which reflects." Herein lies difficulty no. 1. The next is almost as bad, for unless one uses untold care and the right type of plate the photograph will reveal a hundred and one defects in the woodwork, as well as dust and greasemarks on the metal parts. To avoid this, panchromatic plates with appropriate filters should be employed. It is essential, therefore, that before photographing the apparatus it must be cleaned of all dust.

• The Camera

The most suitable type of camera is undoubtedly a quarter-plate or 3½" x 2½". A fast lens is not necessary, but most cameras today have an aperture F/6-F/3.5. A ground glass screen is, in the writer's opinion, essential, for fine focussing can only be obtained by using this, in combination with a dark headcloth, and by running the focussing rachet in front of and beyond the point of focus until pinpoint definition is determined. We say "determined," because to focus correctly requires much critical discrimination. To those readers who are myopic—or shortsighted—critical focussing can best be accomplished *without* spectacles.

The camera-object distance depends upon the size of the object and photographic plate, but assuming the apparatus is of the usual type a distance of 7 or 8 feet might be tried out. A rigid tripod and cable-shutter release are essential to eliminate camera shake at the moment of exposure. If the lateral spread of the set runs out of the picture, then the camera must be shifted back, or, if cramped for space, a wide-angle lens must be used. Distortion must be guarded against by squaring-on the camera to the subject, more particularly if a wide-angle lens is being used.

A suitable background must be prepared. For a radio set of dark color a plain white sheet of card will be found most useful. If an ordinary white linen sheet is used it must be damped and stretched to avoid creases, as these will show up in the photograph as dark slashes. A dark velvet background is suggested for a chromium-plated set.

- **Plate**

The writer has always found that panchromatic (backed) plates, not films, give better results than "ordinary" plates used in daylight. The panchromatic plate enables the lighting factor to be kept fairly constant, since artificial lighting can be used, and is particularly suited to it. On the other hand, when an ordinary plate is used the daylight factor is constantly changing. Another advantage of the panchromatic plate is that when used with the correct filter it enhances the grain and lustre of the woodwork and at the same time tends to subdue scratches and defects. Care must be taken over the arrangement of lighting, for sometimes a scratch or defect, which is not apparent to the eye, stands out in a most glaring manner in the photograph. However, if it is remembered that scratches, etc., show up according to their degree of luminosity, then a little additional trouble taken over an extra exposure, with slightly different lighting, will be considered worth while.

In this type of photography speed is not essential, and a panchromatic plate of about H. & D. 1200 or H. & D. 700, such as panchromatic Special Rapid or Soft Gradation plate, is excellent for the purpose.

- **Lighting**

Serious difficulties will be experienced if this point is not well considered, for a badly placed light, especially where only one is used, will often produce grotesque shadows, the resultant photograph being utterly inartistic.

In a room where the walls are papered light or tiled this helps to reflect the light evenly; but a suitable background, as mentioned above, must be set up with ample margin each side of the set. Side lighting may consist of a white sheet hung on laths. A lookout must be kept for any reflection from the bright metal parts of the apparatus, and this must be done by taking up a viewpoint near the camera lens, and not through the ground-glass screen, for here these points will be missed. Careful scrutiny is essential.

The main lighting should consist of one, two or three Photoflood high-efficiency lamps; also an ordinary 100-watt pearl type to soften harsh shadows. The Photofloods are usually used in aluminum reflectors, but they can be used in an ordinary bracket-type stand. If this is done, careful avoidance of inflammable shades is urged, as these high-efficiency lamps throw out a great heat. It should be remembered that Photoflood lamps have a life of only two hours and are not designed to burn continuously.

The position of the lamps must also be a matter for experiment; but to commence with, one or two Photofloods can be directed from the front sides on to the white background to cut out shadows cast by the set. The third Photoflood could light the set from the front. The 100-watt pearl lamp will be found useful in toning down the general harshness of the lighting, but "flatness" must be guarded against.

One may sum up the subject of lighting in a phrase: the movement of one lamp by even an inch or two may revolutionize a photograph, making success of failure, or vice versa.

• Exposure

Allowance must be made for the filter factor. This is given by the makers. An exposure depends on so many other factors a trial exposure or two is the best method of arriving at the correct time. Make a note of the number of lamps, distance, aperture, filter, plate, developer, temperature, time, etc., and then correct where necessary.

• Negatives and Prints

Negatives should be developed in an M.Q. developer for contrast. They must be sharp for detail, and if intended for reproduction it is recommended that prints should measure 6" × 8", or, better still, 12" × 10". Engravers prefer to reduce from this size. A little of the picture's sharpness may be lost in reproduction, but if the print is "contrasty," sharp and glossy, a good result is certain.

• Summary

Camera: Quarter-plate or 3½" × 2½" on tripod.

Focussing: Ground-glass screen.

Plate: Panchromatic (backed). Speed H. & D. 700-1200.

Filters: Delta, Minus blue, Micro, Gamma.

Lighting: Two or three Photoflood lamps, and 100-watt pearl. Reflector sheets.

Background: Contrast.

Exposure: According to filter factor, or, say, 1-25th to 2 sec. at F/11.

Developer: M.Q. acid fixing.

Print: Contrasty, glossy, 6" × 8" or 12" × 10".

●

A FEMININE operator now holds forth as Chief Engineer of station KIUN, Pecos, Texas. She is Mona Parker, who is a qualified radio operator and possessor of a First-Class Radiotelephone Operator's License.

TELEVISION DEBUT

at San Francisco Fair

TELEVISION, that elusive miracle of the electronic sciences which has been lurking "around the corner" for so many tantalizing years, has arrived at last!

Visitors to the Golden Gate Exposition at San Francisco will not only see practicable home television demonstrated, but will themselves have an opportunity to be televised. This will be the first public showing of "high definition" electronic television on the Pacific Coast.

RCA has erected a large building, with over 5000 square feet of space, on the Exposition grounds to house the television studio and viewing room. Radio facsimile will also be shown, in addition to displays representative of every phase of the radio art.

Guides will direct visitors to the television studio where they may stand before the electric eye of the television camera and be seen and heard by other visitors in an adjoining room to whom they will also be visible through a glass window. Lighting equipment similar to the kind used for motion picture production will provide the necessary illumination in the studio.

In the viewing room, the images will be seen in black and white on the fluorescent surface of the Kinescope receiving tubes, either directly, or as reflected from a mirrored surface. The Kinescope tubes are twelve inches in diameter and give a television image approximately 8 x 10 inches in size.

In the studio, on the transmitting end, the Iconoscope tube, or electric eye, corresponds to the film in an ordinary camera, except that the Iconoscope converts optical images into electrical impulses. The camera lens focusses the subject into a plate that has been coated with millions of miniature photocells. These tiny light-sensitive elements store up or lose electrical charges that correspond exactly to the light and dark portions of the subject. At the other end of the Iconoscope tube is an electron gun, which directs a sharply focussed beam of electrons onto the plate in a rapid back and forth motion, a line at a time, until it has covered the entire surface of the plate, converting the image into electrical impulses.

At the receiving end, the Kinescope tube reverses the transmitting process. The incoming signals are amplified and made to control the intensity of an electron beam which bombards the luminescent surface of the tube. This bombardment builds up the picture by a back and forth motion, a line at a time for 441 interlaced lines, at such a high rate of speed (4500 miles per hour) that the resultant picture looks complete to the human eye at any given moment.

The RCA Exhibit, which will be near the main entrance to the Exposition on Treasure Island, will also include modern broadcasting equipment, marine radio communication and safety devices and many other important services of the radio art. A large part of the building will be furnished as a comfortable lounge in which visitors may rest while listening to recorded music and reviewing interesting murals and photographs depicting the highlights of the radio industry.

The novel building in which these and other marvels of radio will be shown, ultra-modern in design and construction, was planned by John Vassos, noted industrial stylist.

"Hams" Number 51,000

THE Federal Communications Commission announced recently that the number of licensed amateur radio operators in the United States had passed the 50,000 mark, the exact number being slightly over 51,000. The total number of licensed amateur stations is slightly greater than this, it was pointed out, as several operators own more than one station.

While the importance of amateur stations and operators has been publicly demonstrated repeatedly in times of emergencies such as floods, storms, shipwrecks and other disasters, the value of this small army of men and women to the Navy and Army is little understood. A large number of these amateur stations and operators are affiliated with the Naval Communications Reserve and the Army Amateur Reserve System. These organizations offer training which provides practice drills and instruction to enable amateurs to develop accuracy and speed in communication as well as to improve their technique in the operation of amateur stations.

In making public the figures on the number of amateur operators and stations in this country, the Commission pointed out that there are more than a thousand "shut-in" operators. Often these people find their chief contact with the outside world in their radio telephone and telegraph talks with other amateur operators far away. They include not only cripples and the bedridden but a number of blind persons as well. The blind operators, estimated to number more than a hundred, frequently take their license tests in Braille. The tests are sent to the Library of Congress where they are translated and returned to the Commission for rating. The blind operators take the same speed test as other amateurs, demonstrating their ability to send and receive international Morse code signals at the rate of thirteen words per minute.

¶ From Service
February, 1939

IT'S A SMALL WORLD

BY JOHN F. RIDER

IN making these simple statements we recognize, without any intent to disparage, the educational background of the servicing industry in general. By this we mean that by and large the service personnel of the United States, to be specific, are not college or even high school graduates. Of course, there are some who have embraced such educational institutions, but if information gleaned during a number of investigations has any merit or value, then it is quite safe to say that the average serviceman has completed grammar school and about two years of high school. However, this does not limit the application of ideas—new ideas; neither does it prevent further study along any one or more lines of thought.

We make these statements as a preface to what will follow in answer to some people who may say that the ideas here presented are not capable of fulfillment because the average serviceman is not a college graduate.

- Forget Past Performance

If we look back over the years since the inception of broadcasting and critically examine that which has transpired during the past six or eight years in the life of the service industry and note that which lies upon the doorstep, we find it extremely difficult to identify a parallel in any other maintenance field. In other words, we cannot think of a single field of endeavor which is as highly specialized as radio servicing, yet is as broad in its scope. Furthermore, we find it difficult to identify a field of activity in which the maintenance man is confronted with such rapid and complex developments as are to be found in the radio field.

In view of the fact that many of the finest radio engineers admit that radio development, although ostensibly upon a high level, is still in its infancy and we still know very little about its various branches and have very much to learn, there is still time for the industry to depart from tactics and habits of the past and make a new start — to approach upon a front which is more consistent with modern thought—to recognize the limitations and possibly the error of gauging activity by past performance.

In line with the suggestion that we forget past performance for the moment, it is also necessary to forget the fact that remuneration in the servicing field has been at a very low level. Maybe that can be attributed also to the fact that servicemen have been creatures of habit, like all other human beings, and have been very reluctant to try new tactics or new ideas. We shall, therefore, forget, or at least try to forget, that such a condition existed in the past, and see where we arrive by the time this discourse is concluded.

• Serviceman Salesman

Let us consider first the business activities of the servicing industry. The serviceman is the individual to whom merchandise is sold and who is in turn expected to sell merchandise as well as his technical ability. For the present, we shall neglect that phase associated with the serviceman as a customer, but consider him as a salesman. He is that when he sells his technical knowledge to a customer and when he attempts to sell merchandise to his customer.

The fact that one of the paramount functions of a servicing organization is to sell is never given any thought when an individual embarks upon the career of radio servicing. Maybe that is due to the fact that when servicing was first popularized, the sales angle was neglected. Maybe that is so because the schools who first trained men for the servicing field neglected to place sufficient emphasis upon the sales angle. Perhaps it is due to the fact that original articles which stimulated servicing activities back in 1922-1925 did not place any importance upon the fact that a serviceman must also be a salesman, because it was a seller's market.

Years passed but things did not change. There were a few feeble efforts made to convince the personnel in the service field that they were ideally located, maybe not so suited—but ideally located to sell. These efforts went by the board, until the majority of servicemen considered themselves solely technical men and as a matter of fact considered any association with the commercial an actual affront to the dignity of their activity.

The serviceman has erroneously placed himself in too small a world. He has surrounded himself with technical considerations, which in themselves were too narrow and small, as we shall discuss; and which blinded him against seeing the true light of things. Radio periodicals contributed to this condition by not printing enough commercial material—by not educating along selling lines as well as technical lines. We too were guilty of the same thing years ago and we can understand the reasons for the non-publication or limited publication of sales articles. The servicemen did not want them — they craved technical data. That was the answer of the publishers and it was correct—but it must be changed.

More than likely it is true that salesmen are born and not made, but it is also true that when men who have had no sales training of any kind get into a business where sales ability is essential, that guidance along such lines must come from some place. Service circulation of radio periodicals comes from the independent serviceman and the employed serviceman. Both men must sell, the independent man his services and perhaps equipment, and the employed man, whatever his concern has for sale. It is a commonplace condition to find employed servicemen receiving commissions on sales to supplement their income. Sales material of interest to the serviceman, therefore, deserves space in every radio periodical.

- Advertising

If you investigate the operations of maintenance organizations or for that matter of all organizations who have something for sale, you will find that much money is spent in establishing selling tactics—in training men in sales psychology. Such tactics can very well be taught in periodicals to fulfill the needs of the servicing industry. Observation of both independent and employed servicemen during their efforts to sell shows an absence of such a vital thing as the opening approach, the value of negative or affirmative response to situations, and a myriad of other items.

The organizations responsible for service meetings and who are trying to aid the servicing industry can well devote some of the service meeting discussions to methods of selling, to all of the problems associated with selling, which includes advertising. There is one item which has suffered a great deal. At one time some of the manufacturers, who cater to the servicing industry, prepared various types of direct mail literature which was sold to the servicing industry. That type of activity has just about ceased and can well be renewed.

There are various places where service organizations offer their wares, that is, in the form of advertisements. It would not be amiss if magazine articles appearing in radio periodicals and intended for serviceman consumption would embrace the field of advertising.

It is, of course, far-fetched to imagine service station operators devoting time to the study of selling and advertising, particularly direct mail selling. As things stand they do not have the time or the finances, but it is anything but a wild dream to visualize written material covering such subjects as regular items in radio periodicals.

We have seen such material and we make this statement for the benefit of the editors who have included such data in their magazines, but we do not think that sufficient importance or pressure has been placed upon the subject. Our reason for making this statement is that granting a capable individual who does the service work, a service organization possessed of proper selling ability, can always secure the required amount of technical help, but the finest technical man without sales ability is going to find it virtually impossible to make a living. Therefore, selling in its various branches is extremely important. The present servicing world is too small. It must be expanded.

The serviceman must of necessity recognize his present limitations, and he must make up his mind to a change. For one he must become sales-conscious. He must broaden his horizon.

There are servicemen with shops of their own who are earning their keep by being door-bell-pushers. There are plenty of other fields of activity in which the salesmen sell in a similar way, that is, they push door-bells. It might be well for those who prepare material for serviceman consumption, editorially or orally, to investigate those fields and ascertain the manner in which the problems associated with such methods of contact are solved. There must be certain methods of approach which are superior to others, once the door has been opened. These should be established and made known.

A great deal of sales material of various kinds is published for consumption by the set dealer and set jobber and, for that matter, by the various sales organizations in other fields. Why should the service field be neglected?

Advertising, like other forms of selling, can be of various orders—good, bad or excellent in direct mail, telephone book or newspaper form. True that the individual service organization does not spend much money in connection with such activity, but only because the basic revenue is low. Increase the revenue and the amount spent for advertising is increased, but no matter what the money spent, it can be spent to best advantage.

- Business Side

Associated with the selling angle is the business side of servicing. The last year or two has seen more than the usual activity in this connection, but it is not sufficient. That, too, must be broadened. It started with the means of establishing service charges and continues along the same vein. Without any attempt to make the service station operation fully cognizant of capital, assets, liabilities, etc. it is still necessary to convey information to the servicing industry concerning its financial capabilities in terms of the individual establishments.

More than one man who was making satisfactory progress attempted some program of activity, maybe in the public address field, which was beyond his financial status to handle. Working with the servicing industry, the financial condition of the average service establishment is not a mystery so that it is possible to present facts for absorption by the servicing industry on a basis consistent with the amount of money available to work with. More than one parts jobber knows of service shops among his clientele which were virtually ruined by biting off more than they were able to chew. They choked upon what was thought to be a choice morsel.

• Technical Angle

Let us now consider the technical angle and look in upon the narrow world we live in. By and large the majority of material which has appeared in the service press has been devoted to practical radio and in connection with receivers. The suggestion is not being made that a serviceman should become an engineer, although just what will be the exact requirements for successful television and radio facsimile servicing is still an unknown quantity. But what is being suggested is that the serviceman broaden his knowledge of radio along lines somewhat different from what has been presented heretofore.

Much has been said about the fact that service capabilities were not on a par with receiver development. Also that it was necessary for the serviceman to secure a more thorough grounding in radio. However, as a general rule these comments were associated with radio receivers only. Maybe that was wrong. It seems that way because that idea has very definitely narrowed the world in which the service industry operates. It has made the serviceman think too much in terms of receivers. It has stifled any growth of the power of interpretation. It has made too many servicemen feel that all they were concerned with were receivers, that all else was secondary.

There seems to be justification for the belief that such an attitude maintained years ago has contributed greatly to the technical limitations now experienced. In this connection it might be possible to place more blame upon the doorstep of the servicemen than upon those people who serve the servicing industry as magazine publishers or as manufacturers. Many of the editors are guided by letters from readers but not enough readers have taken interest in the full breadth of their much needed knowledge and communicated these needs to the publishers.

There has been too much demand for practical data and too little for that information which would be of general and basic utility. The phenomenon of transmission, and the relation between the antenna and the signal has been neglected on the grounds that the antenna was the least important portion of the receiver installation. Yes, we know that every so often an article would appear in which the antenna would be discussed, but we venture to say that less than 0.1 per cent of all of the technical text which has appeared in magazines during the past ten years was devoted to that subject.

Today, with the advent of television, ultra-high-frequency transmission phenomenon and antennas loom very important.

Strange though it may seem after years of activity, many servicemen do not comprehend the functions occurring in the various parts of a transmitter and find it difficult to answer questions relative to the operation of a transmitter—a broadcast transmitter. These questions are asked by receiver owners—customers—not engineers. More than one serviceman has failed to explain in a logical manner just why WOR with its present directional antenna is not received as well in different parts of Pennsylvania as with the original antenna.

Field strength of transmitters and microvolt sensitivity of receivers, percentage modulation of transmitters and even test equipment have been items to which very little thought has been given, but will require more and more attention as the months roll by. All because so very much attention was placed upon receivers and because the attention of the servicemen was focused upon a very small world, the receiver. Whatever technical information has been given was interpreted in terms of the receiver.

• Test Equipment

Take as a case in point, the actual test equipment which men have used in connection with receiver servicing. Take the oscillator as one item, a very popular piece of equipment, used on practically every service job. It would be a safe gamble, judging by what has been observed in the field, to state that most servicemen who use the equipment are not fully conversant with oscillator circuits—with what type of circuit is used in service test oscillators and what makes these units work—with the significance of 30, 40, or 50 per cent modulation. Some men, but not the majority, understand the relation between the r.f. carrier and the a.f. voltage at various carrier frequencies in such units—this because reference to oscillators has usually been associated with the simplest manner in which an oscillator is used for testing purposes and perhaps a simple explanation of the heterodyne oscillator in the radio receiver.

Now that some attention is being focused upon sensitivity testing of receivers and reference to signal input at the antenna and audio output at the speaker for a certain value of percentage modulation, recognition of what is meant is very meager. The operation of test equipment, like receivers, has been within a very small world—the mechanical operation of a test unit, without regard to fostering comprehension of what is going on in the unit and what is being done when the unit is applied.

Proof of this fact is that servicemen who are asked questions concerning their own test units find great difficulty answering these questions. As a result of continually living in a very narrow world, service procedure and general operation has been brought to a step-by-step level with minimum application of individual initiative and ingenuity. This can be attributed in a large measure to the fact that the presentation of test equipment to its users has been along the lines of what it will do in the simplest words without any description of what is in the device and how the device functions.

A similar situation exists in tube checkers. Today the tubes are checked according to the "Good," "Bad" or "Replace" indication. This is quite in order, but what is deplorable is that the serviceman who is using the device is not familiar with what he is testing, or how and why the indication is attained. Some may say that such a situation is the desired one, in that it may be easier to sell test equipment if the simplicity of operation is stressed. That is correct, but when carried out over a period of years it tends to stifle knowledge rather than augment the servicing capabilities of the individual.

Because of the limited knowledge concerning the internal functioning of test equipment, the majority of servicemen are not able to derive the maximum utility from their equipment. We hope that what is said here is not taken as criticism of the test equipment. It is not intended as such. What is being criticized is the fact that for some reason or other the basic information which would enable the equipment owners to comprehend their equipment properly has not generally been forthcoming, and descriptions concerning the equipment usually placed much more stress upon "how" rather than "why." The "how" of any subject has much less breadth and depth than the "why."

- *Modus Operandi*

It may be very difficult for many of the readers of this to believe us when we say that in many places not more than 50 per cent of the servicemen asked could differentiate between power input and power output of a radio receiver. This does not reflect upon the educational institutions—it reflects more upon what perhaps can be described as the "modus operandi" of the radio servicing industry over a period of fifteen years. In other words, it indicates a definite desire to stay in a certain circuit; to reject outside influences, outside suggestions—to be content with the knowledge at hand without any attempt to broaden this knowledge.

Perhaps a more definite sign of this condition is that so few men express any desire for theoretical articles in magazines. They are content with what they know and feel that they can "get along." This ability "to get by" over a period of years has painted a false picture; it has created a false illusion of the breadth of the radio servicing world. It is not as narrow as many believe it to be and modern developments are going to force the issue very rapidly.

- Too Narrow

The erroneous idea that all there is to servicing is to find the trouble has been created and maintained. Such is not the case. Not only is it necessary to be able to service the receiver, but it is necessary for the serviceman to know what is in the receiver and how the components function.

Take a case in point. The oscillator in a receiver performs a certain role. During the process of servicing, all that is considered is the function of this oscillation in connection with frequency conversion. Seldom, if ever, is any thought given to the manner in which the circuit works—to the function of the various components —to the similarity between this oscillator as an entity and other oscillating systems. Generally speaking, the two considerations embraced in service operations are: (1) Does the circuit oscillate? and (2) At what frequency?

Beyond these two most popular considerations, very little thought is accorded the relation between this portion of the receiver and the mixer. Examine service literature and you will find very little if any reference to the effect of excessive oscillator output voltage upon the operation of the converter or mixer tube, the effect of insufficient oscillator output voltage upon the same tube, etc. Maybe this is because the majority of service troubles isolated in the oscillator tube are of the first two named types, but it is not sufficient to rest upon the laurels of being able to identify those conditions. Given either of the second two named, and the likelihood of discovering the defect in a profitable amount of servicing time is very, very remote—only because the area in which the serviceman focuses his attention is too narrow.

• Another Case

Take another case in point, that of the average r.f. or i.f. transformer. The usual thoughts associated with such transformers during the process of servicing are "opens" and "shorts." Why? Because these are the commonplace complaints and it is felt that beyond this it is not necessary to go. When a condition develops or, as a result of a change in servicing procedure, it becomes necessary to understand a few additional facts concerning such transformers and their effect upon the signal in the system with respect to the tubes associated with them, mystery prevails. Once more you will note the absence in service literature of information which will explain the relation between such transformers and the tubes with which they work. You will note the absence of data relative to where the gain in an r.f. stage is obtained —whether it is achieved in the transformer, in the tube or as a combination of both and the difference between, say, an antenna transformer and an interstage transformer, etc.

Countless similar examples could be cited, but that is unnecessary. Sufficient has been said to substantiate what will follow. We feel confident that if every man who reads these lines will take pen and paper and list all of the subjects associated with normal broadcasting, including the transmitter and the receiver and the process of servicing (with which he comes in daily contact and about which he knows that

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30c a copy—$2.50 yearly
RADIO, Ltd.
7460 Beverly, Los Angeles

APRIL, 1939

AN 813 BANDSWITCHING TRANSMITTER, *by Leigh Norton.*—A description of a transmitter designed for maximum convenience in bandswitching consistent with reasonable power output. A 6F6 is used as a crystal oscillator on either 80 or 40 meters followed by a 6L6 as a doubler-quadrupler to 20 or 10 meters and an 813 as an amplifier. A single switch takes care of all bandswitching operations except in the 813 plate circuit, where coils are changed manually.

HIGH-EFFICIENCY FREQUENCY DOUBLING, *by Frank C. Jones.*—A new doubling circuit in which the third harmonic of the exciting voltage is used to decrease the angle of flow of the doubler plate current. The decreased angle of flow allows higher efficiency in the doubler and, consequently, increased output.

A COMPACT ALL-BAND PORTABLE TRANSMITTER, *by Donald G. Reed.*—A portable transmitter covering all bands from 5 to 160 meters. Five tubes are used in the transmitter and self contained power supply. T21's are used in both the modulator and final-amplifier stages. One interesting feature is the class A-1 operation of the modulator tube, thus obtaining sufficient audio power to fully modulate the transmitter.

RECEIVING PULSES FROM THE IONOSPHERE, *by Albert W. Friend.*—The concluding article of a series on iono-

stub at the center of the antenna that no mismatch occurs on either band.

CHECKING BEAM ANTENNAS WITH THE S-METER, *by S. Gordon Taylor.*—Two charts which enable the "S" meter in a communication receiver to be used in calculating antenna directivity ratios in db, voltage, or current. The meter characteristics of most popular receivers are given.

A SUPERHET CONVERTER FOR 5- AND 10-METER RECEPTION, *by Frank Lester.*—Describing one of the increasingly popular converters for the 5- and 10-meter bands. An r.f. stage employing either a 1231, 1852, or 1853 with both plate and grid circuits tuned is followed by a 6K8 mixer. The converter works into any receiver capable of being tuned to 5.7 Mc.

A PEAK-LIMITING AMPLIFIER FOR AMATEUR USE, *by Robert Macfarland.*—An amplifier employing the Collins compressor circuit for peak limiting. The two sections of a 6N7 or 6A6 are used as the variable control resistance. Complete instructions are given for adjusting the compressor circuit.

A FREQUENCY-CHECKING SUPERHET, *by Dana A. Griffin.*—A rather complicated arrangement whereby broadcast stations of practically any frequency may be used to provide known points in the amateur bands. By accurately determining the i.f. frequency of a superhet, its oscillator frequency may be calibrated against broadcast stations. By also using the oscillator to control the transmitter frequency, the amateur transmitter frequency is, in effect, controlled by the broadcast station frequency.

SAFETY DEVICES FOR AMATEUR TRANSMITTERS, *by George Grammer.*—A review of several representative manual and automatic protective devices for use with amateur transmitters.

A HURRICANE EMERGENCY RECEIVER, *by Gale M. Smith.*—A simple battery-operated receiver designed to cover a frequency range of from 112 to 0.15 Mc. Three type 30 tubes are used in the familiar detector-and-two-step arrangement. Switches are provided for converting the detector to a self-quenched superregenerative circuit at ultra-high frequencies.

MARCH, 1939

A MODERN BAND-SWITCHING SUPERHET, *by Robert B. Parmenter.*—A description of a superhetrodyne incorporating nearly all the desirable features of present-day communication receivers. Seventeen tubes are used in all, including two acorn-tube preselector stages.

FREQUENCY MEASUREMENT AND REGULAR CHECK, *by A. K. Robinson.*—A self-calibrated electron-coupled oscillator and monitor. With the crystal circuit included in the unit, inexpensive amateur-band crystal may be used to check the calibration of the frequency-meter section.

A PORTABLE STATION FOR A.C. OR BATTERY OPERATION, *by Harley E. Steiner.*—Describing a complete amateur station mounted on a 7- by 13½-inch chassis. The receiver is adapted from the Jones "Super Gainer" and uses 6 tubes in all. The transmitter is a two-stage push-pull arrangement using two 6N7 tubes. The receiver audio section is used as a speech amplifier and modulator, the speaker serving as a microphone.

A MINIATURE 100-WATT AMPLIFIER, *by James Millen.*—Using the new type 24 Gammatrons, this amplifier is particularly interesting from a mechanical standpoint. The chassis upon which the amplifier is mounted measures only 3½ by 6½ inches. By mounting the fila-

ment transformer on the separate meter panel and hanging the tuned grid circuit, if used, below the chassis, an extremely compact amplifier is made possible.

ONE CRYSTAL — TWO TUBES — FIVE BANDS, *by T. M. Ferrill, Jr.*—A simplified five-band exciter using a 6L6 as a tri-tet oscillator on the 1.7-Mc. band and an 807 as an amplifier, doubler, or tripler. By employing odd as well as even harmonics of the crystal frequencies a wide range of possible output frequencies is made available.

POOR MAN'S ROTARY BEAM, *by F. G. Southworth.*—A description of a simple rotatable antenna-supporting structure which may be built for less than three dollars. Ordinary strap hinges are used as the bearings and the rotation made possible by the use of bicycle chain and sprockets.

A 15-WATT CRYSTAL-CONTROLLED FIVE-METER PHONE, *by Glenn H. Pickett*—A three-unit transmitter for 56-Mc. operation. Two stages are used in the r.f. section with provision for either 14-Mc. crystal or self-excited operation in the oscillator. The amplifier is a HY-61. The speech-modulator comprises four stages with 6L6's in the output. The third unit is a power supply utilizing an 83.

AN ELECTROSTATIC-DEFLECTION KINESCOPE UNIT FOR THE TELEVISION RECEIVER, *by J. B. Sherman.*—For amateur applications, the electrostatic-deflection type of cathode-ray tube seems to offer more promise than the more expensive and more complicated electromagnetic-deflection type. This article describes a unit containing the high voltage supply and synchronizing and scanning equipment for an 1802 kinescope tube.

A NEW IDEA IN V. T. VOLTMETER DESIGN, *by R. E. Pollard.*—Describing a peak v.t.v.m. in which the slideback operation is made automatic. Two 6L6's are used as d.c. amplifiers following the voltmeter tube and these automatically provide the slideback voltage.

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RECEIVING PULSES FROM THE IONOSPHERE, *by Albert W. Friend.*—The concluding article of a series on iono-

spheric measurements for the amateur. This installment describes the correct method of receiving the pulses and interpreting them.

REBUILDING COLLINS 32-B's *and* 32-F's TO INCLUDE 28-MC. OPERATION, *by Jay C. Boyd.*—A large number of amateurs are in possession of 32-B and 32-F transmitters which are not usable on 28 Mc. This article describes how such transmitters may be changed over to provide highly efficient 28-Mc. operation.

A C.W.-PHONE MONITOR AND FREQUENCY METER, *by Kenneth L. Kime.*—Describing an inexpensive unit for both monitoring and frequency measurement use. A 24A is used as an electron-coupled oscillator coupled into a 56 detector. The detector is followed by another 56 as an audio amplifier.

THE QUADIRECTIONAL RHOMBIC, *by Dave Evans.*—A description of a system whereby the rhombic antenna can be used to give high directivity in any one of four directions. By bringing feed lines into the operating room from all four corners of a square rhombic antenna and providing relays at each corner of the antenna and a switch at the transmitter, the directivity may be altered at will.

SO YOU'RE GOING MOBILE!, *by Raymond P. Adams.*—A discussion of the various problems which must be faced by the amateur who desires to install a 10-meter mobile station in his automobile. Receivers, noise elimination, power supplies, and transmitters are fully discussed.

TRANSMISSION LINES AS CIRCUIT ELEMENTS, *by E. H. Conklin.*—An article clarifying the subject of optimum conductor radius-to-spacing ratios at ultra high frequencies. The author finds some previously published data on this subject to be in error. Charts and curves are given showing optimum ratios for both maximum Q and maximum impedance at various high and ultra high frequencies.

SIMPLICITY AT 56 MC., *by Frank C. South.*—A relatively simple transmitter providing 450 to 500 watts of crystal-controlled output for c.w. and 250 to 300 watts on phone. A 6L6 harmonic oscillator using 40-meter crystals is followed by 6L6 and 807 doublers and push-pull 808's in the final amplifier. The entire r.f. section of the transmitter is built on a single 7" by 17" by 3" chassis.

MARCH, 1939

SUPPORTING THE ROTARY BEAM, *by F. Claude Moore.*—Describing a sturdy supporting structure for the rotatable array. A single boom made up of 1¼ by 5-inch spruce separated by several 2 by 4 inch blocks at regular intervals is the principal supporting element. Full constructional plans accompany the article.

AN IMPROVED U.H.F. R-C SUPERHETERODYNE, *by Frank C. Jones.*—An improved version of the original Jones resistance-coupled superheterodyne. The new model features 2½-, 5-, and 10-meter operation along with increased selectivity and sensitivity.

ELECTRICAL MULTI-MEASUREMENTS, *by James Silverman.* — A single-meter unit which permits inductance, capacity, resistance and a.c. and d.c. voltage and current measurements. The construction of the various shunts and series resistors used is fully described.

AN EFFICIENT SEMI-SKELETON AMPLIFIER, *by Lewis Van Arsdale and John Moran.*—A description of a neat, compact 500 watt amplifier designed for high efficiency on frequencies up to and including 60 Mc. A special plate condenser with center rotor connection contributes materially to the efficiency at higher frequencies. Tubes of the 35-to-50 watt plate dissipation class are used.

Gain in R. F. Stages, *by E. H. Conklin.*—A review of experiments made with typical r.f. amplifiers at 28 and 56 Mc. A chart is given showing the gain obtained with various tubes at these frequencies. A short discussion of some comparisons made between acorn tubes and the new high-transconductance tubes is also given.

A Compact Phone Transmitter Using High-Efficiency Grid Modulation, *by J. T. Goode.*—A transmitter featuring high overall efficiency. The complete transmitter, including power supply and modulator, is built on a single chassis. Parallel 35T's in the final amplifier are modulated by a three-stage speech-modulator using a 42 in the output stage.

Exterminating "Parasitics," *by J. E. Jennings.*—A discussion of the causes and cures of parasitic oscillations in transmitter circuits. Methods of determining the frequency of these spurious oscillations and means for their elimination are explained.

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March, 1939

Etched Foil Electrolytics, *by Stanley H. Walters.*—Due to the increased plate surface area, etched-foil electrolytics allow high-capacity condensers to be built to extremely small physical dimensions. This article discusses the development and properties of the etched-foil type of condenser. Several graphs are given showing some of the characteristics of these condensers.

Amplifier Analysis, *by Glenn H. Browning and Francis J. Gaffney.*—A discussion of the calculations involved in the application of multiple-winding output transformers. Calculations involving determining transformer turns ratios, measuring the characteristics of various transformers, determining the effect of improper impedance match, and the power delivered to each speaker in a multiple system are explained.

February, 1939

Wireless Record Players, *by Ray D. Rettenmeyer.*—A descriptive article covering many of the "remote" record players now on the market. All of these units consist of a modulated oscillator, usually a 6A7, and a simple power supply. Crystal pickups are used in all cases.

Facsimile, *by Fred C. Ehlert.*—Ten stations throughout the country are now giving experimental facsimile service. This article discusses the principles involved in facsimile transmission and reception. A list of the stations now offering this service is also given.

THE T & R BULLETIN
A JOURNAL FOR RADIO EXPERIMENTERS

1/6 a copy
Radio Society of Gt. Brit.
53, Victoria St., London
MARCH, 1939

AN OMNI-DIRECTIONAL LOW-ANGLE AERIAL, *by C. A. Heathcote.*—A description of an antenna combining the properties of both vertical and horizontal types. A vertical doublet is connected to the center of a horizontal full-wave antenna, thus obtaining low-angle radiation and wide coverage in a single system.

THE CATHODE RAY TUBE AND ITS APPLICATIONS IN TELEVISION AND OSCILLOGRAPHY, *by S. West.*—Part II of a series on cathode-ray tube applications. This article covers the principles of electrostatic deflection and defines deflection sensitivity. Constructional data are given on apparatus suitable for experimental purposes.

FOLDED AERIAL EXPERIMENTS, *by H. J. Hunt.*—A discussion of the results obtained over a period of time with a folded "Y" matched antenna. The author finds that such an antenna has marked directional properties.

FEBRUARY, 1939

THE IONOSPHERE, *by K. W. Tremmelen.*—A discussion of ionospheric conditions and methods of interpreting these conditions in relation to short wave transmission. The article is profusely illustrated with graphical data.

THE UTILITY A.C./D.C. TRANSMITTER, *by J. N. Walker.*—A description of a transmitter for a.c.-d.c. operation capable of taking up to 20 watts input to the final stage. Two stages are used, with a push-pull final amplifier; provision is made for operation on the commonly used amateur bands.

AN INTERCHANGEABLE AERIAL SYSTEM FOR SIX-BAND OPERATION, *by Harry Hornsby.*—An antenna system using interchangeable single-wire fed flat tops for each band above 7 Mc. On the lower frequencies, the 7-Mc. antenna is used against a counterpoise. The antenna changing is simplified through the use of hooks on the halyard ropes.

WHY NOT AN "S" METER?, *by J. F. S. Carpenter.*—Methods of connecting a signal-strength meter in typical superheterodyne receivers. Resistance values for suitable bridge circuits are given.

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