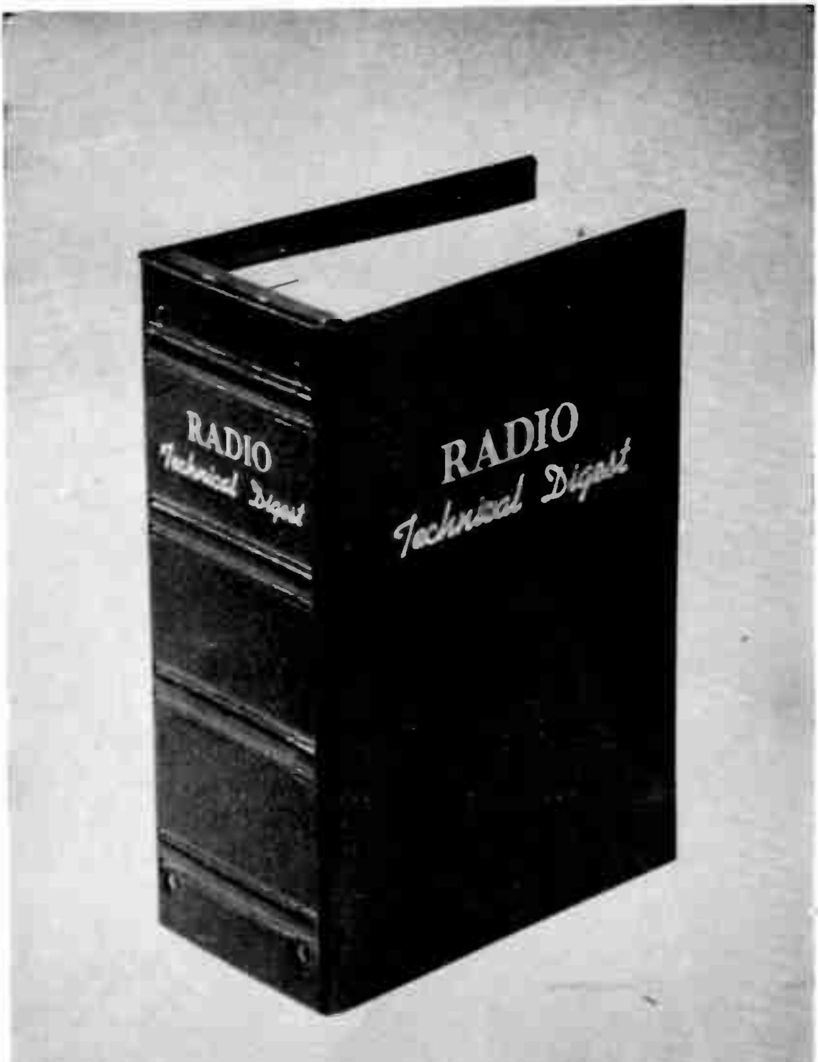
RADIO
Technical Digest

TELEVISION
•
AMATEUR
XPERIMENTAL
and
SHORT WAVE
RADIO
•
ELECTRONICS
•
Radio
ENGINEERING
SERVICE
OPERATING
OMMUNICATIONS

25¢
U.S.A. & CANADA

NOVEMBER AND DECEMBER, 1939


RADIO
Technical Digest
RADIO
Technical Digest

RADIO
Technical Digest

• NOVEMBER - DECEMBER, 1939 NUMBER 14 •

Selections from the World Technical Radio Press

RADIO TECHNICAL DIGEST • A. McMullen, Managing Editor
Editors: W. W. Smith, Ray L. Dawley, B. A. Ontiveros
W. E. McNatt, Jr., Production Manager

25c per copy. By subscription: 12 issues, $2.50 in U. S. A., Canada, Newfoundland, Spain, and all Pan-American countries; elsewhere, $3.00.

Published every two months by Radio, Ltd., 1300 Kenwood Road, Santa Barbara, California. Entered as second class matter August 30, 1939 at the Post Office at Santa Barbara, California, under the Act of March 3, 1879. Additional entry at East Stroudsburg, Pa.

Printed by Hughes Printing Co., East Stroudsburg, Pa., U.S.A.

RADIO
Technical Digest

● NOVEMBER - DECEMBER, 1939 NUMBER 14 ●

Selections from the World Technical Radio Press

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

Editors: **W. W. Smith, Ray L. Dawley, B. A. Ontiveros**

W. E. McNatt, Jr., Production Manager

25c per copy. By subscription: 12 issues, $2.50 in U. S. A., Canada, Newfoundland, Spain, and all Pan-American countries; elsewhere, $3.00.

Published every two months by Radio, Ltd., 1300 Kenwood Road, Santa Barbara, California. Entered as second class matter August 30, 1939 at the Post Office at Santa Barbara, California, under the Act of March 3, 1879. Additional entry at East Stroudsburg, Pa.

Printed by Hughes Printing Co., East Stroudsburg, Pa., U.S.A.

¶ From *Service*
July 1939

LOUDSPEAKER ENCLOSURES

By MAURICE APSTEIN

AFTER spending the past two years in close association with both the engineering department and customers of one of the largest manufacturers of high fidelity speakers in the country, the writer has become firmly convinced that no component of a sound system is as completely misunderstood as the loudspeaker baffle. Particularly since the advent of the enclosed type speaker housing has much confusion arisen as to just how these devices function, and the manner in which to operate them to secure best results. Although the principle upon which the flat baffle operates, isolation of front radiation from that of the rear, seems to be well known in a general way, understanding of the proper handling of even this simplest of acoustic networks seems to be sadly lacking. A short review of the principle of operation of the flat baffle seems to be in order. At the same time it will provide a basis for consideration of the more recent types of speaker enclosure.

- Purpose

The purpose of any baffle is to insure proper radiation of the low frequencies from the cone of a speaker. At these low frequencies the cone operates like a piston, that is, it moves back and forth as a whole, compressing the air in front of it on the forward stroke at the same time that it creates a partial vacuum or rarefaction at its rear. On its backward stroke the cone reverses this procedure, compressing the air behind the cone and creating the vacuum in front. This action may be seen very clearly in Figure 1, where the dots are used to represent molecules of air. In 1 (a) the cone is at rest and the air in front and back is at equal pressure. In 1 (b) the cone has moved forward from the neutral position (shown as a dotted line) and compressed the air in front at the same time that it has rarefied the air behind. In 1 (c) the cone has come back through neutral and has reversed the positions of the compressed and rarefied areas. It is apparent that in the area near

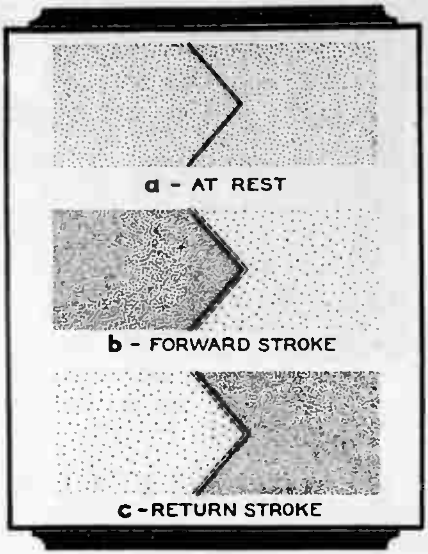


Figure 1. At low frequencies a loudspeaker cone operates like a piston

the edge of the cone, the compressed and rarefied regions of air are adjacent, and that unless prevented from doing so, the air from the compressed area will flow around the edge of the cone into the rarefied area, and that the resultant alternate pressure or vacuum generated at the front of the cone will be materially reduced. A baffle is a device for preventing this effect by isolating the pressure area in front of the cone from the vacuum in its rear and vice versa. In its simplest form it consists of a flat sound-proof partition which acoustically insulates the cone front from its rear. Figure 2 (a) illustrates the simple flat baffle and 2 (b) shows how the sides may be bent back to form the conventional open back console cabinet. In each case the arrow shows the lengthened path that the sound must take in order to travel from the front of the cone to its rear, and thus cause interference.

It should be obvious that the longer the wavelength, or the lower the frequency of the sound to be isolated, the longer must be the path from the cone front to the cone rear. To isolate completely the front and rear radiations at all frequencies, the baffle would have to be infinite in extent. Conversely, for any baffle of finite size, there will be a particular frequency at which the distance from front to back will be just the length re-

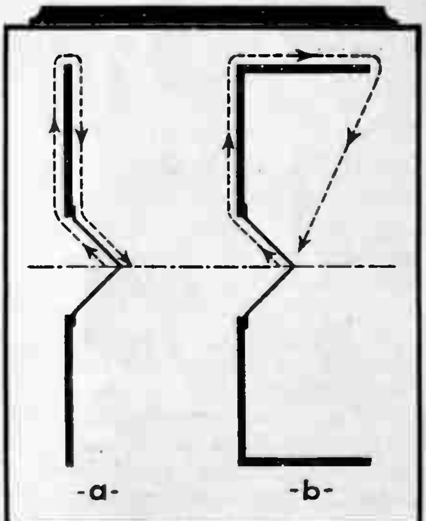


Figure 2. In its simplest form a baffle consists of a flat partition.

quired for the front and rear radiation to meet exactly out of phase and cancel each other out. This critical frequency, common to all flat baffles, is known as the "cut-off frequency," and may be very easily calculated, by the following relation:

$$D = \frac{V}{2}$$

where D is the distance from the cone front to cone rear (feet) and V is the velocity of sound in air (feet per second).

- Square Baffle

In the case of a square flat baffle, the distance from the cone to the edge and back is equal to the diameter of the baffle, so the formula may be said to give directly the diameter of a flat baffle for any cut-off frequency. Based on the above relationship, the required dimensions for square baffles of various cutoff characteristics are as follows:

Cutoff Frequency *(cycles per second)*	Baffle Diameter *(path front to rear)*
20	28 1/4 ft.
30	18 5/6 ft.
40	14 1/12 ft.
60	9 5/12 ft.
100	5 1/2 ft.

It is apparent that the dimensions given above are much greater than the usual dimensions for what is popularly considered a fair sized flat baffle. The term cutoff frequency is probably an unfortunate one since it has led to the popular misconception that the baffle cuts below this frequency in much the same way that an amplifier cuts off, and that no sound or very little, is radiated from the speaker below the baffle cutoff. This is not the case. Below the cutoff frequency of a baffle, the front and rear radiations approach an in phase condition again and the output begins to rise. This is the reason that small baffles three or four feet square which cut off at relatively high frequencies, sound much better than they would if there was actually no sound radiated below the cutoff frequency. This effect is shown in figure 3, which is the response curve of a high fidelity cone speaker mounted in a three-foot square baffle.

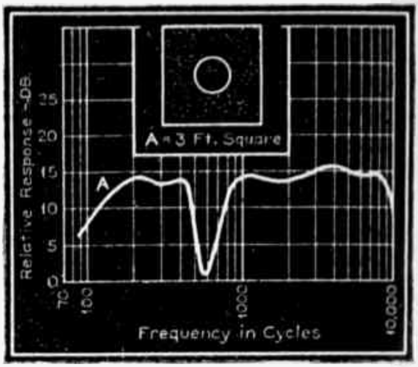


Figure 3. The deep valley at 600 cycles indicates almost complete cancellation.

The deep valley at approximately 600 cycles indicates that at that frequency almost complete cancellation of front and rear radiation takes place. It can readily be appreciated how futile it is to talk about flat amplifier and speaker response, and then mount the speaker in such a way that there is a 20 db valley right in the middle of the response range.

Almost complete correction of this very grave defect in response can be obtained by a few very simple expedients. First of all, a square baffle is one of the worst shapes to use (in spite of its almost universal popularity). This is due to the fact that the path lengths around all four sides of the baffle are equal, and tend to create a valley at the same frequency. If an oblong baffle is used, there will be two paths of different length; one around the sides, and the other around the top and bottom. This will result in two valleys in the response, but neither valley will be as severe as before. If in addition, the speaker is located asymmetrically in the baffle, instead of in the center (the latter is also practically universal practice) still further improvement will result due to the fact that no two paths from front to rear will cause cancellation at the same frequency. If the lower edge of the baffle rests on the floor, and the speaker is located near the floor, cancellation around this edge is completely cut off, and this portion of the radiation will not suffer even at the very lowest frequencies. Mounting the speaker near the floor helps in another way. When a speaker is mounted in a flat baffle, it is radiating into a solid angle of 180 degrees. Mounting it near the floor puts the speaker in a corner, reducing this angle approximately 90 degrees with the result that the air in front of the cone is more restricted, loads the cone considerably better and the cone radiates more efficiently. If advantage is to be taken of this restricted solid angle, however, it is preferable to have the floor covered with a rug or some similar soft material; otherwise undesirable reflections may result.

- **Irregular Baffles**

Figure 4 shows the startling improvement over figure 3 that results when the same speaker is mounted off center in an irregularly shaped baffle resting on the floor, to take advantage of the principles outlined above. This comparison of the same speaker, mounted differently, gives us a perfect example of how excellent electrical response may be completely nullified (and often is) by careless and improper baffling.

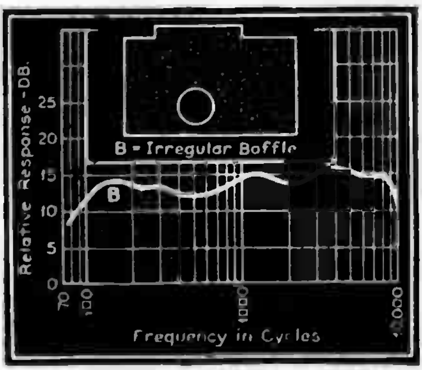


Figure 4. A startling improvement in response is obtained by mounting the speaker off center on an irregular baffle

Another common error in speaker mounting occurs when two speakers are to be mounted on the same baffle. Here again it is almost universal practice to mount the speakers well separated from each other, and symmetrically located with respect to the edges. Actually, best response and increased efficiency will be obtained if the two speakers are mounted as close together as physically possible. A little thought will make clear why this improvement takes place. Since both cones move in phase, the effect of the pressure area in the front of each cone is to act as a load on the other. The result is more efficient coupling from each cone to the air, with a corresponding increase in efficiency and response, particularly at the bass end where loading of the cone is a vital factor.

In spite of these improvements, however, figure 4 also illustrates the fundamental drawback of the flat baffle. Regardless of ingenuity in shape and placement, it is evident that in order to get efficient isolation at the low frequencies required for true high fidelity reproduction, the necessary dimensions are too great for ordinary use. This problem was not particularly acute as long as response down to 150 cycles was considered good bass response. With the advent of really high-fidelity reproducers, however, which in baffles of infinite extent showed good reproduction characteristics to below 50 cycles, it became imperative to develop some form of baffle which would not be too bulky yet would allow complete advantage to be taken of these low frequency characteristics. It was this realization that caused speaker engineers to undertake the development of compact speaker enclosures that would provide sufficient baffling throughout the entire audible range of frequencies.

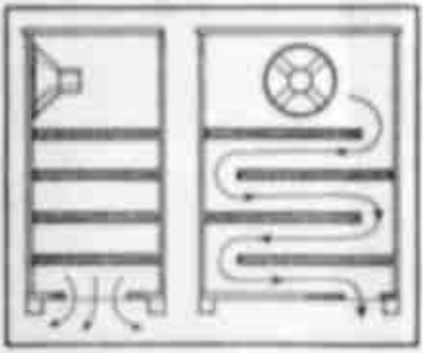


Figure 5. The Stromberg-Carlson Acoustic Labyrinth. The labyrinth works on the principle of feeding the rear radiation into a long tube.

• Acoustic Labyrinth

One of the first of these developments was the acoustic labyrinth (figure 5). This cabinet works on the principle of feeding the rear radiation into a long tube, usually folded back upon itself several times to conserve space. The walls of the tube are lined with a highly absorbent material so as to rapidly attenuate all but the lowest frequencies, and the length of the tube is made great enough so that it will either resonate at the lower edge of the response range of the speaker or below the response range entirely.

With a tube a half wavelength long at the lowest frequency it is desired to reproduce, sound at this frequency emerges from the tube in phase with the front radiation and thus re-inforces the bass notes to some extent. The actual increase in radiation from the rear is, however, of questionable value, as will be explained later. The real efficacy of the labyrinth lies in its excellent baffling action, which can be easily made equal in effectiveness to that of a flat baffle 12 or 15 feet square, without exceeding conventional cabinet size. Because the labyrinth does not build up high back pressures in the tube, there is little need for structural rigidity in the labyrinth itself, with the obvious result that very economical designs are possible.

• Infinite Baffle

The next high fidelity enclosure to appear was the infinite baffle cabinet. (Figure 6.) This is perhaps the simplest device of all in both principle and construction. For a long time it had been considered very poor practice to completely enclose the rear of a cone speaker. Cabinets were always designed with either completely open backs or with some kind of air release, to avoid cabinet resonance and to prevent the building of appreciable pressure within the cabinet at high amplitudes of the cone. More recent investigation disclosed that if the cabinet were made large enough so that its natural period would fall below or at the lower edge of the response range of the speaker and

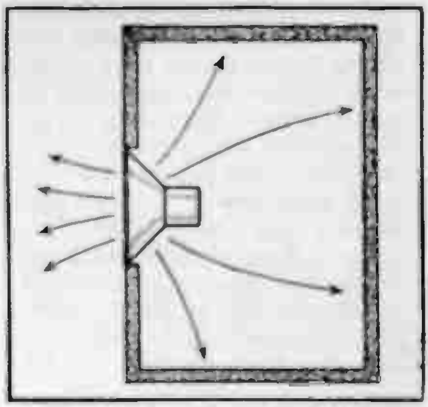


Figure 6. An infinite baffle is perhaps the simplest baffle device both in theory and construction.

if the walls are thickly lined with some highly absorbent material such as hair felt, that the performance was practically equivalent to a flat baffle of infinite extent; hence the name infinite baffle.

Such a baffle is very easy to construct since it merely consists of a solidly constructed box with well braced walls so that there will be no tendency to vibration, the whole lined with felt about ½-in. thick. If the felt is not easily procurable, the very popular felt rug cushion of the "Ozite" type will serve admirably. The minimum size of the cabinet will depend somewhat upon the size of the speaker cone. For a 12- or 15-in., the interior should have a volume at least 8 cubic feet. If the walls are well padded against resonance, shape is not important; thus the above enclosure could be a cube 2 feet on a side, an oblong box 2 by 3 by 1½ ft., or a shallow box 3 by 3 ft. by 11 in., all of

Another common error in speaker mounting occurs when two speakers are to be mounted on the same baffle. Here again it is almost universal practice to mount the speakers well separated from each other, and symmetrically located with respect to the edges. Actually, best response and increased efficiency will be obtained if the two speakers are mounted as close together as physically possible. A little thought will make clear why this improvement takes place. Since both cones move in phase, the effect of the pressure area in the front of each cone is to act as a load on the other. The result is more efficient coupling from each cone to the air, with a corresponding increase in efficiency and response, particularly at the bass end where loading of the cone is a vital factor.

In spite of these improvements, however, figure 4 also illustrates the fundamental drawback of the flat baffle. Regardless of ingenuity in shape and placement, it is evident that in order to get efficient isolation at the low frequencies required for true high fidelity reproduction, the necessary dimensions are too great for ordinary use. This problem was not particularly acute as long as response down to 150 cycles was considered good bass response. With the advent of really high-fidelity reproducers, however, which in baffles of infinite extent showed good reproduction characteristics to below 50 cycles, it became imperative to develop some form of baffle which would not be too bulky yet would allow complete advantage to be taken of these low frequency characteristics. It was this realization that caused speaker engineers to undertake the development of compact speaker enclosures that would provide sufficient baffling throughout the entire audible range of frequencies.

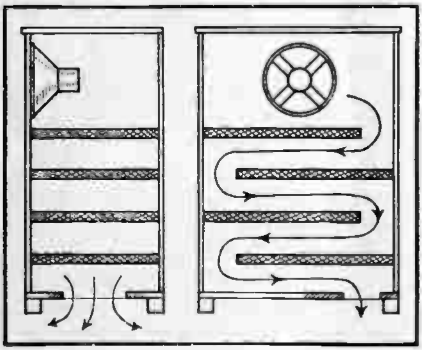


Figure 5. The Stromberg-Carlson Acoustic Labyrinth. The labyrinth works on the principle of feeding the rear radiation into a long tube.

- Acoustic Labyrinth

One of the first of these developments was the acoustic labyrinth (figure 5). This cabinet works on the principle of feeding the rear radiation into a long tube, usually folded back upon itself several times to conserve space. The walls of the tube are lined with a highly absorbent material so as to rapidly attenuate all but the lowest frequencies, and the length of the tube is made great enough so that it will either resonate at the lower edge of the response range of the speaker or below the response range entirely.

With a tube a half wavelength long at the lowest frequency it is desired to reproduce, sound at this frequency emerges from the tube in phase with the front radiation and thus re-inforces the bass notes to some extent. The actual increase in radiation from the rear is, however, of questionable value, as will be explained later. The real efficacy of the labyrinth lies in its excellent baffling action, which can be easily made equal in effectiveness to that of a flat baffle 12 or 15 feet square, without exceeding conventional cabinet size. Because the labyrinth does not build up high back pressures in the tube, there is little need for structural rigidity in the labyrinth itself, with the obvious result that very economical designs are possible.

- Infinite Baffle

The next high fidelity enclosure to appear was the infinite baffle cabinet. (Figure 6.) This is perhaps the simplest device of all in both principle and construction. For a long time it had been considered very poor practice to completely enclose the rear of a cone speaker. Cabinets were always designed with either completely open backs or with some kind of air release, to avoid cabinet resonance and to prevent the building of appreciable pressure within the cabinet at high amplitudes of the cone. More recent investigation disclosed that if the cabinet were made large enough so that its natural period would fall below or at the lower edge of the response range of the speaker and

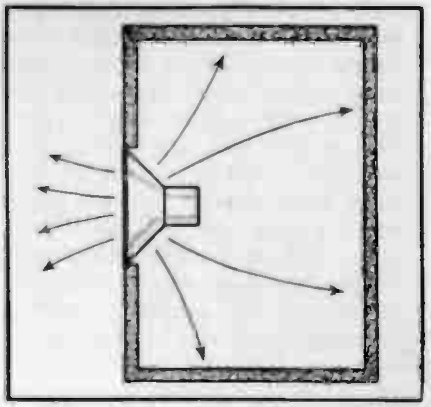


Figure 6. An infinite baffle is perhaps the simplest baffle device both in theory and construction.

if the walls are thickly lined with some highly absorbent material such as hair felt, that the performance was practically equivalent to a flat baffle of infinite extent; hence the name infinite baffle.

Such a baffle is very easy to construct since it merely consists of a solidly constructed box with well braced walls so that there will be no tendency to vibration, the whole lined with felt about ½-in. thick. If the felt is not easily procurable, the very popular felt rug cushion of the "Ozite" type will serve admirably. The minimum size of the cabinet will depend somewhat upon the size of the speaker cone. For a 12- or 15-in., the interior should have a volume at least 8 cubic feet. If the walls are well padded against resonance, shape is not important; thus the above enclosure could be a cube 2 feet on a side, an oblong box 2 by 3 by 1½ ft., or a shallow box 3 by 3 ft. by 11 in., all of

Another common error in speaker mounting occurs when two speakers are to be mounted on the same baffle. Here again it is almost universal practice to mount the speakers well separated from each other, and symmetrically located with respect to the edges. Actually, best response and increased efficiency will be obtained if the two speakers are mounted as close together as physically possible. A little thought will make clear why this improvement takes place. Since both cones move in phase, the effect of the pressure area in the front of each cone is to act as a load on the other. The result is more efficient coupling from each cone to the air, with a corresponding increase in efficiency and response, particularly at the bass end where loading of the cone is a vital factor.

In spite of these improvements, however, figure 4 also illustrates the fundamental drawback of the flat baffle. Regardless of ingenuity in shape and placement, it is evident that in order to get efficient isolation at the low frequencies required for true high fidelity reproduction, the necessary dimensions are too great for ordinary use. This problem was not particularly acute as long as response down to 150 cycles was considered good bass response. With the advent of really high-fidelity reproducers, however, which in baffles of infinite extent showed good reproduction characteristics to below 50 cycles, it became imperative to develop some form of baffle which would not be too bulky yet would allow complete advantage to be taken of these low frequency characteristics. It was this realization that caused speaker engineers to undertake the development of compact speaker enclosures that would provide sufficient baffling throughout the entire audible range of frequencies.

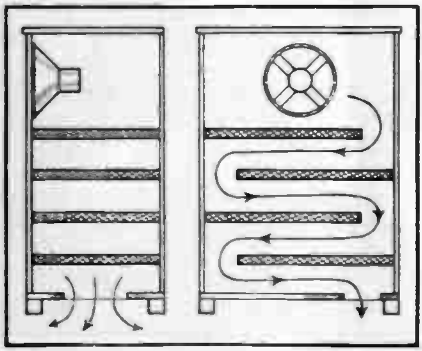


Figure 5. The Stromberg-Carlson Acoustic Labyrinth. The labyrinth works on the principle of feeding the rear radiation into a long tube.

• Acoustic Labyrinth

One of the first of these developments was the acoustic labyrinth (figure 5). This cabinet works on the principle of feeding the rear radiation into a long tube, usually folded back upon itself several times to conserve space. The walls of the tube are lined with a highly absorbent material so as to rapidly attenuate all but the lowest frequencies, and the length of the tube is made great enough so that it will either resonate at the lower edge of the response range of the speaker or below the response range entirely.

With a tube a half wavelength long at the lowest frequency it is desired to reproduce, sound at this frequency emerges from the tube in phase with the front radiation and thus re-inforces the bass notes to some extent. The actual increase in radiation from the rear is, however, of questionable value, as will be explained later. The real efficacy of the labyrinth lies in its excellent baffling action, which can be easily made equal in effectiveness to that of a flat baffle 12 or 15 feet square, without exceeding conventional cabinet size. Because the labyrinth does not build up high back pressures in the tube, there is little need for structural rigidity in the labyrinth itself, with the obvious result that very economical designs are possible.

- Infinite Baffle

The next high fidelity enclosure to appear was the infinite baffle cabinet. (Figure 6.) This is perhaps the simplest device of all in both principle and construction. For a long time it had been considered very poor practice to completely enclose the rear of a cone speaker. Cabinets were always designed with either completely open backs or with some kind of air release, to avoid cabinet resonance and to prevent the building of appreciable pressure within the cabinet at high amplitudes of the cone. More recent investigation disclosed that if the cabinet were made large enough so that its natural period would fall below or at the lower edge of the response range of the speaker and

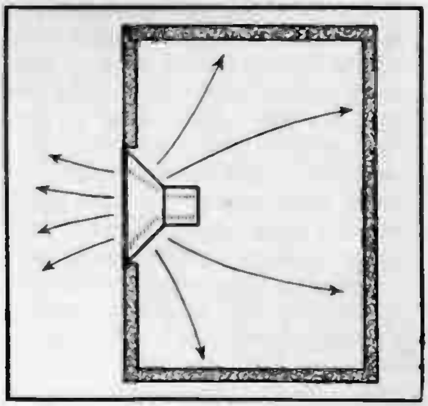


Figure 6. An infinite baffle is perhaps the simplest baffle device both in theory and construction.

if the walls are thickly lined with some highly absorbent material such as hair felt, that the performance was practically equivalent to a flat baffle of infinite extent; hence the name infinite baffle.

Such a baffle is very easy to construct since it merely consists of a solidly constructed box with well braced walls so that there will be no tendency to vibration, the whole lined with felt about ½-in. thick. If the felt is not easily procurable, the very popular felt rug cushion of the "Ozite" type will serve admirably. The minimum size of the cabinet will depend somewhat upon the size of the speaker cone. For a 12- or 13-in., the interior should have a volume at least 8 cubic feet. If the walls are well padded against resonance, shape is not important; thus the above enclosure could be a cube 2 feet on a side, an oblong box 2 by 3 by 1½ ft., or a shallow box 3 by 3 ft. by 11 in., all of

which would give approximately the same results. Eighteen-inch cones, due to greater air displacement and somewhat better bass response, would require about 50 per cent greater enclosed volume for optimum results but would deliver quite satisfactory performance even in the 8 cubic foot enclosure if not operated at too high volume levels. Ten-inch and smaller cones of course may be operated in correspondingly smaller cabinets with equivalent baffling action.

- Bass Reflex

The most recent modern baffle and perhaps the most obscure in principle is the bass reflex and Magic Voice cabinet. These types may be considered a cross between an infinite baffle and an acoustic labyrinth. They are similar and consist of an almost completely enclosed cabinet, partially lined with sound absorbing material, one of whose walls has an opening of definite size for air release and/or bass reinforcement. In the bass reflex variation, this opening is a rectangular port at the front of the enclosure and several inches below the cone of the speaker. In the Magic Voice version there are several openings at the bottom of the cabinet which connect to the interior through short tubes of varying length. The cabinet itself stands off the floor on short legs to allow any sound emanating from the tubes to be radiated into the room. Figure 7 and 8 are simplified diagrams of the construction of these cabinets.

The design of this type enclosure, entails the treatment of the cabinet as a broadly resonant cavity at the low frequencies. The design of the opening is so handled that it acts as an acoustic phase inverter at these frequencies. These conditions are fulfilled by dimensioning the cabinet for proper resonance and by making the reflex opening approximately equal to the cone area. The simple open port does not invert the phase with quite the same effectiveness as the tubular passages of the Magic Voice design, but either method results in a more compact enclosure than the infinite baffle because the cabinet resonance falls within the response range rather than below it. Further economy is possible since complete absorption is not necessary within the enclosure and the padding need not be as elaborate as with the fully enclosed cabinet, nor is rigidity quite as important.

- Performance

From the standpoint of performance there is little to choose between the rear port cabinet and the completely enclosed design. Although the completely enclosed unit is somewhat bulkier and more expensive, its simpler acoustic action tends to make it freer from accidental resonance effects such as the possibility that cone and cabinet resonance might occur at the same frequency which would result in undesirable accentuation of a narrow band of bass notes. It is a popular misconception that since the reflex cabinet makes use of rear

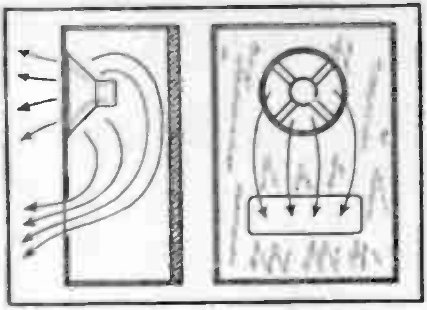


Figure 7. The Jensen Bass-Reflex type of construction is a cross between an infinite baffle and an acoustic labyrinth.

radiation, a given speaker will deliver noticeably better bass response in this type of cabinet than could be obtained from a fully enclosed infinite baffle. A little reflection will make clear why this is not necessarily so. If the radiation from the rear of the cone were equal to that from the front; if the cone basket and magnet structure did not interfere with that radiation; if there were no absorption in the cabinet; if the phase inversion at the port were exactly 180 degrees, and if the radiation efficiency of the port were equal to the radiation efficiency of the cone front itself (then and only then) the gain due to rear radiation would be 3 db. Obviously, none of the above links in the chain from the rear of the cone to the front can be perfect, with the result that in practice the net gain, depending on design, runs between 1½ and 2 db, which is a negligible aural increase.

• True Value

The true value of both the infinite baffle cabinet and the reflex cabinet lies in their common superiority over conventional flat baffles and open back cabinets rather than in any minor advantages one might hold over the other. In addition, frequency response does not tell the whole story of this common superiority. All of the above enclosures are superior to the usual flat baffle in bass radiation pattern, since they eliminate the out of phase area near the edge of the baffle in which area there is practically no bass response. Thus the extension of the cutoff frequency, plus improved radiation characteristics, make it possible to take advantage of the full capabilities of modern high fidelity speakers without resorting to extremely large dimensions.

• Summary

A brief summary of the salient points discussed above may be helpful.

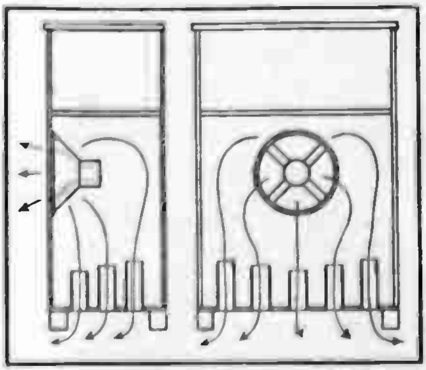


Figure 8. The RCA Magic Voice is also a cross between the infinite baffle and the acoustic labyrinth.

(1) Instead of the conventional practice of mounting a speaker in the center of a square flat baffle, definite improvement in performance may be obtained by irregular dimensioning and asymmetrical positioning of the speaker with respect to the baffle edges.

(2) Mounting the speaker near the lower edge of the baffle, and allowing this edge to rest on the floor, reduces the solid angle into which the cone radiates and provides increased effective baffle area from the floor, both effects contributing to higher efficiency at low frequencies. Care should be taken, however, to avoid excessive reflection from the floor.

(3) The acoustic labyrinth, although somewhat complicated structurally, provides an effective and compact method of duplicating the performance of very large flat baffles without resorting to resonant chambers.

(4) The infinite baffle cabinet, by virtually complete absorption of rear radiation, duplicates substantially the results obtained from a flat baffle of infinite extent.

(6) The full realization of the excellent capabilities of high fidelity speakers can only be obtained by proper baffling, and without such baffling the response obtained may easily ruin the response characteristics of an otherwise excellent reproducing system.

Votes!

IN the June issue of *Electronics* we related the story about a certain large department store that asked its employees to rate certain desirable job chacteristics, and asked the reader to register his vote. Scattering returns are not conclusive evidence that *Electronics* readers think alike on these matters. So we give below the way in which 3,000 men and women voted:

Employees Rating	Job Factor	Employers Rating
1.	Credit for all work	7
2.	Interesting work	3
3.	Fair pay	1
4.	Opportunity to learn	—
5.	Understanding, appreciation	5
6.	Personal counsel	8
7.	Departmental planning	—
8.	Promotion on merit	4
9.	Physical working conditions	6
10.	Job security	2

—Electronics.

¶ From QST*
August, 1939

FREQUENCY MODULATION

Fundamentals

How Frequency Modulation Works; Its Advantages in Overcoming Noise and Interference.

By DANIEL E. NOBLE

TWO 50,000-watt experimental transmitters and several lower-powered transmitters will be placed in regular operation in the Fall using the Armstrong frequency-modulation system. The marked noise suppression which is the important characteristic of the system will make possible a new standard of high-fidelity reception. The writer has been asked to explain the action of this frequency-modulation system without too much technical terminology. With all qualifications aside, the picture looks something like this:

Every amateur knows what frequency modulation is—it's something in his transmitter operation that he doesn't want! To make the picture a little more exact, we shall make use of a pure sine wave alternator. A pure sine wave is a single-frequency wave; that is, no side bands and no harmonics will be associated with it. A perfect frequency meter could locate only one frequency with such a wave. If our alternator is the usual motor-driven type with an external field supply, we can vary the voltage output of the alternator by varying the field current. Let's vary the field current slowly up and down and observe the result. First, the output voltage of the alternator will increase and decrease, and we have a condition commonly referred to as amplitude modulation. See figure 1 (*A*, *B*, and *C*). Second, the output wave is no longer a pure sine wave, and if we examine the wave with our perfect frequency meter we shall find several frequencies

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

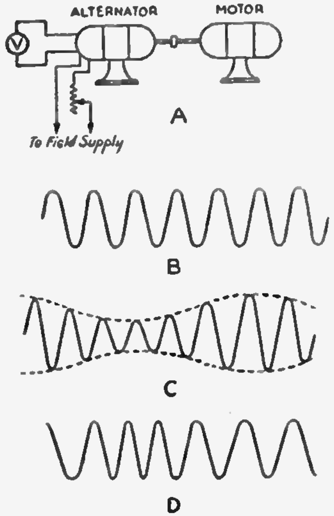


Figure 1. Illustrating amplitude and frequency modulation. A, the motor-driven alternator used as an example; B, output with constant field and constant speed (sine wave); C, output with constant speed and variable field (amplitude modulation); D, constant amplitude and variable speed (frequency modulation).

present, because only the pure sine wave will be limited to a single frequency. So much for amplitude modulation.

- Frequency Modulation

Now regulate the field supply so that the amplitude of the alternator output will not change while the driving motor is made to speed up and slow down. The frequency of the alternator will be determined by the speed of the motor; if we speed up the motor the output frequency will increase, and it will decrease when the motor slows down. Assuming that the amplitude of the output remains constant, we have produced a frequency-modulated wave by the simple process of speeding up and slowing down the motor. What has happened to the wave? First, obviously the wave is no longer a pure sine wave, since the frequency is changing. Second, since the wave is not a pure sine wave, several frequencies will be present (theoretically, an infinite number). When we neglect inertia and speed up and slow down the motor in such a way that the change in speed is at the rate of ten cycles per second, and the cycles are perfect sine-wave cycles, we will produce a frequency series for a 1000-cycle generator something like this: . . . 1000 — 30, 1000 — 20, 1000 —10, 1000, 1000+10, 1000+20, 1000 + 30 . . . and so on to an infinite number of side bands. Although frequency modulation will produce a composite wave made up of the carrier, plus and minus a regular harmonic series of the modulating-signal frequency and the carrier, we are fortunate in the fact that the amplitudes of the side bands decrease rapidly as the signal harmonic number increases.

To go back to our motor-generator again, the motor was speeded up and slowed down to produce our frequency modulation but we didn't say how much we speeded it up or how much we slowed it down. We can change the motor speed so that the frequency will vary instantaneously as follows: 1000→1025→1000→975→1000 cycles, and make the entire excursion in one-tenth of a second for a modulating frequency of ten cycles per second. Or we can go 1000→1050→1000→950→1000 in one-tenth of a second for a 10-cycle modulation frequency. The difference is found in the more extended change in frequency in the second case. This change is called the "deviation." For the first case the deviation is 25 cycles and for the second, 50 cycles. Deviation is then the maximum instantaneous change in frequency. Just to increase the confusion, we might add that we can't find the deviation with the frequency meter since no continuous spectrum is produced but, rather, we produce discrete side bands which may be detected and their physical existence made evident by means of our frequency meter. These side bands may be found far beyond the limits of the deviation. We might define the maximum instantaneous frequency for our special case as the frequency we would get from our alternator if we held the speed constant when the maximum speed was reached. We do not actually produce such a maximum frequency because the *speed does not remain constant.* All this leads to conclusion that we can expect the band-width of the frequency modulated wave to be greater than twice the deviation.

- Producing Frequency Modulation

A frequency-modulated wave may be produced much more readily with vacuum tube equipment than with rotating machinery. Rotating a condenser back and forth to change the capacity in an oscillator circuit will produce a frequency-modulated wave. Placing a condenser microphone in an oscillator circuit in such a way that changes in the microphone capacity will influence the frequency of the oscillator is an obvious means of producing a modulated wave. The circuit used in automatic frequency control systems is an excellent frequency-modulation system.

The modulation method invented by Major Edwin Armstrong is very stable since the carrier is controlled by a quartz crystal oscillator. A 200-kc. oscillator supplies voltage to a phase-shift network from which two components of the carrier are extracted, differing only in phase. One component is 90° out of phase with the other. Mathematically, the difference between the amplitude-modulated wave and the frequency-modulated wave is the difference in the phase relations between side bands and carrier. If the side bands of an amplitude-modulated wave could be extracted from the carrier shifted in phase 90°, and then recombined with the carrier, a frequency-modulated wave would result. Major Armstrong did not extract the side bands but he did arrange to produce side bands without a carrier by means of a balanced modulator working with one of the 200-kc. components mentioned above, and then to combine the side bands with the second component in such a way that the side bands were 90° out of phase with the normal arrangement for carrier and side bands in the amplitude modu-

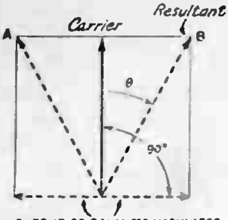


Figure 2. Vector Diagram of phase modulation. The modulator vector reverses, producing a resultant θ degrees ahead or behind the carrier vector. This is equivalent to a sudden change in the time axis, with the result that the frequency changes. The vector will oscillate back and forth between A and B at the modulating frequency. The more rapid the oscillation the faster the change in the time axis, therefore the greater the frequency deviation produced.

lated wave. His result was a frequency-modulated wave of the special type sometimes referred to as a "phase-modulated" wave. Another way to describe the action of Major Armstrong's modulator is to say that he combined a carrier voltage with a side-band voltage which had been rotated through 90°. This gives us the simple picture of two vectors 90° out of phase combining to give the resultant voltage. Figure 2 will assist the reader to visualize the process. As the side-band voltage is increased and decreased, the resultant of the two vectors is caused to shift phase. The shift in phase corresponds to a frequency change, and the amount of frequency change produced will depend upon the magnitude of the phase shift and upon how rapidly the phase shift is taking place. Since the magnitude and the speed of the phase shift is determined by the side-band vector, the deviation produced will be determined by the magnitude and the frequency of the modulating signal. The only difference between pure frequency modulation[1] and phase modulation is the fact that the deviation is a function of the *amplitude* only of the modulating signal for pure frequency modulation while the *frequency* of the signal *also* determines the deviation for phase modulation. A network placed in the audio input amplifier making the output signal voltage inversely proportional to frequency will make the overall response independent of signal frequency, and thus the phase modulator will produce a pure frequency-modulated wave. The actual deviation produced at 200 kc. is small, something of the order of 15 to 20 cycles. Therefore, a series of doublers must be introduced to increase the maximum deviation to 100 kc. A total of twelve or thirteen doubler stages is used to reach the required deviation.

A system of modulation suggested by Murray C. Crosby and developed by Irving R. Weir makes use of the automatic fre-

---

[1] The term "phase modulation" is something of a pain. Actually there are as many types of frequency modulation as there may be functions of X. Phase modulation is one type. The type referred to as "pure" frequency modulation is the unadulterated, holy, sweet, etc. variety in which the deviation produced is a linear function of the modulating signal amplitude only. "Phase modulation" is still "frequency modulation."

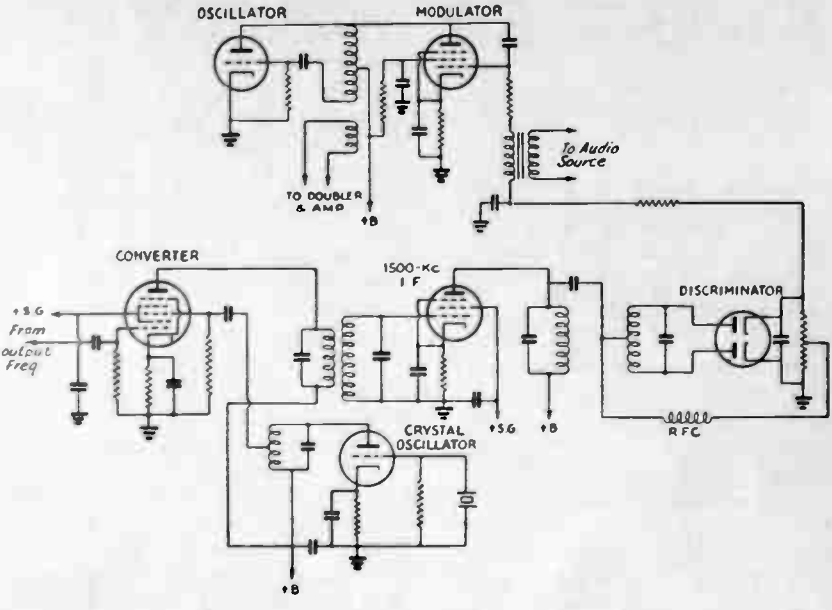


Figure 3. A practicable frequency-modulator circuit, after Weir. The oscillator is frequency-modulated by the a.f.c. tube (modulator) which causes a frequency deviation in proportion to the amplitude of the audio voltage. A small part of the output signal is fed to the converter tube, which is heterodyned by a stable crystal oscillator to give a beat frequency at 1500 kc. The i.f. output operates the rectifier (discriminator) and by providing the modulator with a d.c. bias which varies when the mean oscillator frequency tends to change (a.f.c. action) maintains the carrier frequency constant. Deviations of approximately 30 to 40 kc. may be obtained in the region of 20 Mc. using a 6L6 modulator and 6F6 oscillator. The stability of the system will be determined by the discriminator circuit stability.

quency control variable oscillator for modulating the frequency, and of the a.f.c. discriminator circuit for stabilizing the oscillator carrier. Figure 3 illustrates the type of circuit used. The modulator tube injects 90° out-of-phase current into the oscillator tank circuit. The effect of changing the modulator injector current is comparable to changing the tank capacity in the oscillator circuit. The stabilizing circuit functions in the usual a.f.c. manner.

• Receivers

The receiver requirements are not so complicated as one might suspect. The usual superheterodyne is used with a few additions and changes. The pass band must be greater than twice the transmitter deviation. A limiter precedes the detector, and this limiter has the

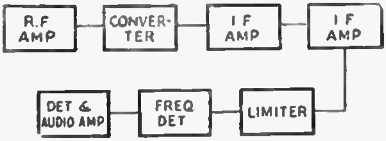


Figure 4. Essentials of a superhet receiver suitable for frequency-modulated signals.

very important function of "wiping off" any amplitude modulation which may have been introduced by noise voltages. The limiter passes on the frequency-modulated wave with constant amplitude to the frequency detector, which changes the frequency-modulated wave into a hybrid wave with both amplitude and frequency modulation components. An ordinary detector then recovers the signal from the amplitude component. Figure 4 illustrates the line-up. Figures 5 and 6 show two frequency detectors.

A simple circuit of the type shown in figure 7 also will act as a frequency detector. The carrier is tuned in on one side of the resonance curve. A steady-state r.f. voltage will result from the unmodulated carrier, and modulation will produce instantaneous frequency changes. Taking *A* as the operating point, any change corresponding to an increase in frequency of the signal will increase the amplitude of the voltage across the parallel-resonant circuit, and an equivalent decrease in frequency will decrease the voltage across the circuit. Therefore, since the modulation produces magnitudes of frequency change or deviation corresponding to the amplitude of the audio modulating signal, and since the rate at which the changes or deviations take place corresponds to the frequency of the audio signal, the voltage appearing across the parallel-resonant circuit will be amplitude-modulated. Frequency modulation will also be present but we are no longer interested in that. Rectification will recover the audio signal. Any receiver of the usual type can be made to receive frequency-modulated signals after a fashion by detuning slightly, but the reader is assured that the "fashion" is not very satisfactory.

- Noise Suppression

Remarkable results in the suppression of noise and interference are possible with the frequency modulation system. Since the limiter wipes off all amplitude variations, noise of this type must

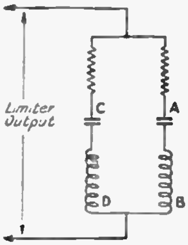


Figure 5. Elementary detector circuit for frequency-modulated waves. CD is tuned to the lower extremity of useful side bands, AB to the upper extremity. The voltage appearing across either circuit is determined by the amplitude of the audio modulating voltage. A hybrid wave appears across each circuit. Rectification recovers the audio component.

appear as frequency modulation produced by the phase shift resulting from the combination of the signal and noise voltages. For the case where the peak noise amplitude is half the signal amplitude and the phase relation between signal and noise is ninety degrees, the maximum phase shift would be approximately 26.5°. Very little frequency modulation will be produced if this phase shift is the result of noise modulated by a *low*-frequency audio component, but the frequency modulation will increase directly with the frequency of the audio noise component. The receiver will display greatest susceptibility to noise frequencies above audibility. Logical design of the receiver would call for a sharp cut-off of the audio amplifier response or, better still, a falling high-frequency characteristic, which will reduce the hiss response. A simple predistortion network at the transmitter will present a compensating rising high-frequency response so that the overall response of the system is flat. This is the arrangement used in the stations now on the air.

The very remarkable effect of the limiter action upon the suppression of interference has been demonstrated by Weir.[2] He reports that with two stations operating on the same channel the stronger station would prevail 100 per cent at the receiver whenever the stronger station's signal was more than twice the strength of the weaker signal. He also reports in the same paper that no interference area of the usual kind existed where the signals were of nearly the same amplitude. In this area the movement of the antenna a few inches would throw one program out and bring in the other one. The presence of standing waves accounts for the phenomenon since the nodes would permit the selection of the required voltage ratio.

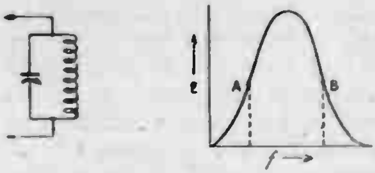


Figure 7. A parallel-resonant circuit will act as a frequency detector when tuned to carrier at points A or B. With the circuit tuned so that the carrier is at A, the voltage across the circuit will rise and fall in step with the deviation produced by the modulating voltage; the result is an amplitude-modulated wave which is also frequency-modulated. A rectifier will recover the amplitude audio component.

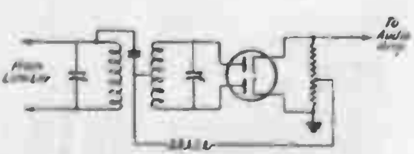


Figure 6. The discriminator circuit combines the functions of frequency detector and rectifier to recover the audio signal.

Mathematically the action of the limiter is rather complicated, but the results of the limiter action

[2] I. R. Weir, "Field Tests of Frequency and Amplitude Modulation with Ultra-High-Frequency Waves," Part I *General Electric Review*, May 1939

are an overall effect of cutting the amplitude of the received voltage in such a way that the strong signal component dominates while the weak signal is suppressed. In other words, the strong signal will always take control of the receiver. The frequency-modulation system permits[2] as much as 25 db gain in signal-plus-noise-to-noise ratio over that possible with an amplitude system of equal carrier strength.

While this gain in equivalent power is due in part to the limiter action it is also the result of the very interesting effect which makes the magnitude of the recovered power at the receiver a function of the modulation deviation. If a deviation of 50 kc. produces voltage *A* at the receiver, then a deviation of 100 kc. will produce a voltage two times *A* at the receiver. Here the received voltage has been doubled without changing the carrier power at the transmitter. In the amplitude case the peak carrier power must increase four times when the modulation changes from zero to 100 per cent. Since without the power change the received voltage increases for the frequency-modulated system with an increase in deviation, it follows that the advantage of the system over the amplitude system will increase as the deviation is increased. The practicable limits must be determined by available channel width. The Federal Communications Commission has assigned 200-kc. channels for the broadcast stations now in operation. For this channel width the deviation will probably be restricted to 80 kc. or less. Present standards seem to point to a modulation index (that is: ratio of deviation to audio frequency) of $\frac{80,000}{15,000}$, or approximately 5.3.

Necessarily this is a very sketchy account of Major Armstrong's invention. The writer hopes that it may serve as an introduction to the subject, and for those who are interested in the more detailed and technical aspects a carefully selected bibliography is appended.

Selected Frequency Modulation Bibliography

1. Carson, John R. "Notes on the Theory of Modulation." *Proceedings IRE,* Vol. 10, No. 1, February, 1922. First paper in which the frequency-modulated wave is analyzed mathematically and the required "band width" determined.

2. Armstrong, Edwin H. "A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation." *Proc. I.R.E.,* Vol. 24, No. 5, May, 1936. Undoubtedly the classical paper in the field. The first published account of the wide-band frequency modulation system.

3. Crosby, Murray C. "Frequency Modulation Noise Characteristics." *Proc. I.R.E.,* Vol. 25, No. 4, April 1937. Mathematical treatment and experimental verification of wide-band frequency modulation *vs.* amplitude noise suppression.

4. Roder, Hans. "Frequency Modulation." *Electronics,* Vol. 10, No. 5, May, 1937. Mathematical analysis of validity of noise-suppression effect in wide-band frequency modulation.

5. Carson, John R. and Fry, Thornton C. "Variable Frequency Electric Cir-

cuit Theory with Application to the Theory of Frequency Modulation." *Bell System Technical Journal*. Vol. 16. No. 4. Fundamental formulas for variable frequency electric circuit theory are developed. Transmission, reception and detection of frequency modulated waves are studied analytically.

6. Roder, Hans. "Tuned Circuits and a Frequency Modulated Signal." *Proc. I.R.E.*, Vol. 25, No. 12, December, 1937. Mathematical treatment of tuned circuits.

7. Weir, I. R. "Field Tests of Frequency-and Amplitude-Modulation with Ultra-High-Frequency Waves." *General Electric Review*, May, 1939, Part I; June, 1939, Part II. A very important paper of interest to both the technical and non-technical readers. Describes a simplified transmitter.

8. Day, John R. "A Receiver for Frequency Modulation." *Electronics*, June, 1939. The first published constructional data on a 7-tube FM receiver.

Photoelectric Effects on Neon Tubes

IN ANY circuit using small neon glow lamps (such as the GE types G-10, S-14, T-4½ and probably others) under conditions where the breakdown voltage is of importance, it is often necessary to consider certain photoelectric effects observable in many of the bulbs commercially obtainable.

The author first observed the effect of light on neon bulbs in a simple audio oscillator used as a nerve stimulator at Harvard Medical School. This oscillator consisted basically of a condenser charging through a high resistance and discharging through a neon bulb. When the cover of the box containing the apparatus was raised, thus exposing the glow lamp to the light, the frequency of the oscillations was increased, more or less proportionately to the amount of light falling on the glow lamp.

Later this phenomena was made the subject of a brief laboratory study, with some quantitative data taken. Voltage across the glow lamps was varied by means of a slide wire, and a meter in series with the neon bulb indicated the point at which breakdown occurred. One neon bulb was measured which broke down at 70 volts when kept in the dark, while in moderate daylight this bulb would begin to glow at about 62 volts, while if a 100-watt arc light were brought within a foot of the bulb the breakdown became about 55 volts.

It was further shown that if the voltage across the glow lamp was held just below breakdown, for the maximum amount of light encountered in a particular application, that the neon bulbs all exhibited properties equal to those of a not-too-sensitive phototube.

In general it was necessary to use an extra stage with moderate gain to get comparable voltage amplification from the associated amplifier, as compared to the amplification necessary from a good gas photo-cell.

The experiments show however that whenever neon bulbs are used in voltage regulators, in simple oscillators of the type first mentioned, or in many other similar applications where continuously uniform breakdown voltage is desirable, that it is necessary either to keep the level of illumination on the glow lamp constant, or better to coat the outside of the glow lamp with an opaque material.

—Arthur K. Baker, Electronics, September 1939.

¶ From Radio
July, 1939

The Expanded "LAZY H" *or* X-H ARRAY

By W. W. SMITH

THE "Lazy H" array, dubbed the *Lazy H* because it looks like an H in supine repose, was pointed out in this magazine three years ago, and its sundry virtues have been plugged at various times since. The array has high radiation resistance, is 100% horizontally polarized, is a low-angle radiator, and is easy to erect.

High radiation resistance means low voltages and a broad resonance curve, which permits use of inexpensive insulators and enables the array to be used over a fairly wide range in frequency. The fact that there is no vertical component in the polarization means that pickup of man-made noise will be minimized when the array is used for receiving. Many supposedly horizontally polarized arrays do not cancel the vertically polarized component completely except at zero and certain other vertical angles.

The Lazy H is essentially a four-element colinear-cophazed "curtain," giving a fairly sharp bidirectional pattern, with an apparent power gain on 10 and 20 meters (where low angle radiation is required) that will make you wish you had put up one sooner.

• Evolution of the "X-H Array"

It is a well-known fact that the directivity and gain provided by two colinear half-wave dipoles can be increased by separating them so that the current loops are somewhat over a half wave apart. Likewise Brown[1] has shown that greater broadside directivity and gain occur when a half-wave radiator is lengthened to 230 degrees. The latter applies to a vertical radiator worked against earth, but by ar-

[1] Brown, "Broadcast Antennas," *Proc. I.R.E.*, Jan., 1936, p. 53.

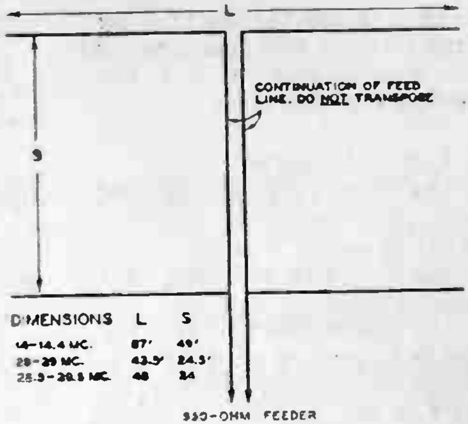


Figure 1. The X-H Array. Good results can be obtained using the array on half frequency. Thus the 10-meter array can be used on 20 meters and the 20-meter array on 40 meters. Let the phasing section (length S) hang loosely, so that the actual separation of the elements is slightly less than dimension "S".

ranging two such radiators horizontally so that they work back-to-back[2], two factors contribute to an increase in gain over the usual arrangement of two colinear dipoles where the radiators are each 180 degrees long and the current loops separated by one half wavelength. The extended arrangement derives an increase in gain both because the elements are 230 degrees long instead of 180 degrees, and because the current loops are separated by 280 degrees instead of 180.

Referring to Mr. Brown's charts again, we see that cophased dipoles in a curtain arrangement do not show maximum broadside directivity or gain at the common 0.5 wavelength spacing, but at approximately 0.65 wavelength spacing.

Observation of the dimensions of the array in figure 1 will show that the radiating element lengths have been increased to 230 degrees and that the spacing has been increased to approximately 0.7 wavelength; otherwise it looks exactly like the familiar Lazy H with two exceptions: the phasing section is not transposed and no matching stub is used.

Increasing the element lengths and spacing beyond 0.5 wavelength results in parasitic lobes being radiated both in a vertical and a horizontal plane. However, the magnitude of these lobes is small, and effects of their presence can be ignored; the advantage of greater horizontal and vertical directivity and increased gain is of much greater importance. It is comparatively easy to increase the gain of any array which does not have much gain to begin with; but when the gain of an array already having a gain as high as that of the Lazy H can be raised several db, it is really an accomplish-

[2] Romander, "The Extended Double Zepp," *QST*, June, 1938, p. 12.

ment. The modified version of the Lazy H array that does just this has been dubbed the X-H (expanded, extended H).

• Two-Band Operation

The X-H array can be used with good results on *half* (not twice) frequency with no changes whatsoever, thus permitting two-band operation.

The gain at half frequency will not be as great as when the array is used on its regular frequency, but there is still gain over a regular dipole. The general shape of the pattern is the same on both bands, but it will not be so sharp when the array is used on half frequency. In other words, when a 10-meter X-H array is used on 20 meters, the feed line will still be sufficiently well matched and the array will still be directional broadside, but neither the gain nor directivity (both vertical and horizontal) will be as great as on 10 meters.

• Summary of Advantages

Summarizing the advantages of the expanded Lazy H over the conventional version, we have the following:

1—Greater horizontal directivity
2—Sharper vertical directivity of main lobe, minimizing fading
3—Increased gain
4—Can be used with good results on half frequency with no change, permitting two-band operation
5—Untuned feeders require no stub or transformer on either band

• Standing Waves

The business of standing waves for some reason has become a bugaboo to many amateurs. It is nice to have a "flat" transmission line—a line which has uniform current—but it is *not* necessary for high efficiency. There can be very little radiation or pickup by a *balanced* two-wire line spaced not more than 6 inches; so the only item with which we have to concern ourselves is to make sure neither the current nor voltage reaches excessive values.

If the current excursions along a line do not exceed 3 to 1, we safely can ignore the standing waves, provided the line is inductively coupled to the output stage. If the line is clipped directly on the output tank, it is a different matter; the losses in the line may still be low, but unless the line is an integral number of half waves long it will couple reactance into the output tank. If one prefers to clip the line directly on the output tank, it is a simple matter to lengthen the line to the next integral number of half waves and thus avoid the reactive effect and consequent detuning of the tank circuit.

In the X-H array, two-band operation called for a compromise in the point of attachment for the feed line. To give a perfect match on both bands, the line should have a surge impedance in the neighborhood of 250-300 ohms. A line of this surge impedance is awkward of construction, and as standing waves will not be bad enough to be serious when a 550-600 ohm line is used, the latter was decided upon. A perfect match may be obtained on *one band* with the 550-ohm feeders by sliding them up the phasing stub a short distance or fanning them out a little either side of the center of the bottom section. Unfortunately it is necessary to slide the feeders one way for one band and the other way for the other band. The point of attachment shown is a compromise which will result in current excursions of about 3 to 1 on both bands.

If the slight reactance appears objectionable, the line should be made an exact integral number of half waves long on the lowest frequency band. Thus if a 10 meter X-H array is to be used on both 10 and 20 meters the line should be a multiple of 34 feet. If used only on 10 meters, the line may either be made any multiple of 17 feet, or else tapped to a point on the array that will give a perfectly "flat" line. The point can be determined by experiment.

- Construction

While the X-H array tunes quite broadly and therefore is not especially critical as to frequency or length, it is nevertheless a good idea to use copper-clad steel-core wire for the array to assure permanency of installation. Cut the elements exactly L/2 long and make the phasing section exactly S long. Soft-drawn wire stretches alarmingly when subjected to continued strain, and should not be used. Hard-drawn copper will suffice for a 10-meter installation, but in a 20-meter installation steel-core wire is advised because of the greater span and weight. If the cost is prohibitive, use steel-core only for the upper horizontal element. There is much less strain on the rest of the array, and *hard-drawn* copper will do for a 20-meter job in a pinch if the *upper* elements are steel core.

Do *not attempt to pull the phasing stub tight*, as it is impossible to do so without having considerable sag in the top section and a bad arch in the lower radiators. It does not hurt to allow the phasing section to whip around a little, so let it hang loosely. It is better to have slightly less than rather than slightly more than 0.7 wavelength spacing. If you try to pull the phasing section tight the mean element spacing will exceed 0.7 wavelength.

The bottom of the array should be at least 10 feet above ground for either a 10- or 20-meter array. There is little point in going higher than this if the antenna is in the clear, but the array may be raised to advantage if surrounding objects seriously "hem in" the lower section of the antenna. Do not raise the 20-meter array any more than necessary to get the bottom section in the clear, as the vertical radiation pattern is already low and quite sharp, and raising the array high above effective earth lowers the angle of radiation still further. Thus on 20 meters it is

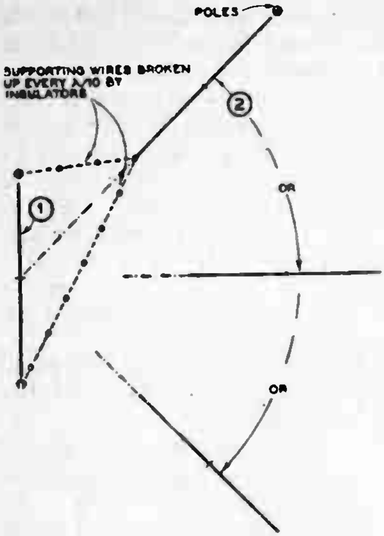


Figure 2. Illustrating how two dipoles or arrays with horizontal elements can be supported from three poles with a minimum of coupling between the two systems. This is an important consideration if maximum directivity is desired.

possible to get the antenna *too* high for medium distance work (1500 miles), though on 10 meters the array can be put as high as you want to go. Sixty-foot poles will be about right for the average 20-meter installation and 35- or 40-foot poles for a 10-meter job. When a 10-meter X-H is used on 20 meters, the vertical directivity is not sufficiently sharp that one need worry about getting the array too high.

In order to obtain the proper phase relationships in the X-H, that portion of the feed line connecting the upper and lower sections of the array—sometimes referred to as the *phasing section*—is not transposed as in the case of the conventional Lazy H.

One effect of the sharp vertical directivity obtained when the X-H is used on the band for which it was cut (resulting from the 0.7 wavelength spacing) is reduced fading. This in itself is an important advantage.

• Two

If two X-H arrays, or dipoles or most any arrays for that matter, are used to cover four directions, one array will excite the other as a result of electrostatic and electromagnetic coupling *unless* care is taken in their orientation. This mutual coupling will result in decreased directivity and a slight loss in gain.

To minimize coupling between two horizontally polarized arrays resonant on the same band, they should be oriented so that a line extended through one of them can be made to intersect the center of the other array. This is illustrated in figure 2. To eliminate the necessity for four poles, antenna no. 2 is supported at one end by means of a "V" branching out to both of the other two poles. These two wires should be broken up thoroughly with insulators every few feet as they are right in the field of array or antenna no. 1.

¶ From Radio News
October, 1939

SERVICEMAN'S EXPERIENCES*

By LEE SHELDON

YOU can always spot a tube customer, because he carries his old ones in a brown paper bag. The bag has a column of delicatessen figures on its side. He places it on the counter and pulls the tubes out, one by one, without saying a word. You stand before him quietly during the ritual; then, after the inner wrappers—sheets of a Saturday supplement—have been removed, he says:

"Can you check these for me?"

"Certainly," I reply. "Step right over here."

This one particular fellow had two *45's*, an *80*, a *27* and four *24's*. Not *24A's*, mind you—*24's*. They were so old you could wipe mercuric oxide off the outside of the bulb with your thumb.

"Rather old, aren't they?" I remarked, to prime him pleasantly after waiting four minutes for the first cathode to heat up and give.

"Best set of tubes I ever had," he answered snapping his suspenders proudly. "In fact, they are the *only* ones I ever had. Came with the receiver!"

"They all wear out sooner or later," I countered, intent upon a sale. I knew Al was in the rear of the store, listening, so I brought all my sales pressure to bear.

But the customer did not respond in the proper manner. He frowned, as if I had insulted an old friend and said: "They *must* be good, or they would have burned out long before this!"

I smiled tolerantly, explaining that a tube was not a light-bulb; that its visible indications had no relation to its efficiency as an electric valve.

"Look!" he said, pointing triumphantly. The needle on the traitorous *Salutary Sales & Service* tube checker, after what surely must have been a tremendous effort, registered *Good!*

"That often happens," I stage-laughed. "Wait until you see the readings of the others." The remaining three *24's* although blink-

* This department appears as a monthly feature in *Radio News*.

ing from age, drove the needle steadily up through *Dead, Very Weak, Weak, Very Moderate, Moderate, Very Doubtful, Doubtful* and over the line to *Good.*

"Hmmm," hummed the customer, marking them "okay" with a red crayon.

I put the *27* in. It was so old the cathode squeaked when the heat hit it, but it registered *Good.*

"Humph!" the customer reenforced.

I knew the two *45's,* being filament tubes, would show their age more definitely than the others. I turned on the checker, and the needle stopped between *Doubtful* and *Good.* I glanced questioningly at the customer; he appeared uncertain for a moment, but when he examined the scale closely, he said: "The pointer is wiggling—the tube must be trying!"

"It's shaking with age," I maintained. "The output tubes have to do with quality. Have you noticed any depreciation of tone?"

"Gets better every day," he replied. "That needle wouldn't quiver if the tube wasn't vibrant and full of life. Here—test the last one."

I put the *80* into position and set my jaw. When I snapped the switch, the needle—after pulling back below zero for a flying start—smacked right over *past Good.* I refined some adjustments, bringing the needle back on scale, but not far enough to be convincing.

"Thanks," the passing prospect said, reaching for the tube. "That's an honest machine you have there, as sure as my name's O'Leary!"

"One moment, Mr. O'Leary," I said, determined to make a sale. "There are other tests. This is the power tube, and one can't be *too* careful!"

Well, I did everything to that rectifier but turn it inside-out. I gave it overload tests, underload tests; I used buttons that had never been touched before; I tested for shorts, for microphonics, for gas, water, and oil. Although our checker is equipped with six or eight visible and audible alarms, none of them went into operation. I was about to give up, but when I turned to O'Leary, he was inspecting one of the tubes we had already passed.

"I'll take one of these," he ordered, handing me the *27.* "Why didn't you *tell* me one of the stems was dirty?"

I pulled one of the new *27's* off the shelf and tested it. This time, the needle wavered uncertainly over *Doubtful* on its way up, but I was too unnerved to care.

"Eighty cents," I announced, dropping the new tube into the brown keg.

"Eighty?" he challenged, "why, I can buy this same—"

"Okay," I conceded from exhaustion, "make it seventy."

I knew my partner would be loaded with sarcasm, so to demonstrate how difficult the sale had been, I entered the rear of the shop with heavy eyelids and arms swinging like an ape's.

Al was at his desk, reading a

magazine. "Listen to this," he said, without looking up. "It says here that 'peasants in Bukovenia shave with their hats on. When a tourist asks why, they invariably ask him if he ever shaved the top of his head.' Isn't that interesting?"

"Get your feet off the desk so I can see your face," I demanded indignantly. "How can you sit back here reading that twaddle while I am out front wearing my test-prods down to the bakelite for you?"

Al snarled, stood up, and slowly tore the magazine in half. "I'm trying to let you down easily," he said. "I never make fun of a person who stumbles, but I have a justifiable squawk if he blames me for not falling with him. That exhibition you just gave reviewed twenty years of bad salesmanship and misuse of equipment!"

"Gwan," I defended, "I'll bet *you* couldn't have given that customer a season pass to the Kentucky gold cache. Besides, we need a new tube tester."

"You and your corny methods confine us to chicken-feed," Al replied. "When a customer comes into the store carrying a bag of tubes, it is an open confession something is wrong with his set. Go after the receiver maintenance first—and *then* sell tubes!"

"You mean I should ask him to walk out with his tubes and bring the chassis and speaker back with him?" I asked.

"It's a cinch no one ever retired on tube profits alone," he replied.

"Foolishness," I said. "Don't tell me I should turn away trade!"

"You shouldn't *force* any sale," was the answer. "Our tube stock and checker are meant to be useful adjuncts to our servicing business—not our main stock in trade."

Just then a customer entered. "Here comes a *brown bag,*" Al whispered, "watch me!"

"I have been to three radio stores trying to get this tube checked," the newcomer declared angrily, "and not one of the servicemen could pass on it. One of them tried to sell me a refrigerator; another offered me a bargain combination flat-iron and goldfish; and the last one tried to get me to leave my car for a carbon and valve job. Failing that, he tried to get me to stand in a stall while he pressed my pants. Before we go any further—is this tube good, or isn't it?"

Al inspected it. "An *874,*" he commented. Then he held it to his ear, tapped it with his finger and handed it back. "It's okay—let me see the others," he requested.

"Do you mean to say," the customer asked, handing the bag to Al, "that I have actually located an old-fashioned radio serviceman, and that all the tube needed for a test was a knowing ear? I had begun—"

Al was unwrapping the newspapers from the remaining tubes, calling their type numbers: "two *81's,* a *10,* some *26's,* and a *27.* Yes, some of us are still alive. Tell me—did your *Kolster* act up a bit before it broke down?"

"Say—your name isn't Holmes, is it?" the customer asked, pleasantly astonished. "No, it didn't—it just stopped. Are all the tubes good?"

"The two *81's* are shot," my partner announced.

"How much are they?" the prospect asked, reaching for his pocketbook.

"Two twenty-five apiece," Al said, "but I won't sell them to you!"

"No?" the customer asked, shedding some of his good-will. "Haven't you any in stock?"

"Sure," my partner replied, "but if I sold them to you, you'd take them home, put them into your set, and burn them out within fifteen minutes—without hearing any music."

"Why is that?"

"Your filter block is shorted. Let me follow you home in the truck, and I'll show you what I mean," Al said, walking to the door and picking up the tool-bag on the way. "You see, I want to sell you exactly what you need to bring your set back to normal—not something both of us will lose money and good-will on."

Al returned with the chassis in about an hour. He lugged the pieces to the bench, and announced: "Filter block, volume control, complete set of tubes. Isn't that better than begging for a premature tube sale?"

"How did you know it was a *Kolster?*" I asked, curious, but unwilling to admit defeat, "and how did you know the filter block was shot?"

"Ever come across another set with the same tube combination?" Al asked. "I guessed on the filter block—the *81's* were both open, and even if they *had* been the trouble, I wouldn't have sold them without making sure he wouldn't ruin the new ones as soon as he put them in—and put me in a spot where I couldn't make a replacement under the guarantee."

"You were just lucky in this one case because of the trouble he had on the *874*," I said. "On another set—"

"—I would have used my head some other way," he answered impatiently. "Ah—how can I change you in five minutes, after you've had the habit of bad thinking for thirty years? Go to the front of the store and think it over for a while!"

I walked out and leaned against the show-window railing. My partner can be very perturbing at times. Of course, he was partly right, but why should I have to admit—

The door flew open. O'Leary handed me a tube.

"Give me back that seventy cents, you daylight burglar," he shouted. "I put it into the set, and it didn't play. What kind of a racket you running here, anyway?"

"I'll go home with you and look at the set," I suggested meekly.

"Not after you sold me a tube I didn't need, you won't," he yelled. "I intend to do business with an honest serviceman—if *there's* a radio store in the neighborhood!"

I refunded his money and walked slowly to the rear of the store with heavy eyelids and arms swinging like an ape's. Al's feet were on the desk, and he was reading half a magazine.

"Listen to this," he said, without looking up. "It says here that 'A certain wide-awake manufacturer attends every convention of twins he hears about, in order to sell cuspidors to spitting images.' Isn't that interesting?"

"Yes," I sighed in defeat, "please read some more."

Al looked up slowly and gave me one of his infrequent smiles. "Another ten years, and I'll make a serviceman out of you," he said.

●

Cats

SOME time ago **Electronics** related the story from England of the discovery that leaks in cables could be traced by pumping a gas smelling of cats through the cable, and then running a dog up and down the outside. C. A. Briggs of Washington, D. C., thinks that he has something of use along this line. He says, 'What is the nature of that cat gas? Is it obtained by passing cats through gas or gas through cats? Some years ago a wood pussie found access to my basement and left a lingering reminder that needed no Labrador retriever to discover. If the cat gas is similar to my basement aromatics, is there a market for the stuff?"—Electronics.

¶ From Pick-Ups
July, 1939

CHIEF ENGINEER

By M. M. BEARD

Nation-wide survey reveals average height, 5 feet, 10 inches; weight, 163; age, 32; technical training, ability, rank high.

BACK of the elaborate and intricate machinery which turns the wheels of radio broadcasting stands that guardian of the air channels—The Chief Engineer. Over 82 million listeners in this country and millions more in foreign lands reap the benefits of his handiwork yet only a comparative few realize that there is such a person. What of this fellow who spends long days and many weary nights in an isolated transmitter building shooting a barrage of voices and music over the ether?

Although these men shoulder tremendous responsibilities in the radio industry and are called upon time and time again to meet the most dramatic emergencies, they seldom are brought to the public's attention. *Pick-Ups*, therefore, decided to tell their story, material for which has been gleaned from a nationwide survey. One objective of the survey was to draw up a composite picture of the Chief Engineer. To obtain a cross-sectional view of him sounds like a major operation. It was. But it was performed without a twinge in so far as the patient was concerned—for the instruments used were a stack of questionnaires, an adding machine and a lot of gray matter contributed by an expert statistician.

Although the operation proved to be a painless one for the engineers it resulted in a terrific headache for the statistician. Out of the 700 and some odd questionnaires distributed, 293 replies were received. Since a number of men replying are responsible for two, three or more stations, the completed survey represents more than 50 per cent of the chief engineers in the country.

Armed with this mass of information, the statistician set to work to record ages, personal appearance, schooling, marital status and numerous interesting highlights in the lives of these radio experts. Into the adding machine went the various ingredients mentioned. Out of the machine, like the genii of Aladdin's lamp, rose the face and form of the typical Chief Engineer.

Here he is—ladies and gentlemen of the radio audience—a most personable representative for America's great Broadcasting industry. He is 32 years old—he measures five feet ten inches in height—weighs 163½ pounds. Brown hair and blue eyes predominate. Our color chart lists 216 brown heads, 33 blonds, 26 black haired chiefs, 7 sandy heads, 3 auburn, 2 red heads and 7 distinguished gray heads. Blue eyes lead the race with a total of 132. Brown eyes, numbering 102, take second place. Coming up in the rear are 40 gray eyes, 10 hazel, 8 green and one lone black eyed engineer. Our typical chief is married and has one child. Bundling the offsprings into the adding machine en masse the statistician found that they number 258. On the basis of those who reported the sex of their children 53 per cent are boys. One chief offered the information that he is the proud granddaddy of two.

- Experience

Our chief has spent six years at his present station and four and one half years as head of the engineering staff. And a typical American he is, as only seven out of 293 were foreign born. Travel has colored his background and broadened the scope of his knowledge for he has visited 19 states and three foreign countries.

Evidently it is ability rather than age that tips the scales in the broadcasting business as the youngest chief, out in Texas, is a mere fledgling of 19 summers while the oldest, in Missouri, will shortly celebrate his 75th birthday. Ages listed range this way—130 between 20 and 30; 138 between 30 and 40; 20 between 40 and 50; two between 50 and 60 and two over the 60 mark.

- Education

Retracing their steps through the days of reading, writing and arithmetic, it was discovered that 278 completed high school—93 received college degrees, 65 had from one to three years of college training, 185 took supplementary courses in radio engineering. The survey shows a grand total of 261 out of 293 with either college or supplementary education. These amazing figures would indicate that broadcasting engineers as a class have reached a decidedly higher level of education than the average technical employee or for that matter than the average business executive in the United States. For many of the engineers, education has meant more than burning the midnight oil—it has meant working at almost any old trade to earn an education. According to the survey 136 worked their way through high school or college—46 worked part of the time during school years.

On a few questionnaires there appeared a rather wistful note indicating that the writers regretted not having had a more thorough technical training. Says one chief, "When visiting technical schools and watching some of the young men at their various experimental procedures, it occurred to me that if these future engineers could realize how important these facts are which the instructors are trying to drive into their heads, they would give their schooling more serious thought instead of rushing through as if education were a necessary evil in their lives."

The comparative few who were denied higher education have certainly proved that this handicap can be overcome. One man in particular who never had a day of high school training has climbed to top rank in his profession. Today he is known among radio experts throughout the country as an outstanding authority on broadcasting technique.

What some of these men have lacked in so-called formal education they have acquired in that well attended Hall of Learning—Amateur Radio. One hundred and seven of our chiefs-on-parade were hams. And very tender hams they were, having succumbed to the deadly bite of the bug at an early age. Our Typical Chief started experimenting with his tubes and wires about the time he first donned long pants. More than a few were tinkering around radio sets at eight, nine and ten years of age.

The survey discloses one young ham who got his start at four. Another chap explains his early interest in radio this way, "I've been interested in things electrical from the day I took out my first library card and found a book on electricity. I bought a 500 mile two slider tuner with crystal detector and have been at it ever since." Still another contracted the fever when he read a copy of Hugo Gernsback's "How to Build Wireless Receiving Sets." "I built one," he writes, "and I've never been cured." One young man "just hung around the transmitter at a college radio station doing odd jobs until they took me on." And here's a chief who blames it all on heredity—says he, "I come from a family of Radio Nuts." But most of these men were drawn to radio because of its mystery and fascination. They just can't help themselves—it's in their blood.

• From All Walks of Life

Although the majority have spent most of their time at broadcasting or in some kindred work, many sampled various jobs in alien fields. In the ranks are ex-teachers, bank clerks, bus greasers, airport mechanics, medical students, truck drivers, factory workers, type setters, druggists, grocery clerks, prospectors, janitors.

As a class they have wandered far over the face of the globe—47 having sailed the seven seas pounding brass as ships' operators. Our most travelled chief chalks up the record of 47 states and 25 foreign countries. Close at his heels are many of his colleagues, missing the high mark by one or two states and countries.

- Adventure!

And what strange and exciting tales these travelers can spin as they keep watch at transmitters during long tedious night hours! Adventure still dogs their footsteps for one never knows what dramatic emergency may tumble upon their broad shoulders.

Here's a chap who worked inside a burning transmitter building trying to save the equipment until he was forced to dive through a window a few minutes before the roof caved in. They piped the show through the local time sharing station and lost only 40 minutes on the air.

Another tells of spending 80 hours in the Pennsylvania mountains using short wave equipment in an attempt to locate a lost child. Antennas had to be sent up with kites and balloons to get a signal out of the mountain area.

A third describes the handling of a shortwave plane job off Barnegat Light Ship when the dirigible "Akron" sank. A fourth aided in the capture of a bank bandit as he followed the chase with a mobile unit.

An exciting tale comes from New Hampshire recalling the 1938 flood. It is told by the engineer who spent four days and nights without sleep operating a transmitter with a temporary generator and Fordson tractor. Another thriller from Oregon describes this happening at Coulee Dam—a huge gasoline scoop shovel exploded, throwing burning oil around the engineer who was arranging a microphone for a broadcast of the construction work at the dam.

Yes, any old emergency is apt to happen and here's a unique one. While operating a relay station from a Japanese rancher's barn, a 60 mile gale took the roof off and sailed it down the hill like a kite. Then came the rains. By piling bales of hay around and over the transmitter the engineer kept the station on the air.

One man broadcasting the approach of a cyclone from the top of a 100 foot tower saw a passenger train lifted from its tracks and completely wrecked. The cyclone missed the transmitter house by a close margin. Pinch-hitting for an announcer who got buck fever had its thrills for the engineer who interviewed four steel workers atop a 440 foot antenna. The five men stood on a narrow platform passing the mike around. Hi—those were dizzy moments!

Flood waters may submerge stations, hurricanes tear down antennas, sleet cripple wires, lightning shatter transmitters but it's all in the day's work for a chief engineer. It is his job to get his signal back on the air and back he gets it in record time.

• Common Problems

So much for emergencies. But what about the ordinary problems which accompany any job? Here's the biggest headache of them all, say our engineers in unison—*Selling the Management the Need for New and Up-to-date Equipment.* This is where technical and non-technical minds clash. The chief engineer follows new developments like a hawk. Sensing the keen competition among stations to win the public's patronage, he realizes that you can't perform miracles with an old, out-dated "rig." He knows that quality programs without quality transmission do not amount to a hill of beans. Therefore, he is constantly striving to improve the quality and range of his signal—while the management is inclined to keep its eye steadily focused on programs, sponsors and the budget.

Second on the problem list is rebuilding old equipment and trying to make it work like new.

These men growl too, about night work—but who can blame them for that! One chap has difficulty in convincing his wife that staying at the transmitter in the wee sma' hours is really necessary. Other problems are: meeting FCC regulations — keeping within the budget—trouble shooting—climbing towers—keeping a semi-technical boss happy though frustrated—pleasing the program department—being a diplomat—and strange as it may sound—keeping busy.

Now for the sunny side of the picture. Designing and installing new equipment brings the keenest enjoyment, as does working with new equipment. These chiefs are on top of the world when the station receives good reports from the FCC or when sponsors compliment them on smooth operation. A few gluttons for punishment actually enjoy trouble shooting. Underneath their joking and nonchalance, these men take their jobs very seriously and derive the greatest satisfaction in the thought that they are serving the public.

• Hobbies Diversified

While the work is extremely confining and although when off the job they invariably remain on call, they find time for a varied assortment of hobbies—some riding two, three or more. Yet even in such moments of relaxation the old bug hangs on, for 138 go in for ham radio. Next popular on the hobby list is photography with 81 clicking cameras. Then there are 33 fishermen, 26 huntsmen, 16 golfers, 7 amateur movie enthusiasts. Others go in for philosophy, psychology, minerology, chemistry, physics, meteorology. And astronomy has turned four of our chiefs into star gazers. The collecting instinct bobs up in the form of stamps, old weapons, match covers, clocks, pipes, trade magazines and Indian relics. Sport lovers seek diversion in boating, baseball, skiing, tennis, bowling, ping-pong, archery. In the ranks too are railway, airplane and boat modellers—metal and wood workers. One man raises dogs, another guinea pigs and a third chickens. An engineer in Indiana is trying out different systems for locating oil, gas, lead and spar—he's been experimenting five years. Another has just completed building a 17 foot cabin cruiser. And there's a chief who reads in five languages.

• On Vacation

Relaxation, too, comes to these men "when and if" vacation rolls around (according to many replies, vacations are uncertain quantities). The wanderlust creeps into their veins at such times. Ninety-five spend these precious interludes traveling. A runner up in popularity is fishing with 41 seeking mountain streams, lakes and the deep sea. Radio still rears its intrusive head—enticing 25 chiefs to drop in at various broadcasting stations and have a look at the other fellow's equipment. Others find their fun camping, farming, flying, swimming, boating and golfing.

Unfortunately, choice of a vacation does not always rest in their hands—time, money and sometimes wives being the determining factors. But they build their air castles and dream of the following ideal holidays: A far-away place with no alarm clocks, no telephones, no radio (this Utopia is going to be an over-crowded resort if wishes come true)—sleep and more sleep—big game hunt in Alaska—two weeks at Bell Telephone Laboratories with free admittance to all departments (we'll have to stretch the Laboratories to get them all in)—a horse, a pack outfit and lots of time—a visit to every broadcasting station in the country—time for experimenting. And travel, how they long for it! By freighter, trailer, car, steamer, plane they would seek new places, new faces, new adventure. Europe, The Tropics, Florida, Alaska, West Coast, East Coast, The New York World's Fair, Treasure Island, South Sea Isles are on their itineraries.

• Opinions of Technical Developments

Calling them back from these phantom voyages, *Pick-Ups* asked them—"What do you consider the most worthwhile development in broadcasting during the past ten years?" Their votes run this way: Stabilized Feedback—44; 110A Amplifier—39; Vertical Radiator—34; Doherty Circuit—27; Modern Microphones—26; Modern Tubes—20; Crystal Control—18; Class B Modulation—18; Directional Antenna—12; 100 per cent Modulation — 11; Facsimile — 8; Network Broadcasts—7; Shunt Excited Antenna—5; Television—5; Automatic Volume Control—3; Coaxial Antenna—3; Armstrong Frequency Modulation—2; Concentric Transmission Lines—2; 500 KW Power—1.

Looking ahead to the future of broadcasting, our chiefs predict the following advancements: Single Band Transmission; Chain Broadcasting of Television using Broadcast Band simultaneously; Binaural System; Radiating systems confined to angles below 5 degrees from the Horizon; Precision Frequency Control without Quartz Crystal or Temperance Controlled Circuits; High Fidelity Tubes large enough to develop 5 megowatts power; Electric Energy by Radio; Television in Color; Broadcasting Odors; Polyphase Transmission; Antenna System which will radiate ground waves only; Two Channels on One Carrier; Long Distance Concentric Lines and a 1000 watt transmitter for $1000.

Back from the future into the past again the survey took them, asking "If you had your life to live over would you be a radio engineer?" What a foolish question *that* was! In chorus, almost unanimously, they answer "Yes."

And so we leave our chiefs, tending their signals backstage in broadcasting's big show—chained with chains of their own forging to the great love of their lives, "Radio."

A NEW type 100-kilowatt radio tube in which the filament can be replaced, the first of its kind in this country, has been developed by engineers of the General Electric Company. Two of the tubes will be used in the new 110-kilowatt transmitter being completed for the General Electric short-wave station W2XAF which now operates on 40 kilowatts. The new transmitter is expected to be on the air by August 1.

These are the largest tubes of their kind yet to be built in this country, and are expected to produce an effective directional power output of more than 600,000 watts, when used with the new Alexanderson panel antenna. It is not anticipated that these tubes will replace the 100-kilowatt tubes in standard, or long-wave, broadcast transmitters.

The filaments of the new tubes can readily be replaced. Instead of the tubes being sealed off when built, an electrically driven pump is attached to them which runs continuously, thereby maintaining the vacuum at all times.

A new-type filament of activated tungsten was used in the tubes which allows greater current at lower voltages. Whereas the 50-kilowatt stations have been using upwards of 15,000 volts to operate the tubes, the new units will operate on from 5,000 to 8,000 volts.

¶ From Aero Digest
September, 1939

Research in Aviation Radio

By F. C. McMULLEN
WESTERN ELECTRIC CO.

IN the United States, the prime emphasis of aviation engineering over many years has been on *safety* in the air. Perhaps as important in achieving safety as the actual design of aircraft itself has been the work of scientists in the field of communications. Aviation radio engineers over 22 years have reduced steadily the element of human error in flying, have pushed the horizon of danger further back, have sent reassuring voices into the sky to guide the flyer home.

Just as the growing railroad industry found the telegraph a tremendous boon in safely routing millions of passengers along the rails, so is aviation fortunate in its contemporary, radio telephony. Behind each piece of communications apparatus in the modern airplane already lies a long tradition of research in the field, during all of which the communications industry has worked hand in hand with the airlines and with various government agencies. Each unit commonplace to the airman of today represents the practical results of intensive scientific inquiry and experiment in years gone by. The laboratory miracle of today gives us the commonplace of tomorrow.

As early as 1917 a Signal Corps officer talked to a squadron of airplanes flying overhead and heard the commander reply. Previous triumphs by telephone engineers who had succeeded in spanning the ocean by radio telephony in 1915, made possible this official demonstration of the ability of the man on the ground to talk with the man in the sky—and get an answer.

During the post-war period aviation prospered. Mail and passenger routes began to weave a net over the map of the U.S. In 1927, it became evident that airmen must have more efficient instruments for navigation and for two-way communication.

Early in 1928 a monoplane whose markings were more familiar on telephone booths than on airplanes became a familiar sight to airport personnel along the Eastern seaboard. The apparently aimless meanderings of this Bell Telephone Laboratories ship were actually careful field-strength surveys, transmission tests, analyses of the frequencies most suitable for aircraft use. In the mountainous West similar tests were being made in cooperation with Thorp Hiscock of Boeing Air Transport and later with Herbert Hoover Jr. of Western Air Express. These simultaneous surveys produced results in increased knowledge ot the best frequency allocations for aircraft communications, in discovery of the necessity for separate day and night frequencies, the use of fixed transmitting antennas, the substitution of a high voltage dynamotor in place of the old wind-driven generator, and countless other contributions.

In the early days of radio telephony the pilot had to tune his receiver by hand, often with extremely poor or no results at all. The obvious need was a device for locking the pilot's receiver in tune with the ground transmitter. Intensive development by Bell Telephone Laboratories produced the AT cut crystal and this problem was solved. This basic development is responsible for the quick-shift multi-frequency radio equipment which enables the airline pilot to make contact with successive ground stations operating on different frequencies, day or night, with a flick of the dial.

- Blind Landing

One of the greatest contributions to safe flight has been research done on instrument or "blind" landing. On Sept. 24, 1929 Lieut. Jimmy Doolittle, guiding his ship from a sealed cockpit, safely landed his plane at Mitchel Field and completed the first successful instrument landing in history.

Two years later Pilot Boggs made a blind landing at College Park, Md. Diamond and Dunmore of the Bureau of Standards had succeeded in developing a complete three-dimensional system which employed a constant-intensity glide path in the vertical plane as well as a runway-localizer and marker beacons. Most of the instrument landing systems which have come into prominence during the past 6 years are based on this development.

In 1933 the Airways Division of the Department of Commerce began experiments on an instrument approach system which had the advantage of simplicity. The pilot flying toward the radio range, picked up from a marker signal his cue to begin his glide and followed through depending largely on his altimeter. This system, together with the Army System adopted by the Bureau of Air Commerce, was deficient because of the inaccuracy of barometric altimeters and was rejected by the airlines. However, with the development of the absolute radio altimeter (terrain clearance indicator) this system might find wider use as it reduces to a minimum the ground equipment necessary for instrument approaches.

Extensive trials are now being carried on with the Metcalf-CAA blind landing equipment. With this system three radio-actuated dots appear on the surface of a cathode ray oscilloscope set in the instrument panel. When these spots line up horizontally with the middle dot exactly centered, the pilot is on course. The advantages of this system are its compactness and the fact that it employs a substantially straight glide path.

Research by vacuum tube engineers succeeded in producing tubes capable of a high-power output at extremely high frequencies, making possible the practical application of this system.

No better demonstration of the evolutionary spirit of research could be found than this development of instrument flying. But research also concerns itself with the removal of flaws in already existing devices, in constant tests so that pilot and passenger may derive the fullest measure of protection in the air. Many a pilot has followed his beam into the storm only to have it obscured by precipitation static. Over a number of years the nature and cause of this static has been sought. It was originally attributed to charged particles striking against the antenna, and a shielded loop such as those used on steamships was proposed by TWA's Jack Franklin. This device was adopted almost universally and was found to operate reasonably well. Precipitation static, however, was by no means completely eliminated. In 1937, therefore, an expedition of scientists, meteorologists and engineers under the leadership of H. M. Hucke of United Air Lines made many field studies under actual flying conditions of snow, dust, and rain to discover that the static was largely caused by discharges from the surface of the plane itself. A trailing discharge wire and suppressor resistor now foils precipitation static.

More recent research has produced the ultra-high frequency radio range, the ground direction finder, the automatic radio compass, the terrain clearance indicator—all contributions to safety in the air, all tributes to research in aviation radio.

• U.H.F. Frequency Ranges

All the radio ranges employed in the U. S. up to this time operate on medium frequencies (200 to 400 kc), but with the multiplication of landing fields, transmitters in this band have become too closely spaced to allow further allocations. Today the CAA is working on ultra-high frequency ranges at Pittsburgh and at Indianapolis which have the advantage over previous systems of substantially eliminating storm static and providing more reliable course indications.

A pilot, flying his regular route, calls in to report progress. As his voice "comes in," a tiny green light flashes on the periphery of a ground glass screen marked with compass indications. The dispatcher calls back, gives the pilot his exact bearings in relation to the field. This Western Electric ground direction finder, completely automatic in operation combines regular two-way communication with a visual indication on the screen of a cathode ray tube.

Research has recently produced another device to reduce the element of human error in the air, the automatic radio compass developed by Sperry Gyroscope Co. and the RCA Manufacturing Co. When this device is tuned to a particular station, a dial needle points immediately the direction of that station and will continue to give the bearings automatically even when the plane passes over the cone of silence.

- Terrain Clearance Indicator

Perhaps the most conspicuous result of recent aviation research has been the extremely sensitive Western Electric terrain clearance indicator, developed by Bell Laboratories and made possible by a new vacuum tube capable of 50 times greater power at high frequencies than any previously produced for aircraft use. Barometric altimeters which indicate the altitude above sea level are often inaccurate as much as forty crucial feet, require a knowledge of the locale for a correct estimate of terrain clearance. The new device employs an ultra-high frequency radio wave which it bounces off the ground. The time of the wave's excursion from plane to ground and back again is indicated almost instantaneously in feet on a meter in the cockpit.

Facsimile communication between ground and air is the subject of much research today. Already tests have been made by RCA, Finch, Teletype Corp. and others which show that the device has considerable promise. Continuous research is expected to develop units of small size and increased reliability.

Even now researchers are probing the possibilities of frequency modulation and its application to aviation. Aviation radio could use its low power requirements, its freedom from cross channel interference, the reduced weight of its equipment, but must overcome the static interference which completely dominates the signal when the noise ratio is high.

At no other time in the history of aviation has there been so much research activity in the field of radio. The CAA is contemplating the installation of a model ultra-high beacon system from Newark to Chicago in order that the research on the behavior of ultra-high waves may be carried on in a 700-mile laboratory under actual operating conditions.

The major airlines have formed development sections in their communications departments, working with the manufacturers' laboratories to produce, perfect and adapt new radio equipment. Research in the processes of manufacturing is being applied to bring the last measure of efficiency to the production of radio equipment.

The research and development facilities of the communications laboratories throughout the world are systematically probing for the germ of an idea that will, by specific application, benefit aviation. New alloys to reduce weight and increase strength, new compounds to eliminate corrosion and reduce the harmful effect of moisture are being sought. Destructive tests simulate a lifetime of service in a few hours. The by-products of research reach the plane only when their absolute reliability has been proved by these tests.

(See pages 52-53 for photographs)

•

Think!

DR. de FOREST sends us a query addressed to him. "I am working to get scientists interested in my thought phone. It is composed of a metal bulb a hundred or more feet in height. The interior parts are analogous to a triode radio bulb. The sounds emitted by the brain as it thinks can be picked up by a radio amplifier of great power and selectivity and rendered audible."—Electronics.

•

"Microscopic" Bearings

COMPLETE ball bearings only 1.5 millimeters (about $\frac{1}{16}$ inch) in overall diameter are now being produced in Switzerland. These bearings, no larger than a pin head, are being used to replace jewel bearings in clockwork, meters and precision apparatus of all types. The bearings are said to show a great reduction in friction over the jeweled bearing.

—Ohmite News.

¶ From RCA Review
July, 1939

A PUSH-PULL U.H.F.
Beam Tetrode

By A. K. WING

THE frequency spectrum above 100 megacycles has proved itself valuable for communication over line-of-sight ranges. Since relatively small amounts of power are satisfactory and it is relatively easy to build efficient antennas for communication at these frequencies, the frequency band above 100 megacycles seems to be eminently suited for aircraft communication from plane to plane or from plane to ground over short distances. It was for such an application that the development of a tube suitable for use in the output stage of transmitters was undertaken.

Consideration of some of the necessary points in the design of a satisfactory ultra-high-frequency transmitter indicates a number of limitations and qualifications which a suitable tube should meet. In order to make the equipment simple and operable at all times its filament and plate power should be obtainable from the regular storage battery, and should be kept at a minimum. To have frequency stability, the transmitter should consist of an amplifier stage driven either by a crystal-controlled oscillator through a frequency multiplier, or by a stable high-frequency oscillator. The transmitter should preferably be capable of operating at several frequencies and the final amplifier stage should operate stably at frequencies up to approximately 250 megacycles. A useful output of the order of 10 watts was chosen as sufficient for requirements.

There are several limitations on the proposed tube which are determined by these considerations. In the first place, the tube must be economical in filament and plate power. Second, because of the difficulty of insulating high voltages at the reduced pressures encountered at high altitudes, the operating plate voltage must be as low as possible. Therefore, a value of 400 volts for unmodulated service was decided upon. Third, the tube must function as a stable amplifier. The necessity for neutralization would render a triode unsatisfactory for operation over a band of frequencies and, consequently, a tetrode or pentode design was indicated. Because it is possible to develop a greater plate voltage swing in a pentode or beam power amplifier than in a tetrode for the same direct plate voltage, and thus to obtain higher plate-circuit efficiency, the beam power-amplifier design was chosen for this tube. The reasons for choosing the beam power amplifier in preference to the pentode will be discussed below. The use of a low plate-supply voltage makes it especially desirable to have the peak plate-voltage swing as high as possible. And last, the tube must be sufficiently rugged to withstand vibration and physical shock without an elaborate mounting. Simplicity in tube and circuit is important to insure satisfactory performance and ease of maintenance.

Besides these requirements, there should be noted those requirements which are imposed by the frequencies at which the tube is intended to operate. The various qualifications which a tube should possess for successful operation at high frequencies have been covered rather completely in the literature.[1 2 3] The important considerations which entered into the design of this tube are summarized below:

1. The tube must lend itself to satisfactory circuit design. The greatest possible amount of circuit must exist outside the tube at any given frequency. In order to meet this requirement, the input and output capacitances and the lead inductances must be kept at a minimum, and the tube must be small in size. For the higher frequencies, the use of transmission lines as circuit elements has the advantage of allowing greater physical size of circuit than when lumped circuits are used. The tube leads should preferably be so arranged that the tube is adaptable to operation in either type of circuit.

2. The leads to the tube electrodes must be of such a size as to carry safely the high-frequency currents to the electrodes and to avoid losses which would reduce the output.

3. In order to minimize the limiting effect of electron transit time, the spacings between electrodes must be kept small. In particular, the cathode-to-grid distance must be small since it is in this space that the electron must be accelerated from a low velocity at the cathode surface to a consider-

---

[1] W. G. Wagener—"The Developmental Problems and Operating Characteristics of Two New Ultra-High-Frequency Triodes," *Proc. I.R.E.*, Vol. 26, pp. 401-414; April (1938).

[2] M. J. Kelly and A. L. Samuel—"Vacuum Tubes as High-Frequency Oscillators," *Bell System Tech. Jour.*, Vol. 14, pp. 97-134; January (1935).

[3] C. E. Fay and A. L. Samuel—"Vacuum Tubes for Generating Frequencies Above One Hundred Megacycles," *Proc. I.R.E.*, Vol. 23, pp. 199-212; March (1935).

¶ From RCA Review
July, 1939

A PUSH-PULL U.H.F.

Beam Tetrode

By A. K. WING

THE frequency spectrum above 100 megacycles has proved itself valuable for communication over line-of-sight ranges. Since relatively small amounts of power are satisfactory and it is relatively easy to build efficient antennas for communication at these frequencies, the frequency band above 100 megacycles seems to be eminently suited for aircraft communication from plane to plane or from plane to ground over short distances. It was for such an application that the development of a tube suitable for use in the output stage of transmitters was undertaken.

Consideration of some of the necessary points in the design of a satisfactory ultra-high-frequency transmitter indicates a number of limitations and qualifications which a suitable tube should meet. In order to make the equipment simple and operable at all times its filament and plate power should be obtainable from the regular storage battery, and should be kept at a minimum. To have frequency stability, the transmitter should consist of an amplifier stage driven either by a crystal-controlled oscillator through a frequency multiplier, or by a stable high-frequency oscillator. The transmitter should preferably be capable of operating at several frequencies and the final amplifier stage should operate stably at frequencies up to approximately 250 megacycles. A useful output of the order of 10 watts was chosen as sufficient for requirements.

There are several limitations on the proposed tube which are determined by these considerations. In the first place, the tube must be economical in filament and plate power. Second, because of the difficulty of insulating high voltages at the reduced pressures encountered at high altitudes, the operating plate voltage must be as low as possible. Therefore, a value of 400 volts for unmodulated service was decided upon. Third, the tube must function as a stable amplifier. The necessity for neutralization would render a triode unsatisfactory for operation over a band of frequencies and, consequently, a tetrode or pentode design was indicated. Because it is possible to develop a greater plate voltage swing in a pentode or beam power amplifier than in a tetrode for the same direct plate voltage, and thus to obtain higher plate-circuit efficiency, the beam power-amplifier design was chosen for this tube. The reasons for choosing the beam power amplifier in preference to the pentode will be discussed below. The use of a low plate-supply voltage makes it especially desirable to have the peak plate-voltage swing as high as possible. And last, the tube must be sufficiently rugged to withstand vibration and physical shock without an elaborate mounting. Simplicity in tube and circuit is important to insure satisfactory performance and ease of maintenance.

Besides these requirements, there should be noted those requirements which are imposed by the frequencies at which the tube is intended to operate. The various qualifications which a tube should possess for successful operation at high frequencies have been covered rather completely in the literature.[1,2,3] The important considerations which entered into the design of this tube are summarized below:

1. The tube must lend itself to satisfactory circuit design. The greatest possible amount of circuit must exist outside the tube at any given frequency. In order to meet this requirement, the input and output capacitances and the lead inductances must be kept at a minimum, and the tube must be small in size. For the higher frequencies, the use of transmission lines as circuit elements has the advantage of allowing greater physical size of circuit than when lumped circuits are used. The tube leads should preferably be so arranged that the tube is adaptable to operation in either type of circuit.

2. The leads to the tube electrodes must be of such a size as to carry safely the high-frequency currents to the electrodes and to avoid losses which would reduce the output.

3. In order to minimize the limiting effect of electron transit time, the spacings between electrodes must be kept small. In particular, the cathode-to-grid distance must be small since it is in this space that the electron must be accelerated from a low velocity at the cathode surface to a consider-

---

[1] W. G. Wagener—"The Developmental Problems and Operating Characteristics of Two New Ultra-High-Frequency Triodes," *Proc. I.R.E.*, Vol. 26, pp. 401-414; April (1938).

[2] M. J. Kelly and A. L. Samuel—"Vacuum Tubes as High-Frequency Oscillators," *Bell System Tech. Jour.*, Vol. 14, pp. 97-134, January (1935).

[3] C. E. Fay and A. L. Samuel—"Vacuum Tubes for Generating Frequencies Above One Hundred Megacycles," *Proc. I.R.E.*, Vol. 23, pp. 199-212; March (1935).

able velocity at the plane of the grid. The effect of an appreciable transit time in this region is to increase the input conductance of the tube. The result of the finite time of transit from cathode to plate in reducing the plate-circuit efficiency has been pointed out by Haeff.[4]

4. Because of the small spacings, the grids are subjected to severe conditions of temperature. The grids, however, must not emit primary or secondary electrons to any appreciable extent. To avoid such emission requires that the grid temperature be kept low and, consequently, adequate provision for cooling the grids.

5. The insulation provided must be sufficient to prevent breakdown at the operating frequencies and voltages. Also, it must not introduce excessive losses at these frequencies.

On the basis of these requirements, consideration was given to the use of a push-pull circuit. Such a circuit offers advantages in design and ease of operation over a single-ended circuit which at ultra-high frequencies is not so straightforward. Because of the symmetrical character of the push-pull circuit, an effective ground plane exists in the circuit which materially simplifies the problem of by-passing and connecting low potential leads. The connection between screens and cathodes in the two units allows the fundamental frequency and odd-harmonic components to cancel out, and leaves only even harmonics to be by-passed. In addition, push-pull operation is well-suited to the use of parallel-line circuits, since the conductors are symmetrical in arrangement. For these reasons, it was decided to design the tube for push-pull operation. In order to keep the space required at a minimum, both units of the push-pull combination were placed in a single envelope. A similar arrangement has been described by Samuel.[5] The spacing between the two units may be made smaller than where separate envelopes are used, and considerable improvement may be obtained from the point of view of length of connecting leads. Those electrodes which are connected together in the push-pull circuit, the screen grids and the cathodes, may be connected inside the tube by a lower inductance path than is possible for two separate tubes. A low-impedance connection between the screen grids becomes an important factor in attaining stable operation at the high frequencies. To obtain maximum shielding between input and output circuits, it is essential that the screen grid be at r.f. ground potential, a condition which is easily met at low frequencies with external by-passing.

[4] A. V. Haeff—"Effect of Electron Transit Time on Efficiency of a Power Amplifier," *RCA Review*, Vol. IV, pp. 114-122, July (1939).

[5] A. L. Samuel and N. E. Sowers—"A Power Amplifier for Ultra-High-Frequencies," *Bell System Tech. Jour.*, Vol. 16, pp. 10-34, January (1937).

At high frequencies, however, the connection from screen to ground through the external by-pass condenser will present considerable impedance, and result in an appreciable r.f. voltage on the screen. When the screens are connected within the tube, the impedance of the lead to the effective ground point may be decreased very appreciably. In a similar manner, the short connection between the two cathodes results in a smaller impedance between the cathodes and the effective ground point, and reduces the effects of degeneration. The smaller spacing between units and the smaller total assembly aid in fulfilling the circuit requirements.

The structure of each unit of the tube has been made that of a beam power amplifier[6] in which directed electron beams are obtained by electrical focusing with properly chosen grid wires, grid side rods, beam confining plates, and electrode shapes and in which it has been found practical to suppress secondary emission effects by space charge rather than by a suppressor grid. Both the space charge in this beam tube and the suppressor grid in the conventional pentode act to form a potential minimum which prevents the relatively low-velocity secondary electrons from passing to the screen from the plate. The use of the beam structure makes the construction simpler and considerably more rugged, and at the same time allows use to be made of aligned screen and control grids with the attendant decrease in screen current. The lowering of the screen current and the consequent decrease in screen dissipation is of importance in transmitting pentodes where screen dissipation is a serious limitation. Economy of high-voltage power is achieved at the same time.

A photograph of one of the early developmental tubes of this type is shown in figure 1 (page 51). The construction will be seen to be somewhat similar to an enlarged acorn-type tube with its low potential leads extending radially through the main seal. The cathode and screen leads may be seen at the front of the tube. The plate and grid leads from the two units extend symmetrically from the top and bottom of the tube, respectively. The input and output sides of the tube are shielded from each other by the flat disc shield which extends horizontally across the tube below the plates. This shield connects to the two cathodes and serves as connection between them. The low plate voltage allows the use of oxide-coated cathodes and mica insulation, both of which increase the ruggedness of the assembly and improve its resistance to vibration. The screen grids are joined together by a low-impedance connection, and from this a common lead is brought out.

The structure shown proved satisfactory in operation, but for three reasons it was thought wise to

[6] O. H. Schade—"Beam Power Tubes," *Proc. I.R.E.*, Vol. 26, pp. 137-181; February (1938).

modify the design. In the first place, the tube occupied considerable space, largely because the radial leads increased the mounting area appreciably over that required for the envelope alone. Second, the radial leads were required to withstand severe strains when the tube was inserted in or removed from a socket. And last, the radial construction did not permit easy fabrication. Accordingly, a redesign was undertaken. The redesigned tube is identified as the RCA-832. The leads which formerly extended radially from the bulb were placed parallel to the grid leads, and were made heavier. This structure gives greater strength and provides increased current-carrying capacity. The tube can be placed in a socket without danger to the seals from strain on the leads. The bulb has been made short and the space required for the mounting has been decreased approximately 50 per cent.

The arrangement of the electrodes was changed only slightly. The plate leads were shortened inside the envelope and a double lead was used to lower the resistance and inductance of the connection. The center shield between the two units was found to contribute nothing to the tube's performance and was eliminated. The ends of each unit were shielded to decrease the number of stray electrons which ordinarily leave the active section and bombard the insulators or the bulb. Such bombardment tends to release secondary electrons which return to the plate by a long transit-time path and, lagging behind the normal plate current pulse, increase the plate loss. Bombardment of the insulators and bulb also tends to release gas which gradually impairs the vacuum and eventually ruins the cathode emission. The screen grids of the two units were joined together by a short connector which forms one plate of a by-pass condenser. The other plate of the condenser was connected directly to the cathode. The combination of the low-impedance connector and the direct high-frequency by-pass maintains the screens very close to ground potential and materially improves the stability of the tube as an amplifier at the higher frequencies.

A photograph of the mount structure with one of its plates cut away to show the arrangement of the electrodes, is presented in figure 2 (page 51). The shields at the ends of the unit are shown, as are the beam-confining plates.[6] These plates or channels extend longitudinally through the structure around the grid side rods and, as their name implies, confine the active area of the tube to the section between the grid side rods in order to improve the uniformity of the electron stream throughout the active area. The arrangement of the electrodes may be seen in the line drawings of figure 3, where the left-hand diagram shows the cross-section of one unit in a plane perpendicular to the cathode and the right-hand diagram shows a section taken in the plane through the cathode axis. The two grids

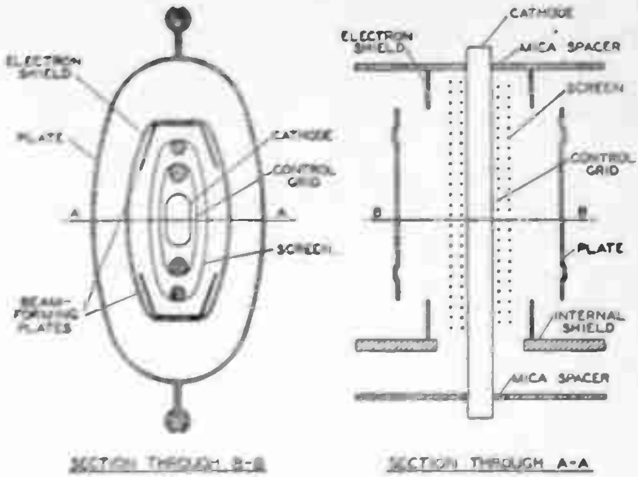


Figure 3. Arrangement of the electrodes in the RCA-832.

are aligned so that the turns of the screen grid are directly behind the turns of the control grid as viewed from the cathode. The control grids are cooled by the use of large-diameter side rods which are connected to a short wide strap having a blackened surface to improve its radiating characteristics. The strap is in turn connected directly to the external grid terminal. This construction serves to conduct a fairly large amount of heat from the grid to the outside of the tube envelope, and at the same time results in a low-resistance, low-inductance grid connection. The screens are cooled in a similar manner. The strap welded to the screen side rods is, however, not blackened and forms one plate of the internal by-pass condenser.

The fact that the finite electron transit time from cathode to plate results in a decrease in plate-circuit efficiency from the value obtained at low frequencies where the transit time is negligible has already been mentioned.[4] As the frequency is increased, the transit time becomes a larger fraction of a high-frequency cycle, and its effect, therefore, becomes greater. The efficiency decreases less rapidly with frequency for amplifier than for oscillator service because of the difference in phase relation between the instantaneous plate and grid voltages in the two classes of operation. In the usual oscillator circuit, the plate and grid voltages are almost 180° out of phase. Because of the time of transit, electrons leaving the cathode under the action of the grid voltage arrive at the plate lagging behind the grid voltage and, consequently, after the plate voltage has passed its minimum. The energy of these electrons is thus higher because of the higher plate voltage than it would be with negligible transit time. As a result, the plate loss is higher and the efficiency is reduced. In an amplifier, on the other hand, the grid voltage is independent of the plate voltage. The plate circuit is tuned so that the plate-current pulse and the plate-voltage swing bear the optimum phase relationship to each other, with the result that the efficiency is higher than for the oscillator case. The efficiency is not so high as at low frequencies, however, because the appreciable transit time causes spreading and distortion of the plate-current pulse and because the electrons are acted upon for a longer time by the plate voltage. The effect is the same as if the angle of plate-current flow were made larger at ordinary frequencies. Increased losses in the leads and electrodes also tend to lower the efficiency obtainable at high frequencies. Because the efficiency falls off, the input must be dropped at the higher frequencies in order that the plate dissipation will not be exceeded. Since the loss in the glass and in the internal insulation increases with frequency and with the voltage applied to the insulation, the voltage on the tube must also be decreased at the higher frequencies.

(See page 51 for photographs.)

Precaution in Mobile Installations

IN MAKING a mobile u.h.f. installation, be careful about placing by-pass condensers from the generator terminals to ground. The majority of cars have a vibrator-type charging control which varies the current fed to the field of the generator in proportion to the amount of charging that the battery needs. When the car has this arrangement there will be more than one terminal on the top of the generator. One of these should be by-passed (the one that goes to the battery) and the other one should not be as a by-pass condenser at this position very likely will burn the points of the vibrator control. The two terminals are usually marked; if not, the one with the smaller wire going to it should NOT be by-passed.

—Radio.

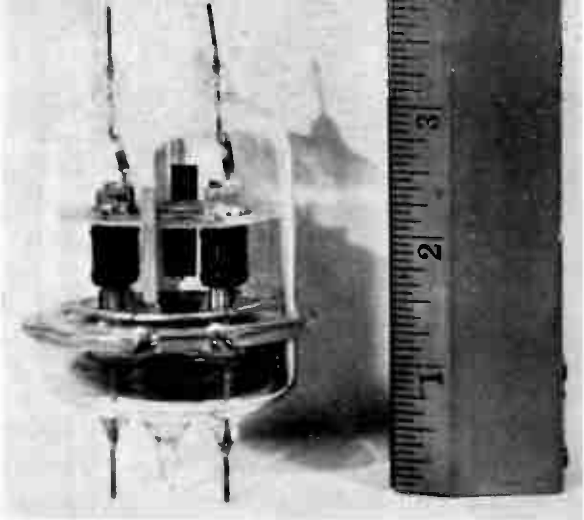


Figure 1. Early developmental type of ultra-high-frequency amplifier tube.

A PUSH-PULL U.H.F.

Beam Tetrode

(Discussed on pages 44-50)

(Illustrations Courtesy RCA Review)

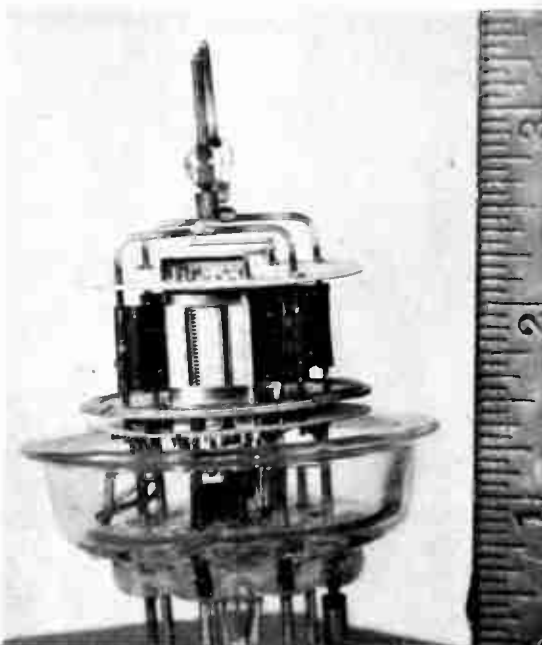


Figure 2. A view of the mount structure of the RCA-832.

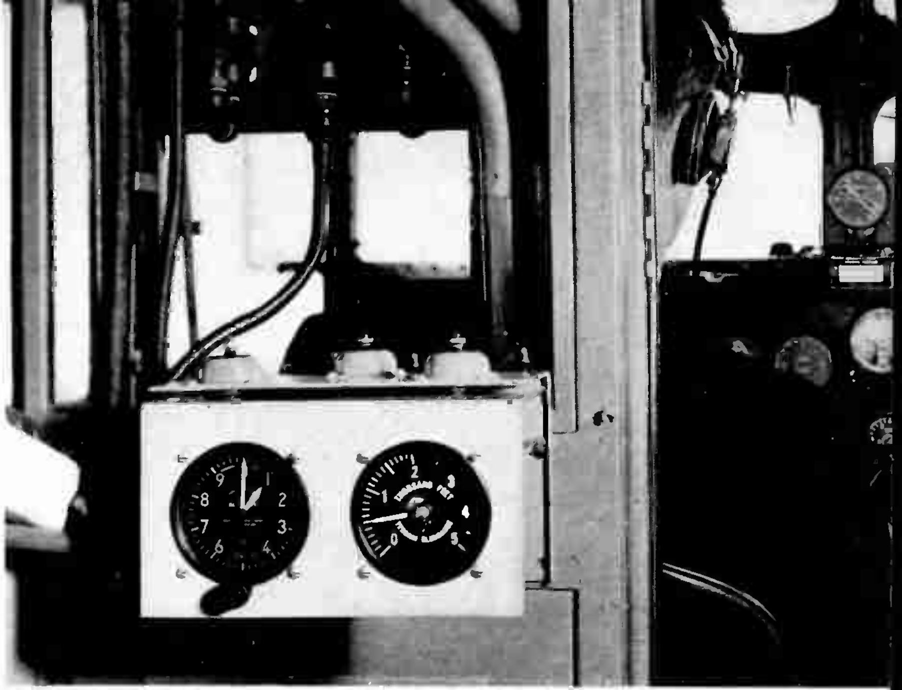
RESEARCH

In Aviation Radio

(Discussed on pages 39-43)

(Illustrations courtesy Aero Digest)

• **Aviation radio research delves thoroughly into quartz crystals by subjecting them to polariscopic examination** (at the Bell Telephone Laboratories.)



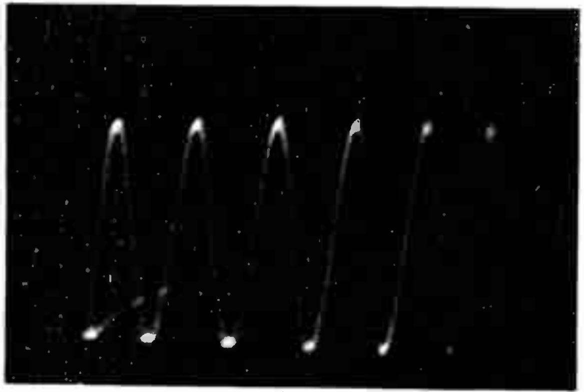
• The latest model of the absolute radio altimeter being test flown. The barometric altimeter (left) reads 1000 ft. above sea level. The radio altimeter right reads 500 ft. above the actual terrain below. The radio altimeter is one of the most outstanding examples of research developments of recent date.

• "Flying Laboratories", such as these of the Bell Telephone Laboratories, bring actual test-conditions within easy reach of the research engineer. Flight-tests are a routine matter in many development organizations.

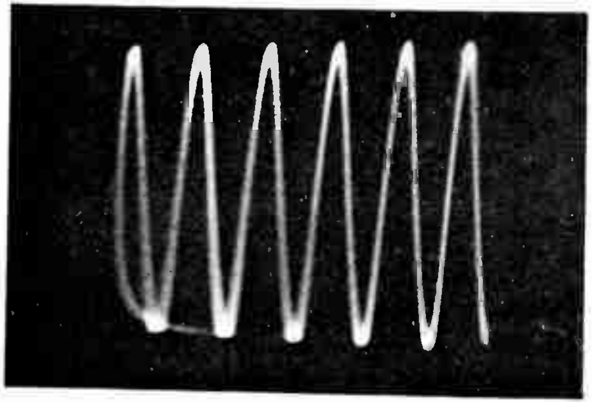
C. R. Tube PHOTOGRAPHY

(Discussed on pages 55-56)

(Illustrations courtesy Electronics)



• Figure 1. Trace of nonrecurring wave photographed from a blue screen on Super XX film developed in fine grain developer and printed on high contrast paper. Used as basis for Table 1, page 56.



• Figure 2. Same as that of figure 1, except writing speed is one-half that used to obtain the other photograph.

¶ From Electronics
July, 1939

C. R. Tube PHOTOGRAPHY

By T. A. ROGERS and B. L. ROBERTSON

THE increased use of the cathode ray oscilloscope in the study of transient or recurring phenomena has necessitated the application of photography in order to obtain a permanent record of the trace on the screen. The photography of cathode ray tube screen traces involves a number of problems, and attention should be given to: (1) the speed at which the electron beam travels across the fluorescent screen, (2) the spectral radiation characteristics of the cathode ray tube screen, (3) the aperture of the taking lens, (4) the spectral sensitivity of the photographic material, (5) the magnification at which the photograph is made, (6) the voltages applied to the electrodes of the cathode ray tube (and especially the second anode voltage), and (7) the developing conditions.

• Writing Speed

The writing speed, or the velocity with which the electron beam traces over the screen of the cathode ray tube, is of greater fundamental significance in discussing exposures than tables covering the general case of recurring phenomena because such tables are not applicable to the recording of single sweeps of non-recurrent waves. The writing speed, on the other hand, is applicable both to recurring and non-recurring phenomena.

From the geometrical optics of a simple lens, it may be shown that the amount of light reaching the film for a given light source varies as $(1 + M)^2$ where M is the magnification. For full size photographs, $M = 1$, but more often the photographic image is smaller than the original so that $M < 1$.

Table I—Writing Speeds for Oscilloscope Traces *

Film	Writing Speed in mm/sec. Green screen	Blue screen
Eastman Super XX	47,000	125,000
Agfa Ultraspeed	22,000	60,000
DuPont Superior	14,000	37,000

* This table is prepared for normal operation of three inch oscilloscope, a lens aperture of f/3.5, with films processed in fine grain developer.

The intensity of the trace on the cathode ray tube screen is roughly proportional to the second anode voltage, if all other electrode voltages are maintained constant, or is roughly proportional to the square of the control grid voltage if other electrode voltages are held constant. Thus, if proper exposure data are available for one set of known voltages, the exposure for other electrode voltage can be estimated.

Most developers are satisfactory for oscillographic photography. For films of normal size a high energy developer should be used and the film developed to maximum contrast in order to record maximum writing speed. On the other hand, if miniature negatives are used, in which the image must be considerably enlarged, a fine grain (low energy) developer may be required, although this will reduce the writing speed which can be recorded satisfactorily.

It now remains to determine the maximum writing speed for which satisfactory traces are obtained. In some experimental work to determine this speed, a three inch cathode ray tube was operated at normal conditions, and a 5000 cycle sine wave from a beat frequency oscillator was impressed on one set of plates and a sweep voltage on the other set of plates. For such sinusoidal traces, the displacement from the reference axis is given by

$$s = 0.5\, A \sin\, (2\, \pi\, ft)$$

where A is the peak-to-peak amplitude and f is the frequency of the voltage. The writing velocity of the electron beam is the time rate of change of the displacement, or

$$V_w = ds/dt = A\, \pi\, f \cos\, (2\, \pi\, ft)$$

which is a maximum for $\cos\, (2\, \pi\, ft) = 1$.

Using these relationships, a series of exposures were made. The image on the film was that which satisfied the minimum requirements for projection printing on a contrast paper. The writing speed was then determined from the size of the image, the frequency of the wave and the aperture of the lens system. The results of this experimental work are shown in Table I which gives the writing speeds for several films for two different kinds of screens, with normal operation of the three-inch oscilloscope and a lens aperture of $f/3.5$. The writing speeds should not be regarded as being absolute. They are given as representative, approximate values determined from many photographs and serve to show results which may be normally expected.

(See page 54 for photographs)

¶ From Service
June, 1939

CRYSTAL PICKUP INSTALLATION

By RALPH P. GLOVER

IF YOU ARE called upon to select and install a crystal pickup for record reproduction you have available a considerable choice of styles, types and prices. The final quality of reproduction, however, depends not only on the pickup itself but also on the method of installation. The response of the very finest crystal pickup can be ruined by failure to observe a few basic, simple installation precautions. Actually, proper installation is a simple matter, and by following the suggestions in this article, you should obtain the really fine reproduction for which quality crystal pickups are noted.

Electrically the crystal is the equivalent of a condenser with a capacity of about 1,500 $\mu\mu$fd. The impedance of the device, therefore, is quite high (100,000 ohms at 1,000 cycles and 1 meg at 100 cycles) and the *lower* the frequency, the *higher* the impedance. Instead of a power generator, the crystal pickup may be thought of as a voltage generator which requires a very high-impedance load so that the greater part of the generator voltage, at all frequencies of interest, will appear across the load.

• Terminal Impedance

Since the impedance of the pickup is highest at low frequencies, it is evident that the choice of load resistance will directly govern the low frequency response. This effect of terminal impedance on low frequency response holds regardless of any other considerations. It is inherent in the use of the crystal with its capacitative internal impedance. Crystal microphones, of course, display the same effect.

Figure 1 shows how the terminal voltage is affected by load resistance alone for a crystal of 1,500-$\mu\mu$fd. capacity. A resistance of 5 meg introduces practically no frequency discrimination while lower values reduce the low-frequency response as shown.

Figure 2 illustrates the effect of load resistance on the response curve of a representative high-quality pickup. Experience has shown that for home reproduction on sets with good speakers, most listeners prefer the elevated bass response obtained with terminations of 0.5 meg or more, and therefore the serviceman should make certain that the point of connection to receiver or amplifier presents a sufficiently high resistance to the crystal pickup. On the other hand, if the speaker is very small, elevated bass response in the pickup is likely to result in bad distortion due to excessive speaker stiffness and poor radiating ability at low frequencies. In such cases, the practical solution is to reduce the bass response of the pickup until the overall performance is suitable. Try 0.5, 0.25 and 0.1 meg terminations until the best results are attained.

Since the crystal is a capacitive generator, the effect of shunt capacity is merely to reduce the voltage output of the pickup uniformly at all frequencies. No frequency discrimination is introduced by capacity only. Actually, however, the use of a resistance potentiometer volume control, in the presence of various circuit capacities, may introduce some high frequency loss. This, however, also occurs with sources other than crystal pickups. The effect can be minimized by methods which will be discussed below.

Many modern receivers have input terminals which will accommodate a crystal pickup. The arrangement is frequently as shown in figure 3 where the receiver volume control is a potentiometer in the first a.f. grid circuit. The

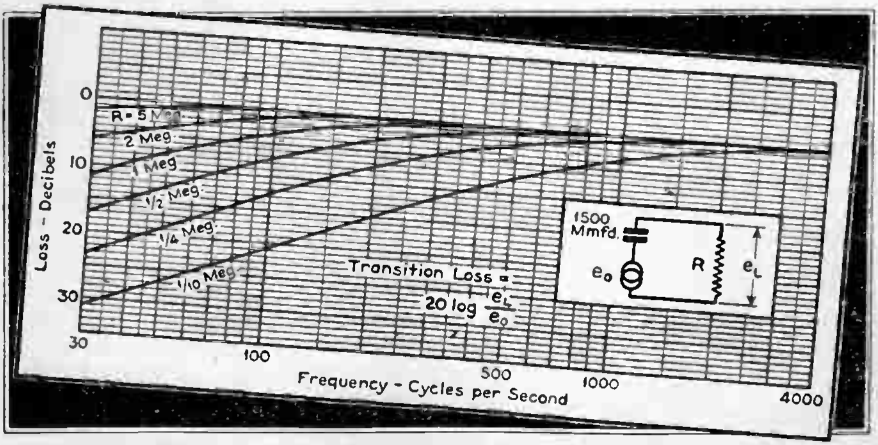


Figure 1. Since the impedance of the crystal pickup is highest at the low frequencies, the choice of load resistance will directly govern the low frequency response.

phono-radio switch simply shifts this potentiometer from the phono input terminals to the detector output and vice versa. The receiver volume control also controls the volume on phonograph. The potentiometer should have a resistance of 0.5 to 1.0 meg. as explained previously for proper bass response. Sometimes tone compensating circuits are tapped into the potentiometer. They will not ordinarily affect the phono reproduction adversely, but if the quality of reproduction is poor, or if the frequency response appears to vary considerably as the volume control setting is varied, it is advisable to test the effect of disconnecting the tone compensating networks from the potentiometer. If they prove to be the cause of the trouble, they should be switched out during phonograph operation. If the receiver employs the volume control method shown in figure 3 but has no provision for phono input, a single-pole double throw switch can be mounted on the chassis and wired as shown. The switch should be located near the potentiometer so that leads will be short and hum pickup possibilities minimized. It is advisable to shield the lead from the phono post to the switch. The switch should make on the phono position before breaking the radio circuit to avoid a thump due to momentary removal of grid bias.

Occasionally the audio system will have such high gain that the pickup will overload the first stage at full volume and necessitate working at such a low setting of the potentiometer that volume adjustments are critical and quality of reproduction may be poor. The remedy is a shunt condenser of

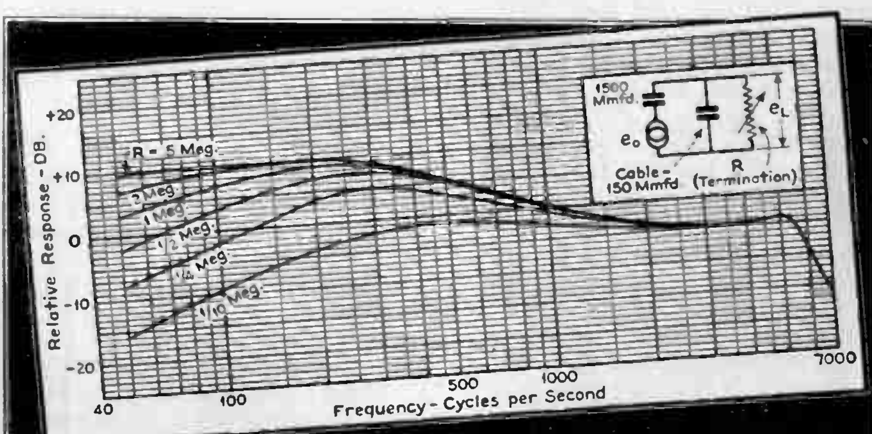


Figure 2. Experience has shown that most listeners prefer the elevated bass response obtained with terminations of 0.5 meg or more across the pickup.

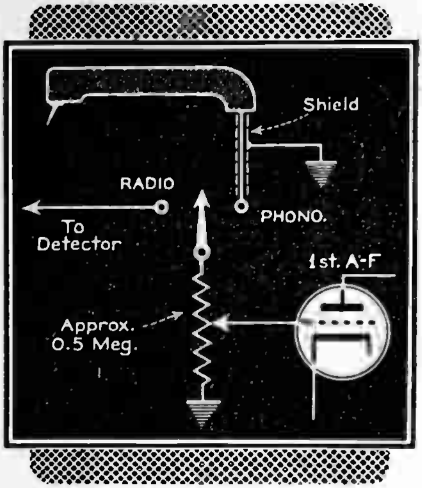


Figure 3. If the receiver employs the volume control method shown, a single-pole double-throw switch can be wired for phono operation.

0.001 μfd. or larger across the pickup at the input terminals. Increase the condenser capacity until there is no overloading apparent on listening test with the receiver volume control wide open. Pay particular attention to the bass reproduction during the listening test, for the maximum peak levels occur at the lower frequencies. Increase the size of the shunt condenser until the bass is clean.

It is always good practice to attain normal loudness with the audio volume control of the receiver almost wide open. At medium and low volume settings, the input capacity of the tube plus stray circuit capacities form an L network in conjunction with the resistance in the upper section of the potentiometer with a resulting loss of the higher frequencies. This effect is largely avoided by operating at near-maximum settings.

When a volume control is provided on a simple crystal record player which is located some distance from the receiver, there will almost always be a loss of highs due to the effect of the connecting lead capacity in conjunction with the potentiometer resistance whenever the volume control is turned down below maximum. There is less loss of highs with a relatively low-resistance potentiometer (of the order of 0.25 meg) but this may be offset by poor bass response, especially if the record player volume control and the receiver volume control are in parallel and combine to present a still lower terminal resistance to the pickup. When the feature of volume control at the record player is not absolutely essential, the reproduction will usually be improved considerably by disconnecting the record player control entirely, depending on the control at the receiver. Of course these remarks do not apply to record players of the wireless type or to those which incorporate an audio amplifier tube following the pickup; in these cases the tube associated with the pickup may effectively isolate the pickup volume control from the connecting line and subsequent equipment.

Many receivers of early vintage have no provision for phonograph pickup connections; others have phono connections which are only suitable for magnetic pickups. The alert serviceman can build up his profits by adding crystal record players to such receivers and by modernizing yesterday's phonograph combinations with crystal pickups. Circuit changes to accommodate the crystal pickup are not difficult if a few fundamentals are kept in mind. In the first place, transformers are *out*! They will *not* provide the proper terminal connections for high-quality crystal pickup performance. Connect the crystal pickup in the grid circuit of an audio stage across a resistance of 0.5 meg or more (which may be the radio volume control) and make certain that no low-impedance circuits are across the pickup.

A common receiver layout includes a power detector feeding the output stage. Radio volume control is probably effected in a preceding r.f. circuit. The best solution is to switch the detector tube grid to a 0.5 meg pickup volume control mounted on the chassis (or motorboard if a combination) at the same time switching the bias to the proper value for class A studio amplification instead of detection. Figure 4 shows one possible arrangement.

As before, the switch blade connected to the grid should make in the phono position before breaking the radio circuit to avoid switching thump. The shunt resistor R_2 must have the proper value to make the parallel combination of resistors afford correct *amplifier* bias. Measure the *applied* plate voltage and then consult your tube manual for the correct bias voltage and plate current for *amplifier* operation.

Divide the required bias voltage by plate current to find the resistance which the parallel combination of R_1 and R_2 must provide. After installing the correct resistor R_2, recheck bias voltage and plate voltage. Occasionally the applied plate voltage will drop and necessitate a slight change in the bias resistor.

The lowered bias resistance for

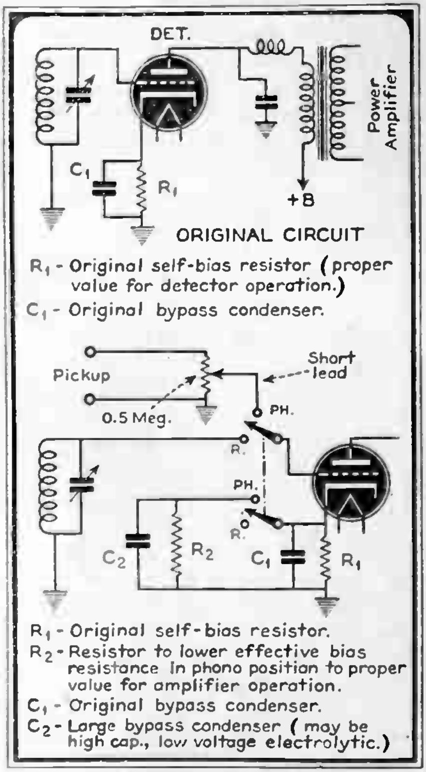


Figure 4. A common receiver layout includes a power detector feeding the output stage. The best solution is indicated.

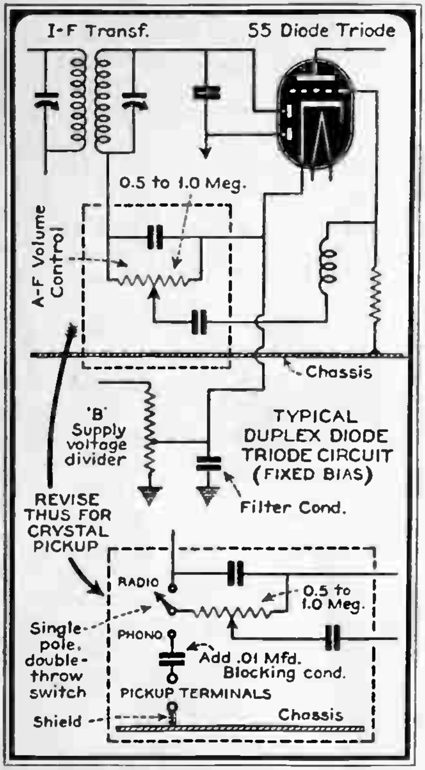


Figure 5. In grid circuits employing fixed bias a blocking condenser should be used to prevent the application of the bias to the pickup.

amplifier operation will require an increase in cathode by-pass capacity. This can be provided by installing a low-voltage high capacity electrolytic or other suitable condenser at C_2. Both the switch and volume control should be located as close to the tube as possible. After these parts are mounted and the set operates properly on phonograph, it is wise to realign the tuned circuit feeding the detector which will probably be a little high in capacity due to that added to the circuit by the switch.

• Diode-Triodes

Frequently the detector and first audio element are combined in a single tube, the familiar duplex-diode triode. Circuit variations are numerous and a careful study of the individual circuit of the particular receiver is strongly indicated before the work is started. The problem is to get at the grid of the triode section, making use of the receiver volume control if possible. Particular attention must be paid to the method by which the cathode is biased.

A circuit in which fixed bias is employed, is shown in figure 5, together with the proper switching circuit for crystal pickup. The only modification is the provision of a single-pole double-throw switch to shift the high-side of the volume control potentiometer from the radio circuit to the phono input with a blocking condenser in series to prevent the application of bias voltage to the pickup.

It is not possible to discuss here all of the diode-triode circuit variations which are used in radio receivers. It should be remembered, however, that even the most complicated circuit can be licked by switching grid and cathode to a separate phono volume control and self-bias resistor and by-pass condenser, respectively. Keep leads as short as possible and shield wires if hum is encountered.

- Equalizing

It has been intimated, elsewhere in this article, that a large percentage of radio set buyers have been educated to prefer excessive bass response. This fact probably accounts for the elevated bass response which is characteristic of most present-day commercial crystal pickups.

Equalization for relatively flat response is easily provided, should an occasional customer prefer high-quality music. As shown in figure 7, all that is required is a fixed condenser and a fixed or preferably variable resistance, connected as indicated. If a variable resistor is employed, any response curve between the fully equalized and the normal unequalized can be obtained at will. The curves shown have been matched at the high frequency end and therefore indicate only the relative frequency response.

- Scratch Noise

It has been a common notion that sharply - tuned rejector circuits would eliminate needle scratch or surface noise in phonograph reproduction. The reasoning seems to have been that the disturbing noise was localized in a narrow band around 2500 or 3000 cycles and that the removal of the audio components in substantially this band alone, would considerably lessen the reproduced surface noise with minimum effect on the general quality of reproduction.

Without going into detail regarding special cases that are of little practical interest, it appears that there are no appreciable benefits in narrow band-elimination from the noise reduction standpoint. Surface noise components are of random character and are distributed

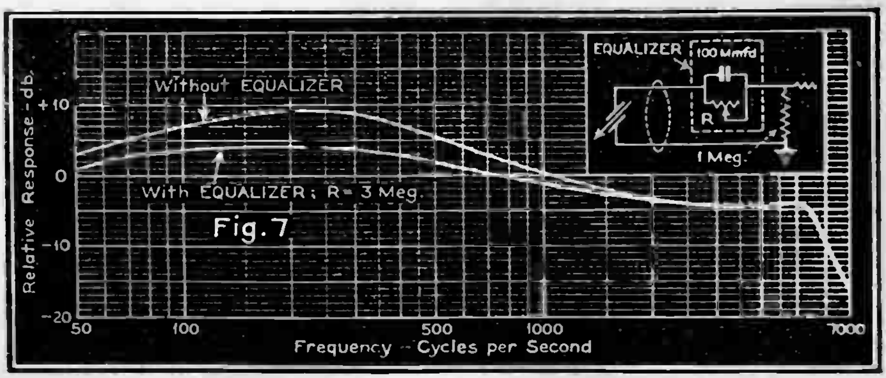


Figure. 7. Equalization for relatively flat response can be provided by means of a fixed condenser and a resistor.

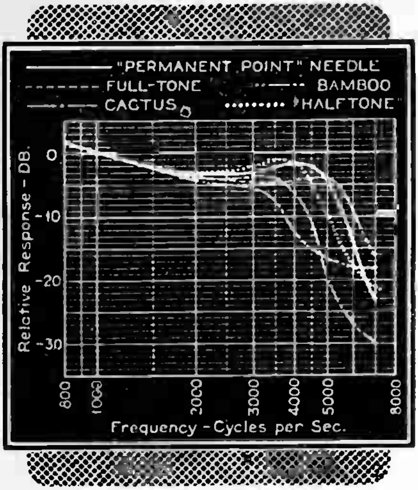


Figure 6. Special needles provide some scratch reduction because they cut-off earlier at the high frequency end.

throughout the entire audio range. Effective noise reduction goes hand-in-hand with reduction in quality of reproduction. Special needles (such as halftone, cactus, bamboo, etc.), provide some scratch reduction because they cut-off earlier at the high frequency end, with of course a corresponding elimination of what may have been recorded in the lost frequency interval. Adjustment of the ordinary tone control of the receiver or amplifier, with its adjustable, tapering high frequency loss, will probably completely satisfy most listeners.

- Additional Hints

Crystal pickups will not withstand temperatures above 125° F. for long periods of time. Make sure that adequate cabinet ventilation is provided. Deflect heat from power and rectifier tubes if necessary with a sheet of asbestos board or other heat insulating material. Check-up with a thermometer placed at the pickup position. Long experience has proved that the temperature limitation is easily satisfied *if it is recognized and given attention.*

Should it be necessary to replace the crystal cartridge or cordage, apply minimum heat when unsoldering and resoldering connections at the cartridge terminals. Cool the lug with a cotton swab dipped in alcohol immediately after removing the soldering iron. Heavy-handed sweating-in of soldered joints at the cartridge terminals is practically certain to ruin the crystal. Quick soldering with minimum heat, immediately cooling the joint is absolutely safe.

"The Sunspot Period" is an interesting 18-page booklet obtainable from the Smithsonian Institute, Washington, D. C. (Smithsonian Miscellaneous Collections, Volume 98, No. 2) for ten cents in coin. It forecasts dates of sunspot maxima and minima.—*W3AIU*

From Radio
October, 1939.

CATHODE MODULATION

By FRANK C. JONES

Some amateurs are grid-modulation addicts; others prefer plate modulation. But it appears we have been passing up a good bet by not using a combination of both. The many advantages of cathode modulation make it safe to predict great popularity for this system.

AN excellent system of modulation has long been overlooked by radio amateurs. The purpose of this article is to bring the system into the limelight and to attempt an easily understandable explanation of cathode modulation.

The audio power required for full modulation with cathode modulation is a great deal less than that required for plate modulation. The average value of audio power for 100% modulation is 10% of the value of d.c. input to the plate circuit of a cathode modulated class C amplifier. Plate modulation with pure tone input requires an audio power of 50% of the class C amplifier input for full modulation. For example, a plate modulated 200 watt transmitter requires an audio modulating power of 100 watts, while the same 200 watt set requires only about 20 watts for cathode modulation. In addition, the cathode modulated amplifier does not require as much grid excitation.

The 200 watt plate modulated set will supply a carrier output of from 130 to 150 watts. A 200-watt cathode modulated set will supply a carrier of from 100 to 120 watts. For further comparison, a 200-watt grid modulated set will supply a carrier of from 35 to 90 watts, depending upon the system of grid modulation. It can be seen that cathode modulation approaches plate modulation in efficiency and will supply roughly two times as much output as can be obtained from a correctly operated grid modulated transmitter.

Cathode modulation is a combination of grid modulation and plate modulation, and is exceedingly

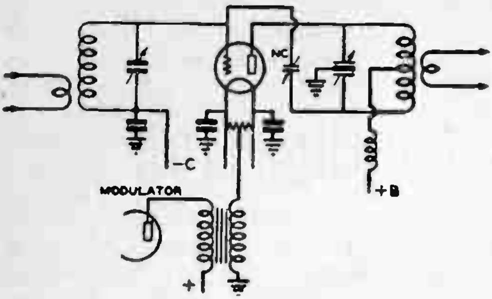


Figure 1. Simplified schematic of a cathode modulated triode r.f. amplifier

simple to adjust for proper operation. The audio power is inserted into the cathode or center-tap lead of the class C amplifier, which is common to both grid and plate circuits. A typical circuit is shown in figure 1, in which the filament or cathode is by-passed *for r.f. only* with a total capacity of not over .005μfd. The modulation transformer works into an average load of about 500 ohms but this value is not critical. Values of load of 200 to 1000 ohms have been tested and found satisfactory in a number of different class C amplifiers. The actual cathode impedance seems to be proportional to $\frac{1}{G_m}$ where G_m is the operating transconductance of the tube.

As far as studio load values are concerned, push-pull or parallel class C tubes are similar to a single tube but with twice as high a value of transconductance or half as great a cathode impedance. An impedance mismatch of 4 to 1 or even 6 to 1 in practice has practically no effect on the quality of modulation; however, some audio power is wasted and a larger modulator stage is required. A value of 500 ohms seems to be optimum for nearly any type of class C amplifier of high or low power. Several manufacturers produce public address or class B output transformers having a secondary designed to work into a 500-ohm load, and most of these have sufficiently heavy wire on the 500-ohm winding to handle considerable d.c.

The audio modulating power is applied to both grid and plate circuits of the r.f. amplifier in figure 1. If 10 watts of sine-wave audio power is applied across a 500-ohm load resistance, the r.m.s. voltage would be 71 volts or the peak value of 100 volts. This value of 100 volts would be applied to the grid bias voltage and also the d.c. plate voltage. The a.f. variation in d.c. plate voltage of 100 volts produces plate modulation of relatively low percentage at normal values of plate voltage supply. A similar variation of a.c. cathode current aids in the plate modulation function. The same a.c. voltage applied in series with the d.c. grid bias produces grid modulation of from 50% to

80%, depending upon the effective grid impedance and whether an external resistance is connected in the a.f. grid circuit to limit the degree of grid modulation. The ideal arrangement is to balance the grid and plate modulation values to obtain perfectly linear modulation up to 100%. Fortunately this is automatically obtained without an external resistance in nearly all types of tubes used in class C amplifiers.

An r.f. linear amplifier or a grid modulated amplifier of conventional type usually operates at about 30% efficiency with no modulation. If the degree of modulation is limited to 60% or 70%, the resting efficiency can be greatly increased and about twice as much carrier power can be obtained. In cathode modulation this effect is used to obtain resting or idle efficiencies of from 50% to 60%. This permits grid modulation up to 70% or even 80%; the remainder is obtained by plate modulation in the cathode circuit.

If the d.c. plate input is 100 watts, an audio power of only 3⅛ watts will permit plate modulation of 25% if the plate impedance is matched. In this example, with 10 watts of a.f. power in the cathode circuit, about 1 watt is needed for the grid circuit modulation and about nine watts is available for plate modulation.

A postive peak of a.f. voltage in the cathode circuit between the tube filament (or cathode) and ground acts as an additional negative grid bias peak which tends to reduce the peak r.f. output from the amplifier. At the same time a positive peak on the cathode reduces the d.c. plate voltage and so further reduces the r.f. output. In a similar manner a negative a.f. peak adds to the d.c. plate voltage and subtracts from the negative d.c. grid bias to increase the r.f. output. From this it can be seen that the grid and plate modulation are in phase, or additive, and the system is capable of reaching 100% modulation easily.

The d.c. grid bias should preferably be obtained from a C bias supply or C battery; however, grid-leak bias can be made to operate satisfactorily. The *grid leak must be by-passed for audio frequencies.* This sometimes causes a little blocking action if the d.c. grid current is not high enough. This effect may be noticed if the crystal oscillator is detuned or quits oscillating, in which case a "singing" action may be set up in the modulated amplifier. No difficulty is present when the set is operating normally.

The d.c. grid current is set at some intermediate value between that for grid modulation and that required for plate modulation. The d.c. grid bias should be several times cutoff value, and if grid leak bias is used exclusively, the grid leak value will be from *4 to 8 times as high as that used for c.w. or plate modulation.* The r.f. driver should be nearly as large as that required to drive the final amplifier as a c.w. transmitter, or roughly half as large as for a plate modulated amplifier of the same power.

Cathode modulation has several

advantages over grid or plate modulation. It is not at all critical in adjustment as regards audio quality. If too much r.f. drive is present, the audio quality does not suffer appreciably, but the modulation capability drops. Similarly, insufficient antenna coupling reduces the potential linear modulation. (Too little antenna load will produce "downward" modulation of antenna current.) Cathode modulation is more efficient than any of the popular forms of grid modulation, and is not as critical to adjust.

Cathode modulation is more economical than either grid or plate modulation for a given power output. The modulator and its power supply are only ¼ to 1/5 as large as for a plate modulated rig with the same carrier output. The class C tube or tubes should be a little larger unless their dissipation rating is high in proportion to plate current and plate voltage maximum ratings. The plate dissipation of a plate modulated set increases with modulation. It decreases somewhat with grid modulation, and usually decreases very slightly with cathode modulation. Therefore, by operating the tubes at a little greater plate dissipation under resting conditions, no larger tubes are required.

The peak plate current is less with cathode modulation, which should result in greater tube life. The plate tuning condenser in a cathode modulated amplifier is smaller physically because only 60% to 70% as much plate spacing is required.

- Transmitter Example

The small transmitter diagrammed in figure 2 has cathode modulation applied to a pair of 6L6G tubes. A carrier output of about 25 watts is obtained with slightly over 40 watts input. Better modulation linearity was obtained with the 6L6G tubes connected as low μ triodes rather than as tetrodes. This amplifier is modulated by a 6F6 tube which has an audio output of about 4 watts. The modulation transformer has a 500-ohm secondary and the 6F6 tube was connected across the 2500-ohm primary. A 6SJ7 high gain pentode drives the 6F6 from an ordinary high level crystal microphone for close talking purposes.

The crystal oscillator is inductively coupled to the 6L6G triode push-pull stage in order to conserve space. The crystal oscillator is an improved form of harmonic oscillator in which 160-, 80- or 40-meter crystals can be used on their fundamental or second harmonics. 10-and 20-meter crystals should be used "straight through," that is, with the 6V6 plate circuit tuned to 10 and 20 meters respectively. The screen grid of the 6V6 is bypassed to the cathode rather than to ground as this gives a circuit in which the adjustable cathode condenser can be set at one value for all bands. The 10,000-ohm 1½-watt resistor in series with the 6V6 screen acts as an r.f. choke to prevent an r.f. short circuit across the cathode circuit. A combination of cathode and grid leak bias in the

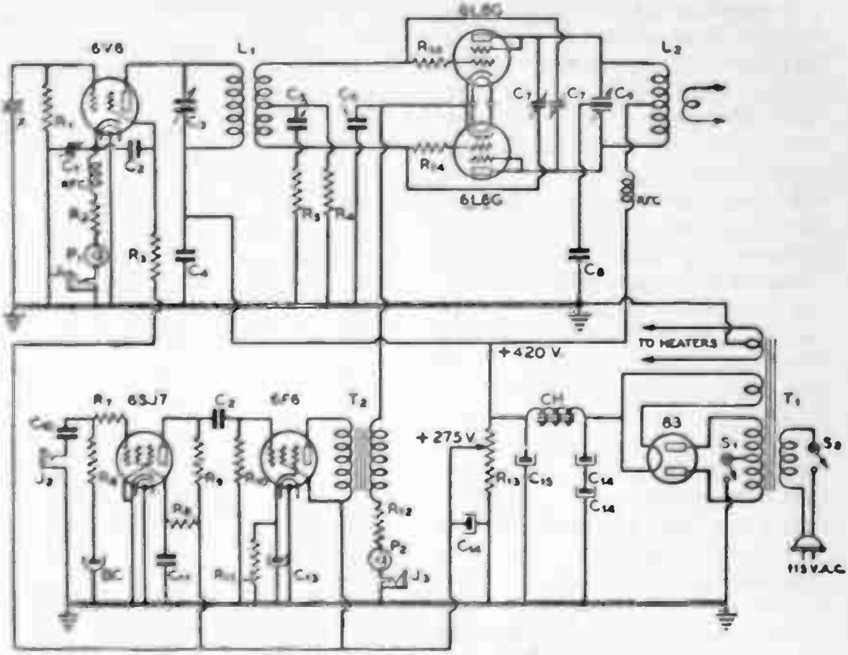


Figure 2. Schematic of the cathode modulated 6L6G phone.

C—170-600 μμfd. mica trimmer condenser.

C—.01-μfd. 600-volt tubular.

C—100-μμfd. midget variable.

C—.01-μfd. 600-volt tubular

C—9.5-μfd. 200-volt paper

C—.005-μfd. 600-volt mica

C—Homemade neut. condenser, 1" by 2" parallel plates

C—.002-μfd. 600-volt mica

C—100-μμfd. per section split stator

C—.01-μfd. 600-volt paper

C—.05-μfd. 600-volt tubular

C—.005-μfd. 600-volt mica

C—10-μfd. 25-volt elect.

C—8-μfd. 450-volt elect.

C—16-μfd. 450-volt elect.

R—100,000 ohms, 1 watt

R—300 ohms, 10 watts

R—10,000 ohms, 1 watt

R—10,000 ohm, 10 watts

R—3000 ohms, 1 watt

R—1 megohm, ½ watt

R—25,000 ohms, ½ watt

R—2 megohms, ½ watt

R—500,000 ohms, ½ watt

R—1 megohm, ½ watt

R—400 ohms, 2 watts

R—200 ohms, 10 watts

R—25,000 ohms, 50 watt

R—50 ohms, 1 watt

T—800 v. c.t., 175 ma.; 6.3 v., 5 a.; 5 v., 3 a.

T—2500 ohms to 500 ohms, 10-watt rating

CH—15-hy., 200-ma. choke

BC—Bias cell

Coils—See coil table

S—Plate on-off Switch

S—A.c. on-off Switch

P—150-ma. 6-volt lamp

P—250-ma. 6-volt lamp

J—Crystal plate current jack

J—6L6G cathode current jack

RFC—2.5mh., 125-ma. choke

6V6 provides for fundamental efficient doubler action and low crystal current for fundamental or second harmonic operation.

The 6L6G amplifier has a ½-μfd. 400-volt condenser connected across the grid leak to pass the audio frequencies. Better linearity was obtained with a 3000-ohm resistor connected in series with the condenser in order to reduce the actual a.f. voltage applied to the grid circuit. Too much grid modulation in comparison to plate modulation in this particular tube arrangement produced a slight curvature on the sides of the triangle or trapezoid as viewed on an oscilloscope. The 6L6G tubes connected as shown have a μ of about 6 and are more easily grid modulated than are medium or fairly high μ tubes. No grid a.f. resistor is needed in transmitters having tubes with a μ of from 25 to 30.

The final amplifier has a combination of cathode and grid leak bias, the former to protect the tubes in case of oscillator detuning or failure of excitation. In the particular layout used, a u.h.f. parasitic oscillation took place in the neutralizing circuit until it was damped out by the use of a couple of 50-ohm 1-watt resistors in the 6L6G grid leads. The neutralizing condensers were each made of two plates 1" x 2" separated about 1/10 of an inch. Neutralization was accomplished by removing the 250-ma. 6-volt lamp

COIL DATA
CATHODE MODULATED 6L6G TRANSMITTER

BAND	OSCILLATOR (1½" dia. forms) Plate	Grid	FINAL PLATE
10	3½ turns no. 20 d.c.c. 1" long. ⅛" separation btwn plate and grid coils	5 turns no. 20 d.c.c. ½" long, c.t.	6 turns no. 14 E. 1¼" long, 1¼" dia., c.t.
20	7 turns no. 20 d.c.c. 1" long. ⅛" separation btwn plate and grid coils	12 turns no. 20 d.c.c. ½" long, c.t.	8 turns no. 14 E. 1" long, 1¾" dia., c.t.
40	14 turns no. 20 d.c.c. 1" long. ⅛" separation btwn plate and grid coils	32 turns no. 24 d.c.c. 1" long, c.t.	18 turns no. 16 E. 1¾" long, 1⅝" dia., c.t.
80	24 turns no. 24 d.c.c. closewound. ⅜" separation btwn plate and grid coils	56 turns no. 26 E. closewound, c.t.	32 turns no. 18 E. 1½" long, 1⅝" dia., c.t.
160	44 turns no. 26 E. closewound. ⅜" separation btwn plate and grid coils	80 turns no. 28 E. closewound, c.t. Shunted with 3-30 μμfd. trimmer	56 turns no. 22 d.c.c. 2" long, 2¼" dia., c.t.

Amp. "grid" windings semi-resonant. Space for best operation before cementing turns on form.

from its socket in series with the 6L6G cathodes—then bending the neutralizing condenser plates while checking the plate circuit with a 2-volt 60-ma. lamp and turn of wire coupled to the plate coil. Pilot lamps in series with the tube cathodes act as tuning indicators when no d.c. milliammeter is available.

The set was built on a 10" x 14" x 3" chassis and fits into a 11" x 15" x 9" cabinet. It has a single power supply built in and requires no expensive parts. Operation in any band from 160 to 10 meters is possible with proper crystals and coils. If the set is operated straight through on the crystal frequency, the 6V6 cathode condenser can be left at about full capacity. However, less crystal reaction takes place when doubling in the 6V6 plate circuit, in which case the cathode condenser should be set at a lower value. Too low a value will cause uncontrolled 6V6 oscillation and r.f. output at other than that of the crystal harmonics. Good active crystals are needed for harmonic operation.

The 6L6G grid coil turns and location on the coil form were chosen to result in about 10 to 15 ma. of cathode current (grid current mainly) when no plate voltage is applied to this stage. Too much grid current or too much r.f. grid drive will not allow 100% modulation to be obtained. Too little grid drive means low carrier output.

The antenna coupling should be fairly heavy so the cathode current is from 125 to 150 ma. The antenna coupling should be great enough to reduce the amplifier efficiency to a point where "upward" modulation of antenna current takes place. A small lamp and turn of wire loosely coupled to the final amplifier coil will serve as an indicator for this test.

Good News

WE HAVE been making the rounds. Servicemen everywhere report an increase in business. We hope that they will realize that this is the result of a local condition and not over extend themselves. They should remember all the lean years that have gone before, and use that information for the making up of a "bad-times fund." If they utilize this minor boom advantageously, they will find themselves in a condition to continue nicely with little fear as to what the future may bring.—Radio News.

From Australian
I.R.E. Proceedings
April, 1939

Increased PHASE-SPLITTER GAIN

By C. A. PARRY

THE phase-splitting system represented by the connections of V2 in figure 1 has become very popular and is a simple and effective means for obtaining anti-phase voltages for driving push-pull a.f. amplifier stages. It has one disadvantage, however, in that its effective amplification in each phase must be less than unity, i.e., the voltage E_0 is always less than the input voltage E_1.

It is the purpose of these notes to discuss a simple modification of figure 1 which considerably increases the overall gain and at the same time retains the desirable features of the basic circuit arrangement.

- Overall Gain of Basic Phase-Splitter With Voltage Amplifier

For purpose of comparison, the overall gain of the circuit shown in figure 1 will be stated.

Let μ_1, Rp_1 = the amplification factor and plate resistance, respectively, of V1,
μ_2, Rp_2 = the corresponding values of V2,
Z_1 = the total plate load impedance of V1,
Z_2 = the total cathode load impedance of V2,
Z_3 = the plate load of V2,

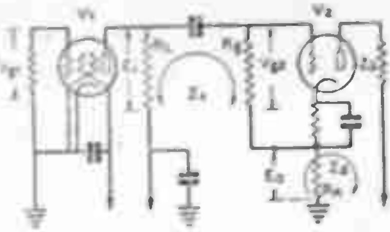


Figure 1.

Vg_1 = the a.c. grid input voltage of V1,

Vg_2 = the a.c. grid input voltage of V2,

E_1 = the a.c. voltage developed across Z_1, and

E_3 = the a.c. voltage developed across Z_3.

Then neglecting reactances (which may be neglected under normal circumstances):

$$\frac{\mu_1 \cdot Vg_1 \cdot Z_1}{Z_1 + Rp_1} = E_1 = Vg_2 + E_3$$

$$= Vg_2 + \left(\frac{\mu_2 \cdot Vg_2 \cdot Z_3}{Z_2 + Rp_2 + Z_3} \right)$$

$$= Vg_2 \left(1 + \frac{\mu_2 \cdot Z_3}{Z_2 + Rp_2 + Z_3} \right)$$

Having established these relationships, the overall gain E_2/Vg_1 from voltage amplifier input to one push-pull grid may be determined and it can be shown that

$$G_1 = \frac{\mu_1 \cdot \mu_2 \cdot Z_1 \cdot Z_2}{(Z_1 + Rp_1) \cdot [Z_2 + Z_3 + Rp_2 + (\mu_2 \cdot Z_3)]} \quad \ldots\ldots (1)$$

In calculations involving the above formulas it should be remembered that Z_2 must equal Z_3 in order to develop equal anti-phase voltages, and that the impedances Z_1, Z_2, and Z_3 take into consideration the effective loading of the following stages.

- Overall Gain of Modified Phase-Splitter Circuit

Now let us consider the modified circuit shown in figure 2. The impedance Z_2 now includes the resistance R_s which, although wired in series with RL, is effectively in parallel with R_k. For convenience of comparison, it may be assumed that Z_3 in figure 2 is equal to Z_3 in figure 1. It will be apparent, however, that the actual value of the cathode loading resistor R_s will

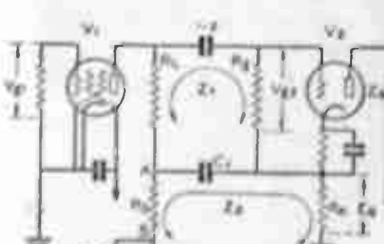


Figure 2.

be different in each case if this condition is to be achieved. For the remaining constants we may use the same nomenclature as previously.

Assuming once again that reactances are negligible, consider the value of E_o due to Vg_2 alone:

$$E_o = \frac{\mu_2 \, . \, Vg_2 \, . \, Z_2}{Z_2 + Rp_2 + Z_3} \quad \ldots\ldots (2)$$

Now it is apparent that this voltage is applied between the points A, B in figure 2 (i.e., across R_s) and, as a result, the valve V1 has a voltage in series with its plate supply, of value E_o and acting 180° out-of-phase with the voltage resulting from Vg_1. The effect of this is to lower the effective amplification of V1.

To demonstrate this, consider the total current circulating through V1 due to Vg_1 and E_o.

Vg_1 produces a current

$$I_1 = (\mu_1 \, . \, Vg_1)/Z_T$$

and E_o produces a current

$$I_2 = E_o/Z_T$$

where, in both cases, $Z_T = Z_1 + Z_2 + Rp_1$.

The resultant current

$I = I_1 - I_2$ and, therefore,

$$= \frac{1}{Z_T} [(\mu_1 \, . \, Vg_1) - E_o]$$

This is so because E_o, and therefore I_2, is itself produced by I_1 and, as a result, I is positive and I_1 is greater than I_2.

Under the new conditions, $Vg_2 = I.Z_1$ and, using the above equations, we obtain

$$Vg_2 = \frac{Z_1}{Z_T} [(\mu_1 \, . \, Vg_1) - E_o]$$

However, an analysis of the circuit shows that E_o cancels out and, consequently,

$$Vg_2 = \frac{Z_1 \, . \, \mu_1 \, . \, Vg_1}{Z_T}$$

or, in other words, the total voltage available at the plate of V1 is effective at the grid of V2. This means that although the effective amplification of V1 is reduced, the overall amplification of the circuit is increased.

This can be demonstrated by substituting the new value of Vg_2 in equation (2) and dividing the result by Vg_1. The overall gain equation obtained as a result of this is

$$G_2 = \frac{\mu_1 \, . \, \mu_2 \, . \, Z_1 \, . \, Z_2}{[Z_T \, (Z_2 + Z_3 + Rp_2)] + (Z_1 \, . \, Z_2 \, . \, \mu_2} \quad \ldots\ldots (3)$$

• Comparison of Results

In order to compare the overall gains provided by the two circuits, we may assume that, in both figure 1 and figure 2, $Z_1 = Z_1$, $Z_2 = Z_2$ and $Z_3 = Z_3$. Under these conditions the relationship G_2/G_1 is given by

$$\frac{\mu_1 \,.\, \mu_3 \,.\, Z_1 \,.\, Z_3 \,.\, (Z_1 + Rp_1) \,.\, [Z_2 + Z_3 + Rp_2 + (\mu_2 \,.\, Z_2)]}{\mu_1 \,.\, \mu_3 \,.\, Z_1 \,.\, Z_3 \,.\, [Z_T\,(Z_2 + Z_3 + Rp_2)] + (Z_1 \,.\, Z_2 \,.\, \mu_2)}$$

The first four terms in each line of this expression cancel out, leaving a fairly simple relationship that may be evaluated by the substitution of practical values. In order to accomplish this, let

$Z_1 = 200{,}000$ ohms,
$Rp_1 = 1$ megohm,
$\mu_1 = 1{,}000$,
$Z_2 = 50{,}000$ ohms,
$Rp_2 = 20{,}000$ ohms,
$\mu_2 = 20$

Z_T is of course, the sum of Z_1, Z_2 and Rp_1.

With these values,
$(Z_1 + Rp_1) = 1{,}200{,}000$ ohms,
$[Z_2 + Z_3 + Rp_2 + (\mu_2 \,.\, Z_2)] = 1{,}120{,}000$,
$Z_T = 1{,}250{,}000$ ohms.
$(Z_2 + Z_3 + Rp_2) = 120{,}000$ ohms, and
$(Z_1 \,.\, Z_2 \,.\, \mu_2) = 200{,}000{,}000{,}000$

Neglecting equal numbers of ciphers in both lines, these figures give us

$$\frac{G_2}{G_1} = \frac{1344}{350} = 3.8, \text{ approximately.}$$

This means that barely a quarter of the input voltage will be required to deliver a given voltage from each phase of figure 2, as compared to figure 1—a worth-while improvement in many circumstances, especially when the simplicity of the alteration is considered.

- Practical Considerations

So far, it has been assumed that reactance is negligible but, obviously, if the frequency transmitted is low enough, the voltage E_o will not be absolutely in anti-phase with Vg_1. The only effect is, however, to lower the gain of the system and unbalance the voltages across Z_2 and Z_3 somewhat.

The extent of this gain, loss and unbalance will be dependent on the capacitances employed and, in figure 2, if $C_1 = 1.0$ mfd., $C_2 = 0.5$ mfd., and $C_3 = 16$ mfd. reactance may be neglected over the usual audio-frequency range.

The next point to watch is the value of Z_2. If we neglect the input impedance of the push-pull valve driven from the cathode load,

$$Z_2 = \frac{R_g \times R_k}{R_g + R_k}$$

The best results usually will be obtained when $R_g = R_k$.

Practical considerations will normally limit R_g to 100,000 ohms, so that if equal values of R_g and R_k are employed, Z_2 will be 50,000 ohms under these circumstances. For balance to be obtained the plate load of V2 (Z_3) must therefore be 50,000 ohms also. This constitutes a major factor in the design of phase-splitting systems using the circuit of figure 2—the phase-splitter plate load resistor must be proportioned in accordance with the resultant of R_g and R_k and not in accordance with the value of R_k alone (as is the case in figure 1).

Because of this, the grid circuit impedance of the push-pull valves assumes somewhat more importance when the system of figure 2 is in use as, obviously, a low value of grid input impedance would have to be taken into consideration when proportioning R_k and R_g. To avoid trouble due to this cause, the push-pull grid circuit constants should be proportioned so as to have as little effect as possible on Z_2 and Z_3.

- **Comparison Under Typical Conditions**

It will be of interest to example the relative gains of figure 1 and figure 2 when somewhat more typical values are employed for the constants in figure 1.

For this purpose, let R_L = 250,000 ohms, R_g = 500,000 ohms and R_k = 100,000 ohms = Z_3. The values for figure 2 remain as given before, as also do the valve characteristics.

This time, only the first two terms in the G_2/G_1 relationship expression cancel out, thus leaving

$$\frac{Z_1 \,.\, Z_2 \,.\, (Z_1 + Rp_1) \,.\, [Z_2 + Z_3 + Rp_2 + (\mu_2 \,.\, Z_2)]}{Z_1 \,.\, Z_2 \,.\, [Z_T\,(Z_2 + Z_3 + Rp_2)] + (Z_1 \,.\, Z_2 \,.\, \mu_2)}$$

In the above expression, the values of the first two terms in the top line are as in figure 2, while the bracketed terms in the same line are all from figure 1. The reverse applies in the bottom line, as here the first two terms are from figure 1, while the bracketed terms are from figure 2.

Owing to the large effective grid circuit impedance of V2 in figure 1, the effect of R_g may be neglected, so the Z_1 = R_L = 250,000 ohms.

Substituting the appropriate values in the expression given above reveals a slightly different ratio. This is because, with the more typical values employed, the gain of figure 1 is slightly higher than in the first example. Even so, the G_2/G_1 ratio is still 222/70, or slightly over 3.1, so that the improvement is still appreciable.

Usually, as mentioned previously, it is not practical to increase R_g in figure 2 beyond 100,000 ohms, but if sufficient high-tension voltage is available, both R_g and R_k may be raised to 200,000 ohms each and Z_3 to 100,000 ohms. Under these conditions the increase in gain is slightly more marked and, in addition, the same voltage output E_o will be realized for the same percentage distortion as will be for the second set of values given for figure 1.

With R_g and R_k giving a resultant of 50,000 ohms, the voltage output obtained from figure 2 will be slightly less, for a given distortion percentage, than with figure 1 when using the second set of values. However, this will rarely be important, particularly as such systems are rarely operated at their maximum voltage output capability. Again, the difference is not very great and, in any case, it should be remembered that the input voltage required to deliver a given output is considerably less in the case of figure 2 than in figure 1.

• Practical Results

Practical results agreed very closely with the ratios arrived at by calculation. For figure 2, a value of 250,000 ohms was employed for RL, which with a grid resistor (R_g) of 1.0 megohm, gave the required value of 200,000 ohms for Z_1. A check on the first calculation, using a vacuum-tube voltmeter and a cathode-ray oscillograph, revealed a gain increase ratio of approximately 4, while a check using the second set of conditions for figure 1 showed a gain increase ratio of 3.

Distortion was not increased to any appreciable extent and the circuit has functioned quite satisfactorily in practical amplifier systems.

Revolution

UNDER this title, **Fortune** in its September issue, tells the lay public that frequency modulation threatens a revolution in broadcasting. Within a month or two there has been a remarkable stampede among broadcasters to get in on this static-free method of transmission. **Fortune** tells of Major Armstrong's efforts, largely unsuccessful, to get the industry behind his work: tells the public of the remarkable lethargy of the industry in failing to grasp the fundamental differences and advantages of FM over amplitude modulation (AM). The radio industry cries for change and new things, but only for little changes — nothing really fundamental. Industry only wants a new type of dial, or a 12-inch speaker in place of an 8-inch speaker—nothing like a whole new set-up that might banish noise and produce out of the air honest-to-God tone fidelity.

But industry had better look up. Long ago, when pentode tubes first threw a jolt into complacent radio receiver manufacturers, the statement was made "by pulling down the shades, you can sleep late in the morning, but you can't keep the sun from coming up." The sun of frequency modulation is surely coming up. Experiments by the General Electric engineers and by those of the Yankee Network demonstrate conclusively this fact.

—Electronics.

¶ From Bell Laboratories Record,
August, 1939

SORPTION OF WATER

by Organic Insulating Material

By R. L. TAYLOR

WHEN insulating materials like rubber and phenol plastics are immersed in water or exposed to humid air large changes may occur in their resistivity, dielectric constant, and power factor. These changes are caused by water which condenses on the surface, adsorbs in the interstices of the material, or is absorbed by soluble impurities. Laboratory studies of these effects help to predict the behavior of such materials in service.

Initially, the rate of sorption* is comparatively rapid whether the substance is immersed in water or water vapor; in most cases the amount of water taken up increases as the square root of the time of exposure. Characteristic sorption curves are shown in figure 1 for soft vulcanized rubber and phenol plastic in distilled water. The phenol plastic reaches a state of equilibrium where sorption ceases, but the rubber, which is elastic, may continue to take up water until it disintegrates and is dispersed throughout the liquid. This is illustrated by the logarithmic graphs of figure 2. At vapor pressures

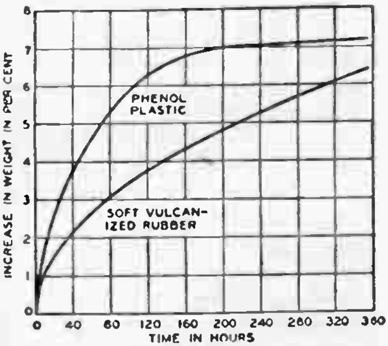


Figure 1. Sorption of water by thin sheets of insulating materials that are immersed in distilled water.

*Sorption is used in conformity with current phraseology to signify the combined effect of adsorption and absorption.

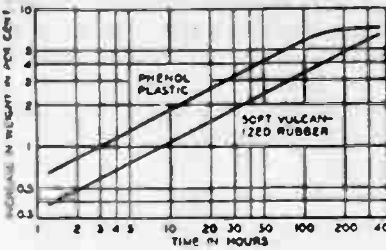


Figure 2. A logarithmic plot of the sorption of water shows the attainment of equilibrium by the rigid material.

less than saturation, equilibrium is reached by both phenol plastic and soft vulcanized rubber but the rate of sorption and final water content are less.

Several factors will cause sorption curves to deviate from straight lines before the point of equilibrium is reached. Among these are changes during the test in temperature or in relative vapor pressure. Leaching of water-soluble materials decreases the slopes of the curves; and the formation of additional water-soluble materials by oxidation shifts the curves upward. The latter is of particular significance because it is a measure of the deterioration of materials when they come in contact with water.

The straight-line logarithmic plot of figure 2 can be used to predict the water content of materials exposed to water for a given length of time, if fixed conditions of temperature and relative vapor pressure are maintained. A rubber piece-part which, for example, sorbs 0.1 per cent water in one day will, in accordance with this straight-line relation, contain about six per cent water after ten years.

In the early stages of sorption the percentage increase in weight of sheet materials when exposed to water varies nearly inversely with the thickness of the sheet, provided its area is large in comparison with its thickness. Since the rate of sorption is given by the slope of a curve showing the increase in weight plotted against the square root of time, the slope for a sample of unit thickness will serve as a sorption coefficient to compare different materials. At room temperature the sorption coefficient for a phenol plastic is about 0.026; for soft rubber, 0.015 and for ebonite, 0.0024. The coefficient describes the rate at which a material takes up water, and is not a measure of the final water content of the material.

It has been demonstrated experimentally for rubber that the logarithm of the sorption coefficient is inversely proportional to the absolute temperature. By using this straight-line relation it is possible to calculate from short-time test data obtained at one temperature the water content of such materials after an extended period of immersion at some different temperature.

An important practical application of sorption data is predicting the changes in dielectric constant which accompany the sorption of water. When sheets of soft vulcanized rubber are immersed in distilled water at constant temperature, the increase in weight is pro-

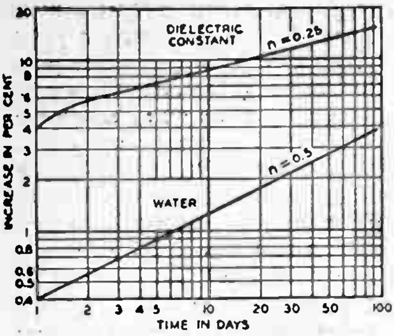


Figure 3. In distilled water both the water content and die-electric constant of a rubber sheet increase.

portional to the square root of time, but the accompanying increase in dielectric constant of the material is proportional to the fourth root of time.

These relations are illustrated in figure 3. There is, however, an initial period when the dielectric constant increases rather rapidly and during which the power factor reaches a peak. The rapid increase in dielectric constant is believed to result from water adsorbed on the inner structure of the material and the slow increase thereafter mainly to water absorbed by water-soluble substances that are in the material.

From the relationships of the preceding paragraph, it is evident that the increase in dielectric constant is proportional to the square root of the water content. A curve illustrating this is shown in figure 4. Although different materials differ in the amounts of water they sorb and in the effect of this water on the dielectric constant, when the relation between dielectric constant and water content is known, a measurement of dielectric constant alone suffices to describe the water-sorbing characteristics of many materials.

Before equilibrium is reached, water absorbed by a homogeneous material such as soft vulcanized rubber does not distribute itself evenly throughout the material but concentrates largely in the outer layers and decreases exponentially toward the center. In many practical cases this exponential distribution proves advantageous; for example, sorption by the insulation on rubber-covered wire. In this case the rubber next to the conductor may remain relatively dry although the amount of water sorbed by the insulator as a whole is appreciable. Wire insulation which has sorbed water in this manner should be considered as graded rather than homogeneous. Curves may be plotted to show the distribution of water in insulation of various kinds and shapes. These curves, with

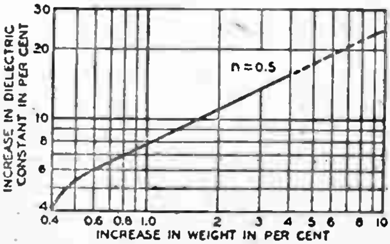


Figure 4. Dependence of the dielectric constant of rubber sheets on the water content.

others of the type shown in figure 4, may be used to calculate the dielectric properties of this type of continuously graded insulation. Information of this character is of practical interest in the telephone plant because of the increasing use of buried wire and the installation of circuits in locations exposed to high humidity.

New Rating System for Transmitting Tubes

AN ENTIRELY new system of ratings for aircooled transmitting tubes has been announced by RCA. Instead of one set of maximum ratings for each tube type two sets of maximum ratings are given. These ratings are designated "Continuous Commercial Service" (CCS) and "Intermittent Commercial & Amateur Service" (ICAS).

The CCS ratings are essentially the same as the former maximum ratings. The ICAS ratings, however, are considerably higher, permit the use of much greater power input, and provide a relatively large increase in useful power output. Complete operating data, including both CCS and ICAS ratings, have been prepared for RCA types 802, 804, 806, 807, 809, 810, and 814, as well as for the new 811, 812, and 828, and can be obtained on request from the RCA Manufacturing Co., Radiotron Division, Harrison, N. J.

It is self-evident that the harder a tube is worked the shorter will be its useful life. Although no rule can be set up which will accurately predict the life performance of an individual tube under specified operating conditions, it is practical to make an estimate of tube life on the basis of average results from a large number of tubes. In average amateur service, a tube operated at the higher ratings can normally be expected to give about 50 per cent of the life obtainable with CCS ratings.

The engineer designing a broadcast transmitter has quite a different problem. A broadcast station may operate tubes on an average of 18 hours a day. Tube failures are expensive both in themselves and in advertising revenue lost because of interrupted programs. Consequently, since reliability is his main concern, he should operate tubes at the CCS ratings, or perhaps even lower. Only in this way can he obtain the long tube life required for continuous commercial services.

In airplane transmitters, tubes may be operated only a few minutes a day. In addition, mechanical failure of tubes may occur prematurely due to the severe vibration and shock to which they are frequently subjected. For these reasons, operation of tubes at ICAS ratings, especially where maximum power output for a minimum size and weight are essential, should be considered. On the other hand, there are installations where it is imperative that the tubes be ready for operation at all times, because failures at the wrong moment may mean damage to an expensive airplane or even loss of human life. The choice of tube operating conditions for any service must, therefore, be based on a careful consideration of all factors.

—Radio, November, 1939.

¶ From Electronics
August, 1939

RULES and STANDARDS for Broadcast Stations

An expert review of the recently promulgated F.C.C. Rules and Regulations and Standards of Good Engineering Practice, which became effective the first of this month—of particular interest to station engineers and operators.

By RAYMOND F. GUY

WITHIN the last few weeks the Federal Communications Commission has released the new Rules Governing Standard Broadcast Stations. They have been in preparation for over a year, were adopted on June 23, 1939, and with one exception become effective August 1, 1939. To supplement these Rules there will soon be released the new Standards of Good Engineering Practice. Both of these F.C.C. documents are of vital interest and importance to all persons connected with the construction and operation of broadcast transmitting facilities. They warrant careful and detailed study by all broadcast engineers. The new Rules first appeared in the Federal Register, Volume 4, Number 126, June 30, 1939. Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. The General Rules and Regulations were adopted by the F.C.C. on May 16, 1939 to become effective June 15, 1939. They appeared in the Federal Register, Volume 4, Number 100, May 24, 1939. It is suggested that the interested reader obtain copies and study them in conjunction with this article.

A knowledge of the background of radio regulation is of importance in understanding the need for these Rules and Standards and should lead to a true appreciation of their merits. Government regulation of radio, to all intents and purposes, began in 1912. Prior to that time it was every man for himself. Stations were few in number, the only limit on power was financial and one appropriated the frequency which struck his fancy, or just operated without worrying much about it. Interference frequently resulted and the arguments which ensued by radio were interesting if not genteel. In some respects it was a ham's paradise. However, the Radio Act of 1912 produced a semblance of order.

The frequencies 1000 kc., 670 kc. and 500 kc. were set aside for ships and amateurs were assigned all frequencies above 1500 kc. For the first time, the assignments of calls by international agreement were made. The excursions of the amateurs into the commercial channels, of which the writer was not altogether innocent, ceased and peace reigned for the next ten years.

The advent of broadcasting shortly after the war, brought a host of new problems. 835 kc. was assigned to this new service. Soon 750 kc. had to be added. As more and more stations clamored for licenses the frequencies of 1000 kc. and 670 kc. were taken away from the marine services and gradually the spectrum between 1500 and 500 kc. was occupied. Continued crowding made it necessary to duplicate assignments and a climax resulted when a Chicago station proved that the Radio Laws did not have sufficient teeth in them to prevent pirating of frequencies. This was the condition which led to the Radio Act of 1927 and the formation of the Federal Radio Commission, later reorganized as the Federal Communications Commission. The problems which faced this body were many and complex.

Under the Radio Act of 1927 and the Communications Act of 1934, the Commission is given broad regulating power over radio communication including the right to adopt Rules and Regulations not inconsistent with the terms of the Act, which Rules and Regulations have the full force and effect of a law.

The Standards of Good Engineering Practice give interpretations and further considerations concerning these Rules and Regulations. While the Rules provide the basis of good engineering practice, the Standards go further and set up engineering principles for use in solving allocation problems. The Standards published are those deemed necessary to ensure compliance with the requirements of the Rules and for operation in public interest along technical lines not specifically enunciated elsewhere. The Standards are based upon the best engineering data obtained in formal and informal hearings and surveys conducted in the field. They were prepared after conferences with engineers, manufacturers and others and supersede all previous announcements or policies of a similar nature enunciated by the F.C.C. on engineering matters concerning standard broadcast stations.

The Commission Engineers early recognized the need for comprehensive data as a guide to satisfactory allocation of frequencies. Take the case of a 5 kw. station as an example. It could produce good daytime or night-time service out to a distance of roughly 50 miles. Beyond that distance the signal would no longer be serviceable but nevertheless, it would be still strong enough to produce interference to other stations on the same frequency, and particularly so at night. Everyone knew that there would exist a "service area" surrounded by a "nuisance area" which became very large at night. But, in terms of potential interference, how large was this nuisance area?

It was desirable that places on the airwaves be found for more and more new stations, that the existing frequencies be used as economically as possible to provide the maximum of public service. These demands could be met only by duplicating more stations on existing channels. However, in order to do so, better technical data on long distance propagation was needed. With the cooperation of broadcast licensees the F.C.C. planned and executed a program of measurements in 1934-1935 which provided the data required. Recordings over various long distances and directions, when analyzed yielded invaluable information. One chart of particular value is shown as figure 1. It is the average value of night-time sky-wave field intensity based upon an antenna which produces a field intensity of 100 millivolts at one mile. Knowing the one mile field intensity of any station, it is possible with this curve to estimate the average field at any point within a radius of 2700 miles. This curve is for the second hour after sunset and is generally used to represent average night-time conditions.

Now suppose we work out a problem in frequency allocation and see how the average night-time curve of figure 1 is applied. The problem: In a certain city there is a 1 kw. regional station. We wish to see how close to it we could locate a second 1 kw. regional station which would produce service to its own 2½ millivolt contour without interference from the existing station.

In the new Rules, Section 3.22, we find the various classes of stations defined. Paragraph (C) (1) states:

"Class IIIA Station"—"A Class IIIA Station is a Class III Station which operates with power not less than 1 kw. nor more than 5 kw., and the service area of which is subject to interference in accordance with the "Engineering Standards of Allocation."

Referring to the standards of Good Engineering Practice we find Table IV "Protected Service Contours and Permissible Interference Signals for Broadcast Stations." This shows that a Class IIIA Station is normally protected, to its 2½ millivolt contour, so our station is in Class IIIA.

The first step is to determine the field intensity of the undesired station that is necessary to cause interference to the desired station. It has been standard practice for many years in the F.C.C. and in the in-

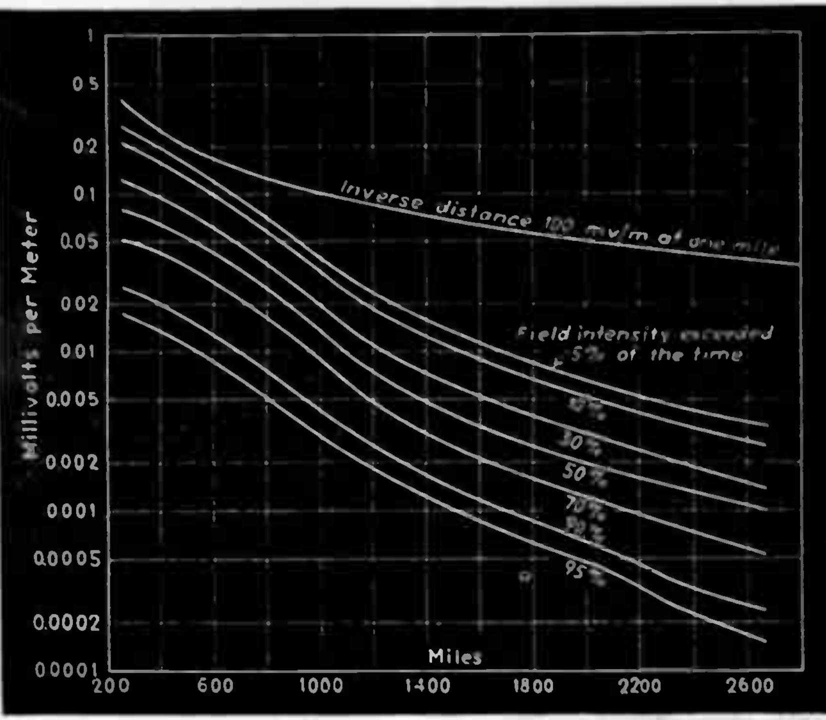


Figure 1. Nighttime average field strengths at distances from 250 to 2700 miles, compiled by the F.C.C. for allocation purposes.

dustry generally to consider that when a ratio of 20:1 between the desired and undesired stations is exceeded, interference exists. Accordingly the permissible interfering signal would be 2500/20 microvolts = 125 microvolts.

Now let's consider further the matter of interference. Is it necessary that the 20:1 ratio be maintained 100 per cent of the time, or could it be exceeded momentarily without seriously degrading service? Since sky waves fluctuate widely in amplitude short bursts of interference occur, and to some degree may be tolerated. After study the F.C.C. and the industry have adopted the figure of 10 per cent as the portion of the time during which the 20:1 ratio could be violated before interference is considered to exist.

Assume that our IIIA Stations use antennas one-quarter wavelength in height. Reference to figure 2 shows that such an antenna, operating on 1 kw. will produce

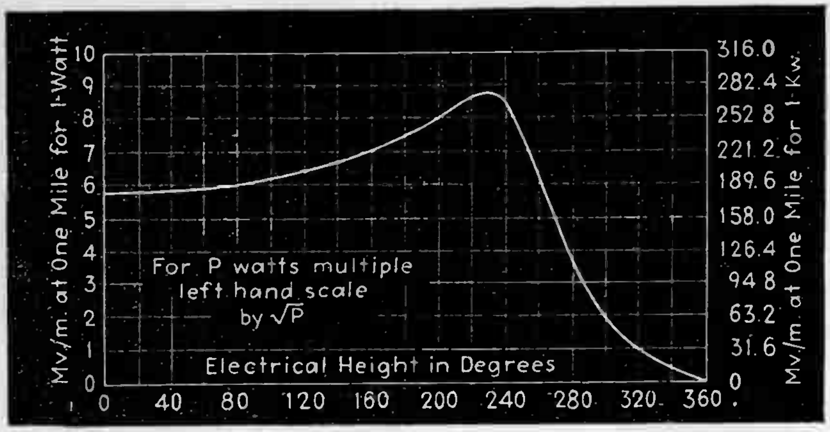


Figure 2. Field strength as a function of antenna height (Data from Fitch and Duttera, NBC). Note the advantage of using an antenna longer than one-half wavelength.

about 190 millivolts per meter at a mile. We now refer to figure 1, the F.C.C. curve of average nighttime field intensity. Since this curve is based upon a one mile field intensity of 100 millivolts and our antennas produce 190 millivolts, we must use a simple conversion factor. Multiplying 125, the value of interfering signal, by 100/190 will give the value of the ordinate corresponding to the distance we seek on the abscissa. It is 66.5 microvolts.

Reading from the 10 per cent curve of figure 1, the distance is found to be close to 735 miles. It is in this manner that the Separation Tables in the Standards of Good Engineering Practice were derived. Tables VI, VII, and VIII on the Recommended Standards are complete allocation tables and constitute a valuable guide to the engineer concerned with allocation problems. Broadcast engineers may consider the time very well spent in studying them. It should be noted in passing that the use of directive antennas makes it possible to reduce the field intensity radiated in certain directions and thus operate stations in some cases with less separation than indicated in the tables.

The allocation tables cover daytime conditions as well as night time. The method of determining the required daytime separations differs somewhat, however. The daytime interfering field is produced by ground waves only. These fields are quite steady in amplitude and therefore the 10 per cent time allowance used for nighttime interference does not apply. Also the method of determining the required separation makes use of daytime attenuation data instead of the nighttime curve of figure 1. The daytime separations are so close that careful allowance must also be made for the distances from the stations to their contours which are to be protected.

Daytime attenuation is caused by two factors:

1. Dispersion, which varies directly with distance.

2. Losses in the earth, caused by its imperfect conductivity and the resulting heating.

Space does not permit further discussion of attenuation. For a simplified treatment of the subject, including easily used curves, the reader is referred to an article by William A. Fitch in the September, 1936, issue of *Electronics*.

The nighttime secondary service area of a station not limited by interference, is considered to be the ½ millivolt, 50 per cent contour. In other words, when ½ millivolt service is obtained 50 per cent of the time, secondary service is rendered. Figure 1 includes a 50 per cent curve.

It was important that standards of frequency allocation be adopted, specifying transmitter powers, etc. It is, naturally, also important that stations operate on the power, etc. for which they are licensed, if the allocation system is to work satisfactorily. It is in such matters as this that stations occasionally run afoul of the efficient F.C.C. inspectors, either by exceeding specified tolerances of one kind or another, or almost equally important, not having suitable indicating instruments to indicate accurately compliance with the Rules.

- Power Measurements

Section 3.51 (a), (1), (2), (b) of the new Rules is of particular interest to station engineers.

All new stations are required to use the direct method of power measurement (antenna I^2R) and all other stations will be required to adopt the method by July 1, 1940. Existing stations using the indirect method (plate power input × given efficiency) are required to use efficiency of 70 per cent, instead of 50-60 per cent as formerly.

Transmitters using plate-modulated final stages must use an efficiency of 70 per cent, instead of 50-60 per cent as formerly, if the maximum rated carrier power is from 100 to 1000 watts, and an efficiency of 80 per cent instead of 65 per cent if the maximum rated carrier power is more than 5000 watts. Stations using Class B final amplifiers must use 35 per cent and those using Class BC final amplifiers must use 65 per cent. Stations using different nighttime and daytime powers must use the same efficiency for both powers.

In general, stations using the indirect method will find it to their advantage to change to the direct method without delay for two reasons:

1. The new efficiencies are severe and in many cases will be difficult to meet in practice. If they are not met the licensed power can not be radiated.

2. Following the final stage

where the power is determined by the indirect method, there are inevitable losses in transmission line and antenna coupling apparatus which further reduce the radiated power.

Measurement of power by the direct method is considered preferable by this writer because it provides assurance both to the Licensee and the Communications Commission that the antenna input power is what it is supposed to be.

The reader is referred to the Standards of Good Engineering Practice for guidance in making antenna resistance measurements and preparing the necessary application to the F.C.C. for authorization to use the direct method. In the *RCA Review* of April 1938 and January 1939, William A. Fitch and William S. Duttera, in "Measurement of Broadcasting Coverage and Antenna Performance," cover the same subject in detail.

Section 11 of the Standards permits short period variations of operating power of 5 per cent above or 10 per cent below the authorized power.

- Frequency Tolerance

Rules Section 3.59 "Frequency Tolerance" is of interest. Until July 1, 1940 all stations are permitted a maximum deviation, from their assigned frequency, of 50 cycles. From then until January 1, 1942 new stations must remain within 20 cycles, and thereafter all stations must.

There are good reasons for this rule. Some years ago, before the 50 cycle requirement became effective, 500 cycles were permitted. If two stations on the same channel each deviated 500 cycles, but in opposite directions, the result was a 1,000 cycle beat note. This frequency falls near the range of maximum sensitivity of the human ear, and also that of the average loud speaker. Therefore even a low value of interfering field intensity was ruinous to service. Reducing the tolerance from 500 cycles to 50 cycles reduced the maximum beat frequency to 100 cycles and in this range the ear, and also most loudspeakers, were relatively insensitive. Therefore a considerably stronger interfering field intensity could be tolerated. The further reduction of the tolerance to 20 cycles confines the maximum beat frequency to 40 cycles, and in this step the gain is perhaps greatest. The ear is quite insensitive to this frequency and the average loudspeaker is conspicuously so.

It would be improbable that the maximum deviations would be experienced. If averages were used they might be, for 500 cycles tolerance, 500 cycles, and for 50 cycles tolerance, 50 cycles. Under these conditions it has been considered that for the larger tolerance, a desired to undesired ratio of signal intensities of 100:1 would be required to prevent interference, but that for the small tolerance 20:1 would produce the same results. It was considered that a ratio of 20:1 between the desired and undesired signals represented a modulation of the desired signal of 5 per cent at

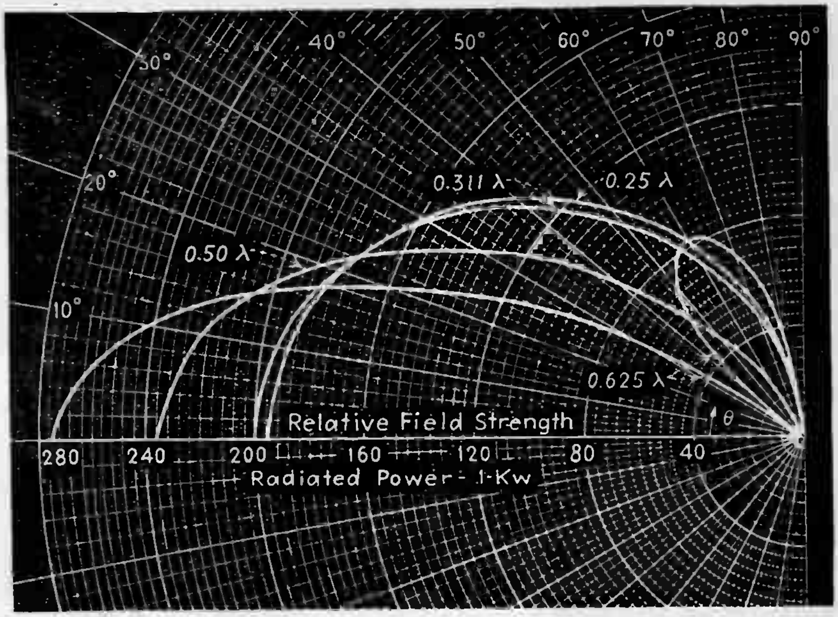


Figure 3. Vertical radiation patterns of antennas of different height (FCC data) showing the advantage of long antennas in producing useful low-angle radiation.

50 cycles, or 5 per cent crosstalk, with equivalent modulating conditions at the two stations.

Sections 3.61 and 3.62 of the Rules require that authorization to modify or replace frequency control apparatus be obtained. However, no specifications are included beyond the requirement that before approval will be considered there must be reasonable assurance that the equipment is capable of maintaining automatically the assigned frequency within the limits specified.

With possibly a few exceptions, equipment now in use, built to meet the 50 cycle requirement, deviates considerably less than 20 cycles. In a great many cases substitution of low-temperature-coefficient crystals should provide the additional factor of safety.

- Radiating Systems

Section 3.45 of the Rules and a corresponding section of the Standards of Good Engineering Practice deal with radiating systems. Stations requesting authority to modify or to build new radiating systems are required to equal or exceed certain minimum antenna efficiencies. Ordinarily, these efficiencies are obtained by building antennas to certain minimum heights since over a significant range the height deter-

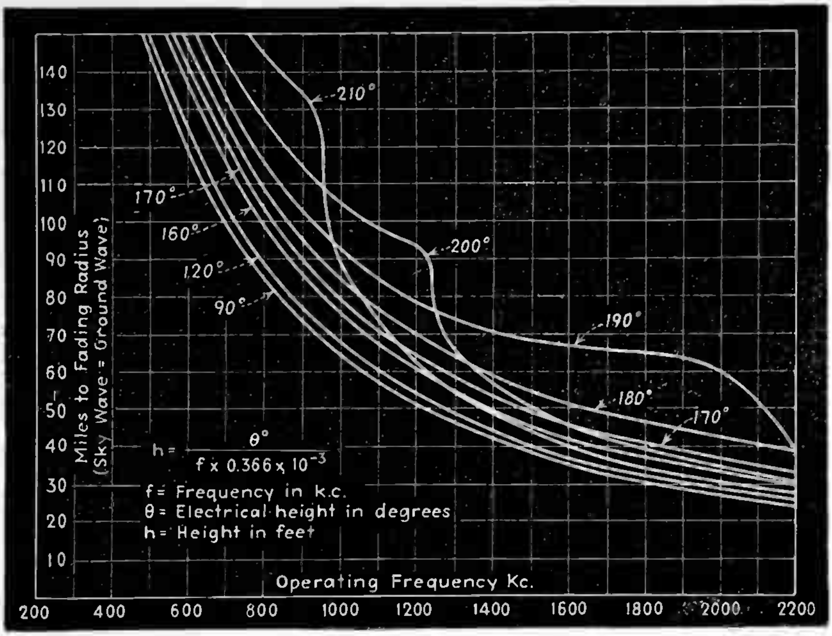


Figure 4. Influence of antenna height on the fading radius, as a function of the operating frequency (NBC data).

mines the efficiency. There are good reasons for doing so, even if it were not required, and particularly so in the cases of the higher-powered stations. Figure 3 shows vertical cross sections of the field distribution from antenna of various fractions of a wavelength in height. The abscissa to the left is proportional to field intensity units. As the height is increased the wave parallel to the earth is increased at the expense of the high angle component.

Since both local and long distance transmission depend upon the wave energy leaving the antenna at angles within 10 per cent of horizontal, all of the useful functions are served better by compressing the field as nearly as possible to the earth's surface. The high angle radiation not only represents wasted power but it causes the fading which degrades service at the boundaries of the primary service area. Figure 4 shows eloquently the effect the antenna height has upon the distance to the fading wall. The improvement actually obtained by the construction of a new antenna at WJZ was described by the writer in the April 1937 issue of *RCA Review.*

Of the new Standards, Section 1, covering "Engineering Standards of Allocation" is probably the most comprehensive. In it standard broadcast stations are classified and defined, service standards are set up for both day and night operation, and the subject of interference, and method of determining it, are dealt with at some length. Much new desired material is presented, including the method of evaluating interference produced when two or more stations cause it. In this connection it is not considered that increased objectionable interference is predominently from a single station, when a signal from another station is added which does not equal 70 per cent of the strongest signal already interfering. For two equal interfering signals, the signal added should not equal 85 per cent of either one. The existence or absence of interference may be determined by actual prescribed methods of measurement, reference to the attached propagation curves, or the distance Tables VI, VII, and VIII.

Section 12 of the Standards specifies a maximum of 5 per cent audio harmonic distortion (voltage measurements of arithemetical sum) for transmitters when modulated up to 84 per cent and not over 7.5 per cent up to 95 per cent. Harmonics up to the tenth are to be measured up to a maximum frequency of 16000 cps, using modulating frequencies of 50, 100, 400, 1000, 5000, and 7500 cps. This Standard may be difficult for some existing stations to meet. Those using Class B final amplifiers with indirect power measurement may find it advantageous to change to direct measurement and then readjust the equipment to improve the distortion characteristics. Operating at 30 per cent efficiency or thereabouts instead of 33 or more will usually permit of considerable improvement if the plate dissipation ratings of the tubes are not exceeded.

The carrier current shift has been made a maximum of 5 per cent. The shift will not be visible on thermocouple instruments but will be observed on the rectifier types, and it may also be observed on the d.c. rectified current meters of modulation monitors.

The unweighted RSS carrier noise should be not less than 50 db below 100 per cent modulation from 150 to 500 cps, and not less than 40 db outside that frequency range. It is not considered that these tolerances apply to the usual long lines network circuit noises since they are beyond the control of the licensee. Elaborate standards are set up covering safety precautions and indicating instruments. The licensee will be wise to study these carefully.

In connection with spurious radiations, including radio frequency harmonics, the Rules and Standards impose only the broad requirement that they do not exceed values conforming with good engineering practice. It is often difficult to determine the degree of harmonic radiation since high frequency harmonic currents produce random standing waves on an antenna which in turn may produce vertical radiation at high angles not measurable at nearby points on the ground. One watt of harmonic power in the antenna can produce a field intensity of over 6000 microvolts per meter at one mile. At one hundred miles it could produce 40 microvolts which could be ruinous to aviation or other services which carry on communication with field intensities that order of magnitude.

Lack of space prevents going into further detail in connection with the new Rules and Standards. To be sure of meeting them stations will need measuring apparatus. A few of the more important instruments would include a variable audio frequency oscillator with very low harmonic content and a meter for measuring carrier noise and audio frequency harmonic distortion.

Years ago the writer inspected a broadcasting station which utilized storage batteries for the plate supply. Following nightly charging cycles, they delivered about 1300 volts for the beginning of each day's transmission. However, the voltage soon began to drop and at signing-off time was barely 400 volts. In an attempt to compensate for this state of affairs, the antenna coupling coil, a well-known standard amateur unit, was pushed along a shelf with a yard stick specially selected for this highly scientific purpose. Fortunately, such bailing wire practices are but a memory. They would be impossible at the present time. And why? Well, in the humble opinion of the writer, with due credit to the licensees who take pride in fine plants, it isn't necessarily because the breed of shoestring operators is extinct.

Broadcast channels are public property entrusted by the F.C.C. to the care of private licensees. The possession of a license imposes upon the licensee the responsibility to serve public interest, convenience, and necessity. Before an applicant can obtain a license he must show that there is a need for service, and he must also show that adequate resources are available to provide it properly. The new technical Rules and Standards are the best and most complete of their kind in the world. Compliance with them will automatically assure high quality transmission, with reasonable efficiency, and will also keep technical departments out of hot water.

●

Credit . . .

TO Sir William Gilbert, one-time physician to Queen Elizabeth, for the name "Electricity." The name was derived from Gilbert's term "electrica" which he adopted from the Greek "electrum," meaning amber. Electrical effects were first noted when amber was rubbed on silk cloth.

—Ohmite News

¶ From Radio
June, 1939.

RADIO AS A PROFESSION

By CHARLES R. LEUTZ

EVERY once in a while some amateur laments the fact that he has spent a lot of time and money on amateur radio and has nothing to "show" for his efforts. During the past twenty years or more the writer has observed the progress of hundreds of amateurs. Some of these young men made the most out of radio opportunities that came up; others did not.

Some people will argue that an amateur is just an amateur and that amateur radio activities should be regarded simply as a hobby. It is true that many men, well established in some other line of business, do find radio an interesting diversion and excellent hobby. However, the young amateur in high school, college, or who has even started to work in some field other than radio, should give serious thought to the opportunities offered in the radio and allied fields.

Years ago the future of radio was so uncertain that it was very difficult for an amateur to decide what course to pursue. Today, any amateur who wants to make a future out of radio can map out a definite program. There are many ways in which an amateur can make his hobby pay as it goes along and also contribute experience of value.

It is best to decide as early as possible just what, if anything, you want to do in radio, that is, whether you want to be a commercial radio operator, a radio executive, a radio engineer, etc.

Assuming an amateur intends to become an engineer, then a university education and degree are essential. Among some of the leading radio engineers and executives active today there are a few who are not college graduates. However, these top executives who are not college graduates usually follow a strict policy of hiring only graduate engineers. Times have changed; years ago experience in radio counted more than education. Today it is exactly the opposite; advanced education is necessary to grasp quickly a summary of the past experiences of the pioneers. In the old days a radio engineer was expected to design transmitters, receivers, antennas, towers, power plants and even buildings. Today, all these individual branches have become so far developed that engineers must specialize on some one subject, or even a sub-division of one subject.

The matter of a college degree cannot be over emphasized. It is essential in order to qualify for many worth-while City, State or Federal Civil Service positions. With few exceptions, industrial employment managers prefer graduate engineers of little experience to non-graduates with long experience. The reason is sound, as the well-educated engineer can adapt himself quickly to new problems. He has the foundation to work out a problem without depending upon precedent.

If the prospective radio engineer cannot afford a college education, there are alternatives. Thousands of scholarships are available from universities in every state. Many cities have colleges providing engineering courses to residents living in the city one year or more. Another alternative is to work in the daytime and take a night course which leads to a college degree in six years.

There are a few commercial radio schools which are accredited and have an excellent reputation. However, there are also dozens which specialize only in taking your money. Before enrolling in one of these private radio schools one should investigate thoroughly, and not put too much stock in their claims without first checking up to see how the graduates fare when it comes to getting jobs. The schools referred to are the resident schools. Most of these schools also offer home study courses, which undoubtedly are a means for advancement but are not nearly so effective as the resident course, where the student attends class and has the benefit of lectures, individual instruction, and more extensive equipment.

Amateur radio activities carried on during high school and college terms need not interfere with studies. As a matter of fact, one can supplement the other in several ways. The smart amateur is not satisfied with a mere ham ticket. He obtains, as early as possible, a commercial radio operator's license. This opens up numerous opportunities to earn money and experience in connection with his college education. During the vacation months there is a chance not only to earn a substantial sum, but to travel as well. The ideal vacation occupation for the student operator is aboard a private yacht. Alternatives include tramp steamers, excursion boats, shore stations or airway positions. Many amusement parks require public address operators for the summer.

There are splendid opportunities for amateurs to earn money in spare time servicing broadcast receivers, public address systems, electrical appliances, talking motion picture equipment and even automotive electrical units. Additional money can be earned retailing broadcast receivers on a small scale.

Returning to the matter of a college education, possibly the most important subject in connection with radio is mathematics. The modern physicist, scientist and engineer thinks in terms of mathematics. It is truly said that if one understands higher mathematics, then "everything is obvious." Aside from the higher mathematics including advanced algebra, geometry, quadradic equations and calculus, the supplementary subjects will depend upon what one intends to specialize in. The specialist in acoustics will be required to design broadcast studios, amplifiers, loud speakers and microphones. The prospective tube engineer should study metallurgy, chemistry, thermodynamics and physics as well as electrical engineering. The transmitter and receiver engineers have to study high-frequency and ultra-high-frequency alternating currents in addition to electrical engineering.

The engineering student holding one or more degrees and completing a year or two of graduate study specializing in some one branch of radio can look forward to immediate employment. Manufacturers are always looking for new, promising talent, young ambitious men that have the proper fundamental education. Aside from the manufacturers of radio and electronic apparatus, other employment possibilities include motion picture studios, communication companies, airways, radio broadcasting companies, teaching positions and the Civil Service openings.

Patent attorneys also require the services of engineers and experts. As a matter of fact the student may plan to supplement his technical education with a law course and become a patent attorney.

Many foreign governments and concerns require the services of American radio engineers from time to time. The radio engineer with a knowledge of one or two foreign languages has an advantage when such openings occur. Spanish is a good language to know in this connection as there is bound to be considerable expansion in South America. A knowledge of French or German enables reading of the European technical publications, permitting one to keep abreast of European developments.

Aside from reading the "ham" magazines, the radio amateur should read regularly good trade papers relating to electronics, electrical engineering and communication. These publications together with books on the subject are available in most public libraries.

A real opportunity that every amateur, student or engineer has before him is the chance to develop something new and valuable, an improvement that will rate a worthwhile patent. The well-known regenerative patent was obtained by Armstrong while he was still a student at Columbia University.

THE TECHNICAL FIELD

in Quick Review

●

RADIO TECHNICAL DIGEST briefly summarizes for its readers the contents of leading radio articles in current technical publications, some of which may appear later in Radio Technical Digest.

COMMUNICATIONS

Bryan Davis Pub. Co., Inc.
19 E. 47 St., N.Y.C.
25c a copy—$2.00 yearly

SEPTEMBER, 1939

CORONA AND IONIZATION DETECTION, *by H. A. Brown and B. H. Weston*—A small corona discharge existing in a comparatively powerful r.f. field is difficult to detect. This article describes a device which allows such small corona discharges to be found on r.f. apparatus or circuits. The detection unit consists of an r.f. oscillator and a three-coil variometer for balancing the effects of r.f. current through two of these coils so that no energy is transferred to the third coil, which is connected to the input of a receiver. When a test sample is placed between the oscillator and one of the variometer coils and the position of the coils adjusted for zero signal in the receiver it is then possible to determine the presence of corona discharge by raising the output of the oscillator until a hiss or whistle caused by the corona is heard in the receiver.

AUGUST, 1939

ELECTRON BEAM DEFLECTION METHODS, *by F. Alton Everest*—The fifth article of a series on the fundamentals of television engineering. Both electrostatic and electromagnetic deflection systems are discussed in this installment. Several circuits are shown for obtaining balanced saw-tooth deflection for use with the electronic system in cathode-ray tubes not having a common terminal for one horziontal and one vertical deflecting plate. Mr. Everest finds little to choose between the two commonly used systems of deflection for commercial use, with the electrostatic system being somewhat more suited to the needs of the amateur constructor.

SOUND MOTION PICTURE FILMS IN TELEVISION, PART IV, *by John A. Maurer*—This installment covers film-scanning equipment. After describing several scanning systems which require a certain film frame speed for their operation, the author concludes that there is need for a projection method that does not have to be operated in synchronism with the transmitter scanning system. The remainder of the article is given over to a discussion of two non-intermittent systems which allow the projection apparatus to be electrically and mechanically independent of the transmitter scanning system.

TELEVISION ECONOMICS, PART VII, *by Dr. Alfred N. Goldsmith*—This part of the series on television economics covers numerous receiver problems and practices. Much of the article concerns the cathode-ray tube and its associated circuits.

electronics

35c a copy—$5.00 yearly McGraw-Hill Pub. Co., Inc. 330 W. 42 St., N.Y.C.

SEPTEMBER, 1939

PICTURES BY WIRE—An article describing several of the portable picture transmitters now being used by the large news and picture services. All of the units described operate on similar principles with minor differences in scanning frequency, carrier frequency and synchronizing arrangements. All are designed to be coupled into ordinary telephone lines either through a coupling coil or by direct connection to the telephone line. One photo service uses a portable transceiver unit which may be operated as either a picture transmitter or receiver by merely throwing a switch.

A TELEVISION RECEIVER FOR THE HOME, *by Donald G. Fink*—The *Electronics* laboratory television receiver modified for home use. The complete receiver, including cabinet and cathode-ray tube, was built for $202 which represents a considerable saving over an equivalent manufactured receiver. A diagram of the receiver is given, as well as photographs of the various units which go to make up the complete assembly.

THE TIME TELESCOPE, *by Beverly Dudley*—A description of a unit which automatically controls the interval between exposures and the exposure length of a motion picture camera for the purpose of taking extremely slow motion pictures. Both operations are controlled by condenser discharge circuits and controls are provided so that the interval between exposures may be any period from 1/5 second up to 1 hour, while the exposure time may be adjusted between 1/10 second and 10 minutes. Through the use of a phototube as a light-controlled resistor in the discharge circuit controlling the closing time of the shutter the shutter speed may be automatically compensated to correspond with different amounts of light.

BESSEL AND HALF-WAVE RECTIFIERS, *by M. B. Stout*—Wave forms of the output voltage and current of a half-wave rectifier are analyzed through the use of Fourier's series. The author finds little accurate information on half-wave rectifiers available in engineering textbooks and states that some of that which is available may be incorrect. Curves are given showing the behavior of such rectifiers under five different conditions of operation.

AUGUST, 1939

TRIGGER CIRCUITS, *by H. J. Reich*—A description of various types of "trigger circuits" in which currents or voltages change abruptly from one stable value to another stable value when a control voltage exceeds or becomes less than a certain critical value. Several complete trigger arrangements are shown along with the basic circuits from which they are derived.

APPLYING FEEDBACK TO BROADCAST TRANSMITTERS, *by L. G. Young*—A rather lengthy article concerning the technique of applying feedback to the older type broadcast transmitter. Both the theory and practical aspects of necessary circuit changes are discussed. Since most of the difficulties encountered in this type of application are due to phase-shift problems, the main portion of the article is given over to an explanation of the proper method of reducing phase shift within the feedback loop. Several examples of the calculations and changes involved add to the article's usefulness.

COAXIAL LINE INSTALLATION—II, *by J. B. Epperson*—This concluding article on coaxial line installation covers above-surface and below-surface installations as well as methods of protecting the line from lightning and the resultant sustained arc often caused by flashover of the protective spark gaps.

CONDENSER-LEAD RESONANCE CHART, *by R. L. Haskins*—The usefulness of by-pass condensers at radio frequencies may often be increased by choosing condensers which, with their associated leads, constitute a series-resonant circuit at the operating frequency. The chart covers condensers of from .001 μfd to 4 μfd and frequencies of from 70 cycles to 40 Mc.

●

OCTOBER, 1939

A COMPACT ¼-KW. RIG, *by Don Mix*—Describing a simple transmitter in the medium-power class. The transmitter is a strictly conventional capacity-coupled arrangement using a 6V6 tri-tet oscillator, 807 buffer-doubler and a 75T final amplifier. A minimum of parts is used throughout.

THE SERIES-VALVE NOISE LIMITER, *by Dana H. Bacon*—A new noise-limiting arrangement utilizing a series diode as the noise limiting element. When used with an infinite-impedance detector positive peaks up to a certain value are passed through the limiter from cathode to plate because of a small positive voltage applied to the plate. When the input peaks exceed the plate potential, however, the current flow through the diode ceases and it becomes a non-conductor, thus giving an effective noise-limiting action. For use with detectors in which the negative half of the signal is used the connections to the noise-diode elements must be reversed.

THE INFINITE IMPEDANCE DETECTOR—A discussion of the advantages and disadvantages of some of the more common second detector circuits. The operation of diode, plate and infinite-impedance detectors is described. A circuit employing a diode and triode for obtaining both infinite-impedance detection and a.v.c. is shown.

THE BAND-EDGE LOCATER, *by Reginald Tibbetts*—A 100-kc. crystal oscillator with a 50-kc. multivibrator and a harmonic amplifier. The unit, complete with power supply, is assembled on a single chassis. Single-ended tubes are used throughout.

THE OSCILLOSCOPE SHOWS—WHAT?, *by T. M. Ferrill, Jr.*—An article describing how to use an oscilloscope to obtain wave-envelop and trapezodial patterns and their proper interpretation. It is shown that each type of pattern has its application in transmitter adjustment and that, for best results, both types of patterns should be used. Circuits are shown illustrating the proper method of connecting the oscilloscope to the transmitter.

A COMPACT UNIT-TYPE AMPLIFIER, *by George W. Shuart*—Another of the popular part-and-bracket amplifiers. This one uses a pair of HK24's and gives an output of 175 watts.

AN R.F. MATCHING NETWORK FOR GENERAL USE, *by Warren M. Andrews*—Describing a simple matching network for matching untuned lines to resistive loads. A set of formulas for determining the required network inductance and capacity is given.

SEPTEMBER, 1939

HETROFIL—AN AID TO SELECTIVITY, *by Raymond W. Woodward*—Describing the use of a Wein bridge to balance out heterodyne interference. The curves given for the compact (3 x 4 x 5 inch) unit show an attenuation of nearly 70 db under optimum conditions.

AN ANSWER TO THE E.C.O. PROBLEM, *by Charles D. Perrine, Jr.*—A simple E.C.O. unit using a 6SK7 and 6V6. The 6SK7 oscillator, in which the heater is operated at the same r.f. potential as the cathode to minimize the effect of cathode-heater capacity variations, is tuned to 160 meters and the 6V6 is used as a doubler to the 80-meter band. Two temperature-controlled crystals are provided for edge-of-band operation. A separate power supply is used with a pair of VR-105's being used to supply a regulated 210 volts to the exciter.

HIGH-Q TANK CIRCUITS FOR ULTRA-HIGH FREQUENCIES, *by Arnold Peterson*—This article concerns the obtaining of high-C and high-Q tank circuits through the use of physically unconventional inductance-and-capacity arrangements. The author shows that it becomes extremely difficult to obtain a high-impedance, high-C tank circuit at ultra-high frequencies when conventional coil-and condenser tanks are used. By combining the inductance and capacity in a single unit, however, it is possible to realize both a high C/L ratio and high impedance, with the result that greatly improved stability is obtained at these frequencies.

A PORTABLE-EMERGENCY UTILITY TRANSMITTER, *by Louis F. Leuck*—A small 6-volt-powered transmitter of straightforward design. The transmitter may be operated either from a storage battery or a 6-volt, 8-amp. transformer. Type 41 tubes are used in both the final amplifier and the Heising modulator.

NEW IDEAS FOR TRANSMITTERS, *by T. M. Ferrill, Jr.*—A high-power buffer-amplifier of unusual mechanical design. The electrical arrangement consists of a T-55 buffer and a pair of 810's as a push-pull amplifier. The mechanical design is interesting in that a combination of "breadboard" and rack-and-panel construction is used. The final amplifier and buffer are built on both sides of a vertical partition mounted at right angles to the panel. Thus all components are made readily accessible and, at the same time, all high-voltage portions of the circuit are behind a neat-appearing panel.

INCREASED OUTPUT WITH GRID-BIAS MODULATION, *by J. A. McCollough*—Describing a method of increasing the peak instantaneous plate efficiency of a grid-modulated amplifier and thus increasing the carrier to efficiency 45 or 50 per cent. The principal requirements of this system are high plate voltage and a well-regulated bias supply which is adjustable over a wide voltage range.

BETTER 'PHONE OPERATION WITHOUT SPLATTER, *by J. R. Bain*—A system of reducing odd-harmonic distortion and the consequent "splatter" in class B modulators. Essentially, the system consists of shunting the modulation transformer with condensers, which, with the transformer leakage inductance, form a low-pass filter. Methods are shown for measuring the transformer inductance and choosing the proper size condensers.

A FEW FEEDER CONSIDERATIONS, *by Byron Goodman*—Describing the results of some experiments conducted with a short 600-ohm transmission line. The most important fact revealed by the tests is that to eliminate all standing waves when a flat line is terminated at taps on a matching stub the length of the stub must be altered after the minimum standing wave point has been found.

DIVERSITY WITH WHAT YOU HAVE, *by S. Gordon Taylor*—A simple system of obtaining the effect of diversity reception without a special receiver. Two receivers are used, each feeding one earphone on an ordinary headband.

●

RADIO

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

OCTOBER, 1939

CATHODE MODULATION, *by Frank C. Jones*—Describing a modulation system which shows some of the advantages of both plate and grid modulation. The principal advantages claimed for the system are ease of adjustment, low audio power requirement, and relatively high efficiency. A small transmitter utilizing the system is shown.

MODEL AIRPLANE RADIO CONTROL, *by E. L. Rockwood*—A unique system airplane remote control which has as its main feature a provision for continuous non-cyclic rudder control. The rudder is operated by a small reversible motor which is so connected that when a rapidly keyed signal is received the motor tends to alternately start in each direction many times a minute. The net result of this operation is that the motor does not turn when the intermittent signal is applied but under full signal or no signal conditions the motor will turn in either one direction or the other.

COMPACT-H BEAM ANTENNA, *by John D. Kraus and Harold E. Taylor*—An H-array in which the horizontal length has been reduced considerably through the use of ¾-wave 2-wire elements. Another application of two-wire elements is shown in a square array which requires but little space. Also shown is a vertical compact-H array in which provision is made for changing the phasing and thus giving two different directional characteristics.

"ROTOLINK" FEED FOR THE CLOSE-SPACED ARRAY, *by W. W. Smith*—The problem of feeding the antenna is a major one in the application of rotatable close-spaced arrays to amateur use. This article describes a simple inductive coupling system between the feeders and the center of a driven element having low radiation resistance.

THEORY AND DESIGN OF A PRECISION FREQUENCY MONITOR, *by G. H. Browning and F. J. Gaffney*—Describing an accurate frequency monitor applicable to amateur usage. Two oscillators feeding into a single mixer are used in the unit. One of the oscillators operates on either 100 or 1000 kc., while the other covers the amateur bands directly or by harmonics. By using the 100-1000 kc. oscillator as a secondary standard and beating the amateur-frequency oscillator against this standard a high degree of calibration accuracy may be obtained. To facilitate accurate setting of the amateur-band oscillator to harmonics of the secondary standard a tuning-eye zero-beat indicator is incorporated in the unit.

SHORT-CIRCUITED TURNS, THEIR EFFECT ON COIL EFFICIENCY, *by Harner Selvidge*—The results of a series of experiments on some representative coils to determine the effect of short-circuited turns on coil Q. A graphical representation of the results observed is given.

SIMPLIFIED RIG CHECKER, *by Ernest Barker* — A description of a simple unit using one tube and a single meter which functions as a combined overmodulation indicator and volt-ohm-milliammeter. The total cost of parts is under ten dollars.

●

RADIO NEWS AND SHORT WAVE RADIO

25c a copy—$2.50 yearly
Ziff-Davis Pub. Co.
608 S. Dearborn St., Chicago
OCTOBER, 1939

THE DELUXE "DIALOMATIC" MOBILE RIG, *by Oliver Read and Karl A. Kopetzky* — The second article of the series on this mobile transmitter. The fundamental mechanical and electrical details of the dial-controlled transmitter are covered in this installment.

RADIO CONTROLLED MODEL SAILBOAT, *by George McGinnis and Colin Campbell*—Describing one of the popular RK62 56-Mc. remote-control arrangements. This one is quite similar to others of previous design in that it uses a rubberband driven escapement to operate the sailboat's rudder. The control unit is located in an automobile and in normal operation the car is driven along the shore so that the boat may be kept in sight at all times.

32-V. POWER SUPPLY FOR THE RURAL MAN, *by Alvin L. Campbell*—Obtaining moderately high voltage from a 32-volt supply has always been somewhat of a problem. This article describes a simple vibrator supply which delivers 400 volts at over 80 milliamperes. The proper method of rewinding conventional power transformers for this service is explained.

A NEW 63 MC. AIRPORT TRANSMITTER, *by Clifford A. Harvey* — With the radio ranges beginning to use ultra-high frequencies this fall, the u.h.f. transmitter gets the "commercial touch." Five r.f. stages are used in the transmitter described, the final amplifier being a pair of X HK 54's. Modulators are another pair of HK 54's. The transmitter output is 100 watts.

100 KC.-1000 KC. FREQ. GENERATOR, *by G. H. Browning and F. J. Gaffney*—Describing a small dual-frequency signal generator which is of use in receiver alignment. The oscillator section employs two separate tank circuits in a electron-coupled circuit. A mixer stage is provided for the purpose of checking the oscillator frequency accurately against WWV.

A PRESELECTOR FOR THE 1.4-V. HAM SUPERHET, *by Harry D. Hooton*—A preselector designed as a companion unit to the 1.4-volt superheterodyne described in the September issue. A screen-grid tickler is used to provide regeneration. Coil data is given for complete-coverage coils from 10 to 270 meters.

SEPTEMBER, 1939

THE DELUXE "DIALOMATIC" MOBILE RIG, *by Oliver Read and Karl A. Kopetzky*—The first article of a series describing a dial-controlled mobile transmitter. This installment describes the 802 optional e.c.o.—crystal oscillator which is mounted near the driver in the car and the dial control system used.

1.4-V. HAM SUPERHET, *by Harry D. Hooton*—A 5-tube superheterodyne designed for complete coverage of the short-wave spectrum from 10 to 200 meters. Tube lineup is 1A7G mixer 1A5G oscillator, 1N5G i.f. amplifier, 1N5G detector and 1A5G audio output. Sensitivity and selectivity are increased by the use of regeneration in both the mixer and detector stages.

1940 RADIO NEWS "ALL PURPOSE" TRANSMITTER-RECEIVER, *by Karl A. Kopetzky and Oliver Read*—The concluding article of a series on this transmitter. The final assembly of the various units is discussed and the power control circuits described. A two-page diagram of the complete transmitter is given.

TINIEST HAM RECEIVER, *by Edward Lindberg*—Describing a "miniature" receiver covering the 9.5- to 700-meter range. The receiver is a.c. operated, using a 6K7 regenerative detector and a 6C5 audio stage. The rectifier is a 6H6. Tube-base coils are used.

●

SERVICE

A Monthly Digest of Radio and Allied Maintenance

25c a copy—$3.00 yearly
Bryan Davis Pub. Co., Inc.
19 E. 47 St., N.Y.C.

SEPTEMBER, 1939

RECEIVER TRENDS FOR 1940, *by Henry Howard*—A discussion of important receiver developments for 1940. The author finds no major innovations in the new models. Motor tuning has disappeared except in the most expensive models. Nearly all models have push-button tuning of some sort, however. Some models use metal cabinets, while one manufacturer has moulded an entire chassis, including sockets and trimming and padding condensers. A few midget home sets are appearing with handles to allow them to be moved from room to room easily.

CONVERTING BATTERY SETS TO 1.4 VOLT TUBES, *by Leland S. Hicks*—There is opportunity for profit for the serviceman, as well as an opportunity for increased operating economy for the customer, in changing some of the later-model two-volt receivers over to the new 1.4 volt series. Equivalent tube types in the two series are given as well as several diagrams showing the changes necessary to replace some of the double-diode two-volt types with the 1.4-volt H5G single diode.

●

Oh Yes....
Your Subscription

Radio Limited
1300 Kenwood Road,
Santa Barbara, Calif.

I want 12 issues of "Radio Technical Digest". Here is my $2.50.

Name______________________________

Street______________________________

City ______________________________

ANOTHER PUBLICATION
BY THE
EDITORS OF
RADIO