RADIOTRONICS

Registered at the General Post Office, Sydney, for transmission by post as a periodical. Single Copy, One Shilling

Volume 19 **August 1954** **Number 8**

THE USE OF MULTIPLE SMALL LOUDSPEAKERS

by F. Langford-Smith

At the present time there is considerable interest in the use of multiple loudspeakers, usually from two to four in number, each of which may be relatively inexpensive. Their applications are in two main groups—those in which the speakers are placed close together to obtain increased efficiency, and those in which they are spaced apart to give some form of pseudo-stereophonic effect.

Before proceeding to a consideration of these various applications, let us first consider the basic principles and then examine some test results with closely-spaced loudspeakers.

Basic Principles.

The electro-acoustical efficiency of a loudspeaker is a function of its radiation resistance. The actual relationship is given approximately by

$$\text{efficiency} = \frac{R_2}{R_0 + R_2 + R_3} \times 100\ \% \quad (1)$$

where R_0 = d.c. resistance of voice coil,

R_2 = radiation resistance,

and R_3 = equivalent frictional and eddy current loss resistance.

In order to demonstrate the relationship between radiation resistance and efficiency, the curve plotted in Fig. 1 has been calculated for the case where $R_0 = 16$ ohms and $R_3 = 0$, or for the general case where $R_0 + R_3 = 16$ ohms. It will be seen that, with efficiencies of the order of 1 or 2%, the efficiency is directly proportional to the radiation resistance, to a close approximation.

If any loudspeaker can be acoustically loaded so that its radiation resistance is increased, without its other characteristics being affected, then its efficiency will be increased thereby. One example of this is the use of a horn, which provides additional acoustical loading and hence increases both the radiation resistance and the efficiency, as is well known. Another, less known, example is the subject of this article.

If two loudspeakers are mounted as closely together as possible, at low frequencies the radiation resistance of each is doubled. If four loudspeakers are mounted

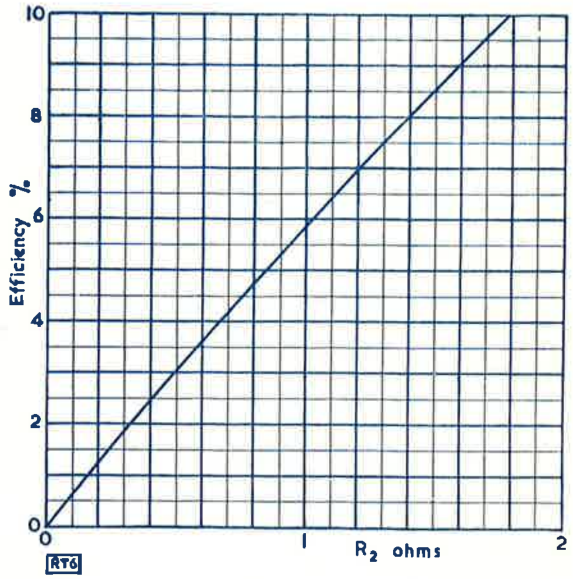

Fig. 1. Electro-acoustical efficiency of a loudspeaker versus radiation resistance (R_2), for d.c. voice coil resistance R_0 = 16 ohms. The equivalent frictional and eddy current loss resistance is assumed to be negligibly small compared with $R_0 + R_2$.

as closely together as possible, then at low frequencies the radiation resistance of each is quadrupled. The complete analysis was made by Wolff and Malter (Ref. 1) and put into a more convenient form by Youngmark (Ref. 9), as shown in Fig. 2. These curves apply to rigid pistons, but loudspeakers approximate to a rigid piston at low frequencies.

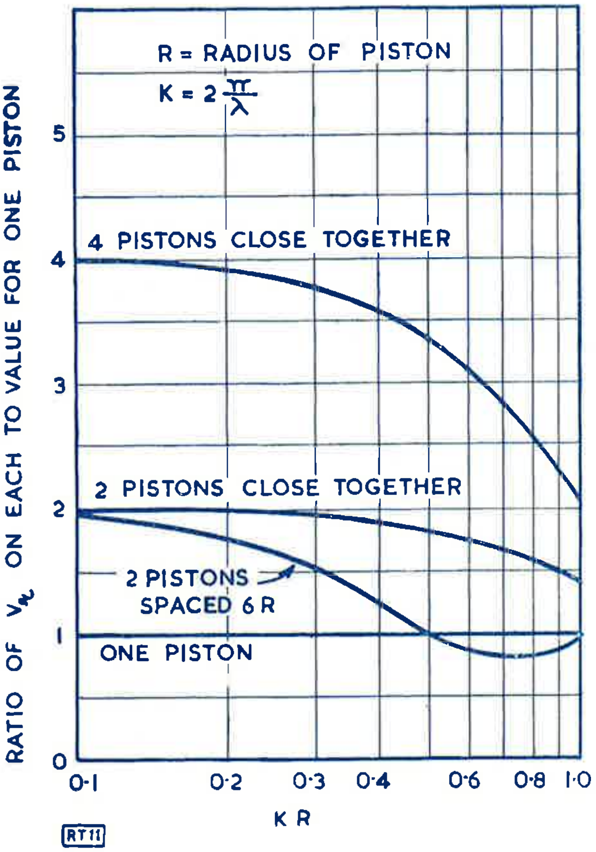

Fig. 2. Radiation resistance of each of a group of pistons compared with the radiation resistance of a single piston (after Youngmark, Ref. 9, based on Wolff and Malter, Ref. 1).

The value of *KR* is proportional to the frequency, and the frequencies corresponding to *KR* = 1 have been calculated for some typical values of piston diameter, expressed in inches for convenience:

Piston dia.	Frequency for *KR* = 1
3 ins.	1440 c/s
4 „	1080 „
6 „	720 „
8 „	540 „
10 „	432 „
12 „	360 „
15 „	288 „

It will be seen from the curves that the value of radiation resistance is rapidly decreasing at *KR* = 1, and it would eventually approach the value for a single piston at higher frequencies.

Thus the application of multiple loudspeakers, closely spaced, is to increase the radiation resistance and hence the efficiency at low frequencies.

The Effect of Increasing the Spacing Between the Loudspeakers.

A particular example is illustrated in Fig. 2 for two pistons spaced 6*R* (= 3 diameters). The effect at very low frequencies is much the same as for close spacing, but the fall-off occurs at lower frequencies than for close spacing.

Experimental Results.

In order to demonstrate the idea, tests were made on 1, 2 and 4 small speakers (6 inch) mounted as closely together as possible on a flat baffle. Actually 4 speakers were mounted closely together in the form of a square; when less than the full number was in use the others were disconnected and covered over with a piece of timber. As the tests were made in a normal listening-room, the calibrated microphone was mounted 12 inches from the baffle to minimize the effects of reflections. With a single speaker the microphone was mounted on the axis, with two and four speakers it was mounted on the axis of symmetry. It is to be expected that the position of the microphone would affect readings at the higher frequencies which are therefore somewhat uncertain, but would not have any significant effect in the low frequency region which was the main object of the tests.

Tests were made during constant peak voltage across the voice coils, using parallel speaker connections in order to eliminate any inter-actions between speakers, as may occur with series connections.

Tests were made on response characteristics, efficiency and distortion.

The frequency response curves are given in Fig. 3. It will be seen that, taking the single speaker as the reference level (0 db), the 2 speaker combination is roughly + 6 db over the frequency range from 170 to 1500 c/s. Now the normal increase from the use of two speakers across a constant voltage source, without mutual aiding, is twice the power of 3 db. Hence the aiding effect accounts for the further 3 db rise. In terms of power output, if for example the power output from a single loudspeaker is 0.1 acoustical watt, then the power output from two speakers widely spaced (without mutual aiding) will be 0.2 watt and that from the same two speakers closely spaced will be about 0.4 watt. Thus the effect of mutual aiding is to double the output from two loudspeakers. This can also be considered in terms of efficiency—suppose that the efficiency of a single speaker is 2%, then the efficiency of two such speakers, closely spaced, will be about 4%.

Referring back to Fig. 3 it will be seen that the four speaker combination is roughly +12 db above the level of the single speaker over the frequency range from 170 to 1500 c/s. The normal increase from the use of four speakers, without mutual aiding, is four times power or 6 db. Hence the aiding effect accounts for the further 6 db rise. The power output will be approximately four times that of the same four speakers widely spaced, without mutual aiding. The efficiency will be about four times the efficiency of a single speaker.

It will be seen that at high frequencies the experimental results do not agree with the theory. The discrepancy is not understood, and it was not possible at this time to make any additional tests by moving the microphone around to check directional effects.

A check was made by the direct measurement of efficiency using thermal noise as the source voltage. With two speakers and white noise the increase in efficiency over a single speaker was + 6 db (± 1 db), thus confirming the results obtained from the frequency response curves. With four speakers the readings for increase in efficiency were + 9 db for white noise, + 9.5 db for scarlet noise (0 to 700 c/s), and about 10 db for blue noise (400 to 16,000 c/s). Although these readings are rather widely spread, and the accuracy of the method used was rather poor, the average value is not significantly below the theoretical value of + 12 db for the low frequencies.

Distortion readings were made at selected frequencies from 125 to 400 c/s, measurements being made on a GR wave analyser and calculated as total harmonic distortion (Fig. 4). In interpreting these curves it is important to remember that constant voltage was applied in all cases, and that the acoustical output per loudspeaker for the 2 and 4 speaker curves is approximately twice and four times respectively that for the single speaker. Since the distortion for the multiple speaker is, over this frequency range, at least of the same order or even somewhat better than that for the single speaker, it is obvious that there would be a marked reduction in distortion for operation of the multiple speakers at the same acoustical output per speaker.

Summing up:

With closely spaced loudspeakers there are thus both increased efficiency and decreased distortion, so that with two or more relatively inexpensive loudspeakers it is possible to obtain quite good all-round performance. The frequency response curves of Fig. 3, particularly the 4-speaker curve, also show a certain amount of smoothing, especially in the important region from 1000 to 3000 c/s, as a result of the averaging of the response from different loudspeakers.

One important feature for wide-range performance is that the high frequency response of small diameter cones is normally better than that of larger cones, unless these are in the very expensive class of real high-fidelity loudspeakers.

A further feature is that the power handling ability of each speaker (the acoustical output power) is increased by the mutual aiding effect without any increased movement of the cone. This is a similar effect to that obtained with horn loading, although to a much smaller extent. It can be looked on as a pressure wave which loads the neighbouring cones.

There is a certain degree of focusing from several loudspeakers in a straight line—this is "line source" used for directional effects in large halls (Ref. 10). Because of this effect it is preferable to mount two speakers in a vertical line, and three or four speakers in a small circle to minimize directional effects.

When two loudspeakers are used in a room better high frequency directional characteristics will be obtained when the two axes are a small angle to one another, e.g. 30° to 45°.

One of the minor questions with the use of multiple speakers is the method of connection, whether series or parallel. It is assumed here that the source impedance is very low.

With parallel connection of any number of speakers, the response from any speaker and its damping are both the same as for a single speaker.

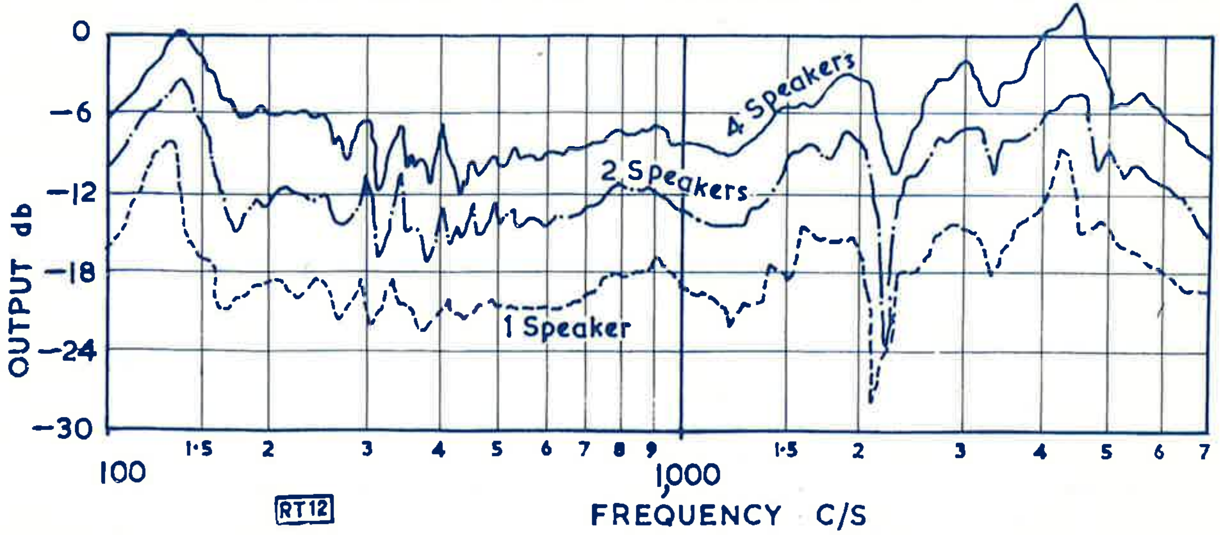

Fig. 3. Experimental frequency response curves for 1, 2 and 4 speakers, with constant voltage applied across the voice coils, parallel connection, 6½ inch speakers, microphone 12 inches from baffle.

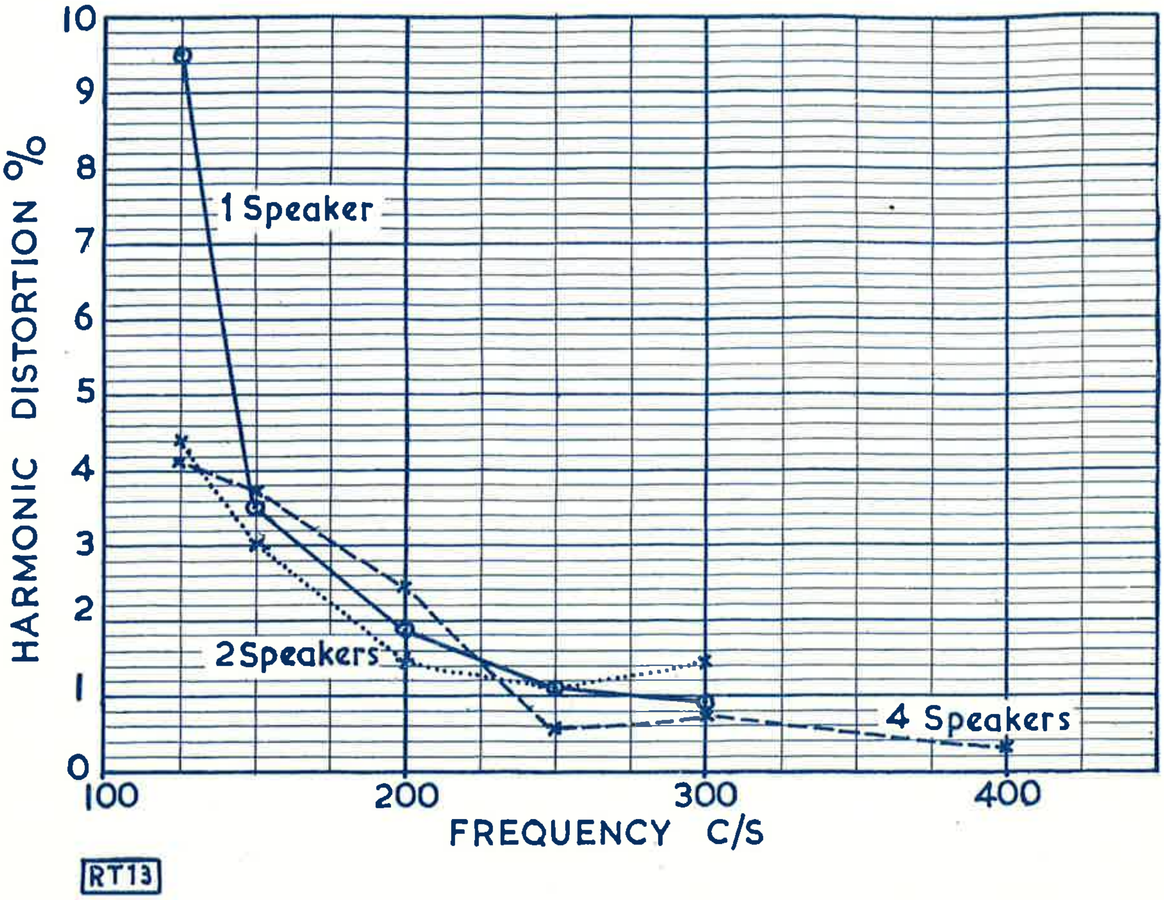

Fig. 4. Distortion readings for 1, 2 and 4 speakers, with constant voltage applied across the voice coils, parallel connections, $6\frac{1}{2}$ inch speakers, microphone 12 inches from baffle.

With series connections of any number of absolutely identical speakers, each speaker will have the same response and damping as that of a single speaker, but in any normal practical case with differences between the speakers it appears that both the response and damping of a speaker will differ from those of a single speaker. It was hoped that there would have been time for tests to be carried out on both series and parallel connections to find which is preferable, but it was not possible to secure four speakers differing sufficiently in their frequencies of bass resonance to make a significant test. It is hoped to describe the results obtained in a later issue of Radiotronics.

General Applications of Multiple Speakers.

Some of the published applications of multiple loudspeakers are given below for the information of our readers.

The Baruch and Lang Loudspeaker.

The Baruch and Lang loudspeaker (Refs. 3 and 11) employs four 5-inch loudspeakers in an enclosure with a volume of only half a cubic foot and is claimed to radiate 0.1 acoustical watt at 3% distortion, with an input of 2 watts and an efficiency about 5%. The response is claimed to be flat ± 3 db from 40 to 12,000 c/s, and the high frequency angular dispersion is 75°. It is a modified acoustical phase inverter (vented baffle) with an array of small holes on one side to provide the requisite port area—15 holes each $\frac{15}{32}$ inch diameter spaced $2\frac{1}{4}$ inches apart.

There is an internal baffle with 21 holes spaced 2 inches apart. These holes provide acoustical resistance to damp down the system resonance to the most desirable degree. In addition, it is claimed that, because the holes are distributed over a large area, the radiation impedance of the array is equivalent to that of a 21 inch cone.

The speakers employed are standard low-cost replacement units, modified to meet the requirements of the system. The optimum dimensions of cabinet and holes, as well as the configuration of holes and the speaker array, are determined by the characteristics of the particular speakers used.

This is a most interesting high-fidelity loudspeaker and enclosure which has been designed to bring the cost within reach of those with limited means—a commercial model is now selling in U.S.A. for less than 25 dollars. The acoustical power output for low distortion is only about a quarter of the value generally regarded as a desirable minimum for large and expensive high-fidelity systems.

Other Applications of Multiple Loudspeakers.

Two or three 6 inch metal cone loudspeakers are used, closely spaced, in a vented baffle with suitable internal acoustical damping, in the G.E.C. enclosure (Ref. 4).

A further application of closely spaced loudspeakers is a corner arrangement of 4 loudspeakers, each with an entirely separate enclosure filling an angle of 22.5° Acoustical internal damping is used (Ref. 8).

Multiple loudspeakers are also used, spaced apart, to provide some form of pseudo-stereophonic effect. One example is the Columbia 360 phonograph (Ref. 5) which has two loudspeakers spaced apart and pointing in opposite directions.

Another example of the use of multiple loudspeakers spaced apart is the Columbia XD sound system in which a pseudo-stereophonic effect is provided by using a small loudspeaker for the high frequencies, radiating at a point removed from the main loudspeaker in which the frequency range is restricted to the low frequencies (Ref. 6).

A still further example is the Kelton loudspeaker, developed by Henry Lang. This uses two speakers in an enclosure 11 × 11 × 23 inches, each in a separate compartment. The 6-inch speaker faces outwards near the top, while the 8-inch speaker faces downwards into a padded cavity with holes for the bass outlet. The back areas of both speakers are filled with sound absorbing material — back radiation is not used. The design is critical. It is designed for maximum performance for a limited outlay of less than 50 dollars in U.S.A. (Ref. 7).

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Editor .. .. Ian C. Hansen

Radiotronics is published twelve times a year by The Wireless Press for Amalgamated Wireless Valve Company Pty. Ltd. The annual subscription rate in Australasia is 10/-; in U.S.A. and dollar countries $1.50, and in all other countries 12/6. Price of a single copy is 1/-.

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INTRODUCTION TO F.M.

by Kenneth Fowler

Brief History.

Radio as we know it today has made tremendous progress since the early days of the crystal receiver some 20 odd years ago. Many important changes and contributions have been made by countless individuals during that time and prominently among them are the basic ideas and improvements of Major Edwin H. Armstrong.

In the early days of radio, he developed the regenerative circuit which added much sensitivity and selectivity to the two and three tube receivers then in existence. Later, he was instrumental in developing the superheterodyne circuit which revolutionized radio reception and is the basic circuit still used in all sensitive receivers today.

The shortcomings of the present system of amplitude modulation have long been recognized by radio engineers, but to Major Armstrong must be given the credit of developing a new system which eliminates most of these shortcomings. This new system is known as frequency modulation which is abbreviated and commonly called F.M. In his laboratory he and his associates worked for approximately 10 years to obtain the recognition which is given this system today. It was necessary for him to build his own station and receivers in order to demonstrate the advantages of this new and radically different system of broadcasting to a sceptical public.

General Electric Engineers recognized the possibilities of F.M. in the early stages and have worked with Major Armstrong to further the development of this new system which today has a large following of broadcasters and manufacturers of receivers.

Commercial broadcasts on F.M. began in January, 1941, and many stations are now operating on schedules required by FCC regulations.

One of the pioneer F.M. stations is the Yankee Network station, WIXOJ, at Paxton, Massachusetts. The success with which this pioneer station operated led many others to follow, with the result that some 550 stations were operating on regular schedule by the end of 1953, covering an area inhabited by a majority of the people in the entire country.

The future of F.M. appears very bright and marks another advancement in the field of radio transmission and reception.

Reprinted from "Frequency Modulation Principals and Practice" by courtesy of Australian General Electric and with acknowledgements to International General Electric of U.S.A.

Advantages of F.M.

The advantages of F.M. over the present A.M. reception in the broadcast band are many fold. Among the most important are higher fidelity, practically noise-free reception, and little or no interference between stations, even from those operating on the same frequency.

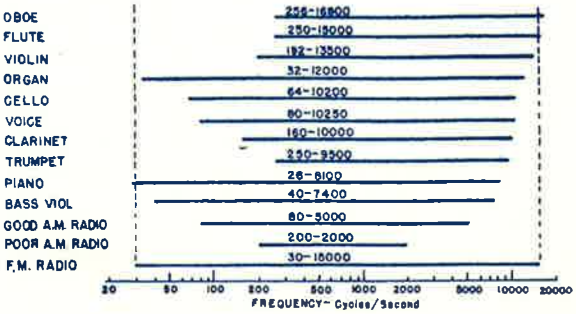


Fig. 1. Frequency response of F.M. and A.M. receivers compared to musical instruments.

The superiority of F.M. reception in regards to high fidelity is shown in Figure 1, which compares the frequency response of two A.M. receivers and an F.M. receiver in relation to the wide range of frequencies produced by various musical instruments and which must be reproduced by the receiver to hear the realism of each instrument.

The fidelity of a receiver is its ability to reproduce all of the fundamental frequencies and overtones inherent in the musical instrument being played. If some of the frequencies, especially the overtones, are destroyed or not reproduced the music is flat and the fidelity is poor. Figure 1 shows the frequency range of various musical instruments and the comparative abilities of typical A.M. and F.M. receivers to reproduce these instruments faithfully. It will be noted that with the F.M. receiver audio range of 30 to 15,000 cycles that it is ample to catch all of the desired frequency response for real high fidelity reception.

An inherent weakness of the present system of A.M. broadcasting makes the further improvement in fidelity impractical. Because of the many broadcast stations and the limited frequency spectrum available, it is necessary to limit each broadcast station to an assigned 10 kc band in which to operate and, since the operation requires the carrier frequency to be centred in each band, the side bands which carry the modulation frequencies can extend but 5000 cycles each way. This condition results in the limiting of audio modulation to 5000 cycles with the consequent elimination of all frequencies above this value. The F.M. broadcasting system operating in a higher frequency spectrum is not hampered in this respect because, in F.M., the channel width does not denote the highest frequency that can be modulated but denotes the dynamic range or modulation intensity instead. In setting up this new F.M. frequency spectrum, a 200 kc bandwidth is allowed for each station, which provides ample dynamic range capabilities.

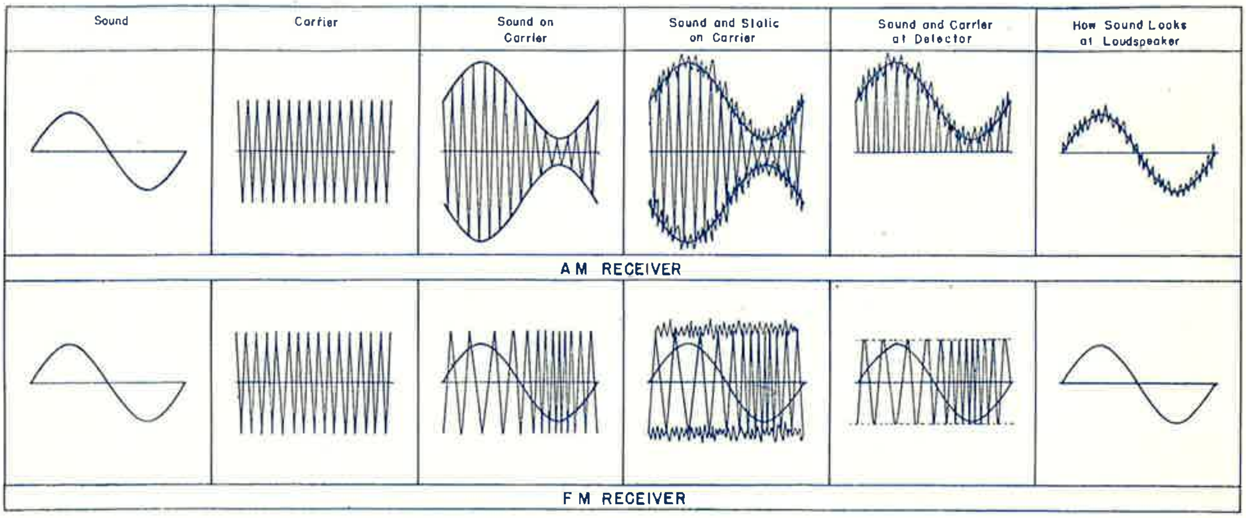


Fig. 2. Comparison between F.M. and A.M. modulation with noise present.

The great advantage of F.M. in eliminating static is shown empirically by Figure 2 which compares a conventional A.M. receiver with an F.M. receiver.

At the left is shown one cycle of the audio voltage after it has left the microphone and is the same for F.M. as for conventional A.M. Next is shown the carrier wave before modulation and is essentially the same in either case.

The third block shows the carrier modulated by the audio wave. In amplitude modulation, the amplitude of the carrier varies in accordance with the audio voltage impressed upon it while the frequency of the carrier remains constant. The F.M. channel is modulated in an entirely different manner. When the audio wave is impressed on the F.M. transmitter, the amplitude of the output waveshape remains constant but the frequency of it varies in accordance with the audio wave. This change in frequency is represented by the carrier wave bunched together in places and stretched out in others, like an accordion.

Next is shown what happens when the modulated waveshape encounters static as it travels through space. Notice that, in amplitude modulation, the static or noise rides on top of the modulation envelope affecting both the r-f component and audio components of the carrier. In F.M. the noise appears as amplitude modulation on the carrier but does not affect the audio components.

In the fifth block, it is shown that with A.M. the entire upper half of the carrier is used during demodulation and consequently the audio components will have noise impulses mixed with it as shown. With F.M. the top and bottom of the waveshape is partially shaved off as shown by means of a limiter and the amplitude variations due to noise are removed. This does not in any way impair the audio output as the entire amplitude of the carrier is not utilized as in A.M. since during demodulation the audio voltage is produced by a change in frequency of the carrier and not by a change in carrier amplitude as in A.M. Consequently, the audio wave or component is free from noise impulses as shown in the block to the right.

Another advantage of F.M. is that interference between stations is greatly reduced, and extensive tests have shown that even when two F.M. stations are in operation on the same channel, the desired F.M. signal will take complete control when the desired F.M. signal strength is more than twice that of the unwanted signal. The result is that no interference will be heard, as compared with A.M., where the desired signal must be at least 30 times the unwanted signal before the interference is even low enough for suitable reception when two stations are operating on the same frequency. This aspect of F.M. will be taken up in more detail later in the course.

Comparison of F.M. and A.M.

One of the best ways to understand Frequency Modulation is to compare it with the more familiar method of Amplitude Modulation.

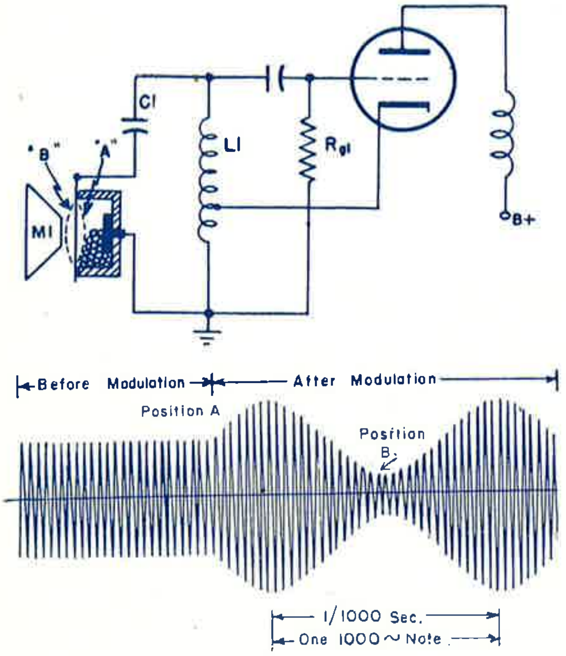


Fig. 3. Elementary A.M. transmitter circuit.

Figure 3 shows a very simple circuit which will serve to illustrate the principles of amplitude modulation. The schematic diagram shows a simple Hartley oscillator with a carbon microphone in series with the tuned circuit L_1C_1.

Where no sound is impressed on the microphone, the output of this circuit will be an alternating current of constant amplitude, the frequency of which is determined by the value of L_1C_1 and appears as shown to the left of the waveshape.

When a sound wave strikes the microphone, the carbon granules will compress and expand, causing its resistance to decrease and increase. This variation of resistance in the tuned circuit causes the amplitude of the oscillator to vary in exact accordance with the variation of the resistance in the tuned circuit as shown at the right portion of the waveshape and results in amplitude modulation of the output of the oscillator. It should be noted that the frequency of the oscillator remains practically constant during modulation since the only constant that varies is the resistance of the tuned circuit. From this, it is evident that the amount that the amplitude of the carrier varies is dependent on the intensity of sound striking the microphone and that there is little or no change in the oscillator frequency.

As shown in Figure 3, the maximum amplitude of the carrier occurs when the microphone diaphragm is in position A and minimum amplitude occurs when the diaphragm is in position B. The rate at which these changes in amplitude occur depends on the frequency of the sound striking the microphone.

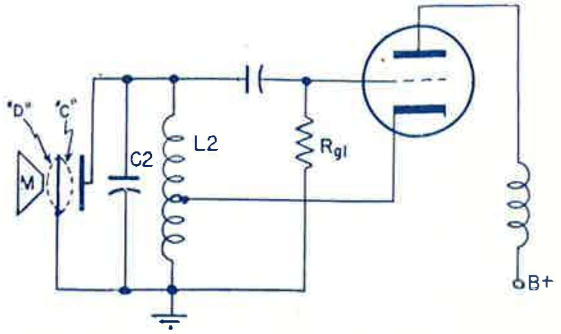


Fig. 4. Elementary F.M. transmitter circuit.

An elementary F.M. transmitter circuit is shown in Figure 4 and is very similar to the one in Figure 3 except for the type and location in the circuit of the microphone.

In this circuit a condenser microphone is placed across the tuned circuit L_2C_2. This takes the place of the carbon microphone in series with the tuned circuit as used for A.M. in Figure 3. As sound waves strike the condenser microphone, the capacity of it changes so as to increase, position C, and decrease, position D, in accordance with the sound waves striking it. The louder the sound, the greater is the actual increase and decrease in the capacity of the microphone. Since the microphone is across the tuned circuit, it can be readily seen that the frequency will vary above and below the mean frequency of the oscillator. The amount that the frequency varies depends on the loudness of the sound striking the microphone; the louder the sound, the more it varies. With no sound striking the microphone, the output of the oscillator is the same as for the unmodulated portion of the waveform shown in Figure 3. However, when sound strikes the microphone, its frequency is caused to vary above and below its centre frequency as shown in Figure 5. It will be noted that the amplitude of the oscillator remains constant during modulation.

It should be remembered that the circuits shown are only for the purpose of illustration and are not actually used in practice.

Figure 6 shows the relation between the intensity of sound striking the microphone and the amount of frequency deviation of the oscillator. It will be noted that the frequency of the sound does not determine the amount that the frequency varies. As shown, the amount of frequency deviation depends on the intensity of the sound signal. For example, if the oscillator is modulated by a sound frequency of 1000 cycles having medium loudness it will vary, let us say, 50 kc on either side of its mean frequency at the rate of 1000 times per second. Now if a sound frequency of only 100~~0~~ cycles strikes the microphone, and has the same loudness or intensity

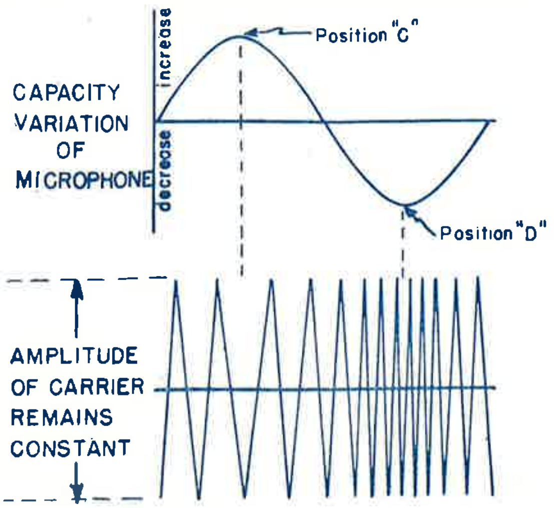


Fig. 5. F.M. carrier variation with modulation.

as the 1000 cycle sound frequency, then the oscillator frequency will deviate the same amount as before—50 kc on either side—but the rate at which it deviates will be only 100 times per second instead of 1000 times as before.

In summing up the differences between the two systems, we find that in amplitude modulation the amplitude variations of the oscillator depend on the intensity of the sound striking the microphone and the frequency of the sound determines the rate at which the changes in amplitude take place.

With Frequency Modulation, the intensity of sound determines the amount that the oscillator varies on either side of its mean or centre frequency and the frequency of the sound determines the rate at which the oscillator frequency varies. In F.M. the amplitude of the oscillator output remains constant.

Modulation Percentage and Frequency Deviation.

As pointed out above in A.M., the amount of variation in the amplitude of the carrier depends upon the intensity or amplitude of the audio signal (modulating) voltage. The amount that the carrier amplitude is varied is expressed as a percentage of modulation.

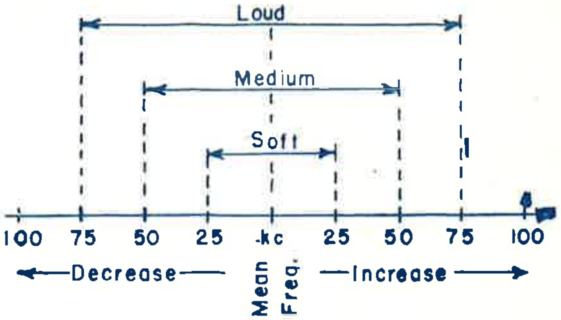
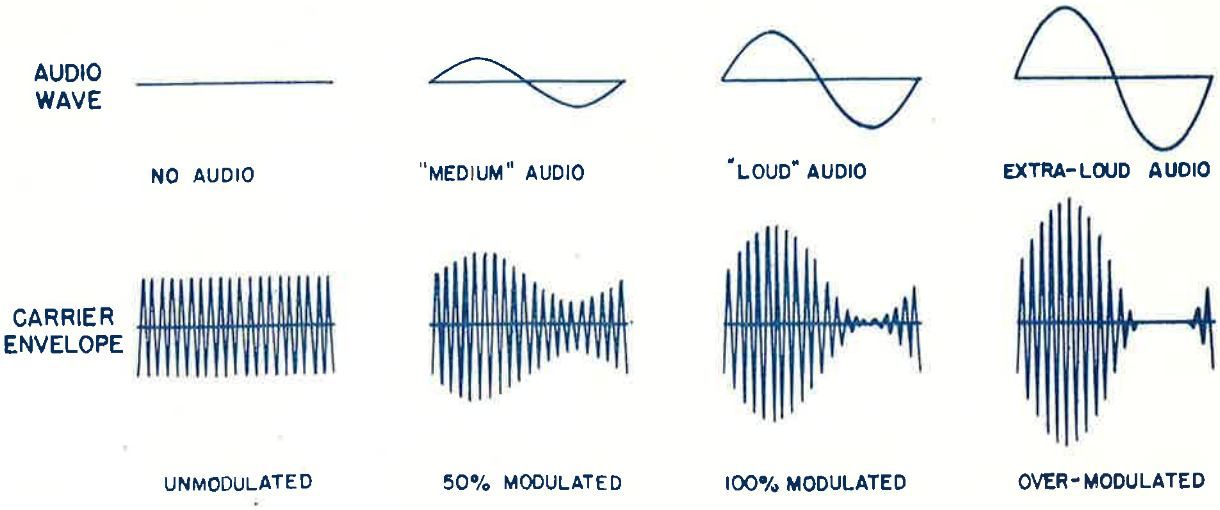


Fig. 6. Frequency Deviation vs. Sound Intensity.

Figure 7 shows an A.M. carrier with various percentages of modulation from zero to over 100% modulation. It will be seen that when the amplitude of the modulating voltage (audio modulation) is greater than the carrier amplitude, overmodulation occurs which results in distortion of the audio signal at the receiver. Consequently, the maximum amount of modulation is limited to 100%.

In F.M., the amplitude of the carrier is not changed by the modulating voltage but, as pointed out before, the frequency of the carrier deviates above and below its mean frequency, depending on the amplitude of the modulating voltage. The amount that the carrier frequency varies from its mean frequency determines the percentage of modulation. This is shown in Figure 8.

Since the present frequency assignments permit the maximum allowable frequency deviation to be 75 kc on either side of the centre frequency of the carrier, then 100% modulation would correspond to a frequency deviation of 75 kc, and smaller amounts of frequency deviation would correspond to smaller percentages of modulation.



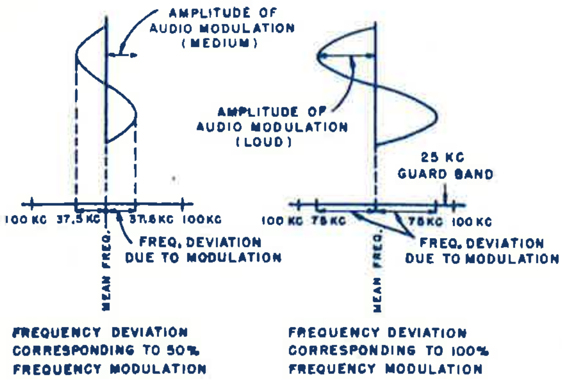


Fig. 8. Frequency Deviation with Modulation Intensity.

Bandwidth Requirements of an F.M. Channel.

In amplitude modulation, the bandwidth of the carrier in the Broadcast Band is limited to 10 kc, 5 kc on either side of the carrier, and its value at any instant depends on the highest audio frequency present in the modulating signal at that moment. This, in effect, limits the highest audio frequency that can be transmitted with A.M. to 5 kc. The side-bands that appear simultaneously on both sides of the carrier during A.M. should not be confused with the frequency deviation that takes place during F.M., since they do not depend on the percentage of modulation but on the rate at which the amplitude of the carrier is varied as shown by Figure 9, which illustrates the relation of the side-band on the carrier to various frequencies in the modulating signal.

In F.M., the bandwidth of the carrier is much wider and is determined by a different factor. At the present time, the bandwidth of each F.M. channel is limited to 200 kc—100 kc on either side of the centre frequency—the frequency deviation of the carrier due to modulation being limited to ± 75 kc. The remaining 25 kc bandwidth on either side of the carrier is used as a guard band.

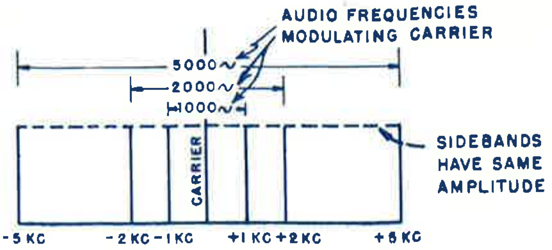


Fig. 9. A.M. Side-bands with Audio Modulation of Constant Amplitude.

Brief Description of An F.M. Transmitter.

Figure 10 shows a block diagram of a typical F.M. transmitter. As shown, the output of the microphone is fed into a speech amplifier. The output from the speech amplifier is used to control a reactance tube which is connected across the oscillator. This reactance tube is very similar to that used in the familiar automatic frequency control system in receivers. The audio voltage from the speech amplifier causes this tube to appear as a variable inductance across the tuned circuit of the oscillator which causes the frequency of the oscillator to vary above and below its mean frequency in exact accordance with the intensity of the sound striking the microphone. The mean frequency of the oscillator is then increased as shown by the frequency doubler stage. This doubler stage also doubles the amount of frequency deviation due to the modulation which allows for a wide range of frequency deviation up to ± 75 kc. The output of the doubler stage then feeds into the power amplifier stage and from there it feeds into the antenna.

The above describes what takes place from microphone to antenna; however, there is another important fact to consider and that is in the stabilization, of the mean frequency of the oscillator.

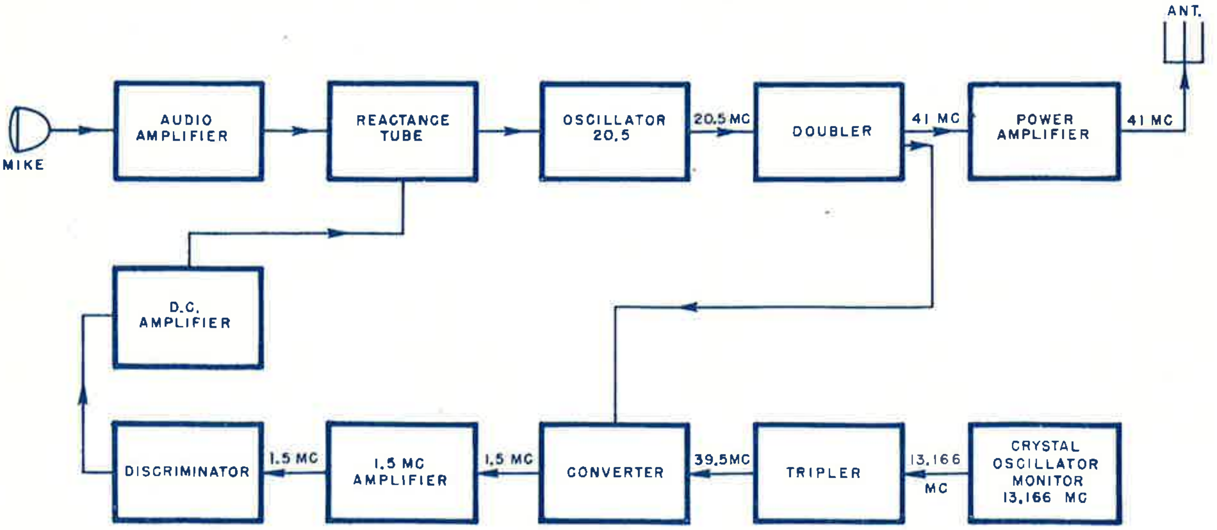


Fig. 10. Block Diagram of Typical F.M. Transmitter.

One of the important requirements of wide-band frequency modulation is that the carrier frequency must return to the same mean value when the frequency deviations due to modulation have stopped.

The lower part of Figure 10 shows how the mean frequency of the transmitter is automatically regulated by means of a crystal monitor. As shown, for this particular case, the frequency of the crystal is 13.166 mc which is fed into a frequency tripler stage which increases the frequency to 39.5 mc. The output of the tripler stage is fed into a converter stage where it is mixed with the 41 mc carrier frequency of the transmitter to produce a frequency of 1.5 mc. This 1.5 mc frequency is amplified and fed into a discriminator circuit (which is of the type used in receivers using A.F.C.) and is so designed that when the transmitter is exactly at the correct frequency the discriminator develops zero output voltage. However, any frequency deviations of the transmitter will vary the difference frequency from the converter and will cause the discriminator to develop a d-c output voltage having a polarity determined by the direction of drift. This d-c voltage after passing through a d-c amplifier is applied to the grid of the reactance tube in such a way as to change the frequency of the oscillator to correct for any drift in frequency. An important point to bring out is that the time constant of the d-c voltage developed this way is large enough so that this stabilizing voltage will be slow acting and will not be affected by the frequency deviations due to modulation, otherwise this frequency stabilization system would have a compensating effect on frequency variations due to modulation and would therefore not work.

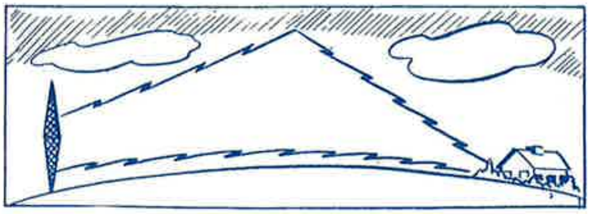


Fig. 11. A.M. Station Propagation Characteristics.

The Propagation of F.M. Signals.

Due to the fact that the F.M. stations operate at much higher channel frequencies than those of the regular A.M. broadcast stations, some consideration should be given to the manner in which these frequencies differ in their travel through space.

The frequencies that have been allocated to F.M. stations are all in the ultra-high frequency range above 80 mc and behave entirely different from the much lower frequencies that are used in the regular broadcast band of 550-1600 kc.

When a signal leaves the transmitting antenna it can be considered as being made up of two components, a ground wave and a sky wave. The ground wave travels parallel to the ground while the sky wave travels out into the upper atmosphere as shown in Figure 11.

At the frequencies used on the regular broadcast band, the ground wave is the most useful during the daytime and follows the curvature of the earth. During the daytime the sky wave does not contribute to the signal strength appreciably and for all practical purposes is lost. However, at night, the refraction of the sky wave from the ionosphere is great and thus greatly increases the range of the transmitter beyond the active range of the ground wave.

At F.M. frequencies the ground wave is greatly attenuated and tends to travel in a straight line, rather than follow the curvature of the earth. Also at these frequencies the sky wave is seldom refracted from the ionoscphere and is of no practical use. For this reason F.M. transmission must depend upon waves passing directly from transmitter to receiver through the space above the ground and the effective range is limited to the horizon range or line-of-sight range between the transmitting and receiving antennas. This is shown by Figure 12.

From above, it can be seen that the transmitting and receiving antenna must be quite high so as to increase the effective range of transmission. It has been found that the dependable range of an F.M. transmitter is about 50 miles, depending upon the height of the transmitting and receiving antenna and the local terrain. However, there have been cases where F.M. signals were received considerably beyond the line-of-sight distance, but these were due to unusual circumstances.

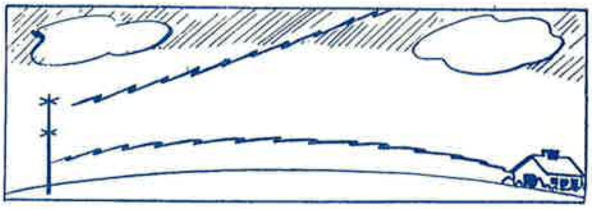


Fig. 12. F.M. Station Propagation Characteristics.

The subject of F.M. receiving antennas and their installation will be taken up in detail later.

New RCA Releases

3A2 Half-wave Vacuum Rectifier. Radiotron-3A2 is a double-ended, 9-pin miniature type of half-wave vacuum rectifier utilizing an indirectly heated cathode. It is designed for use as a rectifier of high-voltage pulses produced in the scanning systems of color television receivers.

Rated to withstand a maximum peak inverse plate voltage of 18000 volts, the 3A2 can supply a maximum peak plate current of 80 milliamperes and a maximum plate current of 1.5 milliamperes.

6448 UHF Beam Power Tube. Radiotron-6448 is a water-cooled beam power tube of unique design intended for operation as a grid-driven power amplifier at frequencies up to 1000 Mc. In color or black-and-white television service, the 6448 is capable of delivering a synchronizing-level power output of 15 kilowatts at 500 Mc or 12 kilowatts at 900 Mc. As a cw amplifier in class C telegraphy service, the 6448 is capable of giving a useful power output of 14 kilowatts at 400 Mc or 11 kilowatts at 900 MC.

Unique in design, the 6448 features a coaxial-electrode structure in which the centrally located plate is surrounded by a symmetrical array of unit electron-optical systems. These embody a structural design which permits not only close spacing but also unusually accurate alignment of the electrodes. Furthermore, effective bypassing of grid No. 2 to cathode is provided by built-in capacitors. Ducts for water cooling the plate, the grid-No. 2 block, the grid-No. 1 block, the rf cathode terminals, and the filament-section blocks, are built in. Other features of the 6448 include low-inductance, large area, rf electrode terminals insulated from each other by low-loss ceramic bushings; relatively low output capacitance; very low feedback capacitance; and a multistrand thoriated-tungsten filament for economical operation, high emission capability, and long life.

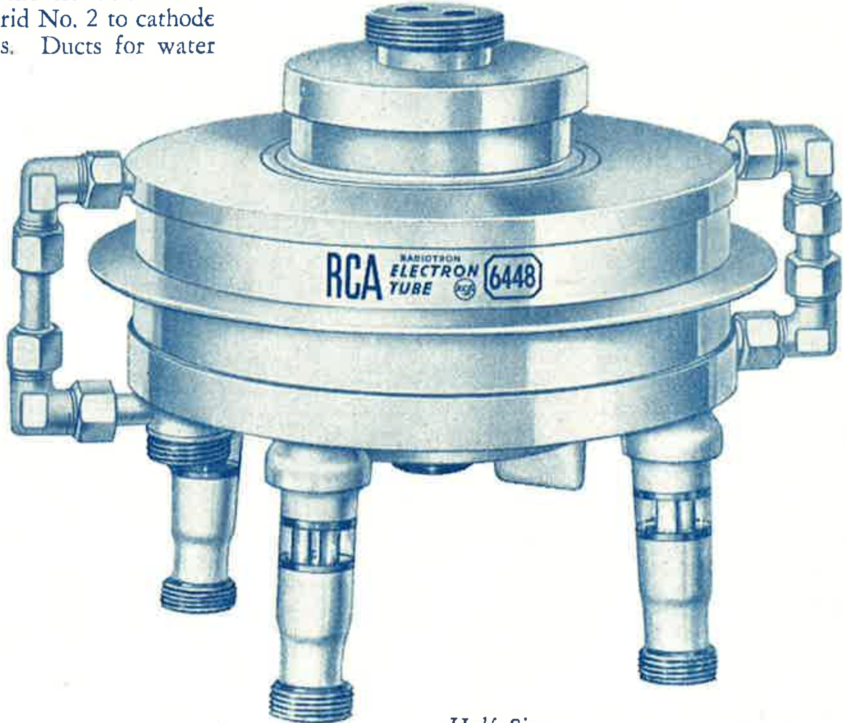
The various features make practical operation of the 6448 as a grid-driven uhf amplifier to provide high gain in television service without the need for neutralisation.

6AS8 Diode-sharp-cutoff Pentode. Radiotron-6AS8 is a general-purpose, multiunit tube of the 9-pin miniature type containing a high-perveance diode and a sharp-cutoff pentode in one envelope. It is intended for diversified applications in television and radio receivers.

The pentode unit, with its high transconductance, may be used as an if amplifier, video amplifier and agc amplifier. It is provided with separate base pins for grid No. 3 and the cathode. This arrangement facilitates the use of an unbypassed cathode resistor to minimize changes in input loading and input capacitance with change in bias without causing oscillation which might otherwise result if grid No. 3 were internally connected to the cathode.

The high-perveance diode, which has its own cathode terminal, may be used as an audio detector, video detector, or dc restorer.

The 6AS8 is provided with an internal shield to minimize coupling between the diode plate and the pentode unit. In addition the plate and cathode terminals of the diode are arranged to minimize capacitance coupling between them.



Half Size.