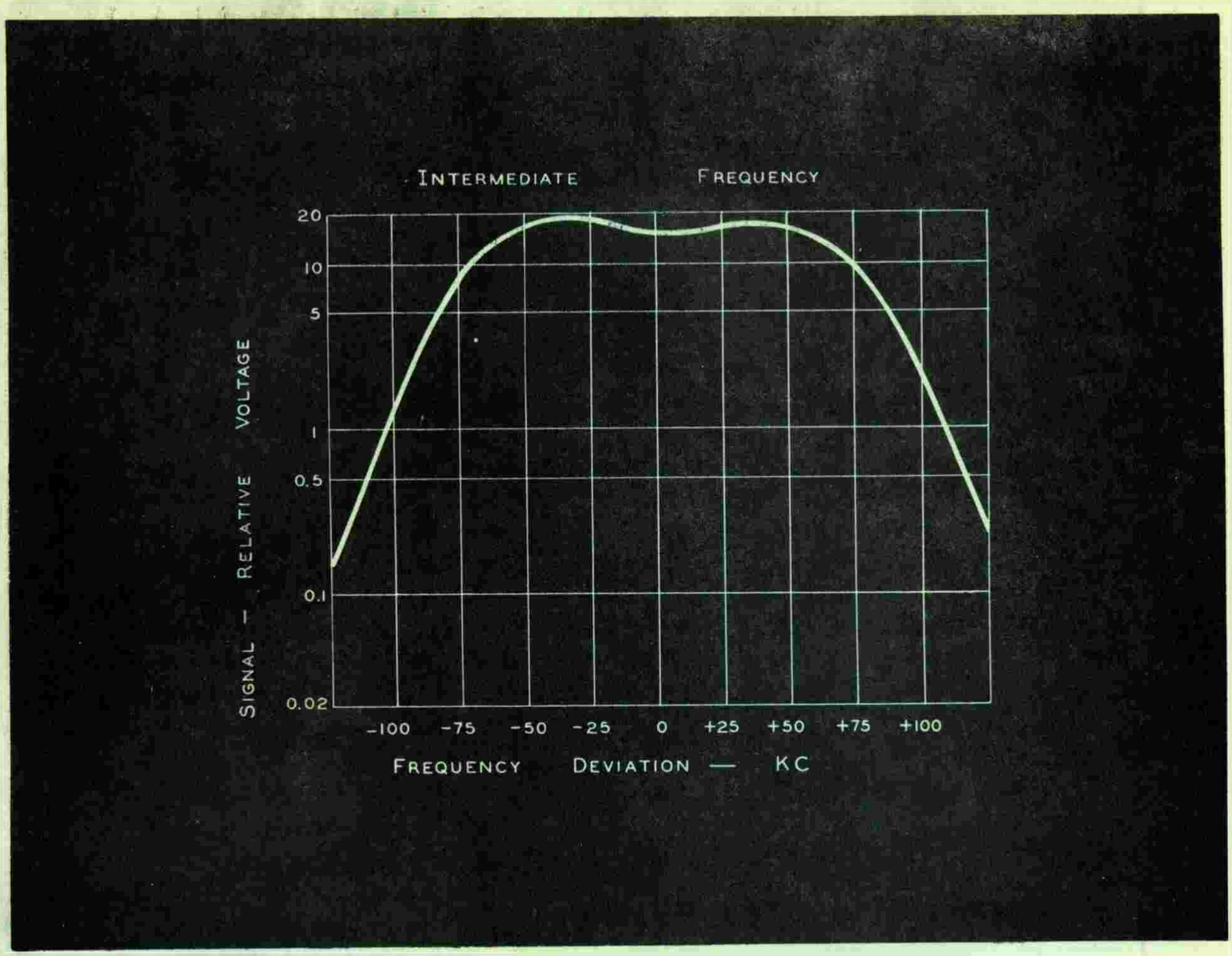

LESSON 72 RA

THE LIMITER STAGE OF AN F-M RECEIVER

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The chief differences between frequency-modulation and amplitude-modulation methods of radio reception are in the fact that f-m receivers have a signal limiter and a discriminator as a detector. That is, both types of receivers are of the superheterodyne type and employ a radio frequency amplifier, a frequency converter, and an intermediate frequency amplifier which are not greatly different other than the frequency range handled by the respective receivers.

Now we shall examine in more detail the two parts of the f-m receiver which are not found in a-m receivers, these parts being the limiter and the discriminator. To begin with we shall consider the limiter. As you will recall, the limiter is really part of the i-f amplification system, acting to remove amplitude modulation from the signal while allowing the frequency modulation to go through to the discriminator without change. Amplitude modulation which is to be cut off usually is represented as in Fig. 1.

To explain the actions which occur in the limiter it will be convenient to use a number of graphs or curves similar to the one in Fig. 2. This curve shows the effect on plate current of varying the control grid voltage, which is the potential difference in volts between the control grid and the cathode.

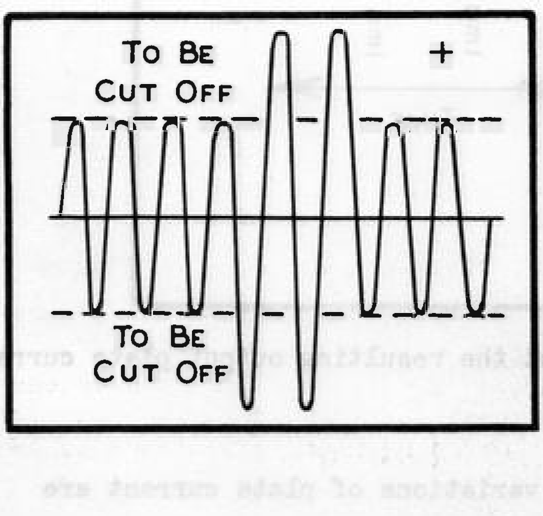


FIG. 1. Amplitude modulation on an f-m signal.

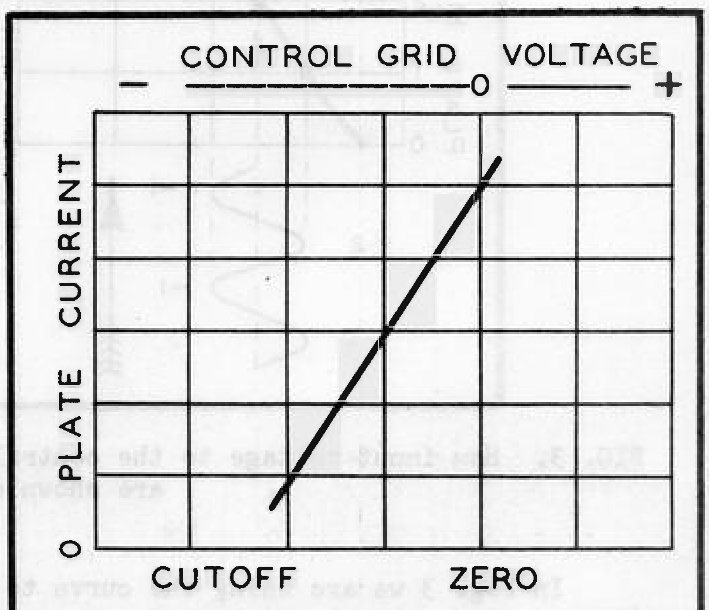


FIG. 2. Effect of control grid voltage on plate current.

The horizontal scale at the top of the graph represents the control grid voltage. One vertical line represents zero grid voltage, with the control grid at the same potential as the cathode. Lines to the left of zero indicate grid voltages which are increasingly negative with reference to the cathode, while lines toward the right from zero represent control grid voltages which are increasingly positive with reference to the cathode. Plate current is represented by the vertical scale, with zero current at the bottom, and increasing values of current toward the top of this scale.

It is highly important to note that, if the control grid voltage is made negative by a certain amount, the plate current is reduced to zero. This condition is called <u>plate current cutoff</u>. The curve showing relations between grid voltage and plate current is straight, or nearly so, over a large portion of its length. But when the grid voltage becomes positive, there commences a slight bending of the curve.

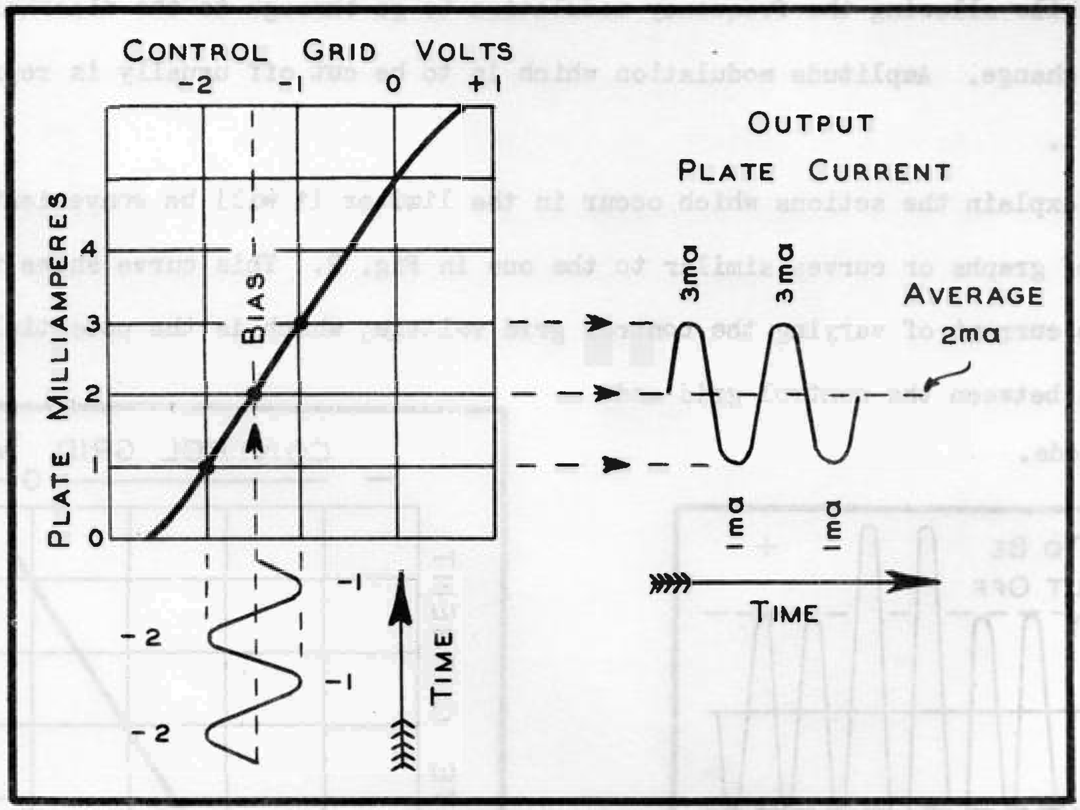


FIG. 3. How input voltage to the control grid, and the resulting output plate current, are shown on a graph.

In Fig. 3 we are using the curve to show how variations of plate current are caused by variations of control grid voltage. The grid bias, which is the average grid voltage, is shown as being 1½ volts negative. The variations of grid voltage, such as reach the grid from a signal, are shown below the graph. The average potential is on the bias voltage line, and the variations of potential carry the grid from 1 volt negative to 2 volts negative.

From the variations of grid voltage we follow straight upward to the curve, and there read the values of plate current corresponding to each grid voltage. It is assumed that the plate voltage and screen voltage remain constant. With the grid 2 volts negative the plate current is 1 milliampere, with the grid at the average biasing voltage of 1½ volts the plate current is 2 milliamperes. With the grid 1 volt negative the plate current is 3 milliamperes.

The changes or variations of plate current caused by variations of grid voltage are shown at the right. Highest peaks of plate current are at 3 milliamperes, the average is at 2 milliamperes, and the lowest peaks are at 1 milliampere. Time is indicated by arrows. The intervals of time between peaks of grid voltage and corresponding peaks of plate current are the same. Consequently, the frequency of the output plate current is the same as the frequency of the input grid voltage.

In Fig. 4 the input signal potential or grid voltage is shown as being of constant amplitude during most of the time, but as having brief increases of amplitude. The bias voltage, which fixes the average value of the varying grid voltage, is 1½ volts. The constant-amplitude peaks of grid voltage are at about 2.7 and 0.3 volts negative. The peaks which bring the grid to 2.7 volts negative cause plate current cutoff, or reduce the plate current to zero. The peaks which cause the grid to become 0.3 volt negative make the plate current rise to about 4.3 milliamperes.

When, as at A, the peaks of increased amplitude of input signal make the grid more than 2.7 volts negative, the plate current remains of zero value, because no matter how negative the grid voltage may become beyond the value for plate current cutoff, the plate current cannot become less than zero. At the opposite peaks, B, of increased amplitude the grid is made about 0.4 volt positive.

The changes of plate current are shown on the right-hand side of the graph. All of the excessive negative peaks of grid voltage have been obliterated so far as their effect on plate current is concerned. All of the negative peaks of grid voltage bring the plate current to zero. But peaks of excessive amplitude of opposite polarity in the grid voltage, shown at B, cause corresponding peaks of excessive plate current as

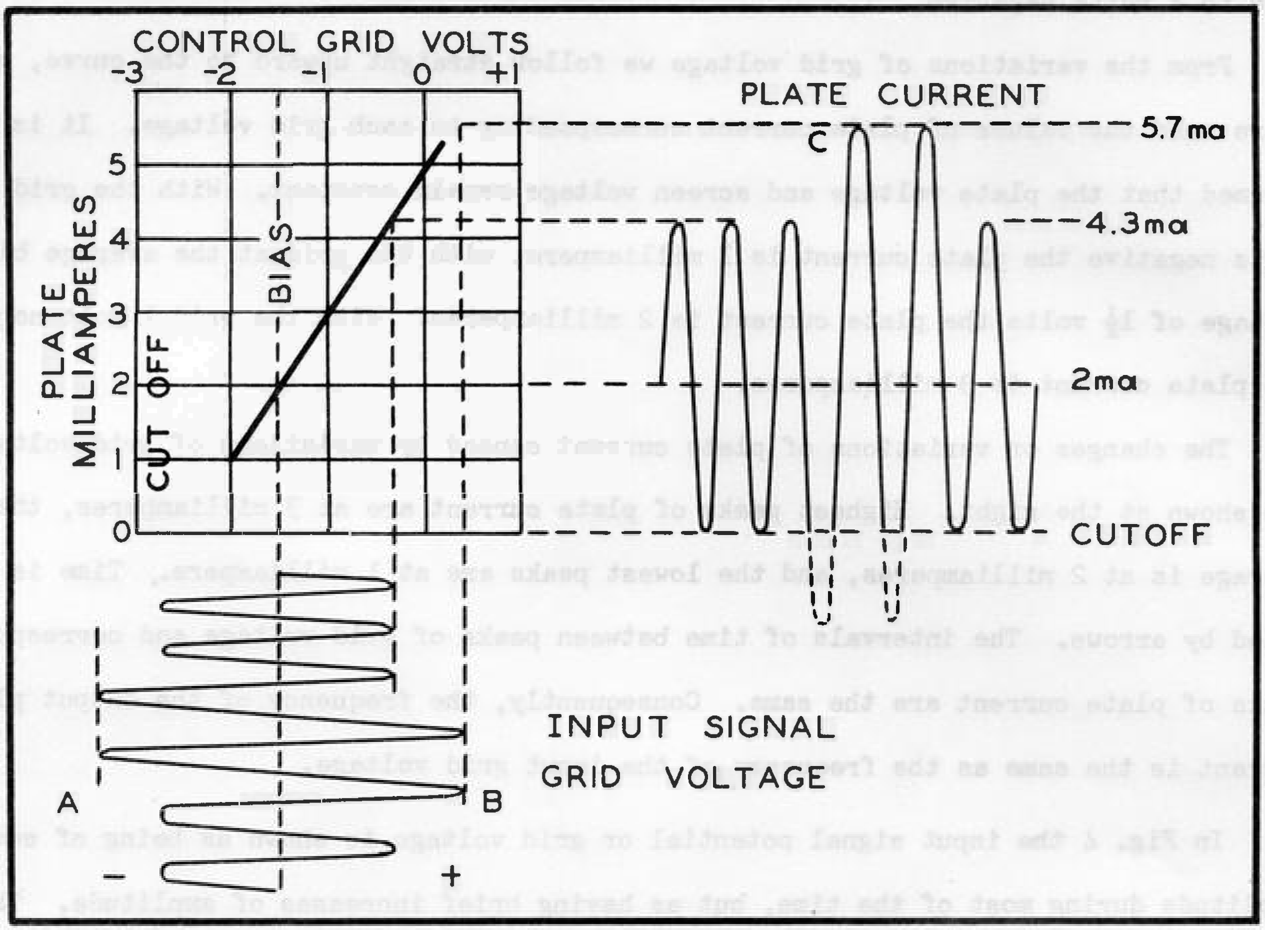


FIG. 4. Variations of input amplitude in one polarity are removed by plate current cutoff.

at C. We have succeeded in getting rid of part of the amplitude modulation of the input signal (the part shown at A) in the plate current, but some (the paft at B) still remains.

Limiter tubes are pentodes of the sharp cutoff type whose curves showing relations between grid voltage and plate current have the general form of the curves in Figs. 2, 3, and 4. These tubes are operated with plate and screen voltages which are much lower than would be used with the same tubes acting as amplifiers. Where plate and screen voltages for amplifier operation might be between 100 and 250 volts, for limiter action both of these voltages might be 60 or less. With low voltages applied to the plate and the screen we have plate current cutoff when the grid voltage becomes only one or two volts negative.

With a limiter tube thus operated, and with the grid bias of a value suited to the signal potentials ordinarily delivered to the limiter from the i-f amplifier, it would be possible to cut off amplitude modulation of one polarity in the manner shown by Fig. 4. But, in addition, it is necessary to cut off the amplitude modulation peaks which occur in the opposite polarity. That is, referring to Fig. 4, we must cut off the peaks at B as well as those at A.

An alternating potential, such as the input signal, consists of a succession of half-cycles in alternate opposite polarities. Either polarity might be called positive, and then the opposite one would be negative. For convenience and uniformity in discussions we usually speak of the half-cycles which are drawn upward on a graph as being positive, as in Fig. 1, and of those drawn downward as being negative. In Fig. 4 we consider the half-cycles which extend toward A as being negative, because they make the grid more negative. Those extending toward B are considered to be positive, because they make the grid less negative, or, with suitable bias, would make the grid positive or more positive.

Using sharp cutoff pentode tubes with low plate and screen voltages allows cutting off negative peaks of amplitude modulation from the frequency-modulated signal. To cut off the positive peaks of amplitude modulation we shall resort to automatic grid bias furnished by a grid capacitor and resistor used in the method called grid rectification.

BIASING BY GRID RECTIFICATION

The principle of grid rectification is shown by Fig. 5. In diagram 1 is shown the control grid circuit of the limiter tube. The transformer at the left is the one whose primary winding is in the output or plate circuit of the preceding i-f amplifier tube. The secondary, which is in the limiter grid circuit, is tuned by a small trimmer capacitor. Between the tuned secondary and the control grid of the limiter is grid capacitor Cg.

Alternating signal potentials are induced in the secondary winding and, through the grid capacitor, these alternating potentials act on the grid and cathode of the limiter. When the signal polarity is such as to make the control

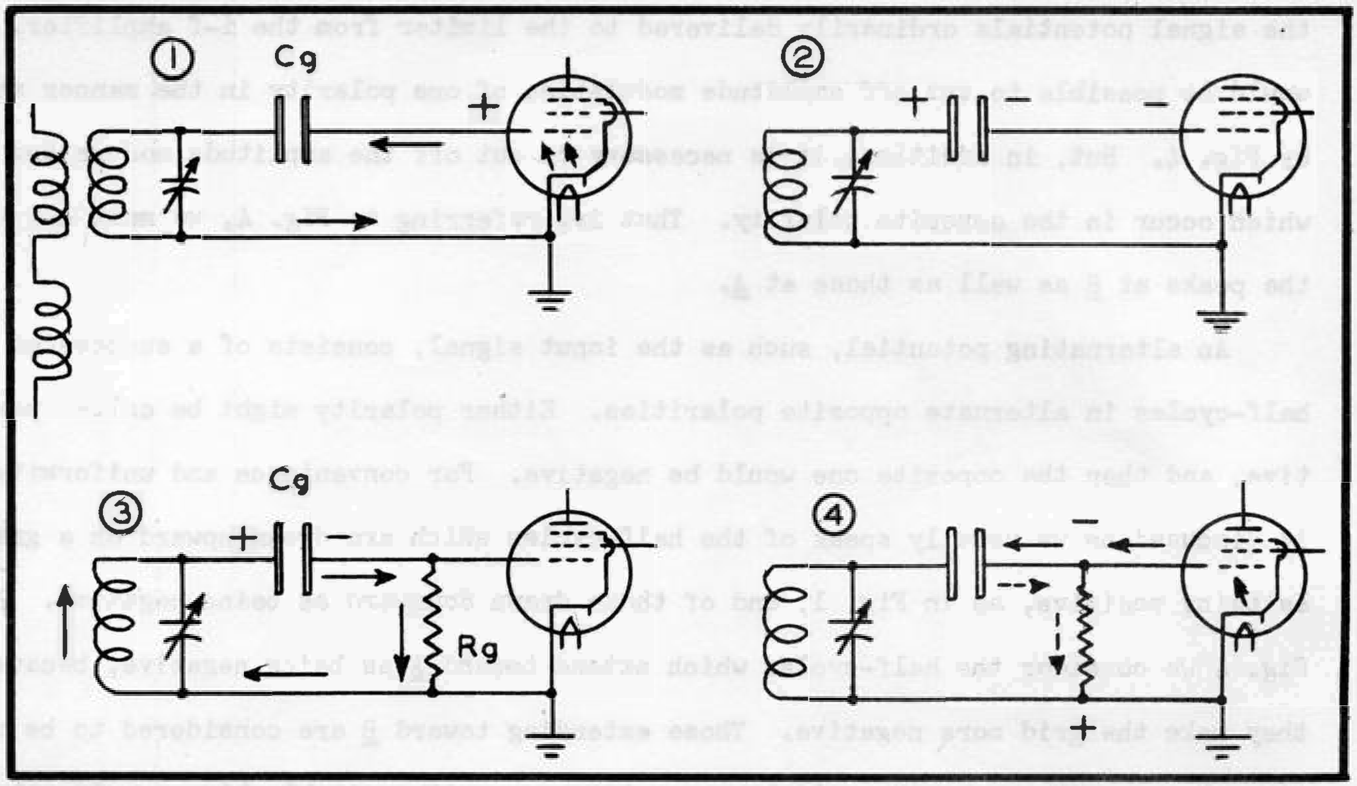


FIG. 5. The principle of producing a bias voltage by means of rectification.

grid positive and the cathode negative, there will be electron flow within the tube from cathode to grid, and in the external grid circuit there will be electron flow from control grid to the side of capacitor Cg which is toward the grid. There will be electron flow also from the other side of the capacitor through the secondary winding and to the tube cathode. When the signal polarity reverses, the control grid will be made negative and the cathode relatively positive. No electron flow will pass from a negative element to the cathode, and so there can be no electron flow within the tube and none of the negative electrons which have accumulated on the right-hand plate of capacitor Cg can leave this plate.

The result of the foregoing action is shown by diagram 2. Succeeding charges given to capacitor Cg have made its right-hand plate highly negative, since no negative electrons can escape from this plate. The right-hand plate is directly connected to the control grid of the tube, and so the control grid is made so highly negative as to prevent further electron flow from cathode to grid within the tube.

Now, as in diagram 3, we connect between control grid and cathode the grid resistor Rg. Electrons flow from the negative side of capacitor Cg through resistor Rg, the secondary winding and the wiring connections around to the positive side of the capacitor. Thus the capacitor can discharge through Rg, while being charged by the actions shown in diagrams 1 and 2.

The capacitor Cg might be compared with the water tank of Fig. 6 into which water is flowing from a pump, just as electrons are "pumped" onto the capacitor plate in diagram 1, while at the same time water is flowing out of the bottom of the tank through a leak, just as electrons escape through resistor Rg. At 1, the water is being added in recurring pulses, as electrons are added to the grid capacitor by pulses of flow coming through the tube on alternate half-cycles. Water is leaving the tank through the leak at the bottom, as electrons leave one side of the capacitor through the grid resistor.

If there are more frequent pulses of water, as at 2, the tank will get fuller. If the frequency in the electrical system is increased, the capacitor will be charged to a higher voltage. More water per pulse, with no change from the original frequency, will tend to raise the water level in the tank as at 3. And greater amplitude in the electrical signal will increase the charge of the grid capacitor. Making the water leak smaller will reduce the rate at which water leaves the tank, as at 4.

Increasing the resistance of the grid resistor will reduce the rate at which the grid capacitor discharges and will raise the potential of the capacitor charge. If we use a smaller tank, it will fill more quickly and the water will rise to a higher level, but the higher level means more water pressure acting on the leak, and the rate of water escape will increase until this rate equals the rate at which water is being

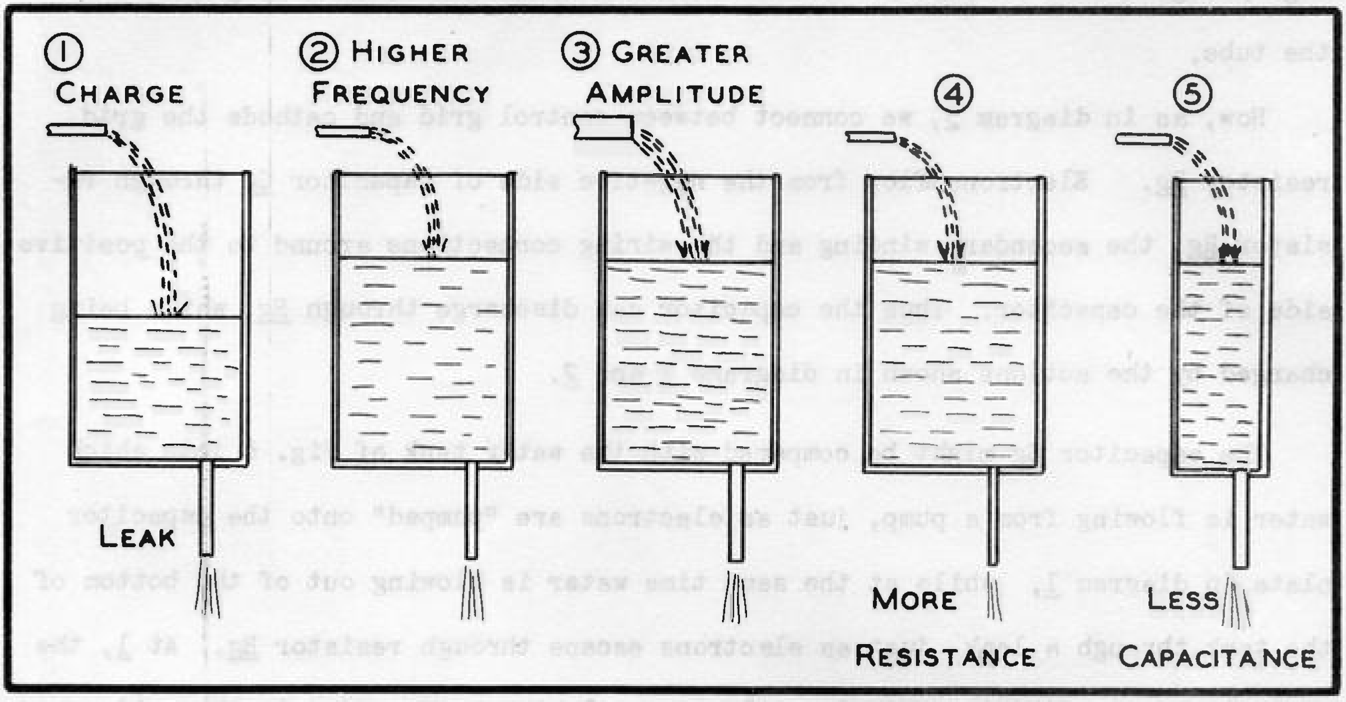


FIG. 6. The grid capacitor acts like a water tank which leaks through an opening acting like the grid resistor.

added. Similarly, if we use a grid capacitor of smaller capacitance, the charge and the voltage across the capacitor will increase.

The converse of each of the factors of Fig. 6 will lower the water level in the water tank, and will reduce the charge and the voltage across the grid capacitor in the electrical system. That is, the capacitor charge and voltage will be decreased by lower frequency, less signal amplitude, less grid resistor resistance, and more capacitance in the grid capacitor. Under actual working conditions the capacitor charge and voltage will become such that the rate of electron discharge through the grid resistor will equal the rate at which the capacitor is being charged. We may picture conditions as in diagram 4 of Fig. 5, where the capacitor is charged by electron flow following the full-line arrows, and is continually discharging through electron flow following broken-line arrows.

The direction of electron flow through the grid resistor, from top to bottom, shows that the top of this resistor and the control grid to which it is connected remain negative with reference to the bottom of the resistor. The bottom end of this resistor is connected to the cathode as shown in diagrams 3 and 4 of Fig. 5.

Connections for a typical limiter stage are shown by Fig. 7. The actions which occur in the grid capacitor and resistor, Cg and Rg, have been explained. It is apparent that, when no signal potentials are being induced in the grid circuit, all charge of the grid capacitor will have leaked away through the grid resistor. Then, with no capacitor charge and no electron flow in the grid resistor, there will be no potential

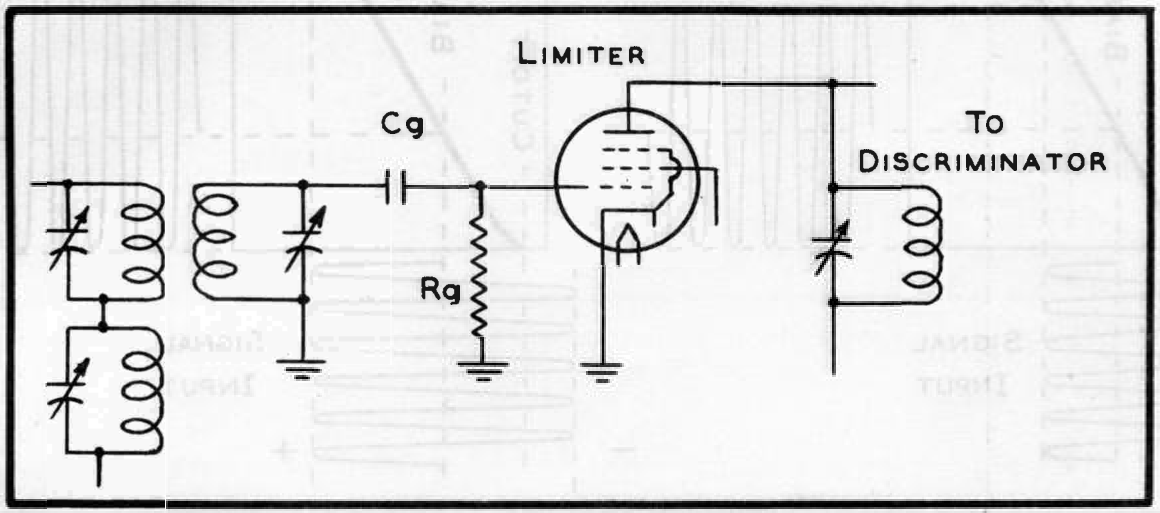


FIG. 7. The circuits for a typical limiter stage.

difference between top and bottom of the resistor, and the control grid potential will be the same as the cathode potential. This means that, to begin with, we have zero grid bias.

As soon as there are signal potentials in the grid circuit, the capacitor acquires a charge, there is electron flow through the grid resistor, and the grid becomes negatively biased. As was shown with the help of Fig. 6, the capacitor charge voltage and the grid bias voltage (which are the same or equal) will depend on the relative values of capacitance in Cg and resistance in Rg for any certain applied frequency and amplitude of the signal.

With a deviation of 75 kc the greatest possible change of frequency will be 150 kc or 0.15 mc. If the intermediate frequency is on the order of 10.0 mc, the maximum

change of frequency will be only $1\frac{1}{2}$ per cent, and this will not cause any great change of control grid bias.

EFFECTS OF VARYING AMPLITUDES

Now let's see what happens when there is a change of signal amplitude, or when there is amplitude modulation of the signal potentials. First, we shall consider the

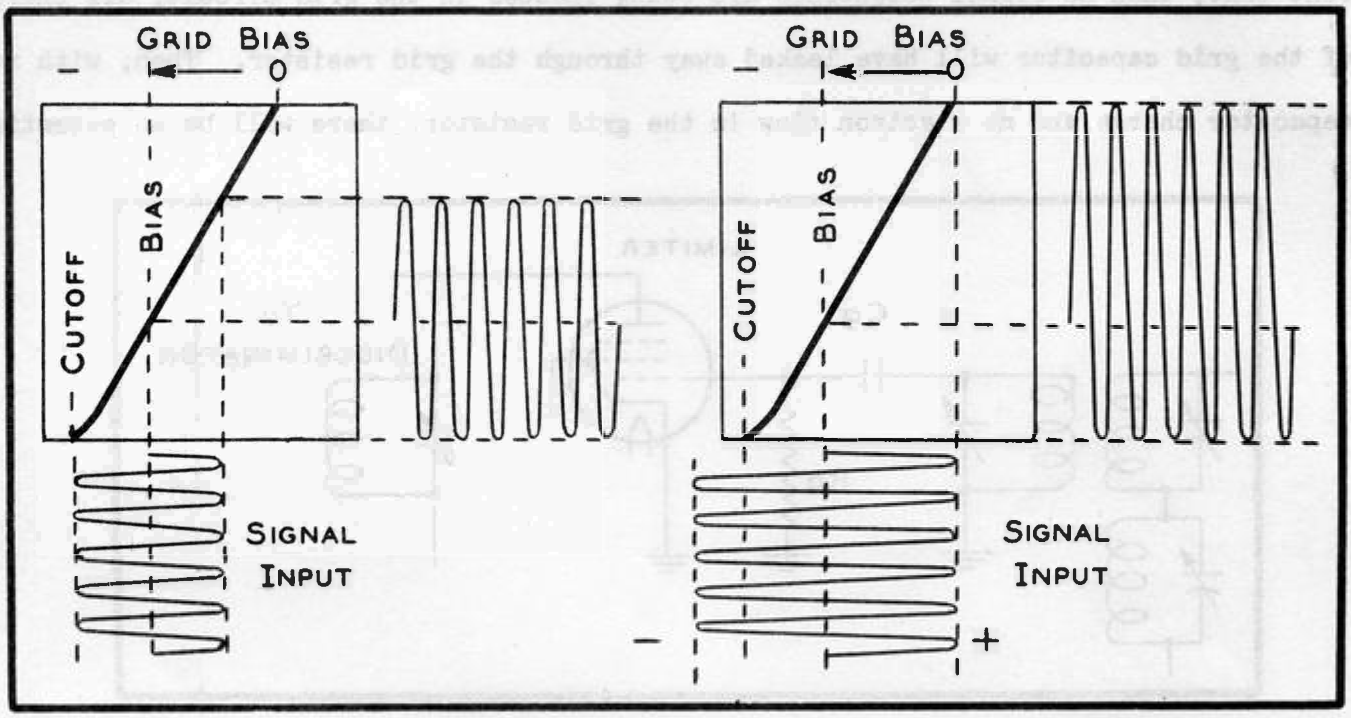


FIG. 8. Constant-amplitude amplification with a fixed grid bias.

constant-amplitude signal input shown at the left in Fig. 8. When the grid is biased to the value indicated on the graph, the negative input potentials extend just to the grid voltage for plate current cutoff and the positive input potentials make the grid less negative, but not positive. The resulting plate current output is a somewhat amplified counterpart of the signal input.

In the right-hand diagram of Fig. 8 the signal input amplitude has been increased. Now the negative signal potentials carry the grid voltage far more negative than the value for plate current cutoff, while the positive signal potentials carry the grid voltage all the way to zero. The resulting plate current output is of constant amplitude, because all of the negative signal half-cycles have been cut off at the zero value of plate current, and all of the positive half-cycles have caused uniform pulses of plate current. Either of the limiter outputs shown by Fig. 8 would be satisfactory, but this is because the inputs are of constant amplitude. Were the input to have amplitude modulation, rather than being of constant amplitude, we would not have the condition shown at the right in Fig. 8, rather we should have the condition of Fig. 4, where the non-uniform input amplitude is reproduced in the upward swings of plate current output.

But when there is an increase of amplitude in the input signal something happens that is not shown at the right in Fig. 8. There we have the same degree of negative bias as at the left in the same figure. Because of grid rectification, explained in Fig. 5, every increase of input amplitude makes the grid bias more negative. The result is shown by Fig. 9. Grid bias is represented by the length of the arrow from zero grid volts to the negative value of the vertical line on which lies the center of the signal input. This bias in Fig. 9 is greater than in Fig. 8. The plate current output in Fig. 9 has less total amplitude (bottom to top) than the output in Fig. 8.

Supposing that the normal constant-amplitude input to the limiter is as shown at the left in Fig. 8. Supposing, too, that for a brief instant of time there is a pulse of unwanted amplitude modulation which reaches the value shown for the input signal at the right in Fig. 8 and in Fig. 9, where the inputs have the same amplitude. This momentary greater amplitude will instantly increase the charge and the voltage of the grid capacitor. The capacitor voltage is the same as the negative grid bias voltage, and so the greater amplitude instantly makes the grid bias more negative, with the result shown by Fig. 9.

Now we are cutting off any negative amplitude signal modulation by means of plate current cutoff. We are effectively holding down any positive amplitude modulation by letting the modulation itself automatically make the grid bias more negative, which holds down the upward peaks of plate current. The overall result is complete limiting of amplitude of the plate current output.

The grid bias, which is the same as the voltage of the grid capacitor, becomes more negative with every increase of input signal amplitude, doing so whether there is a continued amplitude increase such as from a stronger signal or only a momentary

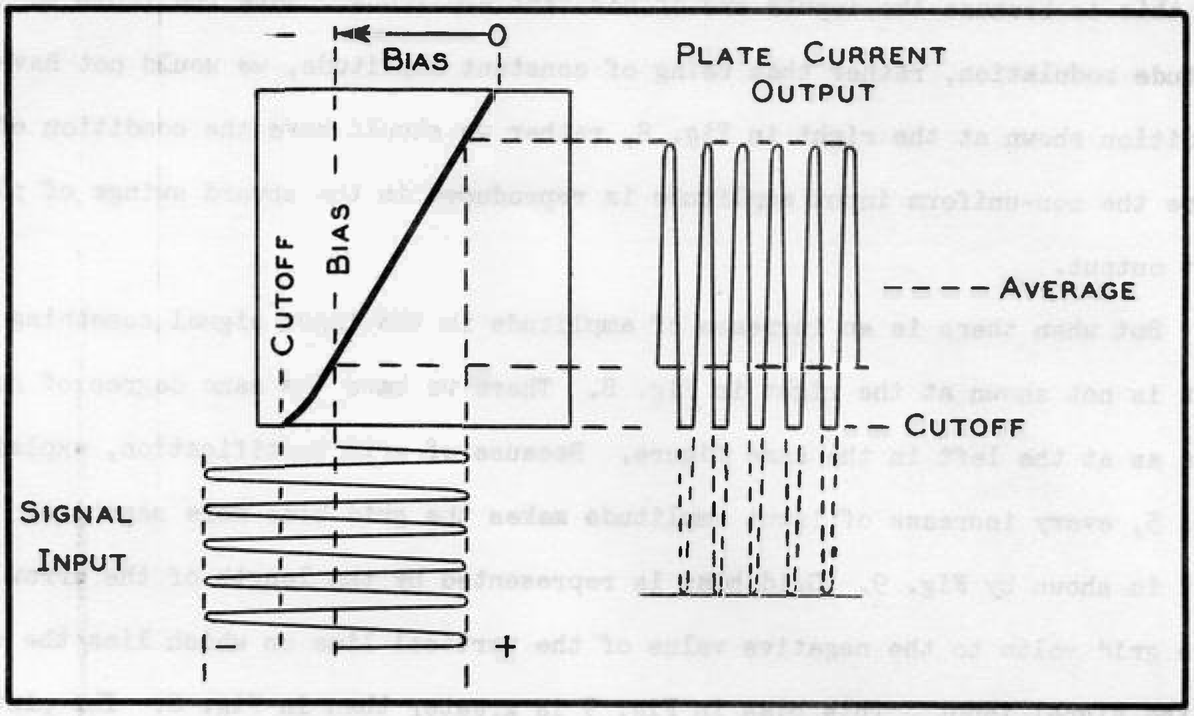


FIG. 9. Making the grid bias more negative limits the amplitude of the output plate current.

increase such as from some kind of interference which otherwise would cause noise in the reproduction.

Looking at the plate current curve of Fig. 9, where are shown by broken lines the parts of the curve removed by plate current cutoff, we see that the bottoms of the remaining downward half-cycles are rather square rather than being rounded as in the usual sine wave form. In an amplitude-modulated signal these "square waves" would mean distortion, they would indicate the production of harmonic frequencies in addition to the signal frequency. With frequency modulation there is no such trouble, because the original variations of signal frequency still form the principal variations of the plate current, and whatever higher harmonic frequencies are produced are rejected by the discriminator input circuits which are tuned to respond only to the intermediate frequency plus the normal deviation from this intermediate.

HOW THE LIMITER ACTS

The performance of a typical limiter stage is shown by Fig. 10. The bottom horizontal scale shows signal voltages applied to the control grid circuit of the limiter. The greater the input voltage the greater would be the amplitude modulation of the input signal, since modulation is measured in volts. The left-hand vertical scale shows output voltages as produced across a load or a coupling device in the plate circuit of the limiter tube.

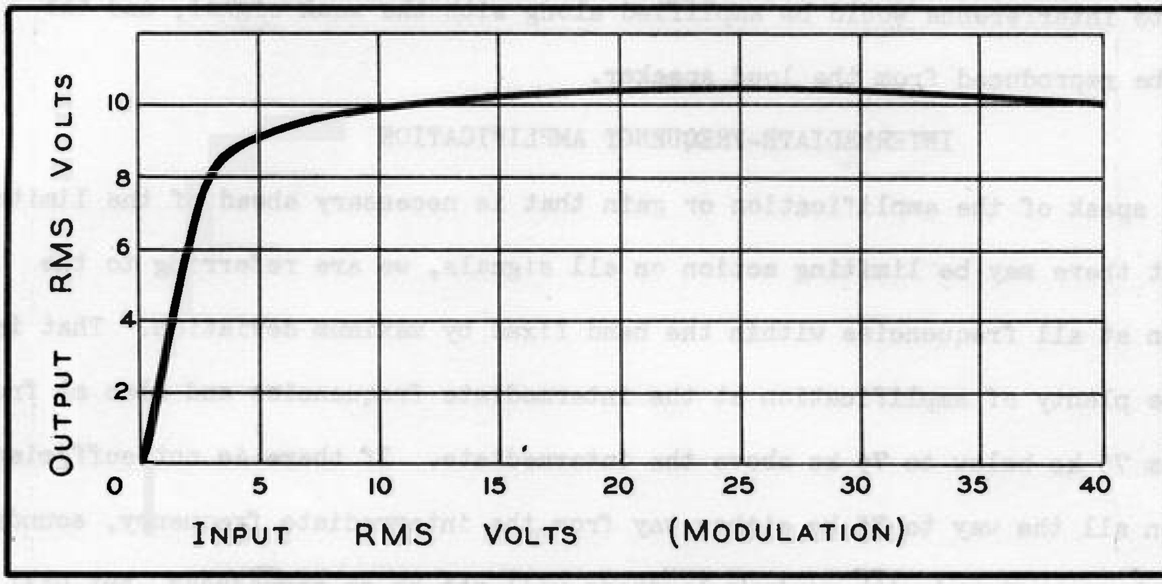


FIG. 10. How the limiter maintains a nearly constant output for all inputs above a certain value.

With zero input there is, of course, zero output. As the input is increased from zero to about 3 volts there is a fairly steady increase of output, and the output rises to around 8 volts. Then the limiting action commences, and with further increase of input voltage or amplitude the output increases more and more slowly until, with a 10-volt input, there is a 10-volt output. With all greater increases of input voltage or amplitude, the output rises very little above 10 volts.

With the limiter performance represented by Fig. 10 it is quite plain that all signals which are to be reproduced should be amplified in stages preceding the limiter so that the minimum signal voltage is between 6 or 7 and 10 volts at the limiter grid. Then all signals are subjected to limiting action, and the limiter output will remain between about 9½ and 10½ volts. Were there to be a sudden and brief increase of amplitude to something like 20 volts, as might result from electrical interference, the resulting instantaneous limiting action would hold the limiter output to only a little more than 10 volts. The interference would not come through the limiter.

Were the amplification ahead of the limiter not great enough to bring the limiter grid input to a value at which limiting takes place, then the weak input signal would be amplified as shown by the left hand end of the curve in Fig. 10. Increases of amplitude due to interference would be amplified along with the weak signal, and the noise would be reproduced from the loud speaker.

INTERMEDIATE-FREQUENCY AMPLIFICATION

When we speak of the amplification or gain that is necessary ahead of the limiter, in order that there may be limiting action on all signals, we are referring to the amplification at all frequencies within the band fixed by maximum deviation. That is, there must be plenty of amplification at the intermediate frequencies and also at frequencies from 75 kc below to 75 kc above the intermediate. If there is not sufficient amplification all the way to 75 kc either way from the intermediate frequency, sounds which should be reproduced with maximum loudness will not be so reproduced, but will come through comparatively weak. This results from the fact that loudness results from large deviations.

In the i-f amplifier stages preceding the limiter there are the double-tuned transformers such as found in all superheterodyne receivers. Such transformers produce double-hump resonance when their primary and secondary circuits are closely coupled. Fig. 11 shows such a double-tuned coupling transformer and the general form of the double-hump resonance curve which results from such coupling. The frequency increases from left to right. The height of the curve at a point corresponding to any frequency indicates the relative amplification which is obtained at that frequency. An amplifying stage operating in this manner provides high gain or amplification over quite a wide range of frequencies. Then, at frequencies either lower or higher, the amplification drops off rapidly. At frequencies outside of the range to be amplified the response of the amplifier is so weak that these other frequencies are practically excluded from the following circuits in the receiver.

Fig. 12 shows the upper part of a double-hump resonance curve which might show

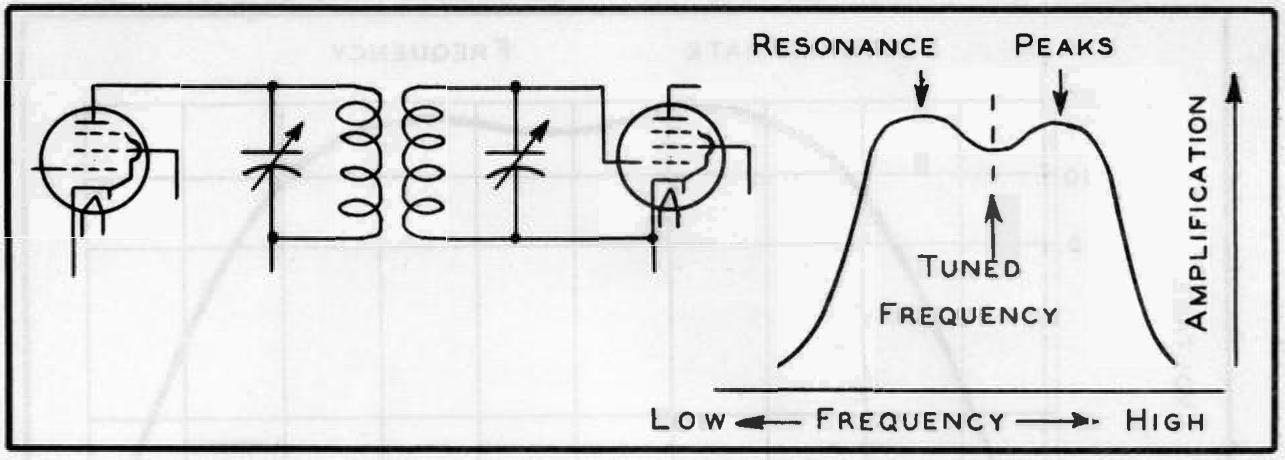
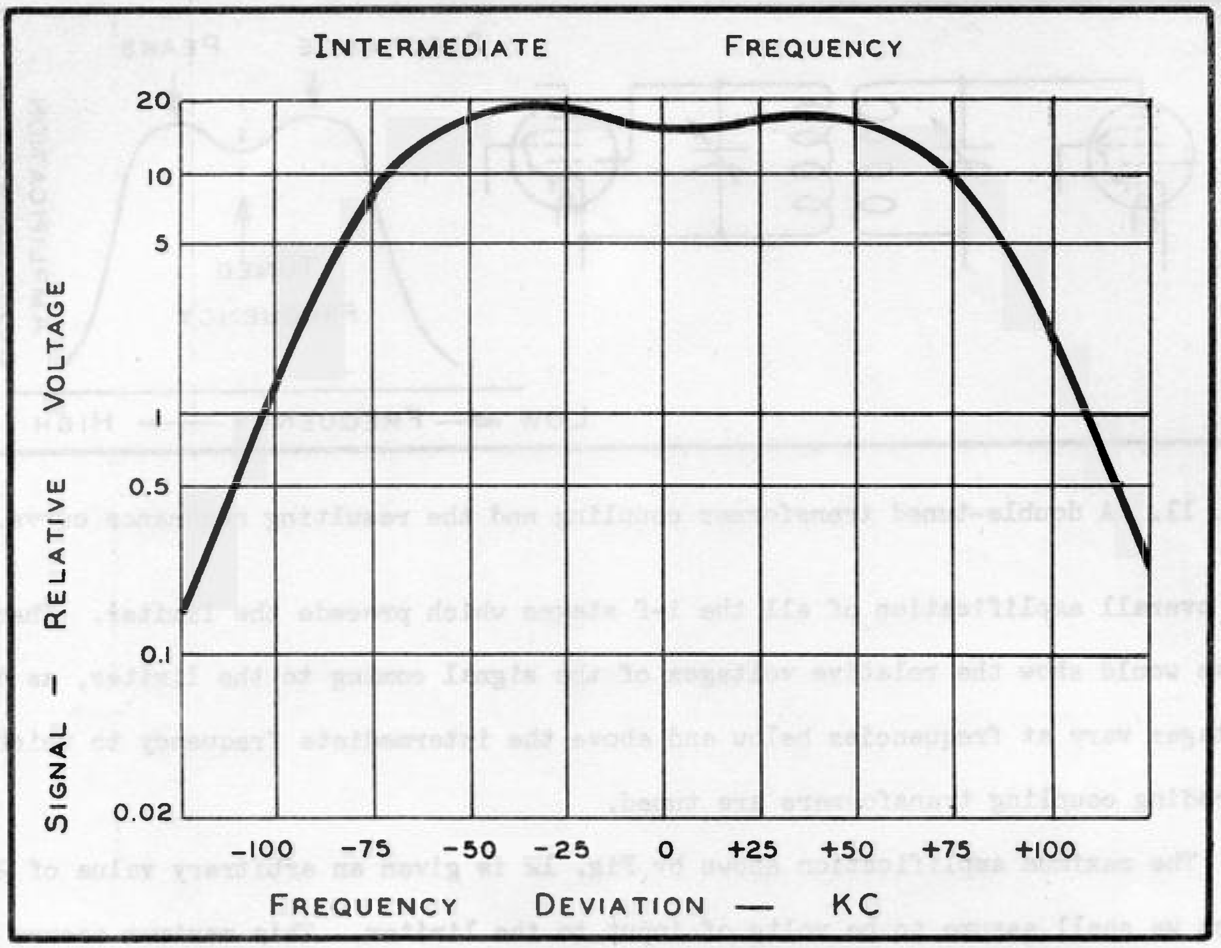


FIG. 11. A double-tuned transformer coupling and the resulting resonance curve.

the overall amplification of all the i-f stages which precede the limiter. Then this curve would show the relative voltages of the signal coming to the limiter, as these voltages vary at frequencies below and above the intermediate frequency to which the preceding coupling transformers are tuned.

The maximum amplification shown by Fig. 12 is given an arbitrary value of 20 units, which we shall assume to be volts of input to the limiter. This maximum occurs at a negative deviation of about 35 kc. At the intermediate frequency, or at zero deviation, the signal is about 16 volts. At a positive deviation of about 35 kc the signal is up to about 18 volts. The maximum deviations, for the loudest signals, will be at −75 and at +75 kc. At the deviation of −75 kc the signal strength is about 9 volts, and at the deviation of +75 kc the strength is about 10 volts.

If you look back at Fig. 10 you will see that input signals of 9 or 10 volts cause full limiting action, and that the limiter output with either of these inputs is practically 10 volts. On the same graph you will see that with any input between 9 and 20 volts the output of the limiter remains between 10 and about 10.4 volts. Now, coming back to Fig. 12, you will see that all of the signal voltages from a deviation of −75 kc right through to a deviation of +75 kc have values between 9 and 20 volts. It becomes plain that all of the signal strengths within the limits of maximum deviations either way from the intermediate frequency will produce a limiter output of between 10 and 10.4 volts. This is because the tuned transformer couplings in the interme-



FIR. 12. A resonance curve representing signal voltage input to the limiter.

diate-frequency amplifier are adjusted to produce the resonance curve shown by Fig. 12.

We are assuming certain very definite values of input and output voltages, and a very definite shape of resonance curve, all for the sake of having definite values and quantities with which to work while illustrating the principles of f-m reception. Other generally similar relations might exist between all of these quantities without affecting the principles of operation.

Now we shall take the signal voltages at the limiter output as represented by Fig. 12 for frequencies below and above the tuned intermediate frequency, and assume that the limiter stage acts on these inputs as shown by Fig. 10. The resulting output from the limiter will be as shown by Fig. 13. Here the limiter output, which will be used for the input to the following discriminator, is of very nearly constant amplitude (about 10 volts) throughout the whole range of normal frequency deviation from 75 kc below the intermediate frequency to 75 kc above that frequency.

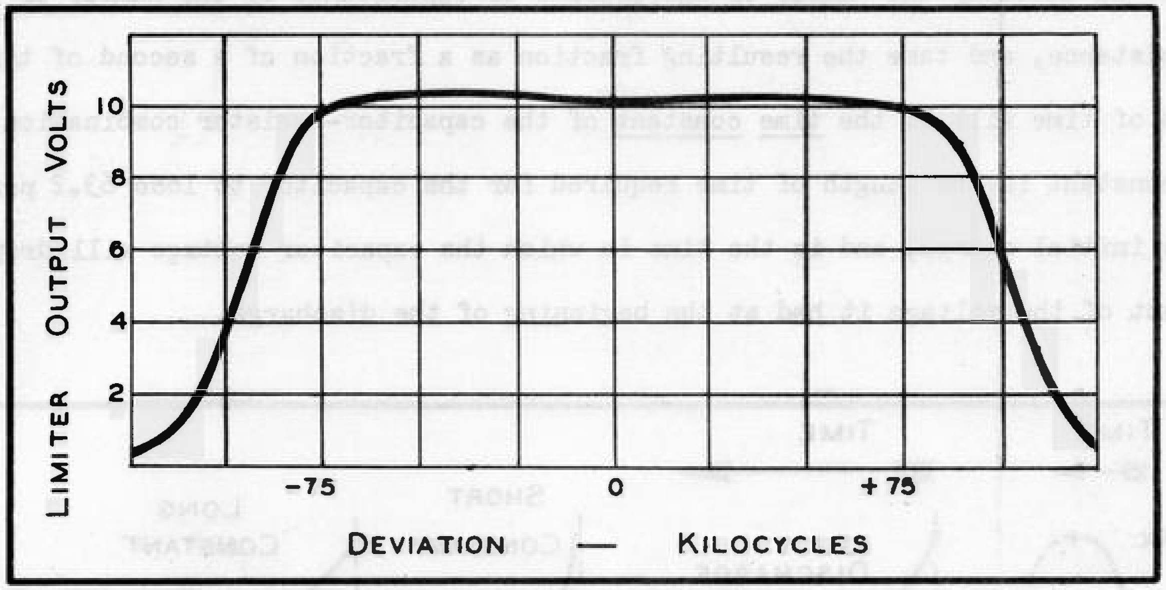


FIG. 13. The limiter output is practically uniform in voltage throughout the range of frequency deviation.

With the performance illustrated by Fig. 13, we have retained the advantage of the double-hump resonance curve in greatly reducing the response at frequencies outside of the desired range, and, at the same time, have insured a constant-amplitude input to the discriminator.

Were the resonance curve showing output from the i-f amplifier any narrower than shown by Fig. 12, the frequencies at deviations near the maximum in either direction would not be carried through the limiter at the desired constant amplitude. In making service adjustments or alignment adjustments on the i-f transformers, the object is to secure a limiter input of the general character shown by Fig. 12.

LIMITER TIME CONSTANTS

Now we have still another matter to be considered in obtaining satisfactory operation of the limiter stage; this being the relation between the capacitance of the grid capacitor and the resistance of the grid resistor. You will recall that the capacitor is charged by pulses of electron flow which occur during those half-cycles of

The intermediate-frequency signal in which the limiter grid is made positive, also that the capacitor discharges through the grid resistor during the intervening half-cycles. To what extent the capacitor may discharge between the charging pulses depends upon the capacitance of the capacitor and the resistance of the resistor.

If we multiply the number of microfarads of capacitance by the number of megohms of resistance, and take the resulting fraction as a fraction of a second of time, that period of time will be the time constant of the capacitor-resistor combination. The time constant is the length of time required for the capacitor to lose 63.2 per cent of its initial charge, and is the time in which the capacitor voltage will drop to 36.8 per cent of the voltage it had at the beginning of the discharge.

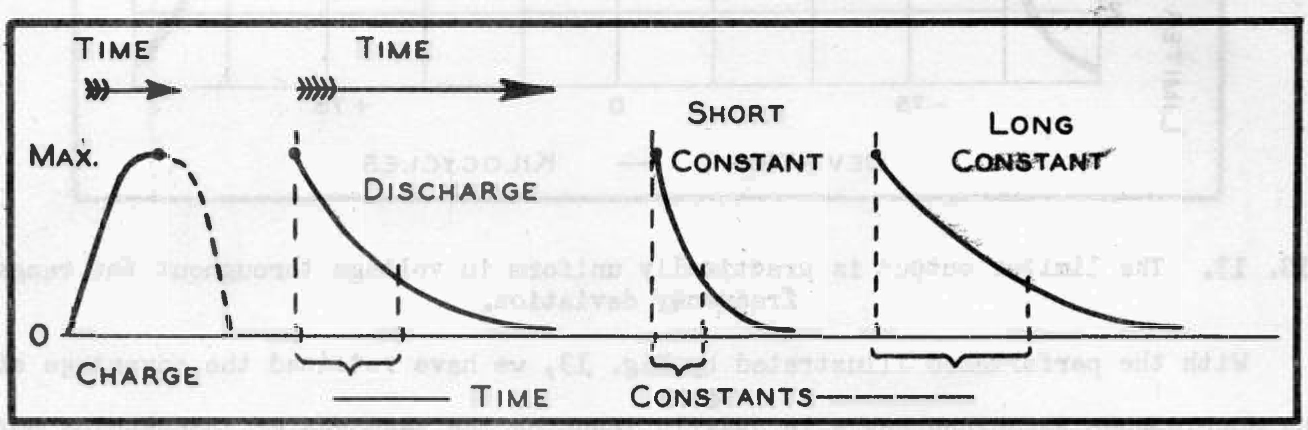


FIG. 14. The capacitor discharge rate varies with the time constant.

The grid capacitor receives its initial charge in the manner shown at the left in Fig. 14. The electron flow for charging is shown as following a sine curve from zero to maximum. At first the charging takes place rapidly, but as the charge increases, the rate slows down. The remainder of the sine curve is shown by a broken line, but during this latter part of the curve, there is no discharge through the tube because there can be no electron flow through the tube.

The grid capacitor discharges through the grid resistor as shown toward the right in Fig. 14. With some certain relative values of capacitance and resistance, the discharge might proceed as shown by the curve marked "Discharge". At first, the charge and the capacitor voltage drop rapidly, but as the charge becomes less, there is a slower and slower rate of discharge. The length of time represented between the vertical broken lines is the time constant; it is the time during which the capacitor loses 63.2 per cent of its initial maximum charge.

If the capacitance, the resistance, or both are made less, the discharge will be more rapid and the time constant will be shorter, as shown by the curve marked "Short Constant". If the capacitance, the resistance, or both are made greater, the discharge will take longer and the time constant will be longer, as shown by the curve marked "Long Constant". The general shape of the discharge curve always is the same, but it is made steeper by combinations of capacitance and resistance which gives shorter time constants.

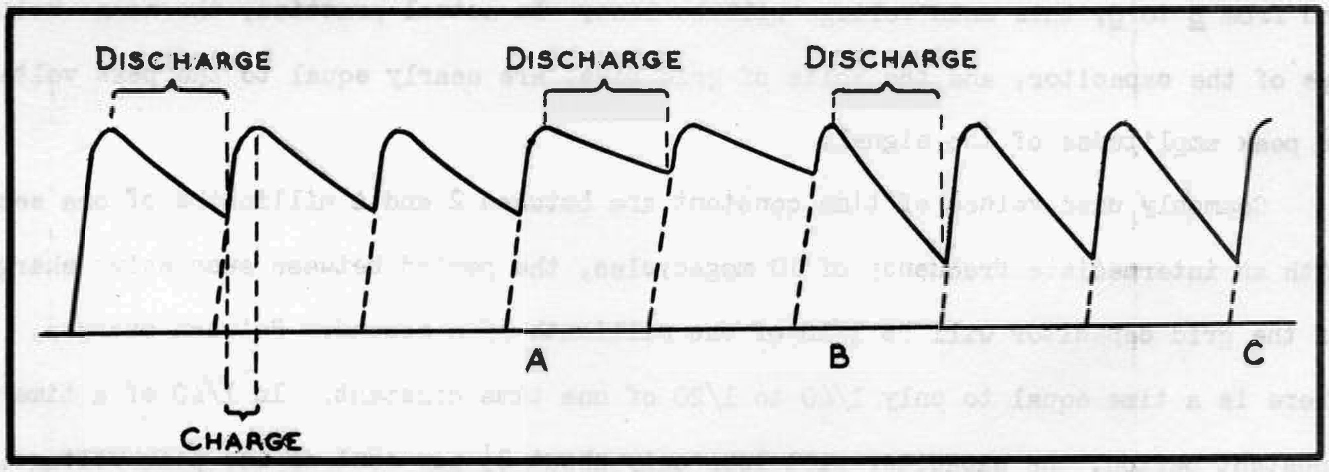


FIG. 15. How the grid capacitor charges and discharges.

Fig. 15 shows how the grid capacitor is alternately charged and discharged. The pulses of electron flow which occur once during each cycle of the intermediate frequency serve to charge the capacitor to a voltage equal to the voltage of amplitude of the signal. Then the capacitor commences to discharge through the grid resistor. But before the discharge is complete, there comes another charging pulse which brings the capacitor voltage back to its original peak values. This charging is followed by another partial discharge, and so the action continues.

From A to B in Fig. 15 is shown the effect of a longer time constant. The discharge proceeds more slowly, and the capacitor is not discharged so much between pulses of charging current. From B to C is shown the effect of a shorter time constant. Here there is more discharge between pulses of charging because the discharge can proceed more rapidly.

The voltage that determines the bias for the control grid is the mean value of voltage, which is about the same as the average of the peak voltages and the voltages at the end of the short periods of discharge. The peak charged voltage always is the same with an input signal of given amplitude. Then the less the discharge, or the less the voltage has dropped before the next charging commences, the higher will be the mean voltage of the capacitor and the more negative will be the grid bias. Between A and B of Fig. 15, the mean voltage of the capacitor will be greater than at the left, and from B to C, this mean voltage will be less. In actual practice, the mean voltage of the capacitor, and the volts of grid bias, are nearly equal to the peak voltages or peak amplitudes of the signal.

Commonly used values of time constant are between 2 and 4 millionths of one second. With an intermediate frequency of 10 megacycles, the period between successive charges of the grid capacitor will be 1/10 of one millionth of a second. Between charges, there is a time equal to only 1/40 to 1/20 of one time constant. In 1/40 of a time constant period, the capacitor will lose only about 2½ per cent of its peak voltage, and during 1/20 of a time constant, the loss will be less than 5 per cent of the peak voltage. Then, with such time constants as mentioned, the grid bias will remain between 95 and 97½ per cent of the peak signal voltage.

We have seen that, in order to maintain the grid biasing voltage, it is desirable to have a fairly long time constant. This gives the effect between A and B of Fig. 15, and keeps the mean voltage of the capacitor high in relation to the input voltage or amplitude. Long time constants require relatively large capacitances, resistances, or both.

But if the time constant is made too long, we get into trouble which is explained as follows. Supposing that there is an interference impulse that momentarily increases the input amplitude to a high value. This will increase the grid bias and will make the grid more negative. If we have a long time constant, with which there will be a slow discharge of the capacitor, the capacitor voltage and the grid bias will remain high after the interference impulse has ceased. With the highly negative grid bias continuing after the signal amplitude returns to its normal lower value, the output of the limiter stage will be reduced. This is because a more negative grid always reduces the average plate current. Then, although the limiter output was prevented from <u>increasing</u> while the interference lasted, the limiter output will <u>decrease</u> for a brief period after the interference ceases. This means that the limiter output does not remain at constant amplitude, but drops after the interference ceases. Now we have an amplitude variation, a reduction of amplitude, in the limiter output, and there will be a noise from the loud speaker.

It is apparent that the values of grid capacitor and resistor with which a given receiver has been designed are not to be changed for other values unless we are capable of figuring out just what will happen after the change.

OTHER TYPES OF LIMITERS

Some receivers have two limiter stages, for the purpose of securing more complete or uniform limiting of amplitude modulation resulting from various kinds of interference. Sometimes we find different time constants in the two stages, each suited to certain degrees of amplitude variations and different lengths of times during which the amplitude may vary from its average or normal constant value. The connections which may be used in a two-stage limiter are shown by Fig. 16. Both tubes are pentodes. The grid biases for both are controlled by a grid capacitor <u>Cg</u> and a grid resistor <u>Rg</u>, whose functions and action have been explained. Coupling between first and second limiters is of the resistance-capacitance type by means of resistor <u>Rp</u> in the plate circuit of the first limiter, with the following capacitor <u>Cg</u> acting as the coupling capacitor. Low plate and screen voltages are used on both limiters.

It would be entirely possible to design and construct a receiver for frequency-modulated signals and to use no limiter stage. The frequency-modulated signals would be changed to amplitude-modulated audio-frequency signals by the discriminator, and the sound signals would be reproduced by the loud speaker. However, the noise-reducing

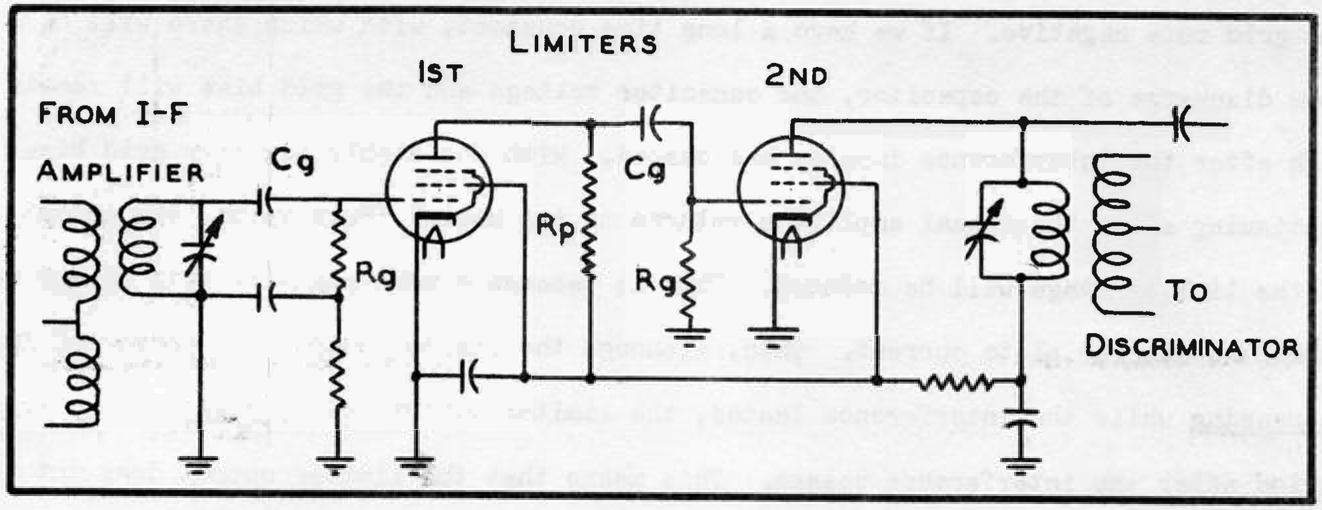


FIG. 16. Connections for one type of two-stage limiter.

advantages of the limiter would be lost, and interference noise would be reproduced along with the desired signals.

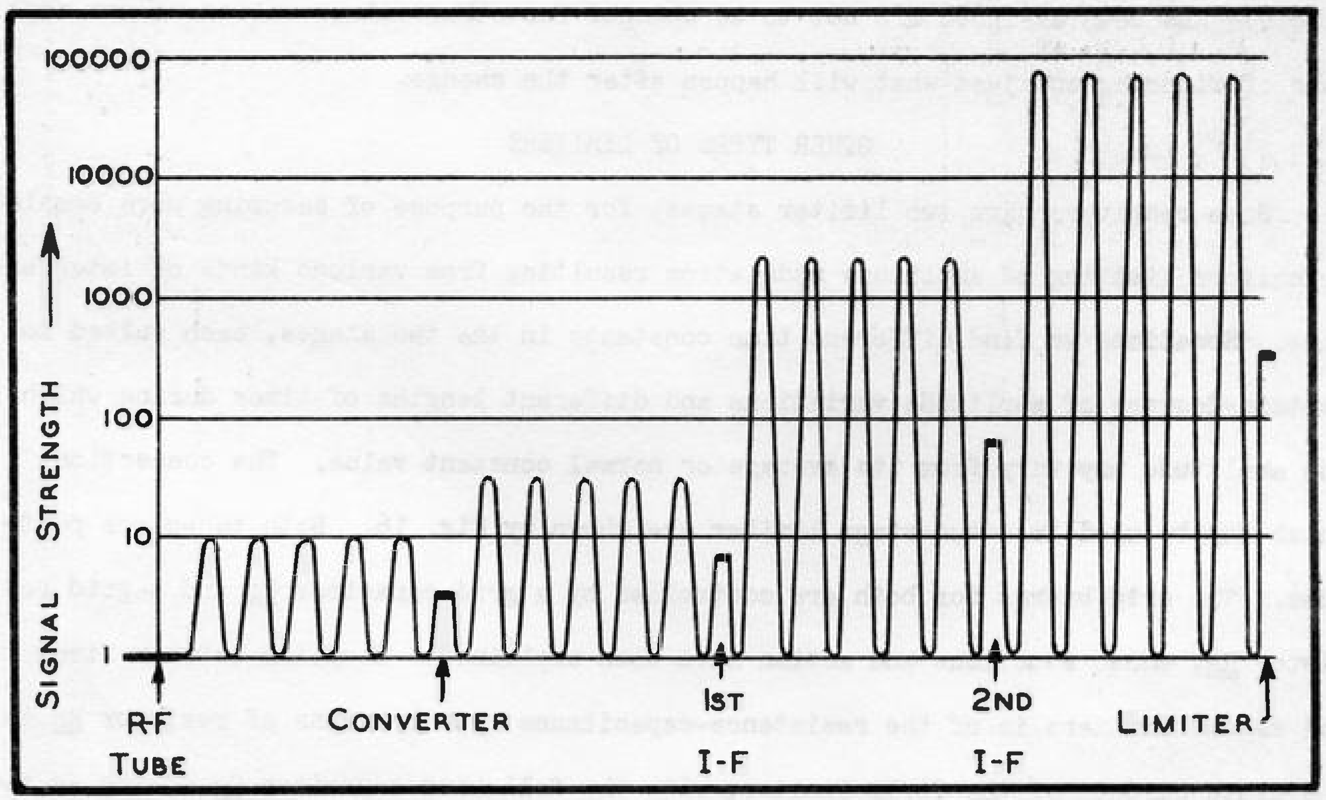


FIG. 17. How the constant-amplitude signal may increase in strength or amplitude in passing through the receiver.

When no one stage is designed especially for amplitude limiting, it is possible to have a certain amount of amplitude limiting in one or more of the i-f amplifier stages. In this connection, we must keep in mind that amplification of any nature means an increase of amplitude from stage to stage. Under ideal conditions, we commence at the antenna with a frequency-modulated signal of constant amplitude. What we wish to do is increase the amplitude from stage to stage while retaining the frequency modulation without introducing variations of amplitude.

We wish to have the strength of the signal increase from stage to stage somewhat as shown by Fig. 17. The amplitude in any one stage and coupling remains of constant value, having no brief fluctuations of amplitude, but the level of the constant amplitude or uniform amplitude is raised as the signal goes from the r-f tube to the limiter input. Each stage might be designed to limit its own output to some suitable maximum voltage, just as the limiter stage in some of our examples has been designed for an output which cannot rise much above 10 volts.

INTERFERENCE CAUSING FREQUENCY VARIATION

We have discussed, at some length, the elimination by the limiter of interference which causes variations of amplitude. But it is possible also to have types of interference which causes variations of frequency. Variations of frequency will pass through the limiter, because the limiter is designed especially to pass just such variations while cutting off variations of amplitude. Frequency variations which represent interference, or noise, then will reach the discriminator and be changed into amplitude modulation at an audio frequency and the noise will be reproduced by the loud speaker. Frequency-varying interference might result from the beating together of two f-m waves having different carrier frequencies or center frequencies. The resulting best frequency, equal to the difference between the two wave frequencies, may be within the range of audible frequencies.

Were we to go through a rather involved mathematical analysis, it would be shown that the fraction of the loud speaker sound output which consists of the interference noise is the same as the fraction found upon dividing the highest reproduced audio frequency by the maximum frequency deviation. For example, with 15,000 cycles or 15 kilocycles as the highest audio frequency which can be amplified and reproduced by the audio amplifying system, and with 75 kilocycles as the maximum deviation for loudest signals, the fraction will be 15/75 or 1/5. Then the interfering noise can be only 1/5 as strong as the desired signal.

Of course, you have recognized that the maximum audio frequency and the maximum deviation were used earlier to determine the "deviation ratio". The deviation ratio is equal to the maximum deviation divided by the maximum audio frequency. With maximum audio frequency of 15 kc and maximum deviation of 75 kc, the deviation ratio is 75/15 or is 5. Thus we find that the greater the deviation ratio, the less will be the strength of interfering sounds in comparison with the sounds of the desired signal.

It is desirable to reproduce high audio frequencies, thus securing good fidelity of reproduction. If we are going to have high audio frequencies, and wish to have a high deviation ratio to reduce interference, we must have a proportionately high maximum deviation. To have high deviation means that the r-f signal frequency will swing widely each way from the center frequency, causing the signal to occupy a wide range of frequencies. Now we know why f-m transmission and reception are carried on in frequency bands where there is room for wide frequency channels; it is so that interference due to frequency variations may be reduced in strength or effect.

EXAMINATION QUESTIONS ON FOLLOWING PAGE