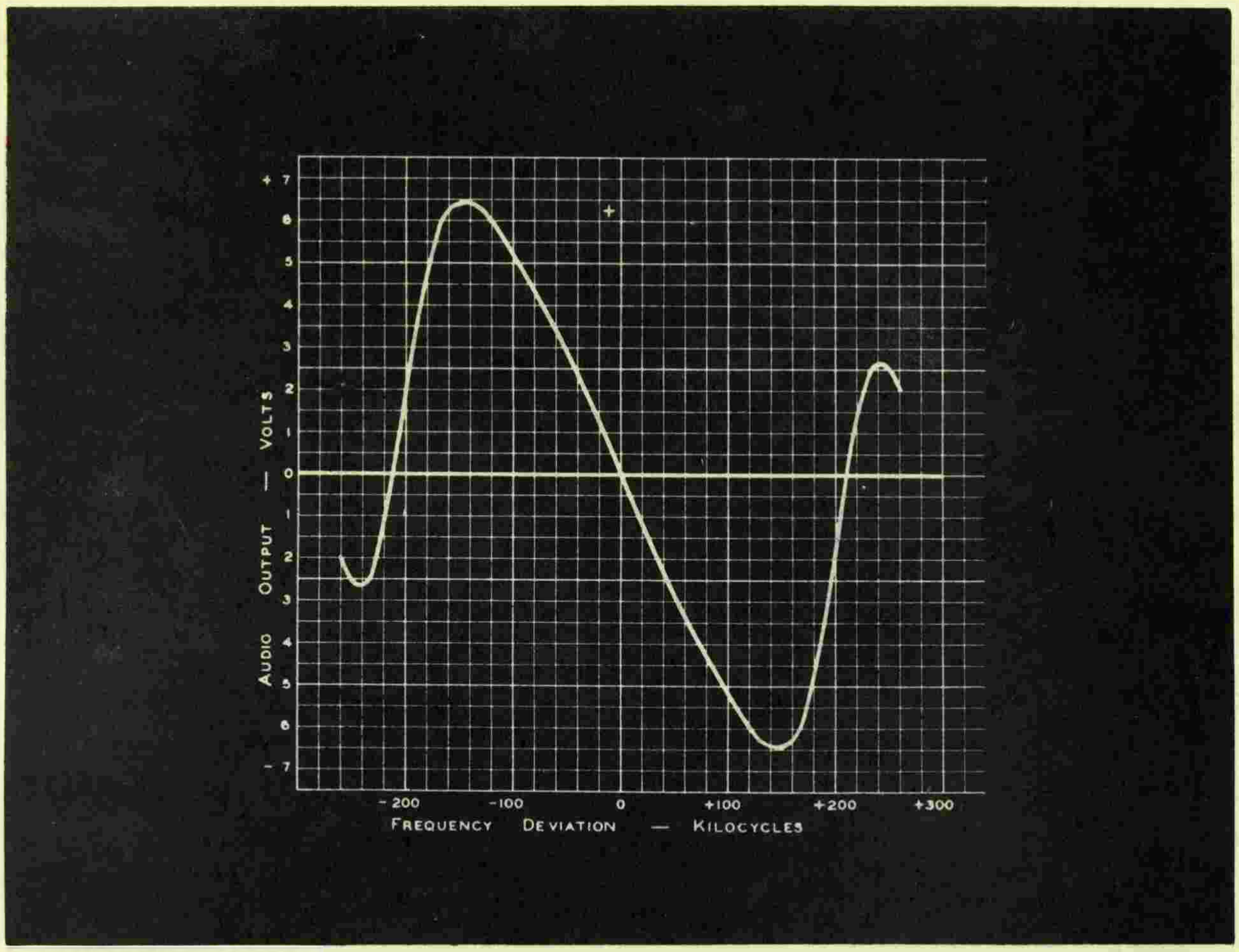

LESSON
75 RA

ALIGNMENT OF F M RECEIVERS

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In testing and adjusting f-m receivers, we encounter some conditions which are quite different from those found during similar work on amplitude-modulation receivers. Therefore, before proceeding with instructions for alignment of the various stages of the f-m receiver, we shall examine the performance of the several stages with a view to discovering just how their performance affects our work.

The method of aligning superheterodyne receivers designed for handling a-m signals is familiar to all radio technicians. It is usual practice to employ a signal generator or test oscillator capable of delivering amplitude-modulated high-frequency signals, to feed these signals into various points of the receiver, and

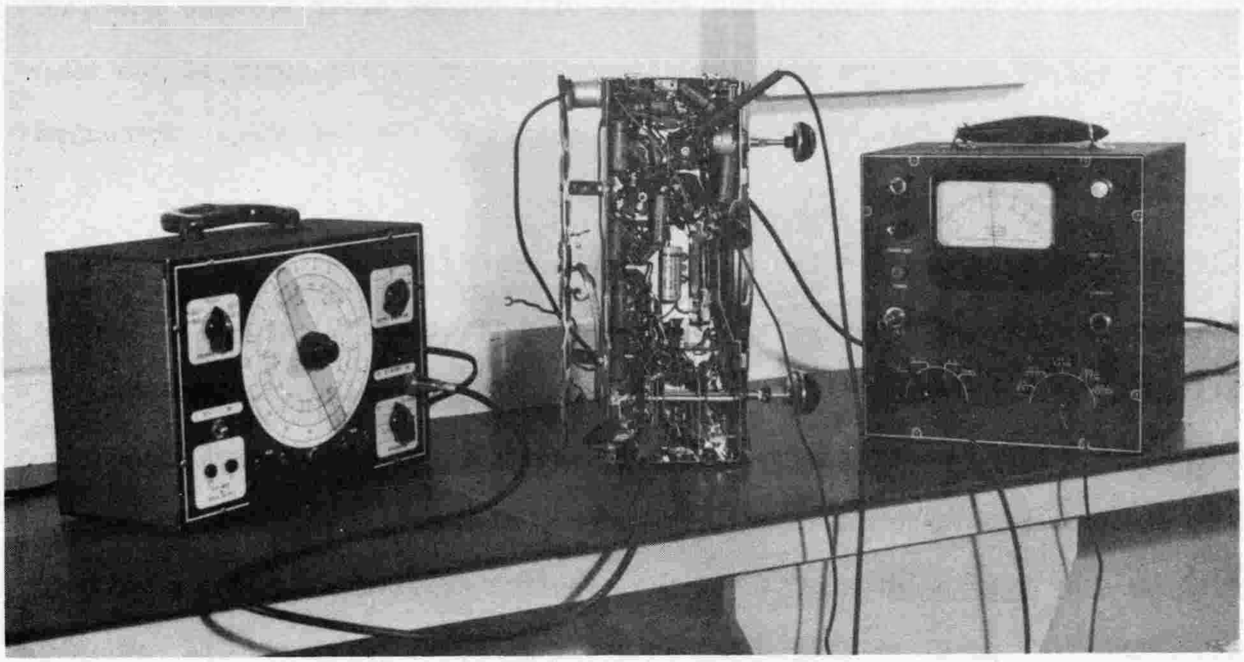


FIG. 1. The f-m receiver may be aligned by using an ordinary signal generator and an electronic voltmeter, as shown, or else with a high-resistance d-c voltmeter.

to observe the output by means of an alternating-current output meter connected to the voice coil circuit of the loud speaker.

The intermediate-frequency transformers of the a-m receiver are adjusted while applying the test signal to either the control grids of i-f amplifier tubes or to the signal grid of the converter or mixer tube. For this part of the work, the test signal is at the intermediate frequency, and is amplitude modulated with an audio frequency to which the output meter will respond. For alignment of the antenna circuits, the r-f amplifier, and the oscillator tuned circuits, the test signal is used at two or more radio frequencies in the standard broadcast or short-wave bands, and is modulated with an audio frequency as usual.

When aligning a frequency-modulation receiver, we cannot use an amplitude modulated signal, because the amplitude modulation would be removed in the limiter stage and there would be no indications on an output meter connected to the loud speaker circuit.

However, for alignment of the antenna, r-f amplifier, oscillator, and i-f tuned circuits of the f-m receiver, we do not have to have a frequency-modulated signal; we may use a constant-frequency signal having no modulation of any kind. The reason that it is possible to use an unmodulated signal will become clear when we consider what happens in all of the stages from the antenna through to the input of the limiter, or, what is the same thing, through to the output of the i-f stage **preceding** the limiter.

In all of these parts of the f-m receiver, the amplification is of amplitude. At the antenna, we have a frequency-modulated (varying frequency) signal of constant amplitude. The amplitude is exceedingly weak. The variations of frequency represent the audio signal being transmitted, consequently we wish to preserve these frequency variations without change. But in order that the limiter may do its work of smoothing out any <u>changes</u> of amplitude, the constant amplitude must be amplified many times. Then the constant amplitude, which is measured in microvolts at the antenna, will be brought up to several volts at the input to the limiter.

As the trimmer or alignment adjustments in all tuned circuits preceding the limiter are varied to bring these circuits more and more nearly into resonance at their correct operating frequencies, the amplitude or high-frequency voltage at the limiter input will rise higher and higher. When all of the adjustments are correct we shall have maximum amplitude or a-c voltage between the limiter grid and ground. If we are able to observe this limiter input voltage, or its effects, while making the adjustments on preceding circuits, it will be just as easy to perform this portion of the work on the f-m receiver as it would be to align the corresponding stages of any superheterodyne receiver.

There are several possible ways of measuring the input to the limiter. The input appears between the limiter control grid connection, point A in Fig. 2, and the

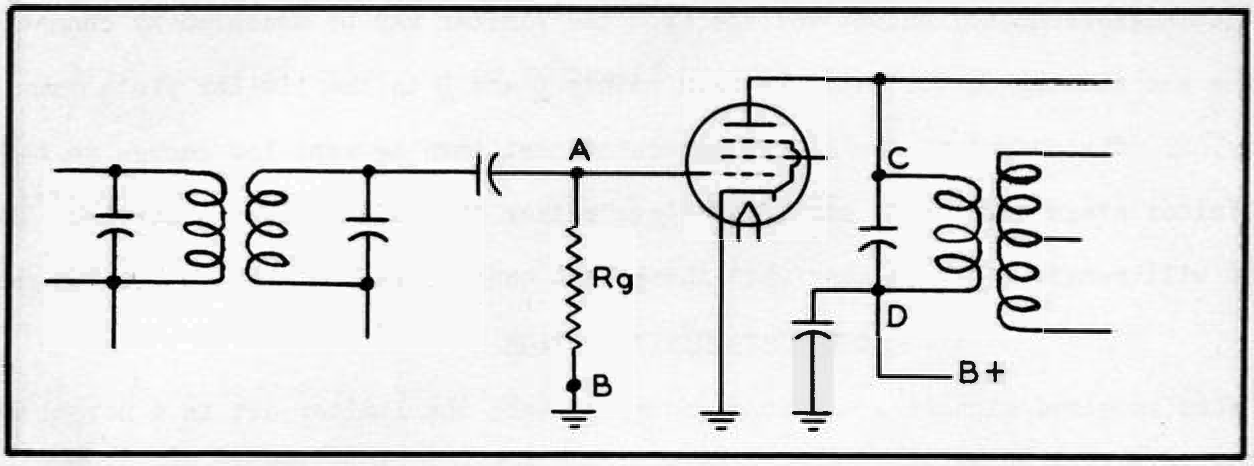


FIG. 2. Points at which the output voltmeter may be connected.

cathode or ground, point B. The easiest way is to connect a high-resistance voltmeter between these two points. The voltmeter may be a direct-current type, of the moving coil permanent magnet style. Such a meter will indicate the voltage drop across the grid resistor Rg. This drop is the bias voltage applied to the limiter tube. As we learned in the lesson dealing with limiter action, this bias voltage increases as the strength of the input signal increases. Then it is necessary only to make the alignment adjustments to obtain maximum voltage between points A and B for any given signal applied from the test oscillator.

A d-c voltmeter used across the limiter grid resistor and acting as an "output meter" should have the highest possible resistance, preferably 20,000 ohms per volt or even more. A 10-volt full-scale meter range will be satisfactory, with the signal generator output kept low enough so that the meter pointer does not go off scale as adjustments proceed.

A direct-current electronic voltmeter, or vacuum tube voltmeter, may be used between points A and B. Because of the very high resistance of such a voltmeter it will have less effect on operation of the receiver than will any moving-coil meter.

If the limiter has no grid resistor across which appear easily measured direct potentials, the high-frequency input voltage may be measured between control grid and cathode of the limiter, or between control grid and ground. Because this input voltage is at the intermediate frequency, it may be measured only with an alternating current electronic voltmeter capable of making measurements at such frequencies.

The high-frequency output voltage from the limiter may be measured by connecting the a-c electronic voltmeter between points C and D in the limiter plate circuit of Fig. 2. The output of the signal generator must then be kept low enough so that the limiter stage acts as an amplifier stage rather than a limiter; otherwise, the output will remain constant even when there is a change of input to the limiter grid.

THE DISCRIMINATOR STAGE

When received signals are strong enough to make the limiter act in a normal way, we have, at the output of the limiter and at the input to the discriminator, a sig-

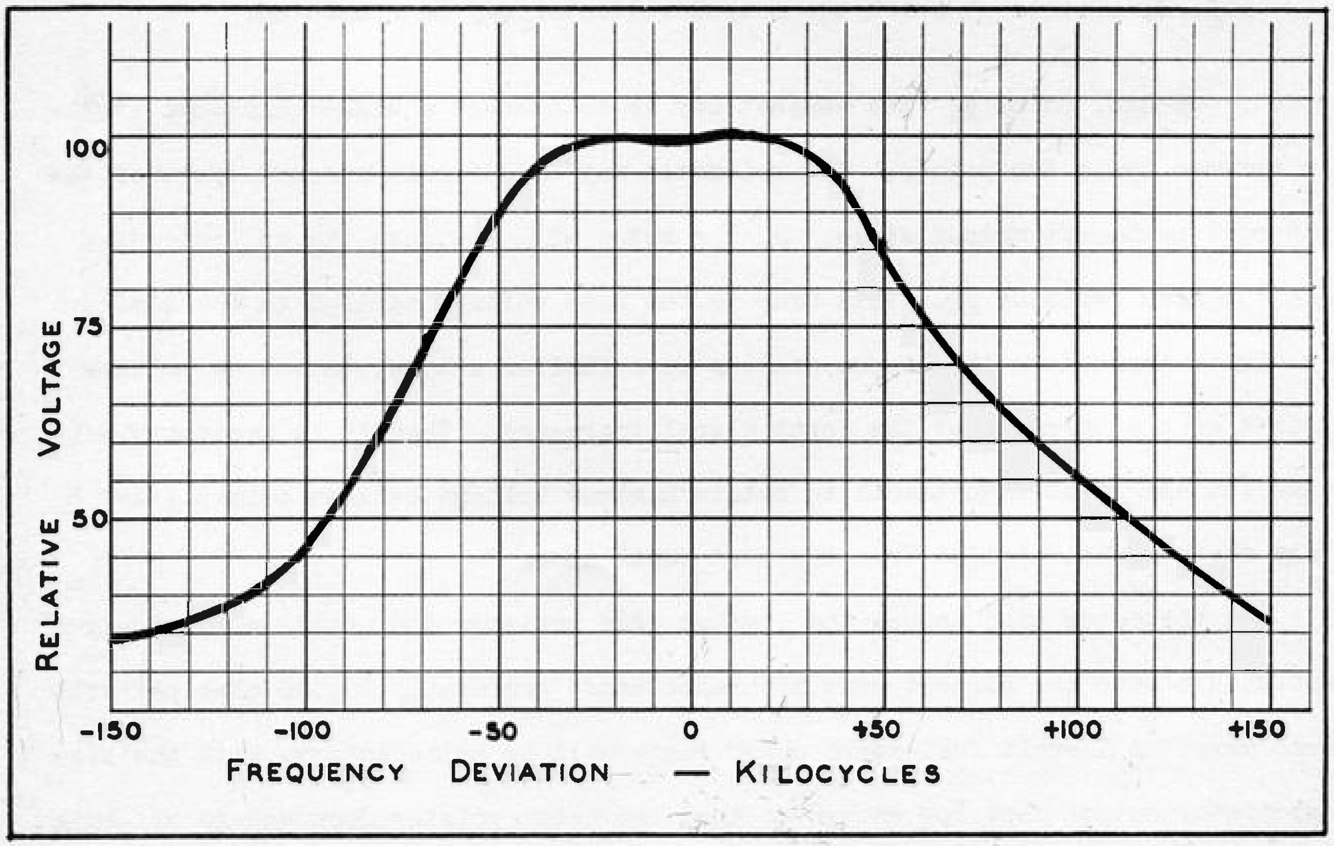


FIG. 3. Resonance curve of a discriminator transformer with no connection to the secondary center tap.

nal without variations of amplitude in any great degree no matter how much amplitude change there may be ahead of the limiter.

The discriminator transformer, between limiter and discriminator tubes, has a tuned primary and a tuned secondary winding. If the connection from the limiter plate circuit to the center tap of the secondary of the discriminator transformer is removed, the transformer acts much like any other closely coupled double-tuned unit. Fig. 3 shows a resonance curve made from a typical discriminator transformer with the secondary center tap open. The transformer provides broad tuning, with a slight dip between the resonance peaks which are below and above the center frequency, to which both the primary and secondary are separately tuned.

When we introduce into the secondary circuit, which includes the diode rectifiers, the additional voltage taken from the primary side, there is a decidedly different behavior of the secondary potential with variations of frequency. It is

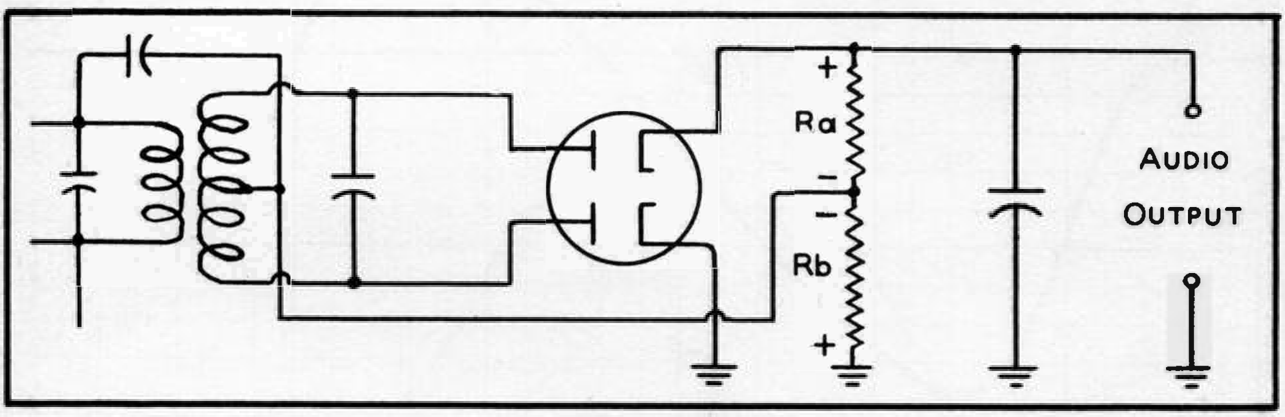


FIG. 4. A circuit showing the principle of many discriminators.

this secondary potential which is applied to the diode rectifiers, as explained in the lesson dealing with discriminators. The result is direct potentials, and accompanying currents, in the load resistors Ra and Rb of Fig. 4, with the polarities opposing each other as indicated by the positive and negative signs.

As the discriminator input frequency is changed from the center frequency to others which are either lower or higher, there are changes in the potentials across the two load resistors. Typical values of these potentials over a wide range of frequencies are shown by the two curves of Fig. 5. The upper curve shows the potential across resistor Ra, and the lower curve shows the potential across resistor

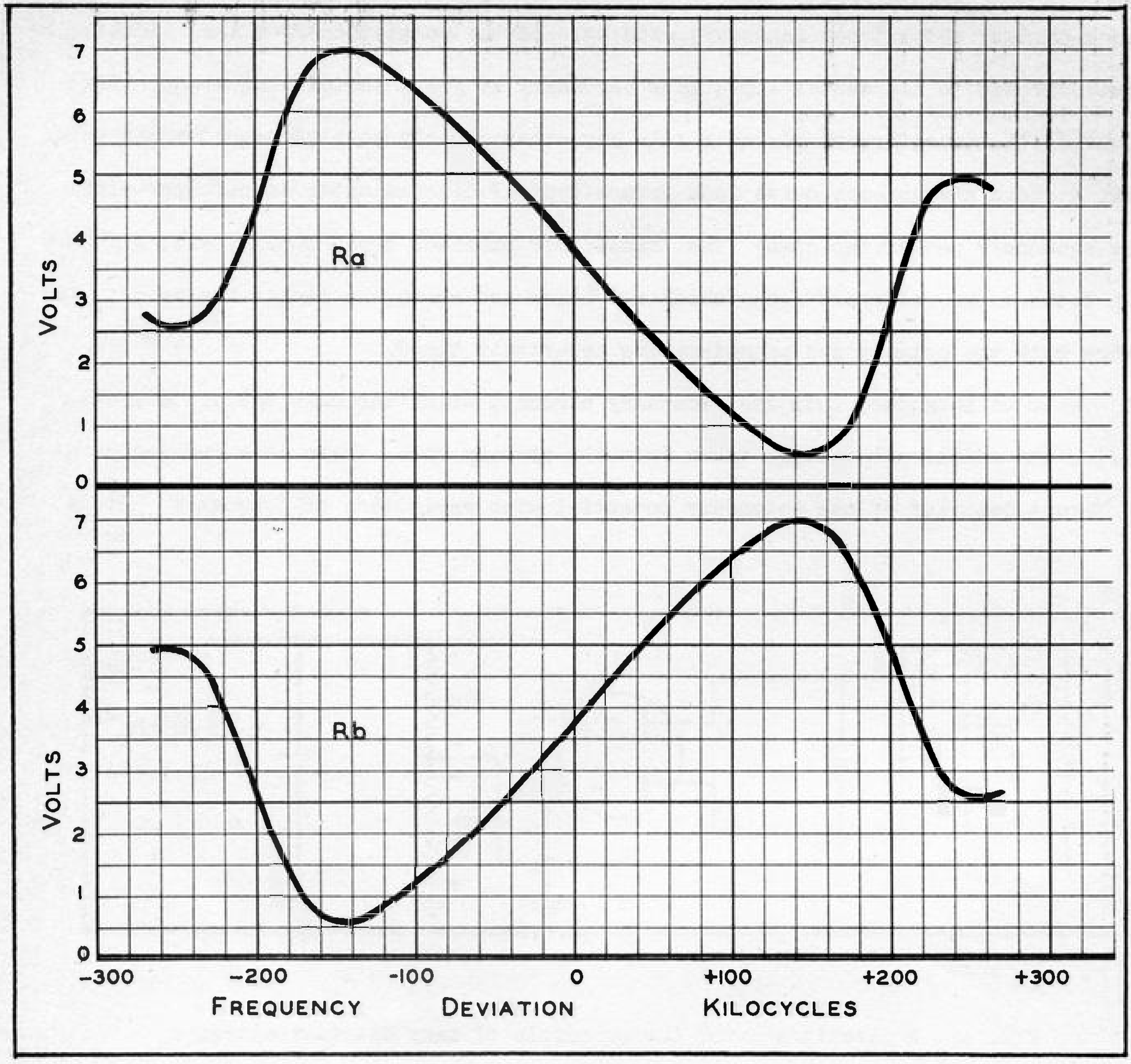


FIG. 5. Variations of voltage across the discriminator load resistors when there are changes of frequency.

Rb. At a deviation of about 140 kilocycles below the center frequency, the potential across Ra has a maximum value of 7.0 volts, while the potential across Rb has a minimum value of 0.5 volt.

As the frequency is increased, the potential across Ra becomes less and less while that across Rb becomes more and more. Finally, at a deviation of about 140 kilocycles above the center frequency, the potential across Ra has fallen to a minimum of 0.5 volt and that across Rb has risen to a maximum of 7.0 volts. Note especially that at the center frequency, or the frequency of zero deviation, the potentials across Ra and Rb are equal. For the time being, we are not concerned with the changes of potential that occur at deviations below and above 140 kilocycles.

The curves of Fig. 5 are "idealized" to some extent, in that they are drawn to show more uniform changes of potential with variation of frequency than you are likely to find should you have occasion to make actual measurements as a matter of experiment. However, there may be considerable non-uniformity in the curves without any great effect on the performance of the receiver.

The audio output voltage from the discriminator is the combined voltage across resistors Ra and Rb of Fig. 4. From the upper end of resistor Ra, there will be a connection through the de-emphasis filter system to the volume control and thence to the control grid of the first audio amplifier tube. The cathode of the audio amplifier will be connected more or less directly to ground, and so is the bottom of resistor Rb connected to ground. Therefore, whatever voltage differences appear between the top of Ra and ground will be applied to the audio amplifier.

The voltages between the top of Ra and ground, or the bottom of Rb, will result from the combined voltages in these two resistors. The voltages across the separate resistors are shown by Fig. 5. Now let's see how these voltages combine. Take, for instance, a deviation of 100 kilocycles negative. The voltage across Ra in Fig. 5 is 6.4 volts, and across Rb is 1.2 volts. We have 6.4 volts trying to make the top of Ra positive, and we have 1.2 volts trying to make the bottom of Rb positive. The 6.4 volts in Ra is opposed by the 1.2 volts in Rb, and the net effect is to make the top of Ra more positive than the bottom of Rb by the difference between the voltages, which is 5.2 volts. So far as the over-all voltage is concerned, the top of Ra is positive by 5.2 volts, and the bottom of Rb, or ground, is negative.

If we go to a deviation of 100 kilocycles positive, the values of the voltages in Ra and Rb are reversed; there is a drop of 6.4 volts across Rb and of 1.2 volts

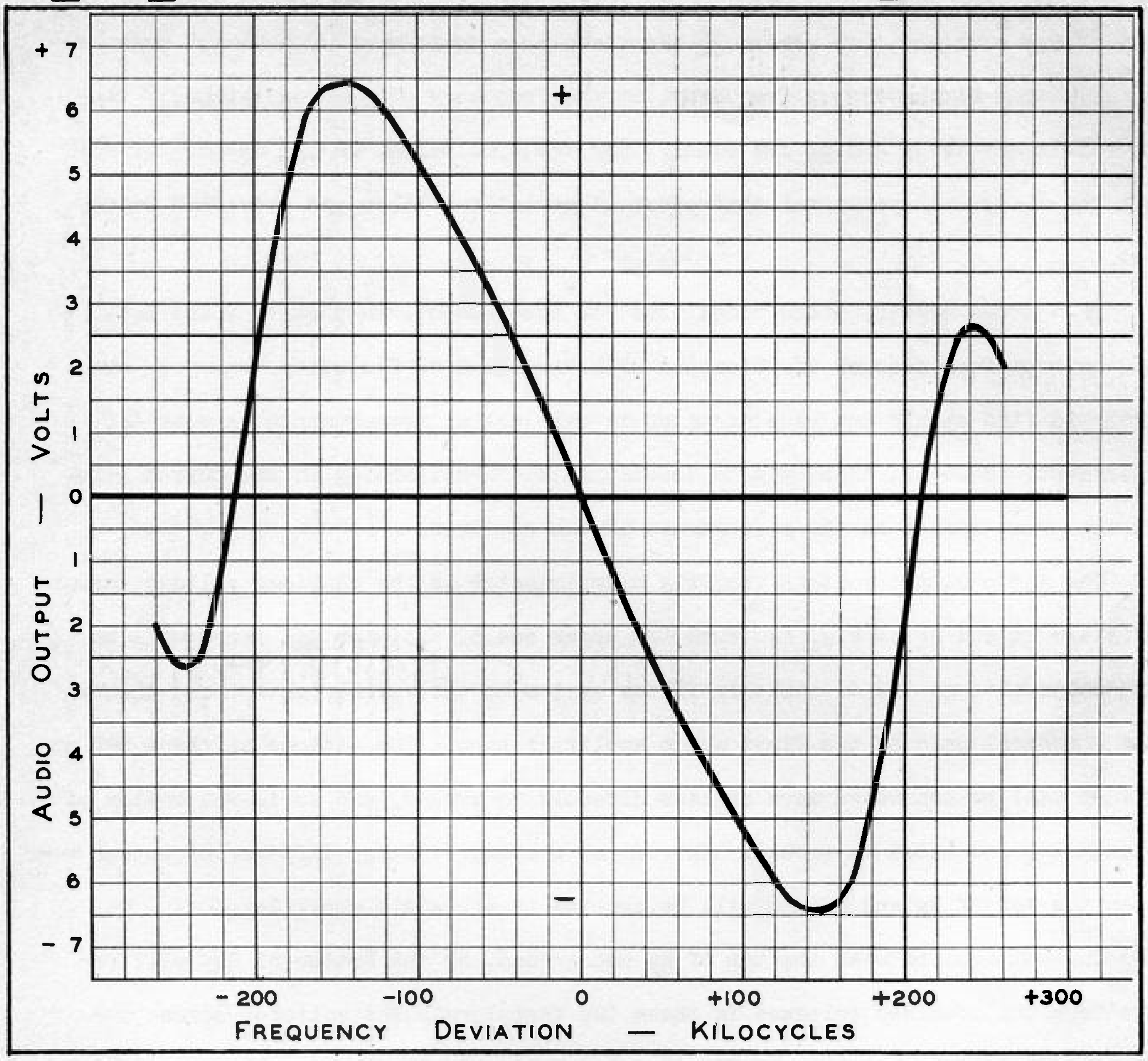


FIG. 6. A discriminator characteristic.

across Ra. Again the difference is 5.2 volts, but now the bottom of Rb is more positive than the top of Ra. In effect, the bottom of Rb is 5.2 volts positive, and the top of Ra is negative.

At zero deviation, which is the center frequency or the intermediate frequency, there is 3.75 volts across Ra and 3.75 volts across Rb. The two voltages balance each other. The top of Ra is just as positive as is the bottom of Rb, and the voltage difference from the top to the bottom of the load resistors is zero.

In similar manner, we might figure out the net audio output voltages for all other frequency deviations. Doing so, and plotting the results on a curve, would give Fig. 6. Here, for a negative deviation of 100 kc. the audio voltage is 5.2 volts positive, for a positive deviation of 100 kc., it is 5.2 volts negative, and at zero deviation, the output voltage is zero; which are the voltages we computed from the curves of Fig. 5. The curve of Fig. 6 is called a discriminator characteristic; it shows how the discriminator performs with deviations of frequency.

Assuming that the maximum deviations will be 75 kc below and above the center frequency, we are interested only in the portion of the discriminator characteristic extending from -75 kc to+75 kc. This much of the curve is nearly straight. Then any deviations, which do not exceed 75 kc, will cause audio output voltages almost exactly proportional to the extent of the deviation. Furthermore, for any given degree of deviation above and below the center frequency, the resulting positive and negative peaks of audio voltage will be of equal amplitudes. The performance of the discriminator must be such that the approximately straight portion of the characteristic extends at least as far as the maximum deviations above and below the center frequency.

The amplitude of the input signal to the discriminator may be increased or decreased. The input still will be of constant amplitude, but this constant value may be relatively great or small. Fig. 7 shows, in a general way, what happens to the discriminator characteristic when the input amplitude is varied. The greater the input amplitude, the greater will be the audio output voltage at the peaks on either side of the center frequency, the farther apart the peaks will be, and the longer will be the approximately straight part of the characteristic on either side of the center frequency. The less the input amplitude, the smaller will be the output voltage; the closer together the peaks will be; and the shorter will be the straight portion of the characteristic.

This means that if the limiter or other stages preceding the discriminator are operated with greater amplitude or greater gain, there will be an increase of audio

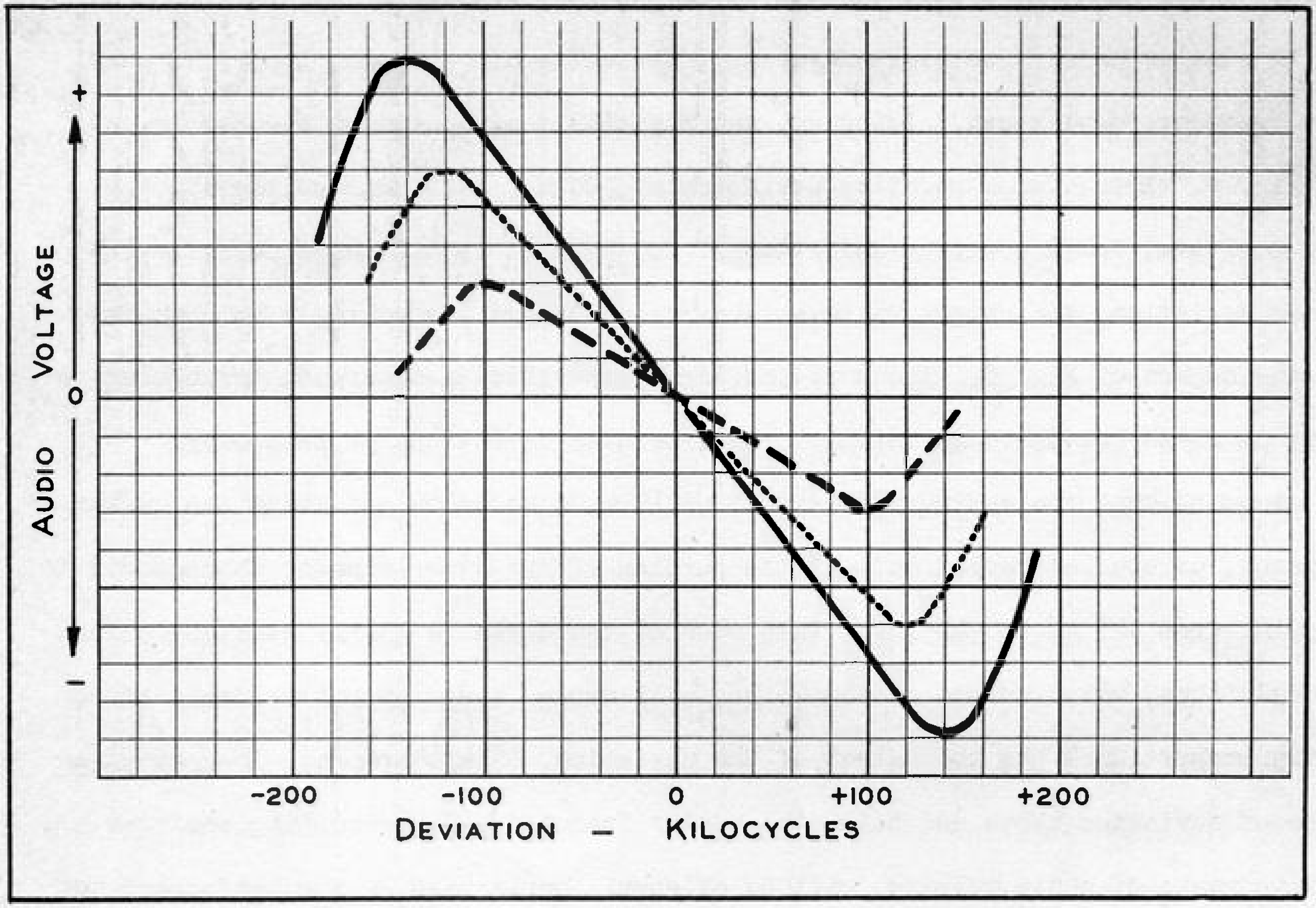


FIG. 7. How the discriminator characteristic varies with changes of input amplitude.

output voltage from the discriminator. Less input amplitude will result in lower audio output voltage.

When adjusting or aligning the discriminator transformer, which is between the limiter and discriminator tubes, there are two objects to be accomplished. First, we wish to adjust the primary circuit so that there is maximum transfer of energy into the secondary at and near the center frequency. That is, we want the performance shown by Fig. 3, with the resonance curve centered at the center frequency or the intermediate frequency.

The second object is to obtain zero audio output at the center frequency, as shown by Fig. 6. Then, when no signal is being transmitted and when there is no deviation from the center frequency, the receiver will be silent. This object is accomplished by adjustment or alignment of the secondary circuit of the transformer.

ALIGNMENT PROCEDURE

In the method of alignment first to be explained, we shall use an ordinary signal generator or test oscillator capable of producing a radio-frequency signal which is not modulated in either amplitude or frequency. Most test generators have provision for turning off the audio modulation.

The generator must be able to produce the intermediate frequency, which will be between eight and fifteen megacycles, also the carrier frequency, which will be between 88 and 108 megacycles. Only the more recent types of generators produce such frequencies directly; meaning that only such types produce fundamental frequencies in these high ranges. However, the types of oscillator circuits used in nearly all test generators produce not only the fundamental frequency to which the generator is tuned, but also quite a few harmonic frequencies. A harmonic frequency is an even or odd multiple of the fundamental frequency. For example, with a generator tuned to 5 megacycles (the fundamental), there will be produced also frequencies of 10 mc (second harmonic), of 15 mc (third harmonic), of 20 mc (fourth harmonic), and so on.

The strength of the harmonics always is less than that of the fundamental. In general, the higher the harmonic, the weaker it is in comparison with the fundamental, but service types of signal generators are quite likely to deliver signals of useful strength at harmonics up to the fifth or sixth. If a sixth harmonic is to be used as an f-m carrier frequency of 98 mc (in the center of the band), the generator would be tuned to 1/6 of 98 mc, or to 16.33 mc. Probably it would be easier to tune to exactly 16 mc and make the adjustments on the sixth harmonic of 96 mc rather than at 98 mc. For adjustments at an intermediate frequency such as 10.7 mc, we might use a second harmonic with the generator set at 5.35 mc, a fifth harmonic with the generator set at 2.14 mc (2,140 kc), and so on.

A difficulty in employing harmonic frequencies, in addition to their weakness, comes in making accurate settings. An error in the fundamental setting is multiplied by the number of the harmonic. For instance, an error of 1/2 mc in setting the fundamental becomes an error of 3 mc on the sixth harmonic.

Generator connections to the receiver circuits are shown by Fig. 8. The "low side" of the shielded cable from the generator output is connected to the metal chassis G of the receiver. If the receiver is of the ac-dc type without a rectifier transformer, and with one side of the power line grounded to the chassis, it is es-

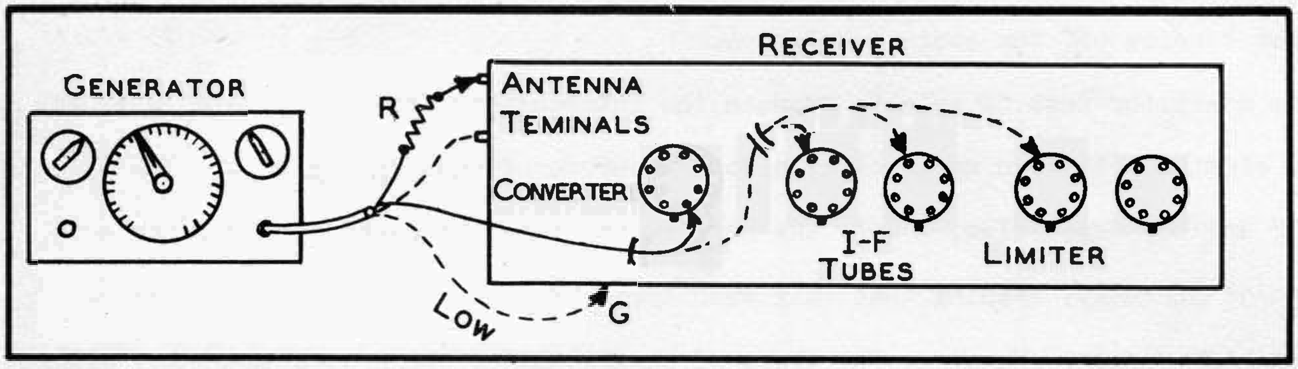


FIG. 8. Connections between signal generator and receiver.

sential to connect a paper dielectric capacitor in series with the low side lead. Otherwise,the "hot chassis" may result in a burned out attenuator in the generator. This capacitor should have capacitance of 0.05 mfd or more, and the working voltage should be 200 or more.

For alignment of the antenna,r-f, and oscillator circuits,the high side of the generator output is connected to one of the antenna terminals with a "dummy antenna" consisting of a 100 to 500-ohm carbon resistor R in series. For these alignments, the low side of the generator may be connected to the second antenna terminal rather than to the chassis in case neither side of the antenna coil in the receiver is connected directly or through a capacitor to the chassis.

For alignment of the discriminator, the high side of the generator may be connected to the control grid of the limiter tube. For alignment of the i-f transformers, the high side of the generator may be connected to the control grid of the tube preceding the transformer being aligned. This means that,for alignment of the first i-f transformer, the generator's high side is connected to the signal grid of the converter or mixer. For all of these alignment connections, from discriminator back to converter, the dummy antenna connected in series with the high-side lead is to be a mica dielectric capacitor of capacitance rating 0.0005 mfd, or preferably larger. A paper capacitor may be used if it is of a non-inductive type, which few of them are.

If the receiver is not badly out of alignment, the high side of the generator may be connected to the signal grid of the converter for adjustment of the discriminator transformer and of all the i-f transformers, instead of connecting it to the grid of the tube preceding the transformer being adjusted. The reason for connecting to each tube, successively, is so that the signal will have to go through only that one tube and then to the primary of the transformer being worked on. This avoids trying to get the signal through preceding stages which may be so out of adjustment that the signal can hardly get through them.

The alignment adjustments sometimes are small trimmer capacitors connected across the various windings, or they may be movable powdered iron cores (slugs). Or capacitors may be used at some places and adjustable cores at others. Whether it is capacitance or inductance that is adjusted makes no difference in the methods of procedure.

The order in which the adjustments are made usually is from the discriminator transformer back through the receiver until reaching the antenna tuning circuits. A commonly followed order is shown by Fig. 9, with the steps numbered from 1 to 11. The first adjustment is of the discriminator transformer primary, the second of the secondary in this transformer. Then comes the secondaries and primaries of the i-f transformers, the oscillator tuned coil,the r-f coupler tuned coil, and the antenna coupler tuned coil.

If the receiver is designed for standard broadcast as well as f-m reception, the standard broadcast alignment is made before the f-m alignment. If there are also short-wave bands, these adjustments are made following the standard broadcast, and before the f-m alignment.

During the adjustments which come ahead of the f-m alignment, there will be corrected any faults in the audio amplifying system and loud speaker. Most signal

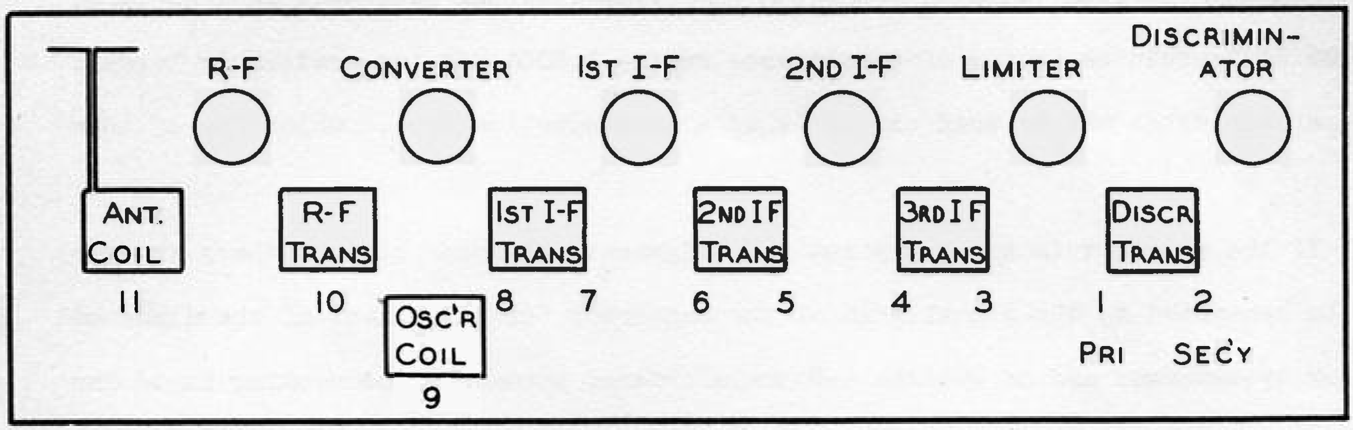


FIG. 9. The usual order in which alignment adjustments are made.

generators have a separate output at a 400-cycle audio frequency which may be connected to the ungrounded side of the volume control or to the control grid of the first audio amplifier during checks on the audio system.

The f-m antenna should be disconnected from the receiver before making adjustments with the generator signals. If there is an antenna connection through a capacitor from the power line, this connection should be taken off the antenna winding of the antenna coupler. The f-m tuning dial should be turned to a point where there is no likelihood of picking up any signals from transmitting stations, and left there except when tuned to certain frequencies during alignment of the antenna, r-f, and oscillator stages.

DISCRIMINATOR TRANSFORMER ALIGNMENT

For alignment of the primary of the discriminator transformer, connect a high-resistance d-c voltmeter or else an electronic voltmeter across either one of the discriminator load resistors. These are the resistors identified as Ra and Rb in our diagrams. Usually, it is better to connect the meter between ground and the connection between Ra and Rb than to make the connection from the discriminator cathode to the junction between the resistors; there will be less noise from the loud speaker. Connect the generator between the chassis ground and the control grid of the limiter, as explained in connection with Fig. 8, or, if the receiver is not far out of line, connect the generator to the converter signal grid. Set the generator at the intermediate frequency used by the receiver.

Adjust the primary trimmer to obtain maximum output, as indicated on the meter. Keep the generator output as low as will give a satisfactory meter reading. Because of the broad tuning of this transformer, it may be difficult to identify the adjustment position for maximum output. To make a check, connect the meter across both load resistors, from discriminator cathode to ground, detune the generator to 50 or

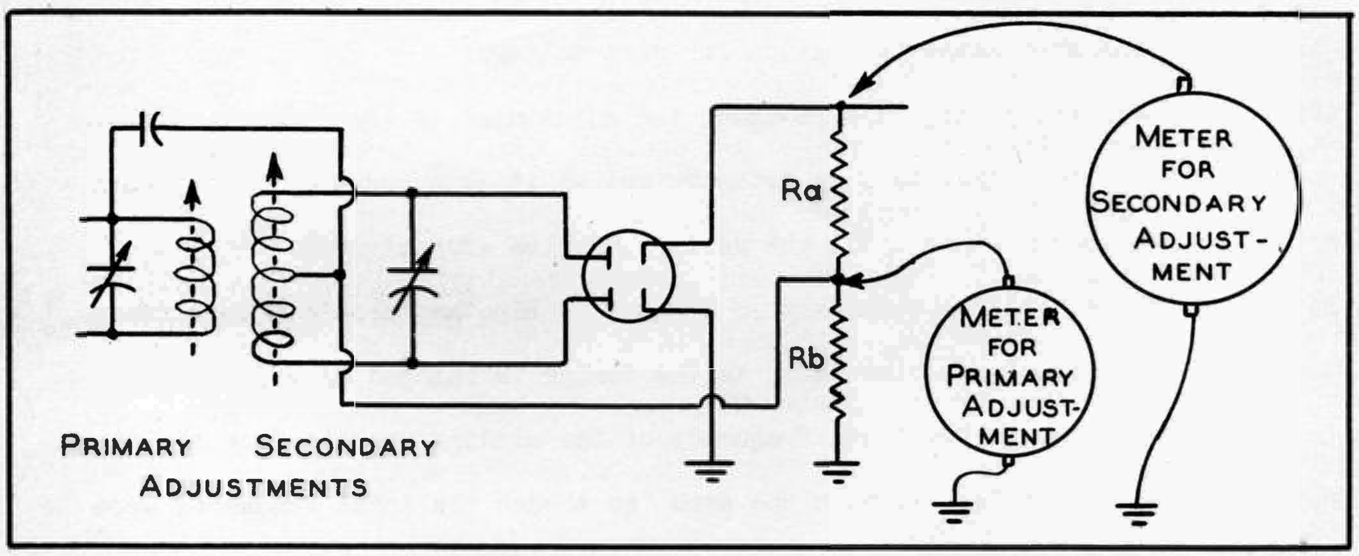


FIG. 10. Meter connections during alignment of the discriminator transformer.

more kilocycles below the center frequency and note the meter readying. Then tune the generator to the same number of kilocycles above the center frequency, and note the meter readying. The two readings should be nearly alike, as may be seen from Fig. 6. If there is much difference, readjust the primary trimmer to make them more nearly equal. Fig. 10 shows meter connections made during adjustments.

For alignment of the secondary of the discriminator transformer, the generator is left connected, as during primary adjustment, and is set at the intermediate or center frequency. The voltmeter is connected across the entire discriminator load, from one of the cathodes to ground, from the top of Ra to the bottom of Rb. The secondary trimmer now is adjusted to obtain zero reading on the meter.

For this secondary adjustment, it is convenient to have a zero-center meter, because during movement of the adjuster, the meter pointer will go from one side of zero to the other side, passing through zero on the way. If the meter is not of the zero center type, use the zero adjusting screw of the moving coil center, or the zero adjusting knob of the electronic voltmeter, to bring the pointer up to some even number on the scale, such as 5.0 volts. Then this point on the scale becomes the temporary zero, and the adjustment is made to bring the reading to this point on the scale. Make the output from the signal generator great enough to get a positive and easily readable meter indication for zero voltage.

After the secondary is adjusted, re-check the adjustment of the primary. Either adjustment may upset the other to some extent, and so it is necessary to work back and forth from one to the other until the desired results are obtained.

It is possible to get the secondary so far out of line as to obtain zero readings with wholly incorrect adjustments. As the tuning is changed by adjusting the trimmer capacitor or core, the tuned frequency of the winding departs from the center frequency, and the effect is much the same as though the input frequency were being varied. We have deviation of tuning rather than of frequency, but the effect is somewhat equivalent to that shown by Fig. 6. If the trimmer adjustment is moved far enough in either wrong direction, the meter reading will change from zero to maximum and then fall back to a zero which is incorrect. When you have the adjustment for the zero reading corresponding to the center frequency, only a slight change of adjustment either way will cause a large change of voltage away from zero. On either of the incorrect zero readings, there will be only small variations of voltage as the adjuster is moved, and there will be much more variation from zero in one direction than in the other. An incorrect zero setting would result in extreme distortion of the audio output.

Whether or not the discriminator characteristic is symmetrical on both sides of zero output voltage, and with equal deviations either way from the center, may be checked by measurements with the voltmeter across the entire discriminator load, as for secondary adjustment in Fig. 10. With equal frequency deviations either way from the center, as brought about by tuning the signal generator above and below the intermediate frequency, there should theoretically be equal voltages. This is apparent from Fig. 6. In actual practice, there may be found differences of as much as 20 or more percent without any noticeable effect on the quality of the audio output, at least so far as an untrained ear can detect any distortion.

I-F TRANSFORMER ALIGNMENT

The essential parts of an i-f amplifying system are shown by Fig. 11. As previously explained, the discriminator transformer A may be aligned with the signal generator connected between the limiter control grid 1 and the chassis ground. For alignment of the third i-f transformer B, the generator may be connected between the control grid of the second i-f tube 2 and ground. For alignment of the second i-f transformer C, the generator may be connected between the control grid of the first i-f tube 3 and ground. For alignment of the first i-f transformer D, the generator may be connected between the signal grid 4 of the converter or mixer tube and ground. With this method, the generator signal goes through only the one tube which is ahead of the transformer being aligned, and the adjustment is independent of the conditions in other transformers.

When only slight re-alignment is required, it is common practice to connect the generator between the converter signal grid 4 and ground while adjusting all the i-f transformers. Then, while aligning transformer B, the signal comes through and is amplified in the converter and in both i-f tubes. While aligning transformer C, the signal is amplified by the converter and the first i-f tube, and while aligning transformer D, the signal is amplified only by the converter tube. With a constant generator output,we would then have the strongest signal in transformer B, a weaker one in C and the weakest one in D.

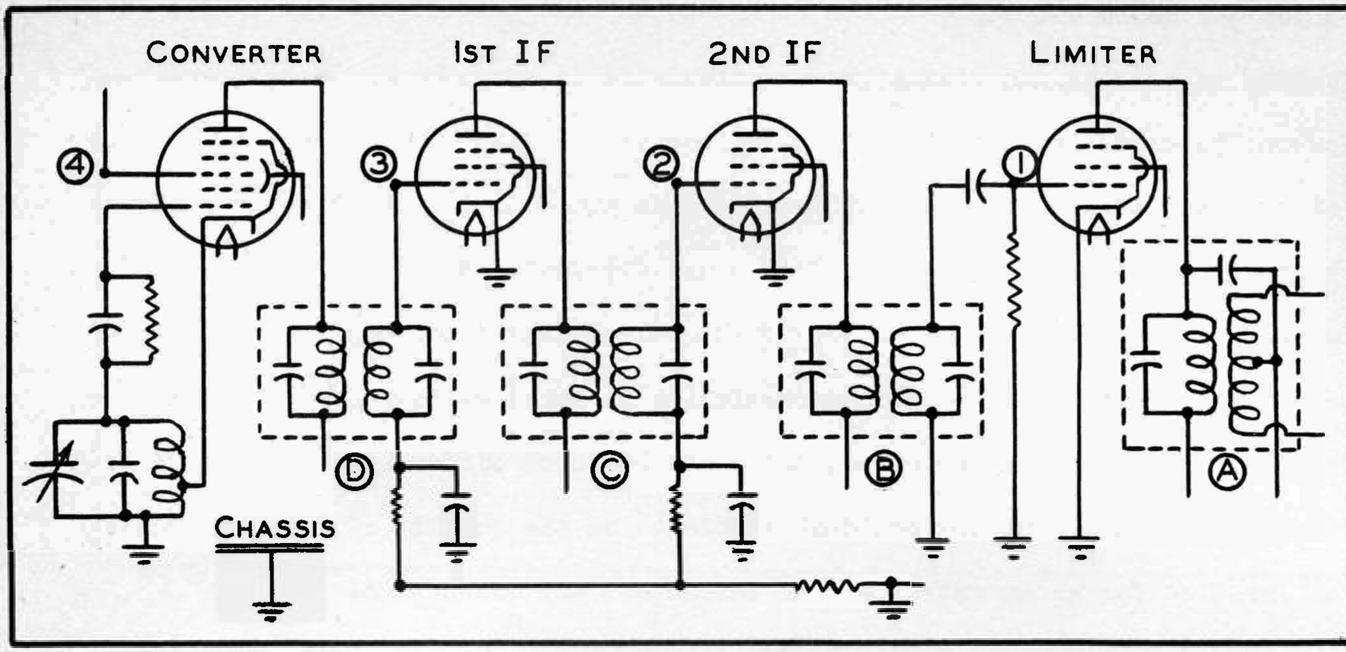


FIG. 11. A frequency-modulation i-f amplifier system.

As the i-f transformers are brought more and more nearly into correct alignment, the output of the i-f amplifying system will increase, and when the adjustments are correct, there will be maximum output from the i-f system, and maximum input to the limiter, for any given strength of generator output.

If the limiter tube is biased by means of a grid capacitor and grid resistor, Rc and Rg in Fig. 12, the output of the i-f system is most conveniently and accurately measured by means of either a high-resistance moving coil voltmeter or else an electronic voltmeter connected between the limiter control grid 1 and the chassis ground 2. The control grid is negative and the ground is positive. This connection places the meter across the grid resistor, and the meter will indicate the direct potential across the resistor and will indicate the grid bias.

If the limiter tube is not biased by grid rectification,output indications may be had with either the high-resistance moving coil voltmeter or the electronic voltmeter connected across either of the discriminator load resistors, Ra or Rb of Fig.

12. This means that the meter will be connected either between 3 and 4 or else between 3 and 5. The connection from the resistor junction 3 to ground (4) is the one

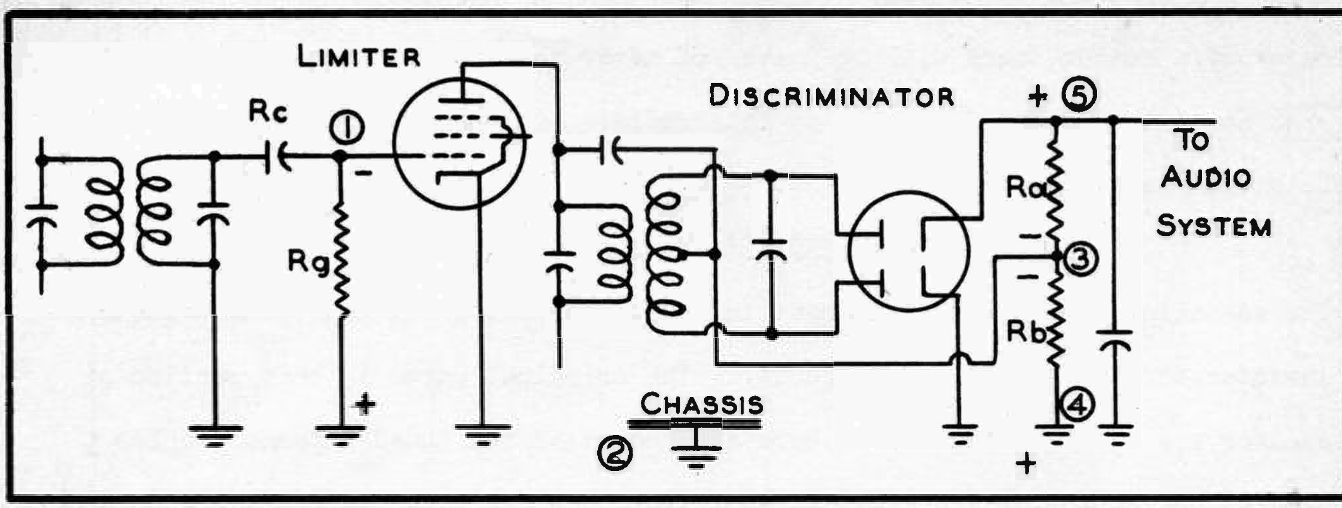


FIG. 12. Points at which the voltmeter may be connected for transformer alignment.

usually employed. The resistor junction will be negative, and the outer ends of the resistors will be positive. For using the output meter in this position, it is assumed that the discriminator transformer is in fairly good adjustment,so that there will be good transfer of energy from the limiter into the discriminator.

The generator is set at the intermediate frequency used in the receiver. The i-f transformers are adjusted, first the secondary and then the primary, in the order of B, then C, then D of Fig. 11. The trimmer capacitors or cores are set for maximum reading on the output meter, using high enough generator output to get distinct readings. The generator output should be reduced as the alignment proceeds, so that the meter readings will not go off scale. The adjustments may be made with a generator output high enough to make the limiter operate, provided the generator will deliver sufficient signal strength. If the loud speaker and audio system are operating, there will be a distinct hissing sound from the speaker while the limiter is not operating as a limiter, but is acting as an amplifier. When the signal is strong enough to cause limiting and cutoff of amplitude variations, the hiss will nearly disappear.

If the output meter were to be connected across both discriminator load resistors, 4 to 5 in Fig. 12, instead of across only one of them, it would be possible to obtain changes of meter reading and peak indications as the i-f transformers are adjusted. But then the peaks will not indicate that the adjustment is for the center frequency. Rather there will be peaks of meter reading at frequencies well below and above the center frequency or intermediate frequency, for reasons which are plain from an examination of Fig. 5.

FRONT END ALIGNMENT

The so-called "front end" alignment includes everything between the antenna and the converter or mixer-oscillator circuit. The principal parts in this portion of the receiver are shown by Fig. 13. Here are indicated the tuned antenna coupler C which feeds the control grid of the r-f amplifier tube, the tuned interstage coupler

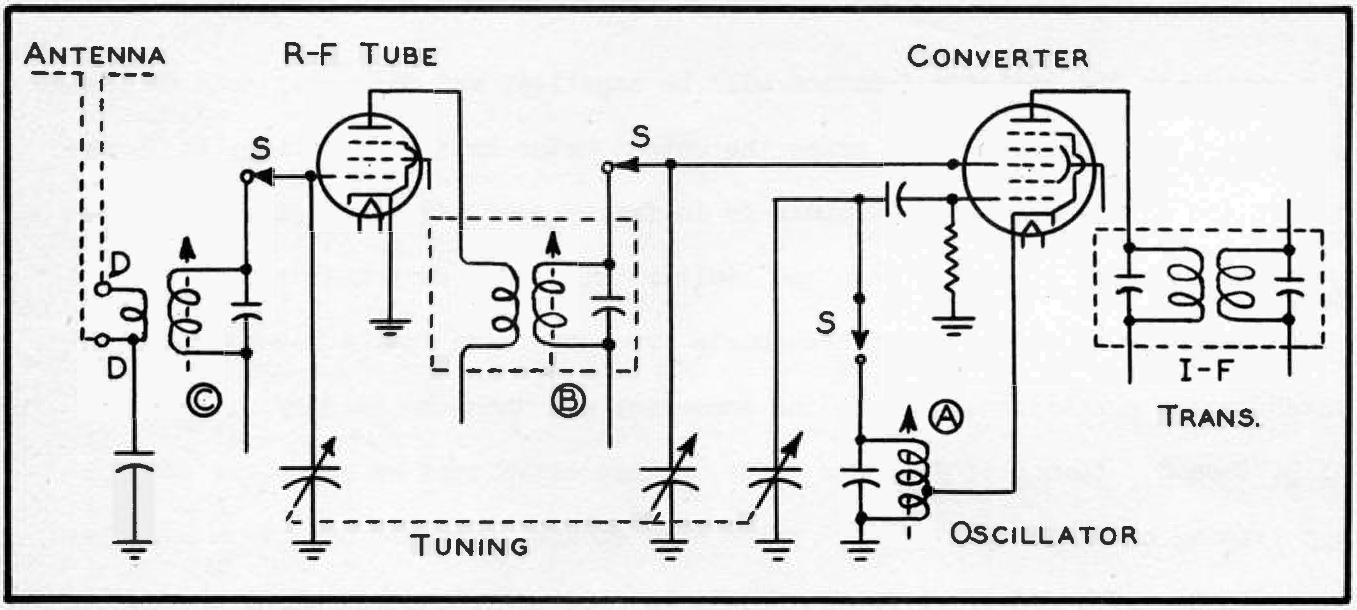


FIG. 13. Alignment adjustments between antenna and converter tube.

B between the plate of the r-f tube and the signal grid of the converter, and the tuned oscillator coil or transformer A connected to the oscillator grid of the converter. In a complete circuit, there would be the band switches, here indicated at S-S-S in the three grid circuits. The grid returns from the lower ends of couplers or transformers C and B would go to the grid biasing potential.

There will be at least three points for alignment or adjustment in this part of the receiver. One will be for the oscillator coil A, a second for the tuned secondary of coupler B, and third for the tuned secondary of coupler C. These adjustments may be by means of trimmer capacitors or else by means of movable iron cores. If there are two f-m bands, there will be a separate set of adjustments for each band, or there may be a complete separate set of three couplers or transformers for each band. In some receivers, there will be trimmer capacitor adjustments for use at the high frequency ends of the bands, and core slug adjustments for use at the low frequency ends. Quite often there will be in the oscillator circuit a trimmer capacitor for use at the high frequency end of the band, and a padder capacitor for use at the low frequency end. All these details of adjustment methods have to be learned by examination of a circuit diagram of the receiver or from examination of the receiver itself.

While making oscillator, r-f and antenna adjustments, the regular antenna is disconnected, as are also any power-line pickup connections, and the generator is connected to the antenna terminals. These terminals are marked D and D (for dipole) in Fig. 13. If there is only one antenna terminal, the high side of the generator is connected to it, and the low side to the chassis ground. In series with the high side lead should be connected the dummy antenna resistor, a carbon type of 100 to 500 ohms resistance. The generator frequency should be set to some point near the center of the f-m band being aligned, but not at a frequency of any near by transmitter. If the generator will not provide a fundamental at this high frequency, it will be necessary to use a harmonic as previously explained.

For observing the output as adjustments are made, connect either the high-resistance moving coil voltmeter or the electronic voltmeter to the same points used for alignment of the i-f transformers. These points are, in Fig. 12, from limiter control grid to chassis ground, 1 to 2, or else across one of the discriminator load resistors, preferably from the junction between the resistors to ground, 3 to 4. All alignment adjustments in the oscillator, r-f, and antenna circuits are made to obtain maximum meter readings.

The tuning dial of the receiver is to be set at the same frequency furnished by the signal generator, or at the harmonic frequency if a harmonic is being used. When adjustments are now made to obtain peak readings on the output meter, the point at which the receiver tuning dial is set will correspond with the actual generator frequency or harmonic frequency. If the generator is not accurately calibrated, or if the harmonic is not correctly adjusted, the receiver tuning thereafter will follow the generator frequency rather than actual received frequencies. For example, if the oscillator fundamental or harmonic really is 96 megacycles when you think it is 98 megacycles, it will be necessary thereafter to set the receiver dial at 98 megacycles in order to tune to 96 megacycles. Both the generator and the receiver should remain turned on for, at least, 15 minutes before making final settings, in order to eliminate the effects of frequency drift so far as possible.

Now the oscillator trimmer or trimmers are adjusted for maximum meter reading. The oscillator frequency, ordinarily, is higher than the received signal frequency, with the difference equal to the intermediate frequency. If the oscillator trimmer has a very wide adjustment range, it will be possible to set it for so much capacitance or inductance as to tune the oscillator to a frequency below the received signal frequency, and have the difference equal to the intermediate frequency. With either adjustment, it will be possible to obtain a peak reading on the output voltmeter. If it is possible to thus obtain two voltage peaks, and if the oscillator frequency should be higher than the received signal frequency, set the trimmer adjustment for the lesser capacitance if the trimmer is a capacitor,or for the lesser inductance with the core farther out of the coil if the trimmer is a movable core.

The next step is to adjust the r-f coupler,B in Fig. 13, for maximum reading on the output voltmeter. The generator output may be reduced so that the meter pointer won't go too high. While making this adjustment,it may be well to turn the receiver tuning dial back and forth a little ways either side of the original frequency setting,thus insuring that the oscillator tuning remains correct for the i-f difference.

The final step is to adjust the antenna coupler, C in Fig. 13, for maximum meter reading. The settings of the receiver tuning dial then may be checked by turning it to various frequencies in the band, varying the generator frequency to obtain maximum meter readings at each dial point, and comparing the dial setting with the generator fundamental or harmonic frequency.

If the alignment is to be considered as completed in a correct manner, all of the adjustments now should be gone over once more to make any needed small corrections. This would mean starting back at the discriminator transformer and working all the way through the i-f transformers, the oscillator, the r-f stage, and the antenna coupler. Another method is to align the discriminator and the i-f stages, then recheck these adjustments before going to the front end, finally aligning the front end and re-checking the adjustments in this part of the receiver.

VISUAL ALIGNMENT

The method of alignment, which has been described, sometimes is called "single frequency alignment" because, at any one time, we adjust the signal generator to some one frequency and observe on a voltmeter the output which exists at this one frequency. The generator frequency may be adjusted either lower or higher than the center frequency, thus simulating the effects of frequency deviation. To determine the outputs over a wide range of frequencies, such as represented in Figs. 3 and 6, would require many separate measurements and would consume much time.

With another method, usually called "visual alignment", we employ a frequency-modulated signal generator whose operating frequency is continually varying in a regular manner above and below a center frequency, just as do actual f-m signals. To observe the output over the entire range of frequencies, we use an oscilloscope on whose fluorescent screen will be traced luminous patterns which show at a glance all that can be told by curves such as those in Figs. 3 to 7.

The vertical input terminals of the oscilloscope are connected to exactly the same points in the receiver as the voltmeter would be connected for single frequency alignment, and the output of the f-m generator is connected to the same points that would be used for connection of the output of the ordinary signal generator for

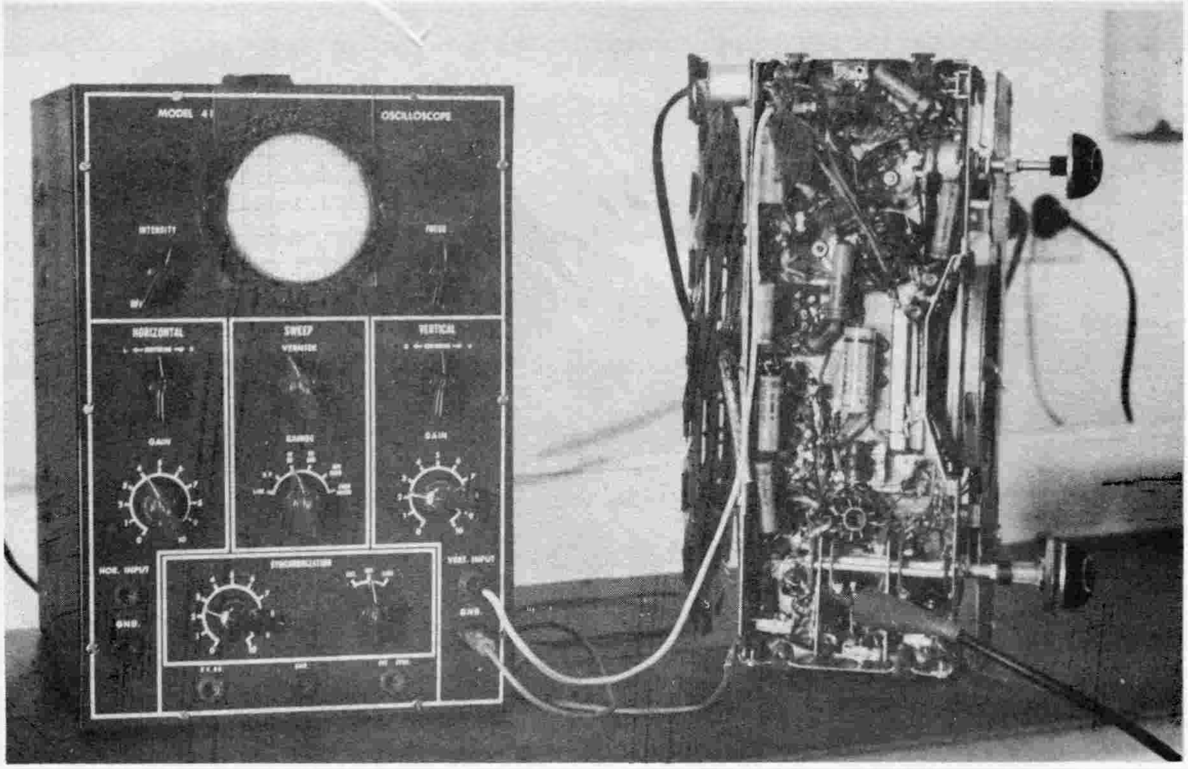


FIG. 14. The oscilloscope connected to a receiver for visual alignment.

single frequency alignment. The simple connections between the oscilloscope and a receiver are shown by Fig. 14.

If the only force acting to cause a trace on the oscilloscope screen is an alternating or varying potential applied to the vertical input terminals,, there will be a single vertical-line trace as at 1 in Fig. 15. With some certain applied voltage, the trace may extend between A and B. With a greater voltage, the trace will extend possibly between C and D. The height of the trace is proportional to applied voltage. If the only force acting to cause a trace is a varying potential applied to the horizontal input terminals of the oscilloscope, there will be a single horizontal-line trace as in diagram 2. The electron beam, where it strikes the screen, moves from E to F and back to E during each cycle of applied potential. This horizontal travel is called the "sweep".

Ordinarily, the forward sweep, left to right or from E to F, takes about 25 times as long as does the return sweep from F back to E. If a complete cycle, E to F and back again, takes 100 units of time, about 96 time units will be consumed in

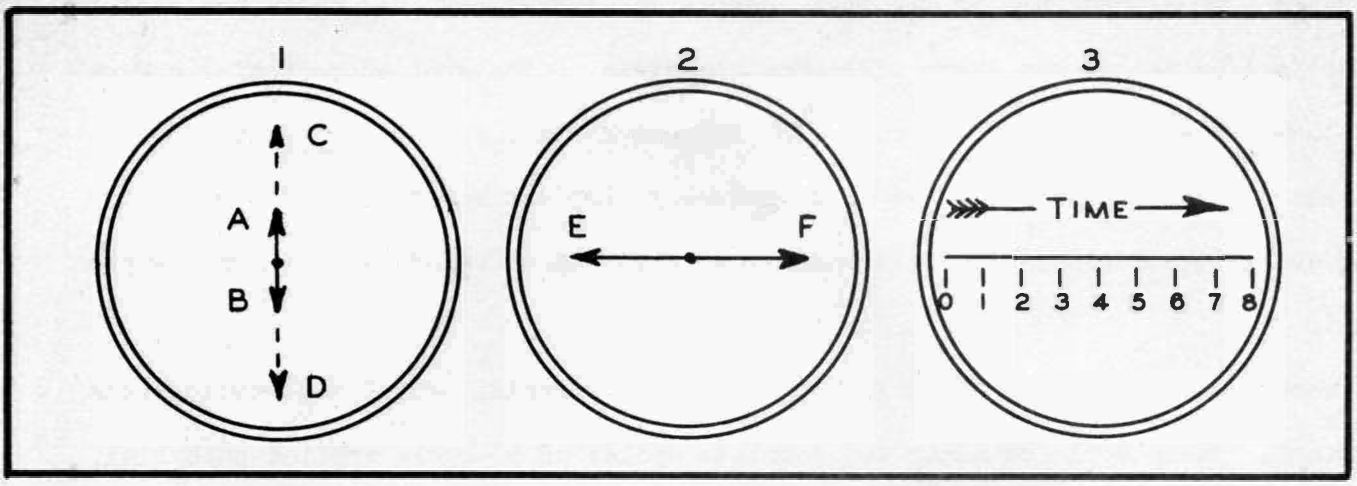


FIG. 15. Oscilloscope traces and the horizontal "time base".

moving from E to F and about 4 units in moving from F to E. The forward trace takes place at uniform speed, so that we might imagine the beam travel to be laid off in units of time as in diagram 3 of Fig. 15.

If we apply vertical and horizontal deflecting forces at the same time, we shall obtain a luminous trace showing the relative values of potential applied during each instant of time. Such a trace is shown by Fig. 16. If we consider that the dark horizontal cross-section line represents zero potential applied to the vertical input, then this trace shows a potential which goes first to a negative peak in the early part of the toal time, then goes to a positive peak midway from left to right, and finally drops back to a negative peak lower than the first one.

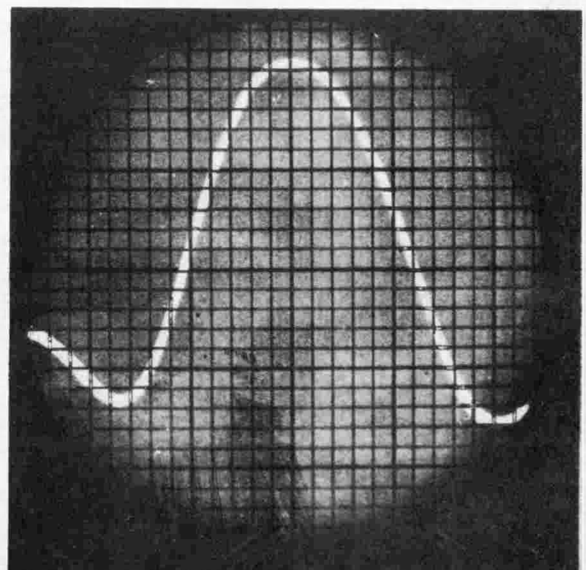


FIG. 16. A trace showing changes of voltage during the time of one cycle.

To obtain a steady trace, the time of beam travel from left to right must have a definite relation to the time in which the applied potential goes through one complete cycle. Then successive cycles of applied potenial will cause the beam to travel the same path or trace during each cycle. For instance, if one complete cycle takes 1/60 second, and if the beam completes its forward and back horizontal travel in 1/60 second, the trace will show one cycle of the applied potential and we may observe the changes of potential with respect to time during the cycle. This is the same as saying that for an applied frequency (to the vertical input terminals) of 60 cycles per second, the horizontal sweep also has a frequency of 60 cycles per second.

Were the beam to take twice as long for its horizontal travel,a 30-cycle sweep frequency, there would be shown two complete cycles of 60-cycle applied potential.

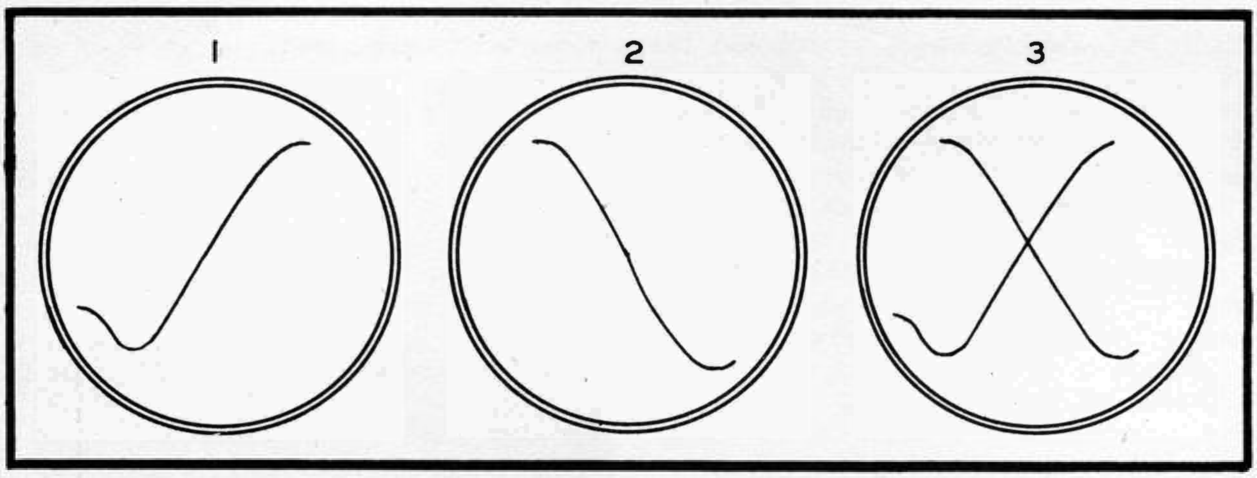


FIG. 17. With a sweep frequency of twice the vertical frequency, we see traces of half-cycles.

The number of cycles shown always will be equal to the number of times that the horizontal sweep frequency is contained in the applied frequency. Were the applied frequency 60 cycles, and the sweep frequency 120 cycles, we would see half-cycles of applied voltage. During one left-to-right travel of the beam, there would be formed the first half of a complete cycle, as at 1 in Fig. 17. During the next left-to-right travel, there would be formed the second half, as at 2. But because the screen remains luminous for an appreciable time after the beam has passed, we would see both halves of the cycle at the same time, as in diagram 3. The cycle appears to be split in half, with one part superinposed on the other. If the sweep frequency is not evenly divisible into the applied frequency, or the applied frequency is not evenly divisible into the sweep frequency, we obtain some peculiar looking trace patterns and some very intricate "lace curtain" effects on the screen.

The deviation frequency of f-m signal generators usually is either 60 cycles or else 400 cycles per second. The horizontal sweep frequency of the oscilloscope then may be set at fractions or multiples of the deviation frequency to bring various numbers of whole cycles or part cycles onto the screen. Some generators have a special terminal from which may be taken a potential at the deviation frequency and applied to the horizontal input terminal of the oscilloscope, thus synchronizing the two instruments. Otherwise it is easily possible to adjust the "internal sweep" frequency of the oscilloscope to a value which gives desired trace patterns.

The extent of frequency deviation in the generator signal must be at least somewhat greater than the maximum deviation with which the receiver is expected to operate. With the usual maximum deviation of 75 kilocycles, the generator deviation usually is made something between 100 and 200 kilocycles below and above the center frequency. Pictures of traces in following pages were made with a deviation of about 200 kilocycles, and by using the internal adjustable sweep of the oscilloscope.

I-F TRANSFORMER ALIGNMENT

To align the i-f transformer, proceed as follows: These are general instructions. If manufacturer's service data gives different procedures, always follow the maker's instructions to the letter.

Disconnect the receiver antenna. Set the tuning dial at a frequency on which there are no nearby stations. Connect the high side of the signal generator through a dummy antenna capacitor to the control grid of the tube preceding the transformer to be aligned, if the receiver is badly out of adjustment, or else connect to the converter signal grid for alignment of all transformers. Connect the generator's low side to the receiver ground or chassis, using a series capacitor with ac-dc sets. Set the generator exactly to the intermediate frequency of the receiver, and adjust the deviation to 100 or more kilocycles. Failure to set the generator at the intermediate frequency will result in irregular traces with extra peaks.

Connect the oscilloscope vertical input to the grid end of the limiter grid resistor, using in series with the lead, a resistor of 0.5 to 1.0 megohm to avoid too

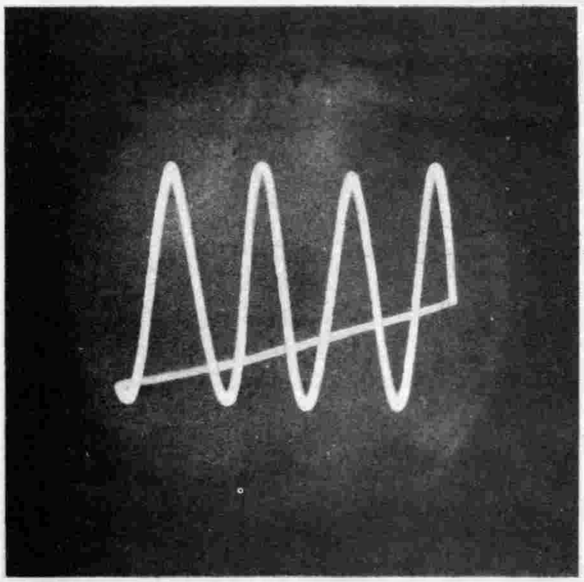


FIG. 18. The sweep frequency is set to show several cycles.

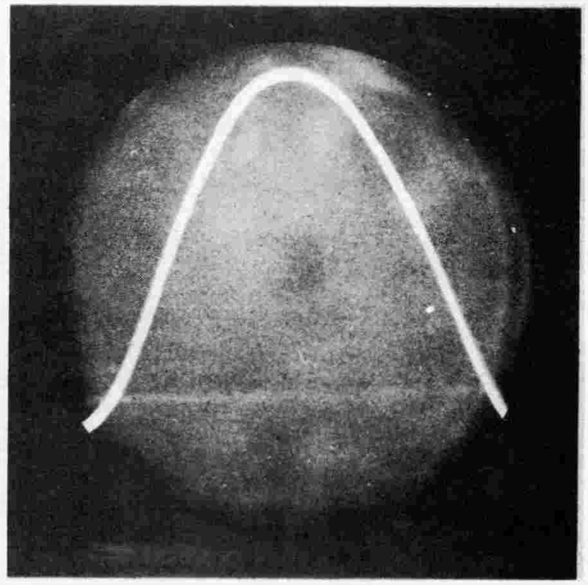


FIG. 19. One of the cycles is enlarged and centered.

much shunting of the grid resistor. Connect the oscilloscope ground to the receiver chassis ground. Use short leads for oscilloscope connections. If the generator has a synchronizing terminal, connect it to the oscilloscope horizontal input terminal and use the "external synch" setting of the oscilloscope. Otherwise set the oscilloscope for "internal synch", set the sweep range to include the deviation frequency of the generator, and adjust the sweep vernier or fine control to get several cycles on the screen - about as shown by Fig. 18.

Now use the horizontal gain control to widen one of the cycles, the vertical gain to regulate the trace height, and the horizontal and vertical centering controls of the oscilloscope to center the one cycle on the screen, as shown by Fig. 19. As shown by Fig. 20, the cross section screen may be placed in front of the cathode-ray tube screen if desired. Figs. 19 and 20 show curves after final alignment. Start with less height, to allow for the height increasing as alignment proceeds.

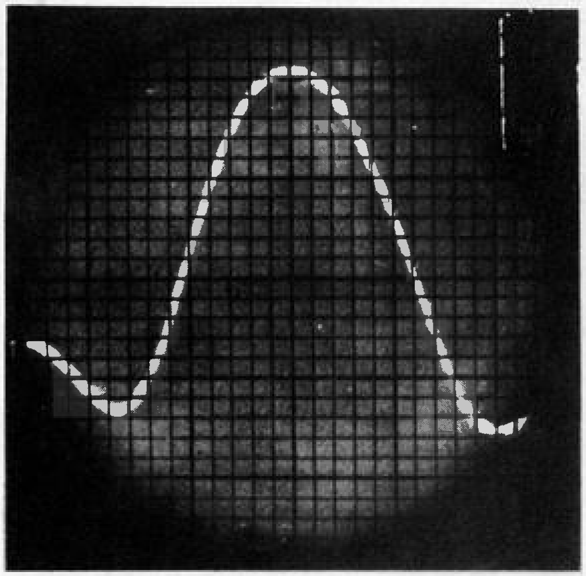


FIG. 20. A single cycle with the cross section screen in place.

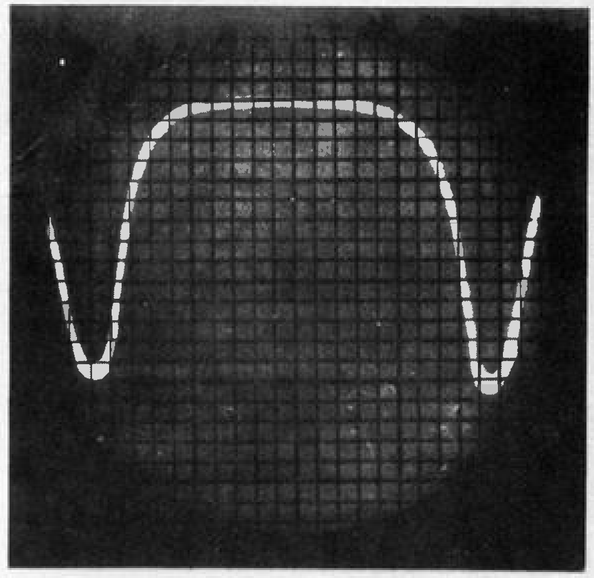
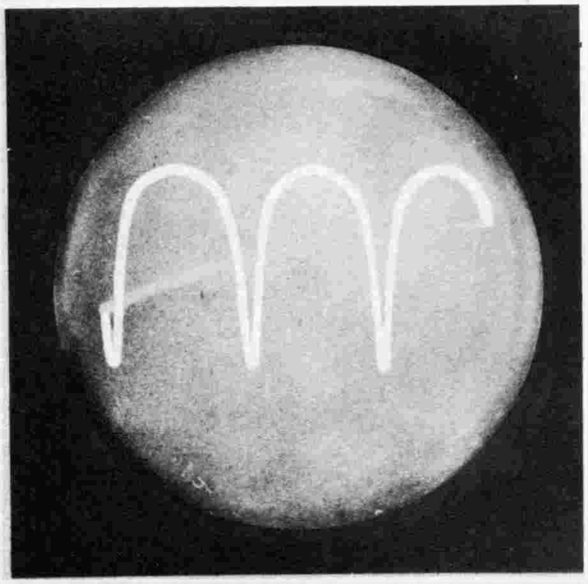


FIG. 21. Very broad tuning with a flat-topped curve.

Adjust the primaries and secondaries of the several i-f transformers to obtain curves of maximum possible height with a waveform about as shown by Figs. 19 and 20, or with even a flatter and broader top. An extremely broad, flat top is shown by Fig. 21. If the trace becomes too high for the size of the screen, reduce the generator output. Do not lessen the height of the trace by using the vertical gain control of the oscilloscope.

FRONT END ALIGNMENT

For alignment of the antenna circuits, r-f stage, and oscillator of the receiver, the oscilloscope may remain connected to the limiter grid resistor just as for i-f alignment. The generator high side is connected through a dummy antenna resistor to the antenna post, or one dipole post, of the receiver, and the generator low side remains connected to ground if one side of the antenna coil is grounded, or is connected to a second dipole post if there are two such posts with neither one grounded, directly or through a capacitor. Set the generator at a fundamental or harmonic frequency between 88 and 180 mc on which no nearby transmitter operates. Set the receiver tuning dial to the same frequency between 88 and 180 mc.



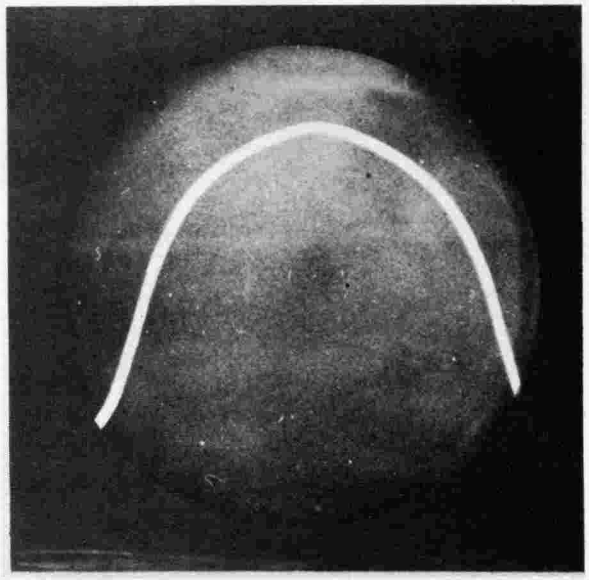


FIG. 22. Several cycles and one enlarged cycle with connection to the antenna.

The trace pattern will be practically the same as that obtained during i-f transformer alignment. Adjustments in the oscillator, r-f, and antenna tuned circuits are made for maximum height of the trace and for a wave of good form, having both sides symmetrical. Fig. 22 shows several cycles and one cycle enlarged as obtained when using an extra wide frequency deviation from the signal generator. It is rather general practice to align the antenna, r-f, and oscillator circuits by the single frequency method, even when using visual alignment for the i-f transformers and discriminator.

DISCRIMINATOR ALIGNMENT

For alignment of the discriminator transformer, the f-m generator high side is connected through an antenna dummy capacitor to the converter signal grid or to the control grid of one of the i-f amplifier tubes, with the generator low side to the receiver ground or chassis. The antenna still should remain disconnected, and the receiver dial kept tuned to a frequency at which there are no nearby stations. The generator is set for the exact intermediate frequency of the receiver, and the frequency deviation is adjusted to a number of kilocycles in excess of 100.

The vertical input of the oscilloscope is connected through a resistance of 0.5 to 1.0 megohm to the audio output point of the discriminator load resistors, which is point 5 in Fig. 12. The oscilloscope ground is connected to the receiver ground or the chassis.

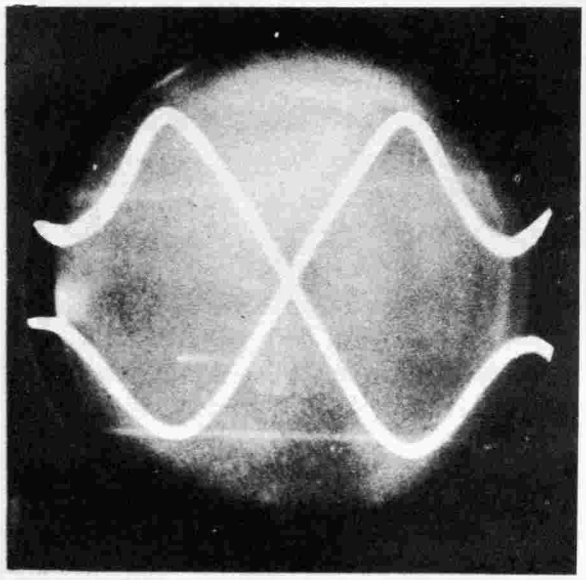


FIG. 23. Discriminator curve with two half-cycles superimposed.

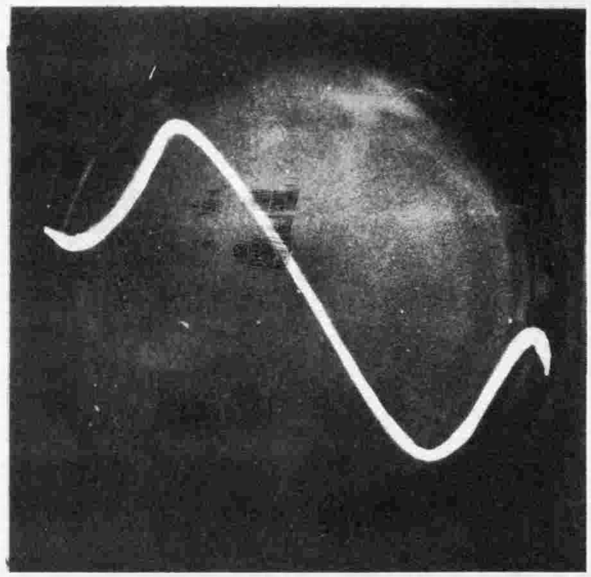


FIG. 24. One of the half-cycles of the discriminator curve.

If the horizontal sweep frequency of the oscilloscope is synchronized from the signal generator, with a connection from generator to oscilloscope, the trace on the oscilloscope screen will have the general form shown by Fig. 23 or else the form shown by Fig. 24. The difference is that Fig. 23 consists of an entire cycle of input potential, as in diagram 3 of Fig. 17, while Fig. 24 shows only a part of a cycle, as at 1 or 2 in Fig. 17. Which kind of trace appears depends on the relation between deviation frequency and oscilloscope sweep frequency.

When using internal synchronization of the oscilloscope, with adjustable sweep frequency, it is possible to produce the trace patterns of either Fig. 23 or Fig. 24 by varying the sweep frequency. With a low sweep frequency to start with, the first steady pattern produced by adjusting the sweep frequency may be the several cycles shown by Fig. 25. By using the gain controls and centering controls, it then is possible to bring onto the screen just one of the crossovers, which will appear as in Fig. 23. With a different adjustment of sweep frequency, it will be possible

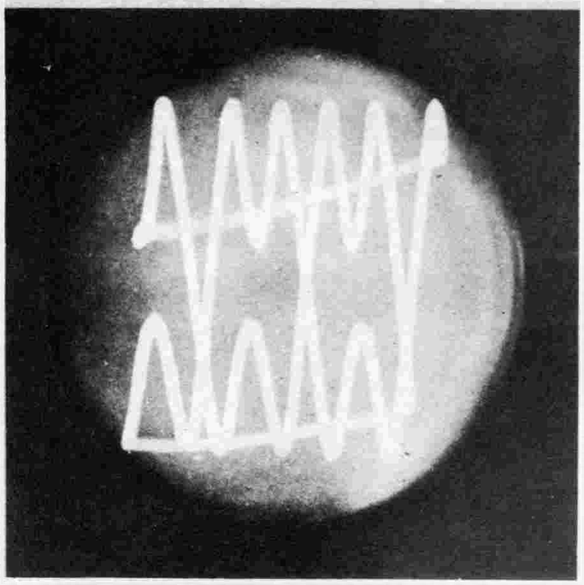


FIG. 25. With a low sweep frequency, the pattern will be like this.

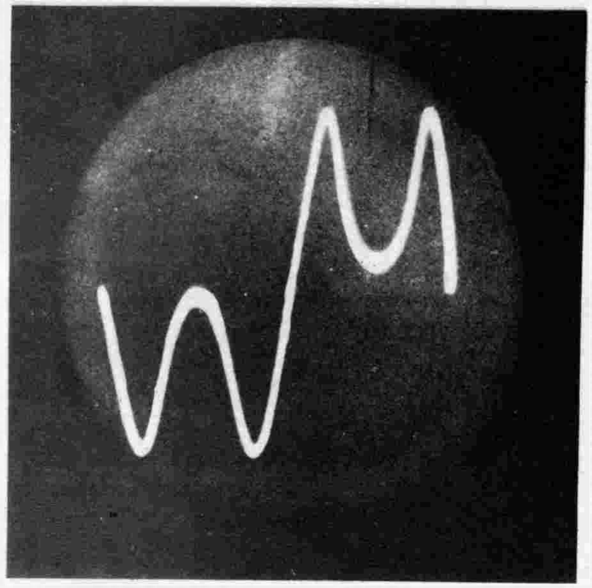


FIG. 26. With a higher sweep frequency, the pattern will be like this.

to obtain the pattern of Fig. 26, or to obtain several successive cycles of this type, of which one may be enlarged and centered on the screen. Thus separating and enlarging the central upward curve of Fig. 26 would yield a trace such as shown by

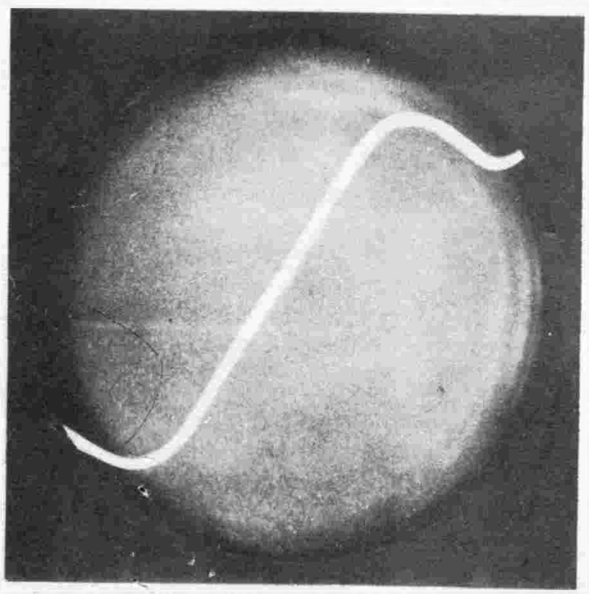


FIG. 27. Discriminator half-cycle with upward sweep.

Fig. 27, and here we have one of the two traces which appear in Fig. 23. Instead of obtaining the trace which is upward from left to right, we might select a different part of the cycle and bring onto the screen a trace which is downward from left to right, as in Fig. 24.

Although alignment may be made by observing either the crossed curves of Fig. 23 or else the single curve of Fig. 24 or Fig. 27, the process is somewhat easier with the crossed curves. The adjustment of the discriminator transformer primary is made to get the curves as straight as possible above and below the crossover. It will be found that turning the primary trimmer one direction will increase the heights of the curves, but will give them greater bends, while turning the trimmer the opposite direction will lessen the height, but will again give excessive curvature.

The trimmer for the secondary of the transformer is adjusted to bring the crossover point midway between the upper and lower peaks which are at the outer, upper and lower ends of the two curves. Turning the trimmer one way will move the crossover upward, while moving it the opposite direction will move the crossover downward. Usually it will be necessary to work back and forth between primary and secondary adjustments to obtain the best overall results.

It is important that the signal generator be set at the exact intermediate frequency with which the receiver is to operate, and that the deviation in frequency be equal on both sides of this center frequency. Incorrect frequency from the generator will make it difficult or impossible to obtain correct alignment, or may allow the production of oscilloscope screen traces which appear correct when the alignment really is far from being correct.

EXAMINATION QUESTIONS ON NEXT PAGE