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# RADIOTRONICS

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**Volume 18** **November 1953** **Number 11**

## *By the way*—

**Our front cover this month is taken from the film "Australia Makes Radio Valves by the Million", and is reproduced here by courtesy of the Australian Diary Film Unit and shows a part of the "cage-making" section. Inset is an operator assembling the component parts of the electrode assembly known as a "cage".**

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**Editor:**
Ian C. Hansen,
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*By K. Fowler and H. Lippert.*

# TELEVISION TEST EQUIPMENT AND ALIGNMENT

## 1. Introduction.

This chapter will discuss in detail the three phases of test equipment and alignment which are considered most important for the proper alignment of TV receivers. These three phases are:

(1) The need for special equipment for alignment of TV receivers.
(2) How this equipment operates.
(3) How to properly use the equipment.

No tool or instrument, regardless of how perfect it may be, can be completely effectual unless it is accompanied by the necessary "know-how". For this reason, considerable space has been devoted to the theoretical aspects of the test equipment which will be used. While many impatient students may feel inclined to skip the theoretical considerations and jump directly into the practical work of actually aligning a receiver by following step-by-step instructions, it must be stressed that a theoretical understanding of what goes on inside the test equipment is more important than the ability to turn the correct knobs. The alignment procedures used on TV receivers are far more exacting than the usual methods employed on broadcast receivers; consequently, the time spent in acquiring a working knowledge of the test equipment involved will be well repaid when unexpected problems arise.

The first section of this chapter will be a brief review of some of the material previously covered in earlier chapters which dealt with the required response characteristics of IF and RF sections of both conventional and intercarrier receivers. We will go one step further, however, and gain an understanding of why the equipment and techniques used on broadcast receivers cannot always be used for TV.

The second phase of this chapter will consider the electrical requirements of the three basic instruments needed to align a TV receiver. These three instruments, the SWEEP GENERATOR, the MARKER GENERATOR and the OSCILLOSCOPE will be discussed both individually and as a co-ordinated team. The specifications included in this section will be valuable to the technician who is thinking of purchasing TV test equipment but who is not too sure of just what is required. To further guide the technician, the inherent weaknesses of some types of equipment are explained, together with simple tests that can be made to determine if the equipment is capable of giving satisfactory results. Finally, a brief description of the features incorporated in high quality, recommended test equipment is presented for comparison purposes.

Practical information dealing with RF and IF alignment of TV receivers completes this chapter. Because it is impossible to describe step-by-step procedures which will apply to all receivers, this information is of a general rather than of a specific nature.

## 2. Alignment considerations — broadcast receivers.

Alignment of the conventional broadcast receiver involves:

(1) Peaking IF amplifier circuits to the correct frequency.
(2) Adjusting the tuning range of the local oscillator so that the desired frequency range will be covered.
(3) Tracking RF and Mixer stages at two or three points on the tuning range.

As far as the IF alignment of the broadcast receiver is concerned, each stage or tuned circuit is tuned to the same frequency. The exact frequency is not too critical and can vary about five per cent. without seriously affecting the performance of the receiver. Tracking of the front end stages on the broadcast receiver again is done by peaking these circuits, first at one end of the tuning range and then the other. If the front end circuits can be properly peaked at the two band ends, it is usually assumed that tracking over the intermediate portion of the frequency coverage is satisfactory.

Notice that in each of these alignment steps only one frequency is involved. All the IF stages are aligned to a single frequency. Alignment of the front end circuits is carried out by making several adjustments, each at a single frequency. From this, it can be seen that a signal generator capable of supplying a single test signal at each of these frequencies is all that is needed to align a broadcast receiver. In some cases, the experienced technician can dispence with a signal generator and peak the circuits on actual broadcast signals. Proper adjustment of the IF and RF amplifier circuits is indicated by maximum sound output from the loudspeaker of the receiver; therefore the ear alone can be used as a rough output indicator.

## 3. FM receivers.

In general, the same considerations apply to most FM receivers. Although a few FM receivers employ over-coupled, resistance-loaded IF transformers which produce a double peak curve such as shown in the dotted portion of Figure 14-1-B, the majority of the sets in use today have an IF response curve similar to the solid curve shown in B. Notice that the overall shape of this curve is quite similar to the response curve of the broadcast receiver shown in A. The nose of the FM curve is much broader but it has a definite peak, as does the AM curve.

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**By courtesy of AGE, with acknowledgment to International General Electric Co. of U.S.A.**

Hence, most FM receivers can be aligned in much the same manner as broadcast sets — by simply peaking the amplifier stages in the IF and front-end for maximum output at the desired spot frequencies. Again, a simple, single frequency source can be used for test signals, the only requirement being that it cover the necessary IF and RF frequencies. Because of the "leveling" effect of the limiter in FM receivers, the ear cannot be used as even a rough output indicator, however, and it is therefore necessary to use a high resistance voltmeter (connected in the limiter grid circuit) as an output indicator. The same single frequency source and voltmeter can also be used to accurately align the discriminator in the FM receiver because again, only a single, spot frequency is involved.

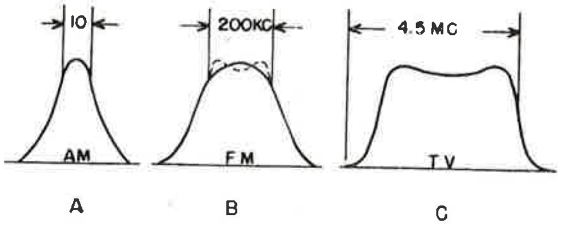

*Fig.* 14-1. *Typical IF response curves.*

It should not be assumed that the relatively simple procedures just described should and can always be used with any AM or FM receiver in existence today. The manufacturers of many high quality AM and FM sets often recommend much more complicated alignment procedures which require fairly elaborate test equipment. Such complications in methods and equipment are necessary, from the manufacturer's standpoint, to insure ultimate performance. Because of the circuit characteristics of most receivers, however, the experienced technician can do a good alignment job with even simple equipment. The reason for this can be seen from Figure 14-1-A and B. With one or two exceptions, simple peaking adjustments are all that are necessary. And, as previously mentioned, such adjustments do not require elaborate test equipment.

### 4. TV receivers.

Let us now consider the response curve shown in Figure 14-1-C. This is a typical video IF response curve such as is found in the General Electric Model 802 service manual. Notice that this is not a peaked curve such as was found in AM and most FM receivers. Instead, the curve is reasonably flat across the top for several megacycles or more. It has no semblance of even a very broad, round "nose", and it cannot have such a peaked response if the TV receiver is to operate properly. Obviously, simple peaking adjustments such as those previously described for AM and FM receivers cannot be used in the alignment procedure because there is no single frequency involved. Rather, an entire band of frequencies approximately four megacycles wide go to make up this response curve. It is this characteristic of the TV video IF circuits which make it necessary to use an entirely different system of alignment.

In AM and FM receivers, the individual tuned circuits in the IF amplifiers are designed so that when all of them are peaked to the same frequency, the overall shape of the response curve is essentially correct. Individual tuned circuits in TV video IF amplifiers, however, are not always all tuned to the same frequency and each alignment adjustment will therefore in some way affect the shape and amplitude of the final response curve. Not only must this response curve be shaped correctly; it must also be aligned so that spot frequencies which correspond to the picture and sound carriers are located within close limits on the desired portion of the curve. Hence, two primary requirements must be met in video IF alignment:*

(1) The overall response curve must have the proper shape.

(2) Key frequencies must be correctly located on the curve.

As will be discussed later, failure to meet either of these requirements will invariably result in a poor picture, poor sound, or both.

The characteristics of the IF circuits used in the TV receiver to amplify the sound portion of the television signal are very similar to those found in the conventional FM receiver. Although TV sound has a narrower deviation (± 25 kc) than regular FM (± 75 kc), the IF circuits used in conventional TV receivers for sound amplification are purposely made broad so that a certain amount of frequency drift in the local oscillator can be tolerated. For this reason, the curve shown in Figure 14-1-B for FM receivers closely approximates the curve found in the sound IF circuits of the TV receiver. This means that we can use our simple peaking system when aligning this portion of the TV receiver. In the TV sound IF system, however, much closer frequency tolerances must be observed than is necessary in the FM receiver.

All television receivers designed to date make use of trap circuits which perform one or more of the following functions, depending upon the particular receiver:

(1) Shape the video IF response curve.

(2) Attenuate undesired frequencies.

(3) Serve as pick-off points for the sound signal.

These trap circuits are nearly always sharply tuned to a single spot frequency, so again, the simple peaking system of alignment can be successfully used when this section of the receiver is aligned. Again, however, the frequency tolerance of the signal used for this alignment must be held within very close limits.

The frequency response characteristics of the RF and mixer circuits in the TV receiver will vary somewhat depending upon the design of the particular receiver involved. Typical front-end response curves are shown in Figure 14-2. As you can see

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* These requirements apply to both the conventional and intercarrier type receiver.

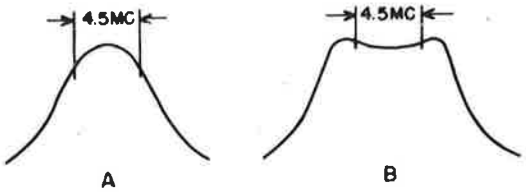


*Fig. 14-2. Typical front-end response curves.*

from this illustration, the curve can be either very broad and slightly rounded at the top, or it can have a "saddle-back" characteristic. Quite often, both of these curves will be found in the front end of one TV receiver because of the different response characteristics of the circuits on the high and low band channels.

Since the front end of the television receiver must be approximately five to six megacycles wide to provide amplification of both the picture and sound carriers, simple peaking adjustments cannot be used in aligning these stages. It might seem at first that peaking adjustments could be used on those channels where the overall response curve has a broad, round nose, as for example Figure 14-2-A. Closer examination of this curve will show that the nose is actually several megacycles wide and for this reason it would be almost impossible to get an accurate indication of just where the exact centre peak is located if simple peaking methods are used. Because of this, the alignment of TV front ends must be accomplished by some manner other than simple peaking.

## 5. Summary of TV alignment requirements.

We have learned from the preceding paragraphs that the following conditions apply to the alignment of a television receiver (either conventional or intercarrier):

(1) Sound IF and trap circuits can usually be aligned by simple peaking methods provided the test oscillator used to supply the signal is accurately calibrated on the frequencies used.

(2) Simple peaking adjustments cannot be used to properly align the video IF and front-end circuits because of the broad-band characteristics of these stages.

## 6. The visual alignment system.

Since the simple procedures used for years to align broadcast receivers cannot successfully be applied to the alignment of television IF and RF circuits, there has been developed a technique called visual alignment, which is relatively new to the service technician. This method of alignment, when properly applied, presents an actual picture of the response curve of the circuit or circuits being aligned. Since the eye is a much more critical detector than the ear, the system is capable of extreme accuracy. Furthermore, there is no guesswork involved, because the entire amplification characteristics of the circuit being aligned can be seen at a glance and corrected if necessary. Finally, alignment by this method can be performed quite rapidly by a competent technician because the visual curve indicates instantly any maladjustment or circuit misfunctioning.

This system of electronic curve tracing makes use of three instruments:

(1) An oscilloscope which serves as the visual indicator and presents the response curve on the face of its cathode ray tube;

(2) A sweep frequency generator which traces the curves; and

(3) A marker generator which indicates the frequency at any point on the curve.

It is important to note that these three instruments must be used as a co-ordinated team. The sweep generator, by itself, is of absolutely no value unless it is used with the oscilloscope. These two instruments, in turn, require the precise spot frequencies supplied by the marker generator because the response curve by itself means very little unless its frequency characteristics are known within close limits.

When we construct actual curves on paper, we often use rulers, scales, and templates to check the accuracy of our work. In the visual alignment system, the oscilloscope can be thought of as the pencil that draws the curves, the sweep generator becomes the hand that guides the pencil, and the marker generator becomes the scale, or standard of comparison that we use to check the accuracy of the electronically produced curve. From this simple analogy, we can realize that actually, only two instruments, the sweep generator and the oscilloscope, are required to produce an electronic response curve. The marker generator is not needed if we desire to merely take a casual look at the response curve of a circuit. Such a curve would give us a rough idea of how the tuned circuits were performing but we would be unable to get an accurate indication of the alignment of these circuits without using our standard of comparison — the marker generator.

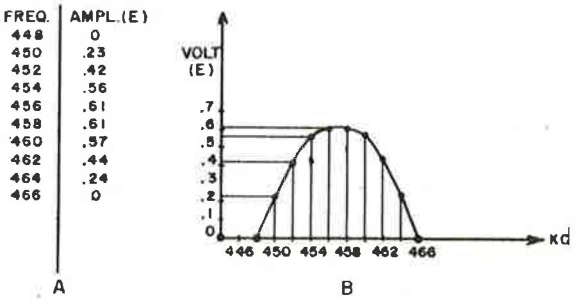
Because of the interdependence of these three units in the visual alignment system, many commercial equipments manufactured today combine the marker generator and the sweep generator on a common chassis and this combination is then marketed as a complete television alignment generator. A companion oscilloscope is generally also available to be used with this combination, although at least one test equipment manufacturer has brought out a complete equipment which contains all three instruments in one cabinet.

Although, as pointed out earlier in this chapter, it is not necessary to use visual alignment when aligning sound IF and trap circuits, the greater accuracy and speed of this system makes its use desirable for these operations. Most sweep and marker generators are therefore designed so that they can be used for the alignment of all tuned circuits found in the television receiver.

Although the marker generator is an indispensable part of the system, accurately calibrated absorption-type wave traps can be substituted for this instrument where cost is an important factor. This will be covered in detail later in this chapter.

## 7. The response curve.

The two columns of figures shown in Figure 14-3-A represent a mathematical relationship between two sets of values — voltage and frequency. The curve in part B of this illustration presents the same information in the form of a graph. Obviously, the graphical presentation tells us more in one glance than the columns of figures tell us in several minutes. Notice also, that the graph gives a continuous picture of the relationship, whereas the tables of figures give us this information in small steps. It is this property of showing graphically and completely the relationship between output and frequency that makes the visual alignment system so valuable and speedy.



| FREQ. | AMPL.(E) |
|---|---|
| 448 | 0 |
| 450 | .23 |
| 452 | .42 |
| 454 | .56 |
| 456 | .61 |
| 458 | .61 |
| 460 | .57 |
| 462 | .44 |
| 464 | .24 |
| 466 | 0 |

A

*Fig 14-3. Tabular and graphical representation of a response curve.*

The response curve traced out on the screen of the oscilloscope gives us the same information as does the curve shown in Figure 14-3-B. In either case, the curve shows how the output of a circuit changes as the frequency is varied. The horizontal scale represents frequency and the vertical scale indicates the amplitude or strength of response within the band of frequencies being investigated. On the hand-drawn curve, the ruled lines on the graph paper are marked off in frequency divisions as shown. With the visual system, however, we cannot conveniently draw marks on the face of the cathode ray tube to indicate frequency; instead, the marker generator or an absorption-type wave trap makes a "mark" directly on the response curve.

The amplitude, or strength of response, which is plotted vertically, is again found on the hand-drawn curve by referring to the ruled divisions on the graph paper. Visually, the exact strength or amplitude can be determined by calibrating the vertical amplifier of the oscilloscope. In general, the exact amplitude obtained with the visual system is not too critical provided it does not exceed a certain level which would result in over-load of the circuits being aligned. The relative amplitude of different portions of the response curve is very important, however. The peaks and valleys of the curve must be held within the limits specified by the alignment instructions you are following and these limits are usually twenty or thirty per cent. This is illustrated in Figure 14-4. In this figure, the overall height or amplitude "A" of the curve is not a critical factor, but the amplitude of the peak "B" with relation to "A" is a vital consideration in the alignment operation. Fortunately, the relative strength of peaks and dips such as these can be found very easily by placing a transparent, scaled mask over the face of the oscilloscope. This mask, which is supplied with most oscilloscopes, makes it an easy matter to count off the total height occupied by the curve in terms of ruled squares. Once this is known, the percentage variation in the dip or peak can be obtained by dividing the number of B divisions by the number of A divisions. For example, if the height "A" extended 15 divisions and the peak "B" extended upward another five divisions, the relative amplitude of the peak would equal 5/15 or .33, which is 33%.

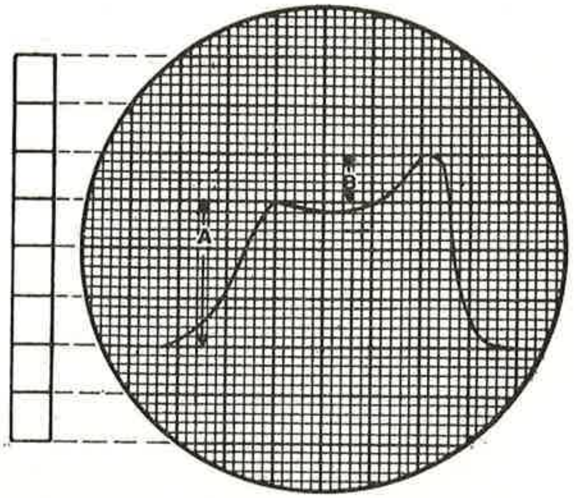


*Fig. 14-4. Relative amplitude of response curve.*

To gain a better understanding of just how the response curve is formed on the face of the oscilloscope, it would be well at this time to examine in detail a simplified method of obtaining on paper, the actual response curve of a tuned amplifier.

## 8. Point-by-point plotting of a response curve.

Figure 14-5 shows how a simple test oscillator can be used in conjunction with a radio frequency vacuum tube voltmeter to obtain the response curve of a tuned amplifier such as the 456 kc IF channel of a standard broadcast receiver. For most accurate results, the output of the oscillator must be constant over the band of frequencies used — in this case, approximately 440 to 470 kcs. In addition, the VTVM must have a flat response over this same frequency band.

The curve is plotted on a piece of graph paper which has linear scales both vertically and horizontally. The frequency band to be investigated, 440 to 472 kcs, is first marked off on the horizontal scale, as shown. Output, in terms of RF voltage, is marked off on the vertical scale. After this is done, the actual plotting can begin.

Turn all the equipment on. Swing the oscillator dial slowly through the frequency band and leave it set at the point where the VTVM gives a maximum reading. Now adjust the output of the oscillator until the meter reading is approximately two volts. Note the frequency setting of the oscillator and the exact reading of the VTVM and place a dot on the graph where these two values meet. This corresponds to point A on the curve in Figure 14-5. It is necessary to take the first reading at this point A in order to adjust the output of the oscillator and thus make sure that the amplifier will not be overloaded at the frequency of maximum gain.

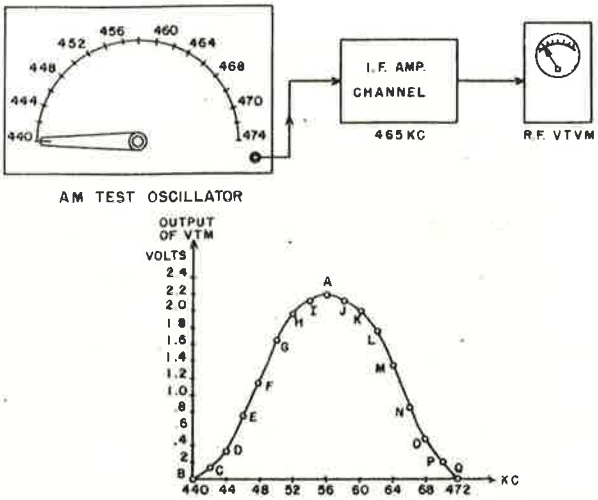


*Fig. 14-5. Point-by-point method of plotting a response curve.*

After point A has been plotted, do not change the setting of the oscillator output control until the entire curve has been plotted. Next, tune the oscillator to 440 kcs and note the meter reading, which will probably be close to zero. (This is because the amplifier will have very little gain at this frequency if it is properly aligned to 456 kc.) Place another dot on the graph at the point where 440 is lined up with the value of the meter reading. This will be point B on the curve.

Move the oscillator dial, next, to 442 kc and again note the meter reading. It should be slightly higher than that obtained at the previous setting. Place another dot at the intersection of 442 and the output voltage. This will be point C. Continue this process of changing the output frequency of the oscillator two kc at a time and plotting the RF voltage against frequency until the entire range has been covered. When you finish, you will have a series of dots, which, when joined together by a smooth curve, show the actual response characteristics of the amplifier.

The oscillator dial scale shown in the illustration has, of course, been expanded for the sake of clarity. It is doubtful that precise, two kc steps could be obtained on the average test oscillator because a much greater band of frequencies is covered by the usual 180 degree swing of the dial. The accuracy of this method of obtaining a response curve is therefore usually limited by the bandspread and calibration accuracy of the oscillator.

In this particular example of point-by-point plotting, readings were taken every two kilocycles. Actually, we do not know what is happening in between the two kcs points but we assume that the response is smooth and therefore we simply join the two kc points together with the curve. If greater accuracy is needed, it would be necessary to plot the response every kilocycle and this, obviously, would give us more points through which the curve could be drawn.

It should be apparent by now that point-by-point plotting, if it is to be done accurately, takes considerable time. It is widely used in laboratories where records of development work must be kept, but it certainly is not a practical method of aligning a television receiver, because if one adjustment is made on the amplifier being checked, it is necessary to re-plot the entire curve to see the effect of that adjustment.

In the visual alignment system, the oscilloscope takes the place of the graph paper and the curve is drawn on the face of the cathode ray tube at a fairly rapid rate — usually 60 to 120 times per second. In addition, the visual curve is a continuous one that reveals the response of the circuits not at two kc intervals, but at all, or an infinite number of points. Because of this speed and continuity, the electronically drawn curve will instantly show the effects of any alignment adjustments that are made, whereas the point-by-point system requires that the response curve be laboriously replotted by hand after each such adjustment.

## 9. Frequency sweeping methods.

The point-by-point plotting system is necessarily slow because the frequency of the test oscillator must be moved manually from one end of the band to the other. In the visual alignment system, the frequency of the oscillator is no longer varied by hand but is, instead, varied electronically or mechanically at a relatively high rate of speed.

One early method of rapidly changing the frequency of the oscillator made use of a small electric motor which was connected to the shaft of the oscillator tuning condenser. Rotation of the motor then caused the frequency of the oscillator to vary at a speed dependent upon the speed of the motor. This early method of sweeping the frequency of a generator, although successfully used, has generally been replaced by less cumbersome methods. The two most popular methods used today are:

(1) Mechanical sweeps which vary the capacity or inductance of an oscillator circuit by means of moving parts;

(2) Electronic sweeps which use a reactance tube or tubes that have the property of acting as a variable capacity or inductance and which thereby vary the frequency of an oscillator.

Each of these types has its advantages and disadvantages, and these will be discussed later. In addition to these methods, there is a third frequency sweeping arrangement used in the new General Electric Sweep Generator which does not fall into either of the two popular categories. This instrument employs a rather unique variable reluctance principle which requires neither moving parts nor reactance tubes. The details of this system will also be covered later in this chapter. Still another method of frequency modulating an oscillator involves the use of klystron oscillator tubes whose frequency is varied by the application of an ac voltage to the repeller plates.

### 10. The mechanical sweep generator.

For purposes of explanation, we will examine in detail the simplest of these systems — the mechanical sweep. The basic circuit is shown in Figure 14-6.

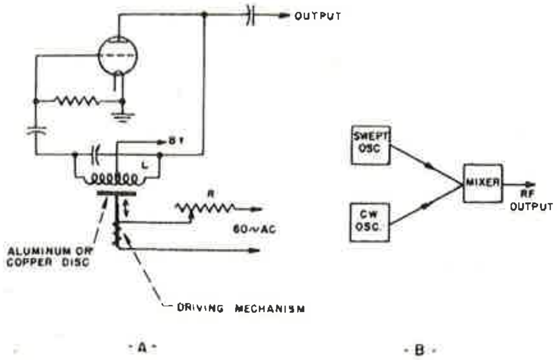


*Fig. 14-6. Basic circuit of mechanical sweep frequency generator.*

In this circuit the frequency sweep is achieved by varying the inductance of the oscillator's tuned circuits. A copper or aluminium disc, which is connected to a driving mechanism, is mounted in close proximity to the oscillator's coil L. When a 60 cycle a-c voltage is applied to the driving mechanism, the disc is alternately forced closer to and away from the coil. This changes the inductance of the coil, which in turn changes the frequency of the oscillator. The amount of frequency change or sweep can be controlled by varying the voltage applied to the driving unit. The voltage control, R, for the driver can be calibrated in terms of frequency sweep, but such a calibration will be only approximate. In practical form, the driving unit is quite often a conventional three to five-inch permanent magnet loudspeaker which has 60 cycle a-c passed through its voice coil. The disc is secured to the paper cone of the loudspeaker so that motion of the cone will move the disc. Although the practical design of this mechanism appears extremely simple, many design factors must be considered if it is to operate successfully and it is therefore not recommended that the technician undertake to construct a sweep generator of this type.

Because of the difficulty of obtaining sufficient sweeping range on the lower, commonly employed IF frequencies, the swept oscillator is usually operated at a frequency much higher than the IF. Its output is then mixed with a second oscillator, also operating at a high frequency, and the difference between the two oscillators is then used for IF alignment. In some instruments both oscillators are made tunable from the front panel to enable a wide range of output frequencies to be obtained. In practically every case, however, only one oscillator is frequency modulated, while the second oscillator operates as a straight, CW oscillator. The basic arrangement is shown in block form in part B of Figure 14-6.

### 11. Effects of sine-wave driving voltage.

Although it would seem that the frequency of the basic oscillator circuit in Figure 14-6 is varied at a 60 cycle rate, this is actually not the case. To understand why this is so, it is necessary to examine closely the functioning of the driver mechanism when the 60 cycle sine-wave voltage is applied to it. This voltage wave is shown in Figure 14-7. Since this voltage varies at a sine-wave rate with respect to time, it follows that the driver will change the oscillator frequency at this same rate. Point A represents the most positive excursion of the wave, and at this point the disc is at its maximum distance away from the inductance.* The frequency of the oscillator is now at its minimum point. One half cycle later, at point B on the voltage wave, maximum negative voltage is applied to the driver and this moves the disc in the opposite direction and places it very close to the inductance. The maximum frequency of the oscillator has now been reached. In other words the complete frequency sweep, from one end of the sweeping range to the other, has been accomplished in one half a cycle, from A to B on the voltage curve. Notice that during this time the frequency changed from minimum to maximum. On the other half of the cycle, from B to C, the entire range is again swept but this time the frequency changes from maximum to minimum.

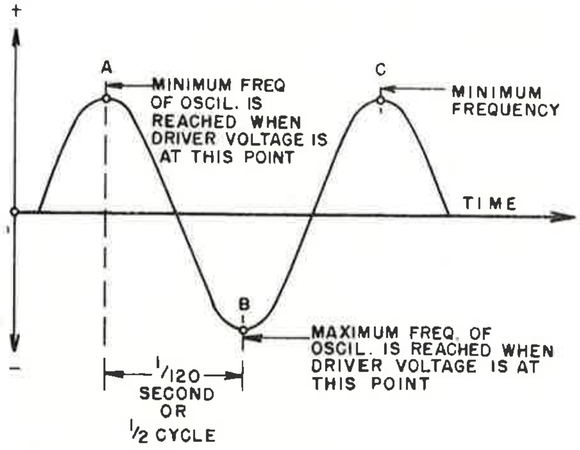


*Fig. 14-7. Frequency variation of sweep generator caused by sine-wave driving voltage.*

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* The actual direction in which the disc moves depends on how the coil in the driving mechanism is connected.

Thus, in one complete cycle, from A to C on the voltage curve, the frequency band is swept twice. When this type of sweep is used in conjunction with an oscilloscope, the first half cycle, from A to B, is called the trace, and the second half cycle, from B to C, is called the retrace. This condition of trace and retrace which occurs as a result of the sine-wave driving voltage must be taken into consideration when the operation of the entire visual system is analyzed. The student should therefore make certain he thoroughly understands this particular phase of sweep generator operation.

Although the time it takes to swing the frequency of the oscillator from one frequency extreme to the other is 1/120 of a second, the rate at which this frequency changes is not linear with respect to time.

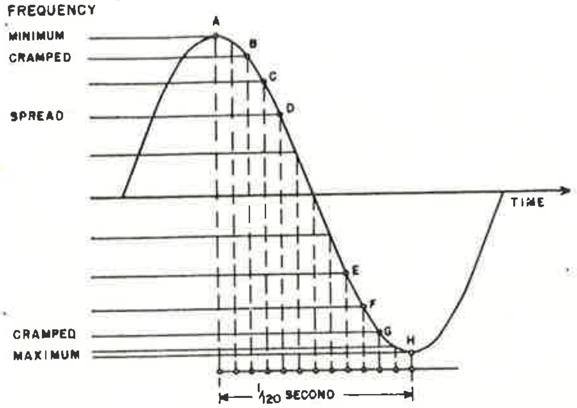

*Fig. 14-8. Non-linear rate of frequency sweep resulting from sine-wave driving voltage.*

This is shown by Figure 14-8. The one-half cycle of driving voltage, from point A to point H, has been divided into equal portions of time. The amount of frequency change for each of these time portions has been plotted vertically. Notice that the frequency divisions which result are by no means equal. Thus, during time A-B the frequency change is extremely small because of the shape of the sine-wave voltage between these points. The frequency change is greater between points B-C, and is even greater between C-D. Between points D-E the rate of frequency change is fastest because the sine wave is now almost a straight line. The rate of change then slows down again as points E-F, F-G, and G-H are reached. The effect of the sine-wave driving voltage, therefore, is to cramp the frequency at either end of the cycle and to spread it out at the middle of the cycle. This non-linear rate of frequency sweep (with respect to time) occurs with any sweep generator that employs a sine-wave voltage for driving, and this applies to mechanical, electronic and variable reluctance type sweep generators. Again, this characteristic plays an important part in the operation of the visual alignment system.

From the preceding discussion of the mechanical type sweep frequency generator we can summarize, as follows, the characteristics of any sweep frequency generator which uses 60 cycle sine-wave for driving:

(1) The frequency varies from one extreme to the other in 1/120 of a second.

(2) One complete cycle of sine-wave driving voltage causes the frequency of the oscillator to sweep from one end of the band to the other and then back again. This occurs in 1/60 of a second.

(3) The frequency of the oscillator varies at a sine-wave rate — not at a linear rate — with respect to time.

Because of characteristic (1), the radio frequency vacuum tube voltmeter obviously cannot be used as an output indicating device for alignment purposes when a sweep generator is employed. Such a meter, or any other meter for that matter, cannot indicate a voltage which changes amplitude at this rate of speed. For this reason it is necessary to use an oscilloscope. The electron beam which traces the pattern on the screen of the cathode ray tube of the oscilloscope has an extremely small amount of inertia, and it can therefore faithfully follow the rapid fluctuations of voltage which are produced when the sweep frequency generator is connected to a tuned amplifier for alignment purposes.

From our study of the point-by-point curve plotting method we learned that two sets of values are required to produce a response curve. The oscilloscope, likewise, must be supplied with two sets of values, or voltages, if it is to trace a response curve on its screen. The next logical step, then, is to study the exact manner in which these two voltages are applied to the oscilloscope and how they are combined to produce a response curve. In doing so, we will tie in the theory of the sweep generator covered in the preceding pages.

## 12. Horizontal deflection in the oscilloscope.

Basically, the oscilloscope is an electronic device which can show the relationship between two voltages. The indicating device is, of course, the electron beam which impinges upon the screen of the cathode ray tube and thereby produces light. This beam, when at rest, produces a very small, sharp spot of light on the screen of the tube. If the beam is moved up and down rapidly, persistence of vision (as well as the persistence of the tube face) blends the rapidly moving spot into a vertical line. Rapid horizontal motion of the beam, likewise, will produce a horizontal line. When the beam is simultaneously deflected vertically and horizontally, any variation between a horizontal line and a vertical line can be produced. The figure or curve so produced depends upon:

(1) The relative strength of the voltages applied to the horizontal and vertical deflection circuits of the oscilloscope;

(2) The relationship of the voltages to one another with respect to time — in other words, their phase.

It is important to note that an a-c or fluctuating d-c voltage must be applied to both the horizontal and vertical deflection circuits of the oscilloscope to produce a response curve of any kind. This is because the curve is traced out only as long as the electron beam remains continuously in motion. Steady d-c voltages will momentarily deflect the beam but they will not maintain it in motion, hence no figure will be produced on the screen of the cathode ray tube.

Nearly all oscilloscopes incorporate a linear sweep generator which deflects the beam horizontally at a uniform rate of speed with respect to time. In our study, however, we will consider not a linear horizontal deflection but, rather, a sine-wave rate of horizontal deflection. The reasons for this will become apparent when the sweep frequency generator and the oscilloscope are combined as a team.

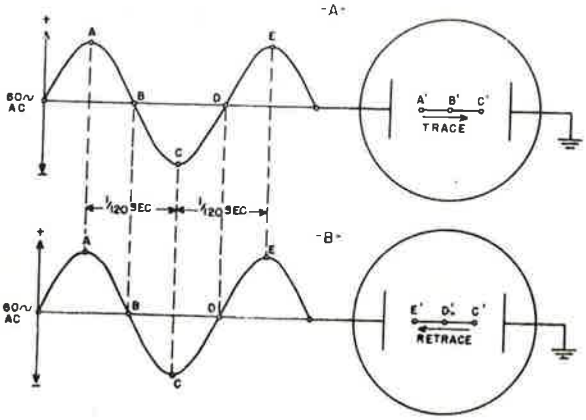

*Fig. 14-9. Effect of 60-cycle sine-wave voltage on horizontal deflection circuit of oscilloscope.*

Figure 14-9 illustrates the action that takes place when a 60 cycle sine-wave voltage is applied only to the horizontal circuit of an oscilloscope. In the upper drawing, at the particular instant when the sine wave is at point A, a positive voltage is applied to the horizontal plate of the cathode ray tube and this pulls the beam from its neutral position in the centre of the tube to the far left, as shown. As the sine-wave voltage varies from A to B, less positive voltage is applied to the deflection plate and this causes the spot to move back toward the centre of the tube. At point B, the voltage is instantaneously zero and the spot is therefore exactly in the centre of the screen because there is no voltage to deflect it. From B to C on the sine-wave, the voltage is changing from zero to a negative value and this deflects the beam from the centre of the screen to the far right to point C', as shown. Thus, on the first half of the cycle, from A to C, the beam is deflected from left to right.

The lower half of this illustration shows what happens on the other half of the cycle. At point C, the spot is at the extreme right, where we left it in the upper figure. Now, however, the voltage is changing from negative toward zero, or from C to D. This makes the beam move back toward the centre of the screen which it reaches at point D. Between D and E, the horizontal plate becomes more and more positive and this attracts the beam back over toward the left side of the tube to E'. On the second half of the cycle, therefore, the beam travels from right to left. In actual practice, it is not possible to distinguish between the movement of the beam from left to right and then right to left because the paths overlap and all we can see is a single horizontal line. For purposes of identification, however, the left to right movement of the beam is called the trace, and the right to left movement is called the retrace.

Sinct the voltage that is being applied to the horizontal circuit is, in this case, varying at a sine-wave rate, it follows that the beam in the cathode ray tube also moves at a sine-wave rate. That is, the speed of the spot is not constant with respect to time but, instead, varies as the shape of the applied voltage. This effect causes the beam to move more slowly at the edges than it does in the centre of the tube, as shown in Figure 14-10. This slower motion of the beam at the edges makes the ends of the horizontal line on the screen of the oscilloscope appear somewhat brighter than the centre.

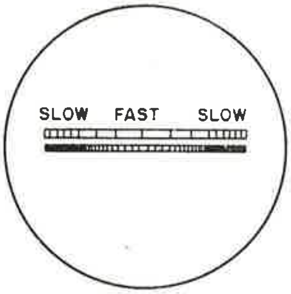

*Fig. 14-10. Bright edges on trace-retrace line.*

To summarise the effects of a 60-cycle sine-wave voltage applied to the horizontal circuit of the oscilloscope:

(1) The beam traces a complete horizontal line in 1/120 of a second.

(2) One complete cycle of voltage causes the beam to sweep horizontally from one side of the tube to the other and then back again.

(3) The beam moves horizontally at a sine-wave rate of speed — not at a linear rate of speed.

## 13. Frequency sweeping plus horizontal deflection.

You have, by this time, probably noticed several similarities between the effects of a 60-cycle sine-wave voltage on the sweep frequency generator and on the horizontal deflection circuit of the oscilloscope.

These similarities can be listed as follows:

(1) The frequency of the sweep generator varies at a sine-wave rate. The beam in the oscilloscope moves horizontally at a sine-wave rate.

(2) The frequency of the sweep generator varies from one extreme to the other in 1/120 of a second. The horizontal beam in the oscilloscope traces one horizontal line in 1/120 of a second.

(3) One complete cycle of voltage causes the sweep generator frequency to vary from one extreme to the other and then retrace. In the oscilloscope, one complete cycle causes the beam to trace one horizontal line and then retrace.

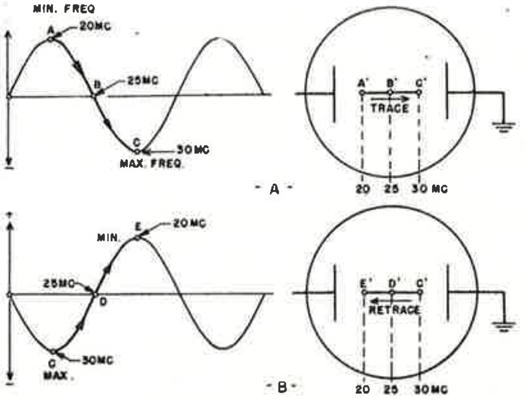

*Fig.* 14-11. *Synchronization of sweep generator frequency and horizontal deflection of oscilloscope.*

From this it can be seen that if the same source of voltage is used to sweep the generator frequency and the horizontal deflection circuit in the oscilloscope, the horizontal deflection on the oscilloscope will be synchronized to the frequency of the sweep generator. Figure 14-11 illustrates the synchronized action that takes place on the trace and retrace portions of the cycle when the same voltage source is used for both the oscilloscope and the sweep generator. Assume that the generator frequency is being swept from 20 to 30 mcs by the sine-wave voltage shown in Figure 14-11A. Assume also, that this same sine-wave voltage is being applied to the horizontal deflection circuit of the oscilloscope. At point A on the voltage curve the generator frequency is at a minimum, or 20 megacycles. The voltage at this point is maximum positive and this deflects the oscilloscope's beam to position A′ on the screen. That is, A′ on the oscilloscope corresponds to 20 megacycles. At B on the voltage curve, the voltage is zero and the centre frequency of the generator is reached (25 mc.). Zero voltage on the horizontal deflection circuit of the oscilloscope will not deflect the beam and at that instant, therefore, it will be in the centre of the tube, at B′. B′ on the oscilloscope, therefore, represents 25 megacycles. The maximum frequency excursion of the generator is reached at C (30 mc.) and this negative voltage also deflects the beam to the extreme right, to position C′ on the oscilloscope. Considering only the horizontal line on the oscilloscope, we can say therefore that this line represents a frequency scale because it is moved in unison with the frequency of the sweep generator.

On the second half of the cycle, shown in the lower part of Figure 14-11, the same action occurs, but this time the frequency of the generator is changing in the opposite direction and the beam is also moving in the opposite direction. On the retrace, therefore, we obtain a reversed duplicate or a mirror image of the condition encountered during the trace. It is interesting to note that the frequency divisions in the horizontal plane will be absolutely linear, even though a sine-wave rate of deflection is being used. This is because both the sweep generator and the oscilloscopes beam are being varied at the same rate of speed. Thus, when the rate of frequency change in the sweep generator is relatively slow (as is the case at the top of the sine-wave voltage curve) the horizontal deflection in the oscilloscope is correspondingly slow. Likewise, on the straight portion of the curve, when the frequency of the generator is changing relatively fast, the beam in the oscilloscope is also moving fast. Thus, the fixed relationship between frequency change and horizontal deflection results in linear divisions of frequency on both the trace and retrace portions of the cycle. This is shown in Figure 14-12. Observe, however, that this relationship will hold true only so long as the same voltage source is used for both instruments.* It is not essential, however, that this voltage be 60-cycle a-c. The system will operate just as well with 120 cycle saw-tooth voltage, for example, although the trace and retrace characteristics will not be the same as those described for 60-cycle sine-wave operation. Many technicians make the common mistake of using the internal saw-tooth (linear) generator in the oscilloscope for horizontal deflection in conjunction with a sine-wave driven sweep generator.

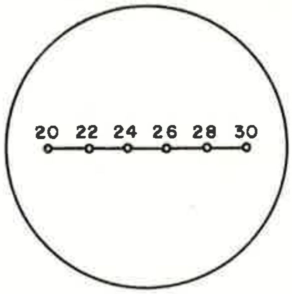

*Fig.* 14-12. *Linear frequency distribution on horizontal axis of oscilloscope.*

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* The voltage used to drive the sweep generator and the horizontal deflection circuit of the oscilloscope can be obtained from different sources, if necessary, but these voltages must have the same waveshape and they must also be directly or harmonically related in frequency.

Although the frequency of these two sources may be the same, the difference in their wave shapes will result in a distorted response curve.

The amplitude or strength of the voltage applied to the horizontal deflection circuit of the oscilloscope is unimportant so long as it is sufficient to produce enough deflection. The physical length of the horizontal trace has no direct bearing on the operation of the system because it always represents the total frequency sweep of the generator. Thus, the horizontal trace line might be two inches long in a small oscilloscope and four inches long in a large oscilloscope. In either case, the total length of the trace represents the total frequency sweep of the generator.

In practice, the a-c voltage applied to the horizontal deflection circuit of the oscilloscope is supplied by the sweep generator and this voltage is the same as that used to sweep the generator frequency.

## 14. Development of the response curve.

We have studied in the preceding pages the method by which the horizontal deflection of the oscilloscope is synchronized to the sweep generator so that it represents a frequency scale. The final step in the formation of the response curve on the screen of the oscilloscope is the application of a voltage to the vertical deflection circuit of the oscilloscope.

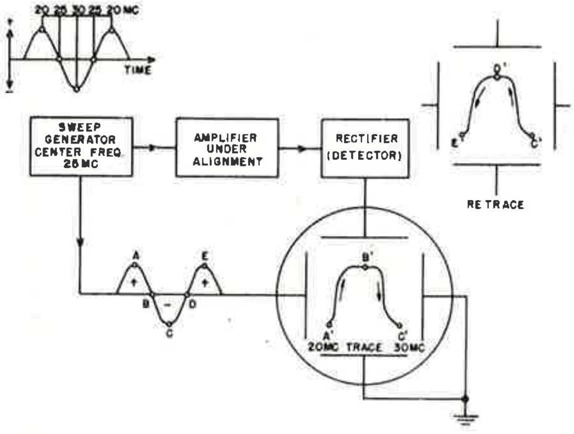


*Fig.* 14-13. *Development of the response curve.*

Since the horizontal deflection represents frequency, the vertical deflection must represent amplitude, or strength of output. This output voltage must be obtained from the output of the amplifier being aligned, just as we obtained an output voltage from the amplifier in the point-by-point plotting system. Figure 14-13 shows in block form how connections are made between the sweep generator RF output, the amplifier being aligned, and the vertical and horizontal deflection circuits of the oscilloscope. (Although the oscilloscope connections are shown directly to the vertical and horizontal plates for simplicity, in actual practice the amplifiers built in the oscilloscope are used to amplify the voltages before they are applied to the cathode ray tube plates.) Notice that the radio frequency output of the amplifier is not applied directly to the vertical circuit of the oscilloscope but, rather, is fed through a rectifier, or detector. This rectifier demodulates the varying radio frequency output of the amplifier and produces a d-c voltage which fluctuates at the sweep rate in proportion to the gain of the amplifier over the frequency band being investigated. Thus, as the sweep generator sweeps its frequency through the resonant circuits of the amplifier, the d-c voltage output of the rectifier will vary, depending upon the amplification characteristics of the amplifier. This varying d-c voltage, which represents the amplitude of the response curve, thus deflects the beam in the oscilloscope vertically while the a-c voltage applied to the horizontal deflection circuits simultaneously deflect the beam horizontally. In practice, an external rectifier is not required because the demodulated signal output can be taken from the receiver's second detector.

Referring to Figure 14-13, assume that the sweep generator dial has been set to a centre frequency of 25 megacycles and the sweeping range adjusted for a ten megacycle sweep — in other words, from 20 to 30 megacycles, or five megacycles either side of the centre frequency. Let us now follow the action which takes place as the 60-cycle sine-wave voltage simultaneously varies the generator frequency and deflects the cathode ray beam horizontally.

At the extreme positive half of the cycle, point A, the generator has been shifted to 20 megacycles. At that same instant, this same positive voltage on the horizontal plates of the oscilloscope pulls the beam to the extreme left of the screen to A'. Since the sweep generator is five megacycles away from the resonant frequency of the amplifier, amplification is very low and relatively little voltage is fed into the rectifier and the vertical plates of the oscilloscope. The vertical plates therefore have very little effect upon the position of the beam. Following the a-c cycle to point B, we find that the generator frequency is now 25 megacycles. At the horizontal plates of the oscilloscope, zero voltage is being applied and the beam is at the centre of the screen, horizontally. The sweep generator, however, is now at the resonant frequency of the amplifier, which means that maximum amplification is taking place and a relatively high d-c voltage is therefore applied to the vertical plates of the oscilloscope. This pulls the beam up to position B' on the oscilloscope. At point C on the sine wave the generator frequency is 30 megacycles, the response of the amplifier is again very low and consequently very little vertical deflection is obtained. The maximum negative voltage applied at this instant to the horizontal plates deflects the beam to the extreme right side of the screen to point C'.

On the other half of the cycle, from C to E, the same action occurs in reverse and the retrace produces an almost identical curve on the screen of the cathode ray tube, as illustrated in the upper portion of Figure 14-13.

Although we have touched on only three frequency points in describing the operation of the system, the actual response curve is made up of an infinite number of such points within the band of frequencies being swept by the sweep generator.

## 15. Effects of phase shift.

Because of slight phase shift effects,* the retrace portion of the curve may not follow precisely the trace path, and this will result in a separation of the curves, as shown in Figure 14-14. To correct this condition, most sweep generators incorporate a simple phasing control in the a-c supply voltage fed to the horizontal circuit of the oscilloscope. This phasing control is simply adjusted until the two curves merge into one.

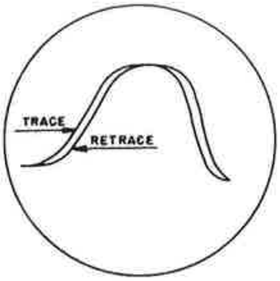
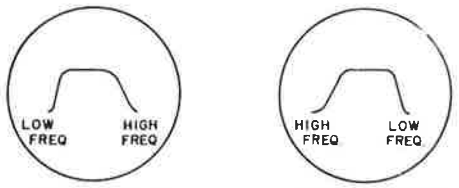


*Fig. 14-14. Effect of phase shift.*

## 16. Phase reversal.

It is standard practice in the visual alignment system to place the low frequency side of the response curve on the left side of the oscilloscope screen, as shown in Figure 14-15. Because of circuit arrangements in test equipment, the opposite condition is sometimes encountered when the equipment is set up and this can quickly confuse the inexperienced technician. Some sweep generators therefore incorporate a PHASE REVERSAL switch that reverses the phase of the voltage applied to the horizontal deflection circuit of the oscilloscope. The effect of this phase reversal is shown in Figure 14-15. In part A, the phase is correct and the low frequency side of the response curve is at the left of the screen. In B, however, the phase is reversed and the high frequency side of the response curve is at the left. By manipulation of the phase reversal switch either of these conditions can be obtained, although, as previously mentioned, usual practice places the low frequency at the left. So far as alignment is concerned, correct alignment can be carried out with either phase provided care is taken in properly identifying the frequency markers.



CORRECT PHASE

-A-

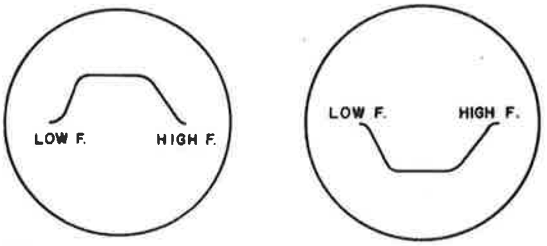
REVERSED PHASE

-B-

*Fig. 14-15. Effect of phase reversal.*

## 17. Polarity of output.

Thus far, in all the discussions and illustrations, we have assumed that the response curve has a positive polarity. That is, maximum amplitude is in an upward direction, as illustrated in Figure 14-16A. Quite often the polarity of the response curve is reversed, as shown in Figure 14-16B, and this effect can again confuse the beginner. Actually, either positive or negative polarity can be used in the alignment process, and the polarity obtained under alignment depends upon the particular point at which rectified output is taken from the receiver. Manufacturers' service literature shows either polarity in their illustrations and there are at present no hard and fast rules governing this because the polarity is bound to change with variations in alignment procedures. This should cause the technician no trouble because equally accurate results can be obtained regardless of the polarity of the curve on the oscilloscope.



POSITIVE POLARITY RESPONSE

-A-

NEGATIVE POLARITY RESPONSE

-B-

*Fig. 14-16. Effect of negative and positive polarity output.*

## 18. Retrace blanking.

Some of the more elaborate sweep generators are designed so that the RF output is cut off during the second half or retrace portion of the a-c driving voltage cycle. The effect of this retrace blanking is shown in Figure 14-17. The trace is produced in the usual manner, with the a-c sine-wave voltage sweeping the frequency from the low frequency to the high frequency limit during the first half of the cycle, from A to B. On the second half of the cycle, from B to C, however, the sweep generator RF output is cut-off or "blanked" so that it is zero, although this second half cycle of a-c voltage is still

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* Between the 60-cycle a-c voltage applied to the horizontal deflection circuits of the oscilloscope and that used to sweep the frequency of the sweep generator.

applied to the horizontal deflection circuit of the oscilloscope. With no RF output from the generator during the second half cycle, there will be no vertical deflection and the oscilloscope beam will therefore be affected only by the horizontal deflection circuit.

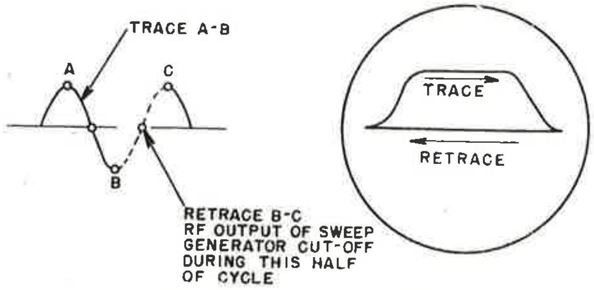

*Fig.* 14-17. *Effect of retrace blanking in sweep generator.*

The result is a straight line, or a base line, on the retrace, as shown. Retrace blanking, or simply blanking, as it is often called, is extremely useful during the alignment process because it produces a reference base line from which all critical vertical measurements can be taken. Without retrace blanking, the exact position of the bottom of the curve, or the base line, must be assumed. Retrace blanking also eliminates the split trace and retrace characteristic caused by phase shift. When blanking is employed, however, it is still necessary to first adjust the phasing control with blanking off for a merging of the trace and retrace, after which blanking can be turned on. If this is not done, phase shift will distort the response curve.

## 19. The marker generator.

As previously mentioned, either a marker generator or a calibrated, absorption-type wave trap can be used with the sweep generator to "mark" precise frequency spots on the response curve. Since the marker generator is the more popular of the two instruments in use today, we will discuss it first.

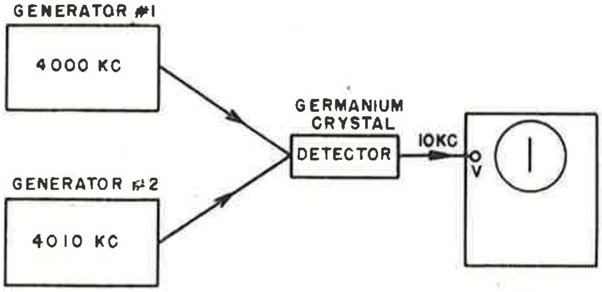

*Fig.* 14-18. *Development of an audio frequency beat note by mixture of two rf signals.*

In order to understand clearly the manner in which the marker generator makes a mark on the response curve, it would be well to review briefly the heterodyning principle by which it works. It is well known that when two radio frequency signals are combined or mixed, there will be developed two new frequencies which are equal to: (1) The sum of the original frequencies; (2) the difference between the original frequencies. A practical example of this is shown in Figure 14-18 where two r.f. signal generators have their outputs mixed or detected in a germanium crystal. If the generators are set to 4000 and 4010 kcs, respectively, there will be present at the output of the detector the sum of 4000 and 4010, or 8010, and the difference, 10 kc, or 10,000 cycles. Since operation of the marker generator nearly always involves the use of the difference signal between two radio frequencies, we will not consider further the sum frequencies produced in the mixing process.

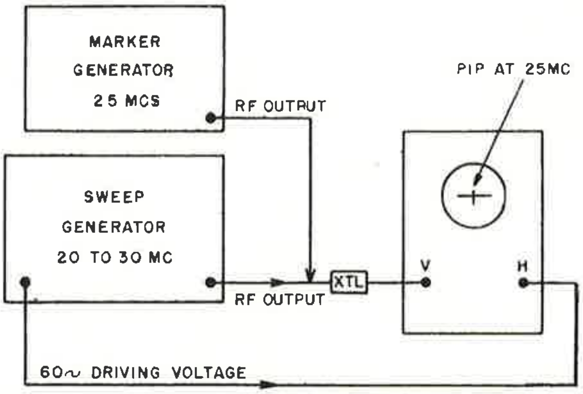

*Fig.* 14-19. *Connection of marker and sweep generator.*

If the output of the detector is now connected to the vertical deflection circuit of an oscilloscope and no horizontal deflection is used, the ten kilocycle beat note will trace a vertical line on the screen of the oscilloscope, as shown. Although the original RF signals as well as the sum signal may be present at the output of the detector, they will not add to the vertical deflection because the vertical amplifier circuits of most oscilloscopes are not capable of passing these high frequencies. In other words, it is the low frequency beat frequency difference between the two radio frequency signals that produces the vertical deflection.

The next step in the study of marker insertion is to replace one of the generators with the sweep frequency generator and make connections to the oscilloscope as shown in Figure 14-19. Notice that horizontal deflection is now provided by the a-c driving voltage from the sweep generator. As pointed out previously, the horizontal deflection so formed will actually be a frequency scale, the length of the horizontal line representing the total frequency sweep of the generator. The RF outputs of the sweep generator and the marker generator are again combined or detected in the germanium crystal and applied to the vertical deflection circuit of the oscilloscope. Assume that the sweep generator is sweeping from 20 to 30 megacycles and that the marker generator is set to 25 megacycles. As the sweep generator sweeps from 20 to 30 megacycles it must pass through the frequency of the marker generator 25 megacycles, and, as it does, a low frequency beat signal will be developed in the output of the detector. This low frequency voltage is fed to the vertical deflection circuit of the oscilloscope where it causes a small vertical mark or pip to appear at the point on the horizontal deflection line which represents 25 megacycles.

It might appear at first that the detector would continuously detect or demodulate the output of the two generators as well as their frequency difference and therefore always feed a demodulated signal into the vertical deflection circuits. This does actually occur, but if the generator RF outputs remain constant and the instantaneous frequency separation between the generators exceeds the frequency response characteristics of the oscilloscope, no vertical deflection will occur. As the sweep generator frequency passes through the marker generator frequency, however, a low frequency a-c signal equal to the instantaneous frequency difference between the generators is developed in the detector and vertical deflection therefore takes place at this low frequency rate. If the oscilloscope's vertical circuits respond only to very low frequencies, the marker or pip will be sharp, as shown in Figure 14-20A. If, however, the vertical circuits are capable of passing fairly high frequencies, the pip will become much broader, as illustrated in Figure 14-20B. Since it is desirable to have the pip as sharp as possible, the condition shown in B can be changed to that of A by connecting a suitable by-pass condenser from the vertical deflection input post on the oscilloscope to ground. This condenser will by-pass the higher beat frequencies developed during the time the sweep generator is approaching and passing the marker frequency, and this will narrow down the pip.

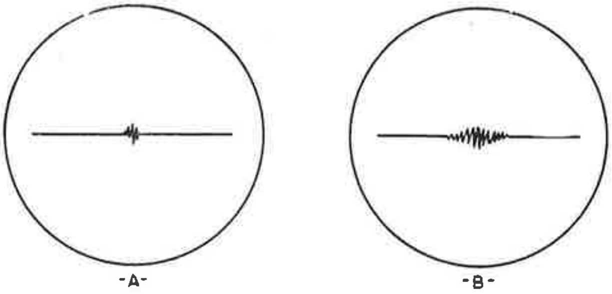

*Fig. 14-20. Effect of oscilloscope vertical response on marker pip.*

From a practical standpoint, the arrangement shown in Figure 14-19 will function as described only if the oscilloscope has high gain vertical amplifiers. The actual sweep width of the sweep generator can be quickly checked by this method, because it is only necessary to move the marker pip from one end of the trace to the other and observe the frequency difference between these two points on the marker generator frequency dial.

Figure 14-21 shows how the marker generator is used when visual alignment is carried out. In this case, the marker signal is fed into the amplifier together with RF output of the sweep generator and the beat frequency difference appears at the detector, together with the demodulated voltage which represents the amplitude characteristics of the amplifier. If too much output is fed from the marker generator into the amplifier, overload will occur in the amplifier and detector and the response curve will be pulled out of shape, as illustrated in Figure 14-22. It is therefore essential that the output of the marker generator be carefully controlled during the entire alignment process so that it never affects the actual shape of the response curve.

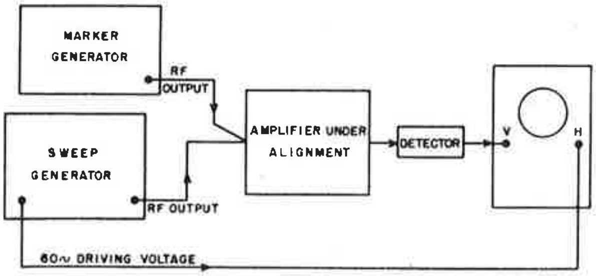

*Fig. 14-21. System of marker insertion.*

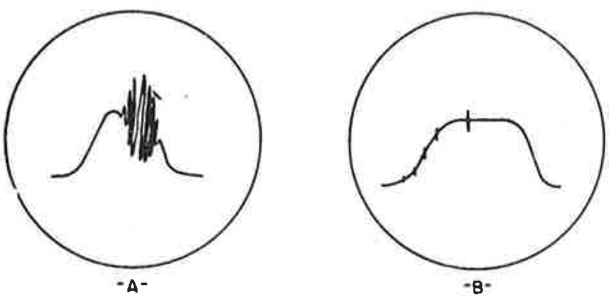

*Fig. 14-22. Undesirable marker pip condition.*

This system of marker insertion has one serious disadvantage in that the marker signal must pass through the tuned circuits being aligned. Thus, the amplitude or strength of the marker on the response curve will depend upon the gain of the amplifier at that particular frequency. If the RF output of the marker generator remains constant, it will be found that the marker pip is large on top of the response curve, but it will slowly decrease in amplitude as it is moved down the skirt of the curve until, when the base-line is reached, it will disappear. This is shown in Figure 14-22B; because of this characteristic the RF output of the marker generator must usually be varied as its frequency is moved around on the response curve, else overload may occur at the top of the curve or the pip may disappear before it reaches the bottom of the curve.

## 20. Improved method of marker insertion.

Because of the shortcomings of the system just described, there has recently been developed a unique and greatly improved method of producing marker pips on the response curve. This method has the advantage of not passing the marker generator RF output through the circuits being aligned and the markers developed are therefore entirely independent of the response characteristics of these circuits. This means that marker amplitude will not vary with the gain of the amplifier and makes it possible to place markers right down at the bottom of the response curve where the gain of the amplifier being aligned is zero.

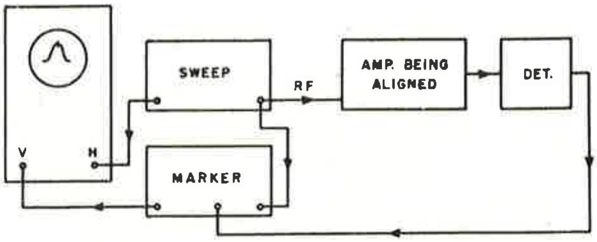

*Fig. 14-23. Improved system of marker insertion.*

Interconnections between the various instruments for this method of marker insertion are shown in Figure 14-23. RF output from the sweep generator is fed, as before, into the amplifier being aligned. A portion of this same output, however, is also fed into the marker generator. The low beat frequency difference between the sweep voltage and the marker voltage is detected in the marker generator and this marker voltage is then amplified and shaped by special marker amplifiers. The demodulated output of the amplifier under alignment is also fed into the marker generator where it is combined with the marker voltage and then applied to the vertical deflection circuits of the oscilloscope. Obviously, the marker generator in this case is of special design because it must do much more than merely furnish a single radio frequency signal.

## 21. Marker insertion with the absorption type wave trap.

In comparison to the marker generator, the absorption-type wave trap is an extremely simple device. It consists of a parallel-tuned resonant circuit capable of covering the sweeping frequencies used in the alignment process. This tuned circuit is loosely coupled (i.e., brought near the coils in the receiver) to the tuned circuits being aligned in the receiver, as shown in Figure 14-24. As the sweep generator RF signal sweeps through the resonant frequency of the trap, a small amount of power is absorbed by the trap at that particular frequency. This reduces the RF signal fed through the circuits in the receiver at that frequency and the result is a small, inverted notch on the response curve. The position of this notch on the curve will correspond to the resonant frequency of the wave-trap.

Since the notch rides on the response curve produced by the amplifier under alignment, its size will be affected by the gain of the amplifier, just as the marker pip was affected. Some provision must therefore be made to vary the wave-trap coupling because too much absorption will either distort the curve or make the marker too broad to be accurate, while insufficient coupling will cause the notch to disappear.

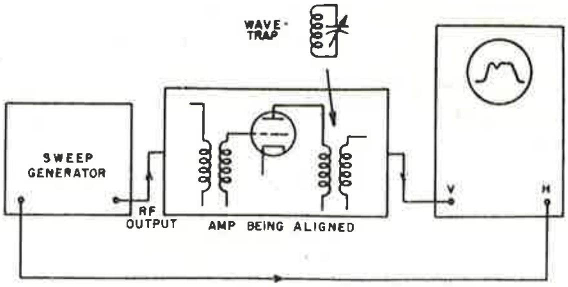

*Fig. 14-24. Use of wave-trap for marker insertion.*

The primary advantage of the absorption type wave-trap over the marker generator is that the former operates on the fundamental frequency only, whereas the generator may produce harmonics which often cause spurious pips to appear on the response curve. The wave-trap, however, can only be used on tuned circuits which have unshielded coils, because it is necessary to obtain electrical coupling by bringing the trap near the tuned circuits being aligned. This disadvantage is overcome if the trap is built into the sweep generator so that it can absorb power from the sweep before it is fed into the receiver.

## 22. Practical sweep generators.

As mentioned earlier in this chapter, the majority of television sweep generators commercially available make use of either a mechanical type sweep or a reactance tube sweep. Of these two systems, the mechanical sweep is by far the more popular. Although the reactance tube sweep was used extensively in the past in FM sweep generators, it has not been used too widely in TV generators because of the difficulty of obtaining a wide enough sweeping range. Most of the popularly priced TV sweep generators therefore use the mechanical system which was described previously in its basic form. If carefully designed, this system is capable of excellent performance, but it does have the disadvantage of requiring moving parts which are subject to mechanical fatigue and which quite often produce audible noise and vibration.

Regardless of the frequency sweeping method used, there are certain requirements which must be met if the sweep generator is to satisfactorily perform the alignment functions for which it was designed. These requirements are:

(1) High output;
(2) Constant output over the sweeping range;
(3) Wide sweep range;
(4) Good sweep linearity;
(5) Effective output attenuation and low leakage.

In addition, the generator must of course be capable of covering the various I.F. and R.F. frequencies found in the television receiver.

The first requirement, high output, is necessary because of the inherent low gain of individual RF and IF amplifier stages in the television receiver. If, for example, the generator has insufficient output on the fundamental frequencies used by television stations, it will be impossible to look at the response curve of a "front-end" alone because the detected output from these circuits will be too small to produce a response curve on even a high-gain oscilloscope. This same shortcoming would also make it impossible to examine the response characteristic of a single, broad-band IF amplifier. An RF output of at least .1 volt over the RF and IF frequencies is therefore required.

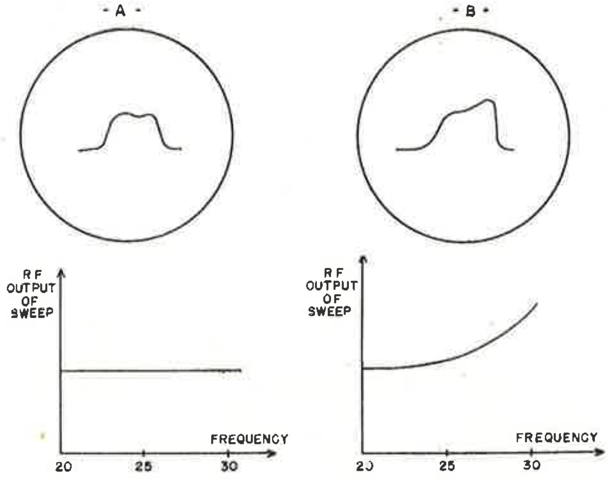

*Fig. 14-25. Undesirable effect of amplitude modulation in sweep generator.*

Requirement (2), constant output over the sweeping range, is essential if an undistorted response curve is to be obtained. Figure 14-25A shows the ideal condition in which the output of the generator remains absolutely constant over the range of 20 to 30 megacycles. The response curve shown in this portion of the drawing is a typical one which is obtained when the generator output is constant. In part B, however, the RF output of the generator rises sharply at the high frequency end and this causes more voltage to be fed into the amplifier under alignment at the high frequency end. This rise in output will distort the response curve from that shown in A to that shown in B. In other words, the response curve obtained under these conditions no longer represents the true response of the circuits being aligned. The natural tendency of the technician is, of course, to make adjustments on the amplifier until the peak of the response curve has been levelled off. Since in this case the peak is caused by the sweep generator and not the amplifier, misalignment will obviously result.

If the entire response characteristics of a single RF or IF stage are to be displayed on the oscilloscope, the sweep generator must be capable of sweeping ten megacycles and preferably fifteen megacycles. Failure to meet this requirement (3) means that it will be impossible to view the entire response curve, as shown in Figure 14-26, where the visible portions of the curve are shown as a solid line and the missing portions of the curve are dotted.

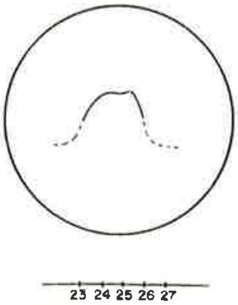

*Fig. 14-26. Effect of insufficient sweep width.*

Many sweep generators have sufficient sweep range but fail to meet requirement (4) which states that the sweep must be linear — that is, the frequency excursions on either side of the centre frequency to which the generator is set must be equal. Thus, setting the centre frequency to 25 megacycles and adjusting the sweep width control to ten megacycles should, in the ideal case, produce a sweep from 20 to 30 megacycles. Quite often, however, it will be found that the sweep excursion is much greater on one side of centre frequency than on the other, as shown in Figure 14-27. In this example the sweep is actually ten megacycles wide but the frequency distribution is not linear, because the generator covers only two megacycles on the low frequency side and then stretches out eight megacycles on the high frequency side. As a result of this condition, the low frequency side of the response curve will be chopped off, as illustrated. A simple method of actually measuring the frequency excursions of the sweep generator was shown in Figure 14-18.

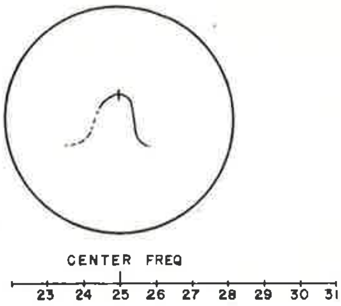

*Fig. 14-27. Effect of non-linear frequency sweep.*

The last requirement, (5), effective output attenuation, and low leakage, must be met so that the over-all response characteristics of the TV receiver from antenna terminals to the second detector can be examined without overloading the receiver circuits. If the output of the sweep generator cannot be reduced sufficiently, the overloaded circuits will produce a square-topped curve such as shown in Figure 14-28. It is usual practice, after alignment has been completed, to examine the over-all response of the receiver with the gain or contrast control "wide-open" in order to simulate weak-signal reception conditions. This test requires a relatively weak input signal from the sweep generator of 50 microvolts or less. Stray leakage and ineffectual attenuator circuits in the sweep generator will make this test impossible.

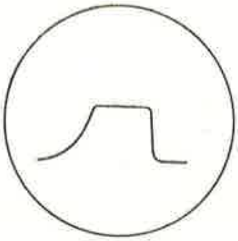

*Fig. 14-28. Typical response curve obtained from overloaded if amplifier.*

### 23. Practical marker generators.

In its simplest form, the marker generator consists of a stable, accurately calibrated signal generator, capable of covering the frequencies used during the alignment process. Although these basic requirements of stability and accuracy might appear to be easily met with a conventional AM test oscillator, a break-down of these requirements as applicable to TV alignment will show that this is not true. To enable precise visual alignment, the marker generator must possess the following characteristics:

(1) Dial calibration accuracy of ½ of 1% on all frequencies used.

(2) Low frequency drift after initial warm-up.

(3) Good mechanical stability; i.e., zero frequency shift when accidentally jarred.

(4) Zero frequency shift with changes in output loading.

(5) Output frequency not affected by line voltage variations.

(6) Zero mechanical and electrical backlash in dial mechanism to permit accurate frequency resetting.

(7) Effective output attenuation and low leakage.

Practically all conventional AM test oscillators fail to meet (1) and many others fail on one or more of the remaining counts. To examine (1) more closely, a dial calibration accuracy of ½ of 1% means that if the dial is set to, say, 20 megacycles, the actual frequency must be within 20 × .005, or 100 kilocycles. Furthermore, the dial must have a scale which is expanded enough to permit legible readings of 100 kilocycles in this frequency range. The average test oscillator is generally calibrated every one megacycle in this range of frequencies and it then becomes impossible to interpolate these divisions down to 100 kc. For this reason alone, the practice of using a standard AM test oscillator as a marker generator is not recommended.

For IF alignment only, the marker generator should cover a range of 20 to 50 megacycles so as to include the new IF band of 40 to 50 megacycles, as well as the presently employed band of 20 to 30 megacycles. A single marker frequency of 4.5 megacycles is also required for the alignment of audio IF channels of intercarrier type receivers. Although the second harmonic output of a 20 to 30 megacycle marker generator can be used on the new, high IF band, it should be remembered that the dial calibration and drift error as well as the frequency output are doubled when this is done. In addition, spurious response will often be created by various stray beats between the fundamental frequency output of the marker and the sweep generator and these will show up as unrelated pips or markers on the response curve.

Although the initial frequency calibration of the marker generator may be well within the tolerances specified, ageing of the equipment may cause this calibration to change, and it is therefore good practice to check the calibration periodically against a known frequency standard such as a crystal controlled oscillator. Such an oscillator should have high harmonic output and a frequency tolerance of .05% or better, to ensure accurate calibration at the higher harmonics in the 40 to 50 megacycle region. Some commercial instruments include such a calibration circuit as part of the complete marker generator.

When a marker generator capable of supplying only one marker at a time is used in conjunction with a sweep generator for IF and RF alignment, it is necessary to do considerable frequency resetting of the marker generator as alignment is carried out. This is because the response curve must be almost continually checked at more than one point. This problem can be simplified somewhat by using more than one marker generator, and setting each one to a different frequency. Another solution lies in the use of a crystal controlled modulator circuit which modulates the variable frequency marker and produces side-band markers which remain fixed in frequency with relation to the primary marker. This system is used in the General Electric Type ST5A Marker Generator which is to be described.

Although a stable, variable frequency oscillator can be employed as a marker generator for front-end alignment of TV receivers, practically all commercial equipments today use harmonics of accurately ground, low frequency crystals for this purpose. Such crystal markers are extremely stable and accurate and have the added advantage of requiring no tuning if used in a properly designed circuit.

## 24. Oscilloscope specifications.

Up to this point comparatively little space has been devoted to the operation of the oscilloscope because this instrument was used by many servicemen before the advent of FM and TV and its theory of operation should, therefore, be familiar to those who have practised radio servicing.

If the oscilloscope is to be used for visual alignment only, then the primary requirement is sufficient amplification in the vertical deflection amplifiers. The high frequency response characteristics of the vertical and horizontal amplifiers need not be particularly good because both of these circuits are supplied with low frequency a-c or fluctuating d-c voltages (usually 60 cycles). In order to correctly display these waveforms, however, it is essential that the vertical circuits of the oscilloscope have good low frequency response. This low frequency response does not have to be flat down to the extreme limits but it should be capable of passing four or five cycles per second, at reduced amplification, otherwise the response curve obtained will be distorted. The high frequency response of the vertical circuits should be at least ten times the frequency of the waveform to be observed. Since in most visual alignment operations the vertical circuits are fed with a fluctuating d-c voltage that varies at a 60-cycle rate, the response should be flat to at least 600 cycles. This figure can be met by almost any oscilloscope. The vertical amplifier should have a sensitivity of at least .05 volts RMS per inch. This means that with the gain of the vertical circuit at maximum, a voltage of .05 volt applied to the vertical input circuit terminals will deflect the beam vertically one inch.

Since the horizontal circuits in the oscilloscope must pass only a sinusoidal 60 cycle voltage, its frequency response requirements are even less critical than the vertical circuit.

If the oscilloscope is to be used for the examination of waveforms in the horizontal and vertical scanning circuits of the TV receiver, as well as for visual alignment, the requirements of the vertical amplifier in the oscilloscope become more severe. In addition to high sensitivity, the vertical circuits must also have an extended high frequency response to at least 500 kilocycles and preferably to several megacycles. To prevent heavy loading of the TV scanning circuits when their performance is checked on the oscilloscope, the input impedance of the vertical circuit should be as high as possible and the capacitance shunting should be extremely low. Typical figures for a good oscilloscope are one megohm input impedance shunted by 10 mmfd. Many oscilloscopes, in order to reduce the input capacity, include a special probe to be used in the examination of circuits which cannot be heavily loaded.

Although not essential, an internal source of calibrated voltages which can be used to calibrate the vertical deflection sensitivity of the oscilloscope is a useful adjunct, especially when checking waveforms in the deflection circuits of the TV receiver. Such calibrating voltages enable the technician to determine the peak-to-peak amplitude of the waveform being measured without the use of an external voltmeter or calibrator.

Generally speaking, the horizontal circuits of nearly all oscilloscopes have adequate sweeping ranges for waveform checking. The highest sweep frequency used in the oscilloscope for deflection circuit tests is usually half the horizontal scanning frequency, or roughly eight kilocycles. If the oscilloscope is to be used for visual alignment, the horizontal input circuit must include a switching arrangement whereby the internal saw-tooth generator can be disconnected to permit the application of the external horizontal deflection voltage from the sweep generator.

If the electrical specifications set forth above can be met, the size of the cathode ray tube employed in the oscilloscope is a secondary consideration. Either a three inch or a five inch tube is satisfactory, although the five inch tube is preferable from the standpoint of comfortable viewing.

## 25. Miscellaneous test equipment.

Additional equipment required for TV alignment and service operations includes a good quality vacuum tube voltmeter, a 20,000 ohm per volt multimeter, and a high voltage multiplier for the latter instrument.

The VTVM should have an external radio frequency type probe to permit a-c voltage measurements in the RF, IF and video amplifier circuits. The d-c input impedance should be as high as possible — ten megohms or greater, so that lightly loaded circuits such as grid bias points can be measured without altering the circuit operating conditions. The D-C voltmeter range of the VTVM should go to at least 300 volts and should also have a low range scale of 0-3 volts.

The multimeter is required for service checks of a-c and d-c voltages and currents, as well as for resistance measurements. Since the maximum range of this instrument is generally 1000 volts, an external multiplier probe should be available to extend this range to approximately 15,000 volts. This range will enable the measurement of all picture tube second anode voltages with the exception of projection type tubes.

## 26. General-Electric television test equipment.

The three instruments to be described were designed as a co-ordinated team for the alignment and servicing of all types of television receivers. Although created primarily for laboratory work, this equipment represents the ultimate for large service shops where accuracy and speed of alignment are essential. The three units to be discussed are the Type ST4A Sweep Generator, the Type ST5A Marker Generator, and the Type ST2A Oscilloscope.

The ST4A Sweep Generator does not use either reactance tubes or the mechanical type sweep, but instead, employs the variable reluctance principle to vary the frequency of an oscillator's tuned circuit. The basic circuit arrangement is shown in Figure 14-29. The oscillator coil, $L_2$, is wound on a powdered iron core which is placed between the pole pieces of a laminated iron reactor, $L_1$. The reactor has 60 cycle voltage fed through its winding and the resulting change in flux varies the permeability of the powdered iron core. This permeability change causes the inductance of $L_2$ to alternately increase and decrease, which, in turn, varies the frequency of the oscillator. By varying the amount of 60 cycle voltage applied to the reactor, the sweeping range of the oscillator can be controlled from approximately 500 kilocycles to more than 15 megacycles. Other features of the instrument include retrace blanking, phase reversal switch and phase control, and extremely low amplitude modulation.

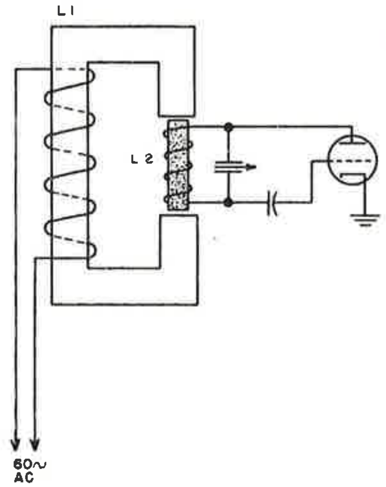

*Fig. 14-29. Basic circuit used in GE variable reluctance sweep generator.*

The complete specifications are listed below:—

FREQUENCY RANGE — Continuously variable from 4 to 110 mc and 170 to 220 mc in two bands.

SWEEP WIDTH — Linear from 500 kc to more than 15 mc.

OUTPUT VOLTAGE — Greater than 0.1 v. from 4 to 110 mc. Greater than 0.5 v. from 170 to 220 mc.

OUTPUT ATTENUATION — Continuously variable from maximum to 20 microvolts.

LEAKAGE — Stray fields less than 10 microvolts as measured by a two-inch pick-up loop six inches from the case in any direction.

OUTPUT IMPEDANCE — 20 to 60 ohms, depending upon setting of attenuator.

The ST5A Marker Generator was designed as a companion unit to the ST4A Sweep Generator. The marker frequencies generated in this instrument are not fed through the circuits under alignment, but rather, are super-imposed on the receiver output response curve. This makes the markers entirely independent of the response of the tuned circuits, and enables marker display on the base line of the response curve where the actual gain of the circuits is zero. In addition, a unique crystal modulator circuit is used whereby the fundamental marker frequency can be modulated by either a 1.5 mc or 4.5 mc crystal to produce as many as five crystal controlled markers on the response curve.

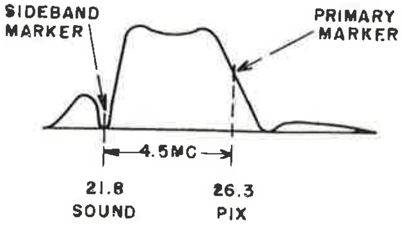

*Fig. 14-30. Generation of sideband marker by means of 4.5 mc. modulation.*

For example, assume that the marker generator has been set to 26.3 mc., which places a pip on the response curve shown in Figure 14-30. If the 4.5 megacycle modulation is now introduced, sideband markers 4.5 mc. away from 26.3 will be generated. If the 26.3 marker corresponds to the picture carrier, then the sideband marker 4.5 mc. removed (or 21.8) corresponds to the sound carrier, because by FCC definition the sound and picture carriers of any television station are always separated by 4.5 megacycles. The same crystal can also operate at 1.5 mc. intervals from the picture carrier to supply simultaneously markers spaced at 1.5 mc. intervals from the picture carrier for determining band pass and adjacent channel response. Thus, only one marker generator dial setting is required for complete IF alignment. The crystal can also be used to calibrate the tunable IF marker oscillator. Other specifications of this instrument are as follows:—

FREQUENCY RANGE — 15 positions selector switch selects 12 crystal controlled frequencies for picture carrier, plus three tunable IF ranges: 19-27 mc; 27-37 mc; and 37-50 mc. Crystal accuracy .02%, IF range accuracy .5%.

CRYSTAL MODULATOR — Single crystal ground to operate at the fundamental or third mechanical mode depending upon tuned circuits selected. This provides markers at 4.5 mc. or 1.5 mc. as well as high harmonic 4.5 mc. for dial calibration.

The ST2A oscilloscope features high vertical deflection sensitivity, excellent frequency response characteristics, external, low capacitance probe, and built-in calibrating voltage sources. Other specifications are listed below.

INPUT IMPEDANCE (VERTICAL) — AC — 1 megohm shunted by 36 $\mu\mu$fd.
DC — 1 megohm shunted by 80 $\mu\mu$fd.
Probe — 1 megohm shunted by 10 $\mu\mu$fd.

FREQUENCY RESPONSE (VERTICAL) — +0%-50% from 20 cycles to 1 megacycle with gradual reduction in response beyond 1 megacycle.

SENSITIVITY (VERTICAL) —
AC — .015 V. RMS per inch.
DC — 2.0 V. DC per inch.
Probe — .2 V. RMS per inch.

HORIZONTAL SWEEP RANGE — 10 cycles to 100 kilocycles in six ranges.

CALIBRATING VOLTAGES — Seven AC voltages of power line frequency; .3, 1.5, 3, 15, 30, 150 and 300 volts with 15% accuracy.

## 27. Alignment sequence.

Because of the many circuit variations encountered in modern TV receivers, it is impossible to list a step-by-step alignment sequence which will hold true for all receivers. For this reason, the service technician should always consult the manufacturer's service notes on the particular receiver he is planning to align. In many cases, the sequence of operations must be strictly adhered to because of circuit interactions. Departure from the recommended procedure will, in these receivers, result in improper alignment. In general, however, the following sequence is followed for the alignment of conventional receivers:—

(1) Sound I.F.
(2) Sound and Adjacent channel traps.
(3) Video I.F.
(4) 4.5 mc. Sound-Trap (if used).
(5) Front-End.

The following order is usually followed for the alignment of intercarrier sound receivers:—

(1) Video I.F.
(2) Adjacent channel Traps.
(3) Sound-Traps (if used).
(4) Sound I.F. (at 4.5 mc.).
(5) Front-End.

It should not be assumed from these listings that every receiver that is serviced requires complete alignment. In most instances, a quick operating check will show whether the receiver requires alignment and quite often, a touch-up of one or two trap circuits or audio I.F. transformers is all that is required.

Experience has shown that it is rare indeed to encounter a television receiver in which all the tuned circuits require alignment (unless it has been tampered with by unauthorised persons). Yet, many inexperienced technicians often assume this to be the case and spend many unnecessary hours realigning an entire receiver, whereas all that may actually be required is the readjustment of one trap circuit.

## 28. Symptoms of poor alignment.

In general, a television receiver will not drift out of alignment overnight, or even over a period of many months. If the receiver has been performing satisfactorily and then suddenly fails, the chances are that the failure is caused by some defective component rather than by a change in alignment. Nearly all the alignment adjustments made on a TV receiver, if properly locked after manipulation, will hold their adjustment over long periods of time. Usually, after the receiver has been in operation over a period of a year or more, the effects of heat, humidity, dust, etc., may cause the receiver circuits to slowly change their resonant characteristics, and if this gradual change continues, the receiver will eventually require realignment of some of its circuits. Because of the broad-band characteristics of the RF and IF tuned circuits, slight changes in the components that make up these circuits will often have no effect on the overall operation of the receiver. As is to be expected, sharply tuned circuits such as audio I.F. traps, adjacent channel traps, carrier set traps, etc., are more critical with respect to slight changes in component tolerances, and these circuits should therefore always be checked first and adjusted, if necessary, before the rest of the circuits are realigned.

The usual symptoms of poor trap alignment in the conventional receiver are: (1) weak or distorted sound; (2) sound bars in picture; (3) fine grains in picture; (4) poor picture detail; (5) poor tracking of sound and picture. Conditions (1) and (2) can be caused by poor alignment of sound rejection or take-off traps in the video I.F. circuits. Occasionally, maladjustment of an adjacent channel trap will permit the audio signal from an adjacent channel station to filter into the video I.F. circuits, and this will produce the same symptoms. A fine graininess in the picture (3) can be caused by poor alignment of the 4.5 megacycle sound-trap in the video amplifier circuit. In those receivers which employ a trap to set the picture carrier at the 50% point on the I.F. response curve, maladjustment of this trap can cause condition (4). Naturally, there are many other defective conditions and external interferences which can produce the same symptoms, but this should not prevent the technician from first checking the trap circuits.

Because of differences in circuit arrangement, some of the trap circuits used in the intercarrier type receivers are not as critical as those found in the conventional set. Sound take-off traps, if used, are tuned to 4.5 megacycles, and are therefore relatively stable compared to sound-traps tuned to the 20 megacycle region. Adjacent channel traps will have the same characteristics in the intercarrier receiver as they have in the conventional set, and this also applies to 4.5 megacycle sound traps connected in the video amplifier circuits of some of the later model intercarrier sets. Probably the most critical adjustment in most intercarrier receivers is the secondary adjustment of the ratio detector transformer used in the 4.5 megacycle sound channel. If this circuit is not correctly set, the amplitude modulation appearing on the 4.5 megacycle sound carrier will not be removed completely, and this will cause a sharp buzz in the audio output of the receiver.

Poor alignment of the front-end circuits in the TV receiver (conventional and intercarrier) will generally show up in the form of poor picture detail or poor sensitivity. Quite often, the RF amplifier and mixer circuits can be off considerably without too seriously affecting the performance of the receiver, and the only positive check that can be made is to examine the response curve of the front-end by the visual alignment method. If the local oscillator in the front-end is too far out of alignment, it may be impossible to properly tune in the picture or sound. This will usually show up on only one channel unless incremental* type inductances are used, in which case several channels may be misaligned.

In many instances, defective tubes or improper antenna installations will produce symptoms identical to those caused by poor R.F. or I.F. alignment. (Poor picture detail, low sensitivity, distorted sound.) The possibility of these defects should always be investigated and corrected, if necessary, before poor alignment is judged to be the cause of the trouble.

### 29. Alignment preparations.

Although it is sometimes possible to "touch up" one or two trap circuits in a TV receiver by removing the back and reaching into the cabinet, in most cases the chassis must be removed from the cabinet and placed on a work-bench during alignment. If the picture tube is part of the chassis, it should be removed and stored in a safe place to prevent possible breakage and injury to the technician. Generally, removal of the picture tube will not upset the operation of any of the circuits to be aligned unless the receiver has the heaters of its tubes connected in series.

If the receiver employs a transformerless type power supply, do not connect it directly to the power line. Use an isolation transformer! Failure to observe this precaution may ruin your test equipment.

Receivers which employ A.G.C. (Automatic Gain Control) often require the connection of an external bias battery to the IF circuits during alignment.

This is because the bias for the IF tubes which is normally developed by the TV signal is not generated during alignment. The amount of external bias voltage required and points of connection are always specified in the manufacturer's service notes and these recommendations should be followed exactly.

Before proceeding with alignment, the receiver and test equipment should be permitted to warm up for fifteen or twenty minutes.

### 30. General alignment precautions.

(1) Before aligning, make sure the receiver is in otherwise good operating condition.

(2) Always follow the manufacturer's recommendations. Do not attempt to use short-cuts in an effort to save time.

(3) Be sure all the receiver operating controls are set to their recommended positions before starting alignment.

(4) Use proper alignment tools. These should include an insulated hex wrench and screwdriver for mica trimmer adjustments and a narrow-shanked screwdriver for slug adjustment.

(5) Do not try to force adjustments which have been locked with cement. Use acetone or a similar thinner to soften the cement first.

(6) Make sure the output cable of your sweep generator is properly terminated. Consult your test equipment instruction book for this information.

(7) Make all ground leads as short as possible, especially when working near the head-end circuits. Follow the manufacturer's recommendations regarding location of ground leads on specific points on the chassis.

(8) Remember that intermediate frequencies of 20 to 30 megacycles and 40 to 50 megacycles are much more critical with respect to lead dress than 455 kc! Make the connections from your test equipment short and use the recommended isolation resistors and condensers in series with these leads.

(9) When aligning IF's, be sure the front-end is not influencing the response curve. To prevent this, switch to a channel where no interference is noticed.

(10) Do not overload circuits by applying too much signal input. If in doubt, use just enough signal from the sweep generator to obtain a response curve.

### 31. Alignment hints.

Occasionally, because of circuit interaction in the receiver, the response curve obtained on the oscilloscope will jitter vertically. This is sometimes caused by the vertical scanning circuits in the receiver and can be remedied by temporarily removing the vertical oscillator or vertical output tubes.

Another interference condition sometimes encountered is modulation of the response curve by the horizontal scanning frequency from the receiver.

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* An incremental inductance is a tapped coil. See GENERAL ALIGNMENT PROCEDURE-FRONT END, for details.

This will produce an effect similar to Figure 14-31 in which a muddy, indistinct response curve is obtained. Here again, the remedy is to temporarily disable the horizontal output circuit. It is generally not a good idea to remove the horizontal oscillator tube because this may sometimes remove the bias on the horizontal output tube and cause it to burn up in time. The bias developed by the horizontal oscillator is also sometimes used for IF and RF stages.

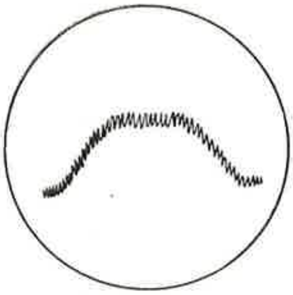


*Fig. 14-31. Modulated IF response curve.*

Improper termination of the sweep generator output cable or improper grounding of the equipment can be checked by grasping the cable and watching the response curve. A change in the shape or size of the curve as this is done indicates that standing waves exist on the cable and this must be corrected before alignment is attempted. If an external terminating resistor is used at the end of the sweep generator output cable, be sure it is a non-inductive carbon type, and not a wire-wound. If the output cable termination is correct, additional ground straps may be required between the receiver and sweep generator. These ground straps should be as short and heavy as possible.

Shielded cable should always be used between the output of the receiver and the vertical deflection terminals of the oscilloscope to prevent stray noise and signal pick-up. Connections between the sweep generator and the horizontal terminals of the oscilloscope should also be made with shielded cable, for the same reasons.

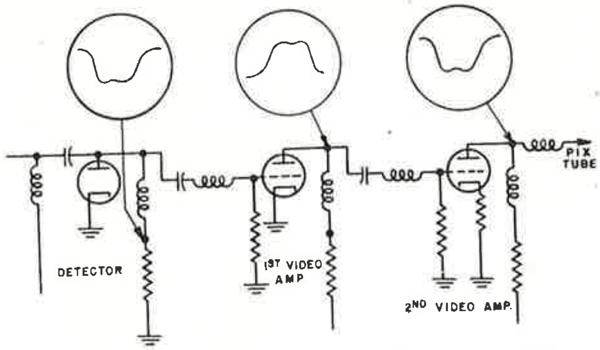
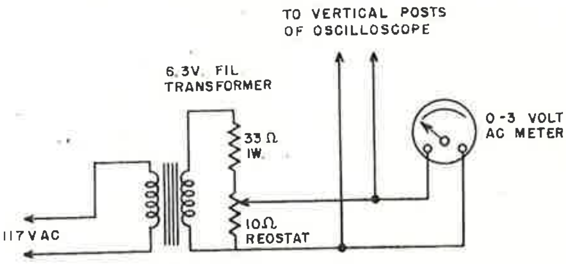


*Fig. 14-32. Polarity change in video IF amplifier.*

Although output from the receiver is nearly always taken from across the load resistor in the detector circuit, it is sometimes advantageous to take the output from one of the video amplifier stages following the detector. These stages will amplify the response before it is applied to the oscilloscope and this amplification is useful in cases where the oscilloscope does not have sufficient gain to display a large response curve on the screen. It must be remembered, however, that the polarity of the output signal will change each time it passes through an additional amplifier stage, as shown in Figure 14-32. Occasionally, low frequency phase shift in these amplifier stages will cause the response curve to be tilted up on one side slightly and this effect may be serious enough in some instances to make it impossible to determine the exact characteristics of the curve. In this case, output must be taken from the second detector.

Many inexperienced technicians make the mistake of feeding too much signal from the sweep generator into the circuits being aligned. If these circuits are overloaded, the effects of the alignment adjustments may not show up on the response curve and this, of course, leads to much confusion. A quick check for over-load is to increase the output of the sweep generator and watch for a corresponding increase in the vertical size of the response curve on the oscilloscope. If the response curve size increases only slightly or flattens out at the top when this is done, over-loading is taking place. The obvious remedy is to decrease the output of the sweep generator and then increase the vertical gain of the scope so as to bring the response curve back to its original size on the screen. For best results, the manufacturer's recommendations regarding the signal output to be maintained at the second detector should be followed. (This voltage is generally in the neighbourhood of one to three volts, peak-to-peak.) In other words, the output of the sweep generator is varied during each step in the alignment process so that the output of the detector and hence the vertical size of the response curve remains constant. If this is to be done, the vertical amplifier in the oscilloscope must first be calibrated for the peak-to-peak output recommended. After this, the vertical gain control on the oscilloscope is left alone and the size of the response curve (vertically) is controlled by varying the output of the sweep generator.



ADJUST RHEOSTAT UNTIL METER READS .35 OF PEAK TO PEAK VOLTAGE DESIRED.
EXAMPLE: 1 VOLT, PEAK TO PEAK DESIRED.
METER READING SHOULD BE .35 X 1 OR .35 VOLT

*Fig. 14-33. Oscilloscope calibration circuit.*

## 32. Calibrating the oscilloscope.

The vertical amplifier in any oscilloscope can be easily calibrated by means of a variable source of ac voltage and an accurate low range ac meter. The components and hook-up are shown in Figure 14-33. To calibrate the scope, first turn its vertical gain control to zero and adjust the rheostat to the correct voltage reading on the ac meter. Then slowly increase the vertical gain control until the vertical deflection fills approximately three-quarters of the screen. Leave the gain control set at this position and do not change its setting again during the alignment process. If the response curve is too small or too large vertically, adjust its size by increasing or decreasing the output of the sweep generator. In this way, the output of the second detector will have to remain approximately constant.

## 33. General alignment procedure — IF circuits and traps.

Practically all television receivers are aligned by a step by step process, starting from the last tuned circuit nearest the audio or video amplifier and working forward toward the front end. Shown in Figure 14-34 is the general procedure used for the alignment of video IF stages.* The oscilloscope remains connected to the picture second detector and the sweep generator is moved forward. Thus, the effect of each additional stage can be observed as the alignment progresses. Alignment instructions usually show the response curve that should be obtained at each step and it is therefore only necessary to adjust each tuned circuit until the response curve on the oscilloscope duplicates the published curve. Critical frequency points on the curve are indicated by marker pips in the service notes and these frequencies are checked on the actual response curve by means of the marker generator. The primary requirements in the video IF are proper bandwidth, fairly flat response, and correct location of the picture carrier on the high frequency slope of the curve, and proper attenuation of the sound carrier.

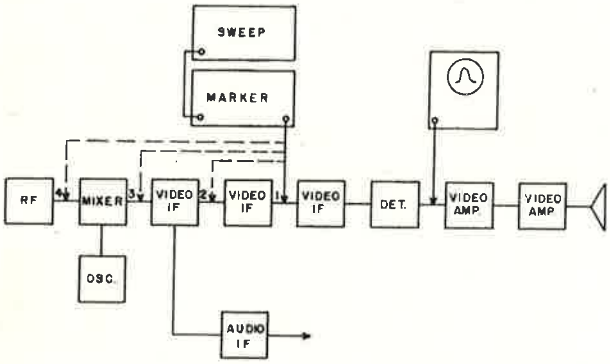


*Fig. 14-34. Typical video IF alignment procedure.*

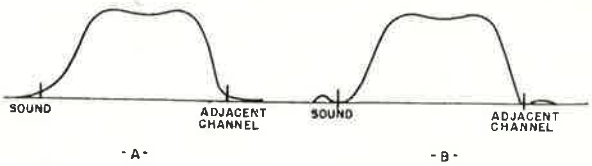


*Fig. 14-35. Effect of improper trap adjustment on IF response curve.*

Sound rejection and adjacent channel traps can be aligned along with the IF circuits if the alignment equipment uses the internal marker mixing system that permits display of markers on the base line of the response curve. This is done by tuning the marker generator to the trap frequency and then adjusting the trap until the amplitude response at that point on the curve is at a minimum. Figure 14-35 illustrates in part A the condition which may be encountered if the sound and adjacent channel traps are not properly aligned. Part B shows correct alignment of the traps. Notice that in this case, the response of the curve at the sound and adjacent channel frequencies is at a minimum; that is, the markers are now directly on the base line, which means that the traps are correctly rejecting these frequencies.

If the marker equipment is not capable of showing markers on the baseline, as is the case when the marker signal is fed through the receiver's tuned circuits, a different method of trap alignment should be used. One such method uses an amplitude modulated signal generator which is connected to the grid of the stage preceding the trap, as shown in Figure 14-36. If trap #4 is a sound-trap to be adjusted at 21.8 mc, then the AM generator is set to produce an AM signal at 21.8 mc and connected to point A.

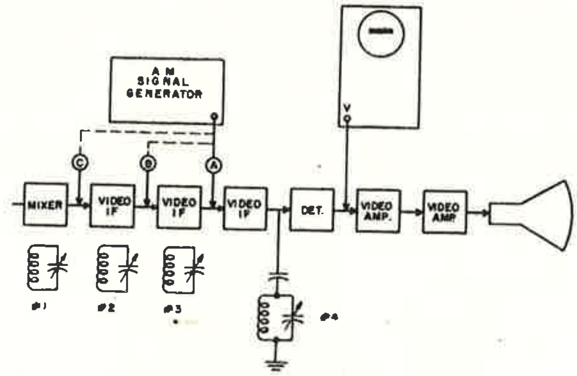


*Fig. 14-36. Trap alignment with an AM generator.*

The oscilloscope is left connected to the second detector and the trap is simply adjusted for minimum modulation response as shown by the oscilloscope. To align trap #3, the AM generator is set to the rejection frequency of this trap and connected to point B, after which this trap is again adjusted for minimum response on the oscilloscope. This procedure is followed right up to the mixer stage until all the traps have been adjusted to their proper frequencies.

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* This applies to both conventional and inter-carrier receivers.

Sound IF circuits in the conventional receiver can be aligned with an AM signal generator and high resistance voltmeter, or the visual method can be used. If the first method is used, the voltmeter is generally connected across the limiter grid resistor. The AM generator is adjusted to produce an unmodulated signal at the sound IF, and is fed into the first stage, as shown in Figure 14-37. The IF transformers are then adjusted for maximum meter reading. The discriminator transformer is aligned by feeding in at the same point an amplitude modulated signal and detuning the secondary slightly until the modulation note is heard in the loudspeaker. The primary is then adjusted for maximum tone output, after which the secondary is adjusted for minimum output. Detuning the secondary slightly either way should increase the sound output from the loudspeaker and this test should be made to insure that the secondary is tuned to the zero centre point rather than off to one side. The final adjustment should, of course, be made for minimum output at this centre point.

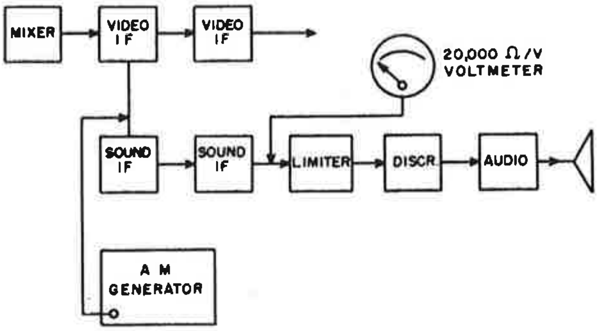

*Fig. 14-37. Sound IF alignment with AM generator.*

When the visual method is used for sound IF alignment, the sweep and marker generator are fed into the input sound stage and the oscilloscope is first connected across the limiter grid resistor. The IF stages are then aligned for the proper response curve. The oscilloscope is then connected to the output of the discriminator and the discriminator transformer is aligned for the familiar "S" shaped response curve. It should be remembered that when the conventional type marker generator is used for this operation, it will be impossible to see the marker at the centre of the "S" curve because the amplification at this point is zero.

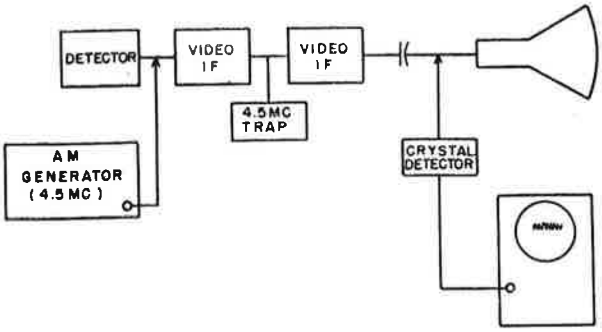

*Fig. 14-38. Adjustment of 4.5 mc video amplifier trap.*

Intercarrier sound IF stages can be aligned by the same methods, although the aligning frequency is now 4.5 megacycles. For best results, however, the final adjustment of the ratio detector transformer secondary should be made while the receiver is tuned to a station transmitting test pattern and tone. This adjustment should be set for minimum amplitude modulation or buzz from the loudspeaker.

4.5 megacycle-traps in video amplifier circuits can also be aligned while the receiver is tuned to a station transmitting test pattern and tone. To do this, the receiver fine tuning control is detuned until the 4.5 megacycle "graininess" just begins to show up on the test pattern. The trap is then carefully adjusted until the graininess is at a minimum, or disappears completely. Some manufacturers recommend the use of an accurately calibrated 4.5 megacycle AM signal, and a crystal detector network, connected as shown in Figure 14-38. With a 4.5 megacycle amplitude modulated signal fed into the video amplifier, the trap is adjusted for minimum modulation on the oscilloscope.

## 34. General alignment procedure — front ends.

Correct alignment of front ends requires (1) bandwidth of each channel be approximately five to six megacycles wide; (2) The response curve be properly centred within the limit frequencies for each channel; (3) Maximum amplitude or gain on each channel consistent with correct bandwidth. These requirements can be checked only by the visual alignment method because, as previously mentioned, the broadband characteristics of these circuits rules out simple peaking methods.

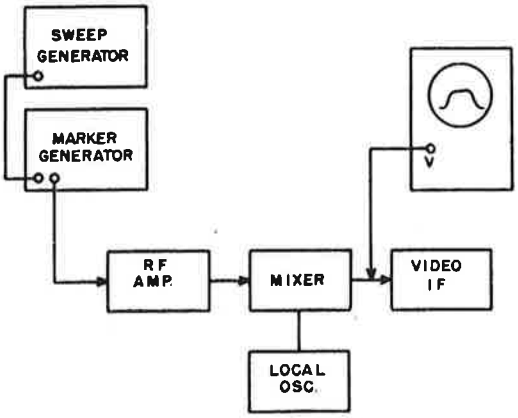

*Fig. 14-39. RF and mixer alignment set-up.*

Figure 14-39 illustrates in block form how the test equipment is connected. In this case, the converter or mixer stage becomes the detector which demodulates the alignment signal before it is applied to the vertical circuit of the oscilloscope. The sweep generator and marker generator are usually fed into the antenna terminals through suitable matching networks that enable the single ended output cable of the sweep generator to be properly connected to the balanced 300 ohm input of the receiver. The proper matching networks are usually shown in the alignment instructions or in the instructions for the particular Sweep Generator used. The RF and mixer tuned circuits are then adjusted, channel by channel, for a duplication of published curves. It is essential that the manufacturer's instructions be followed exactly during these operations because in many cases the alignment adjustment for one channel will affect the alignment of other channels. This is especially true if incremental type inductances such as those shown in Figure 14-40 are employed. This type of inductance consists of a series arrangement of coils in which the proper amount of inductance is selected for each channel by the selector switch. As can be seen from the illustration, $L_1$ and $L_{10}$, the channel 13 coils, are always in the circuit, regardless of which channel is selected. These coils must therefore be adjusted first because they will affect the tuning of all the remaining lower channels.

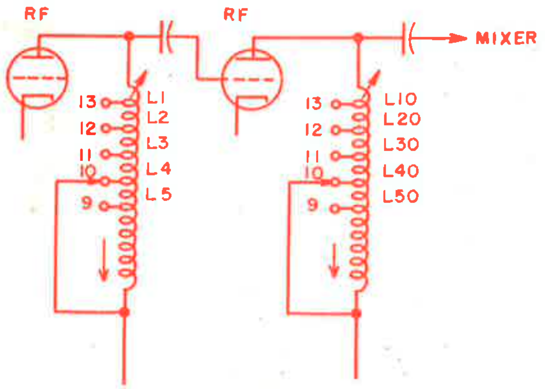

*Fig. 14-40. Incremental type inductances in front-end.*

Correct local oscillator alignment can be checked together with the overall response characteristics of the receiver by employing the connections illustrated in Figure 14-41. The sweep and marker generators are fed into the antenna terminals of the receiver and the oscilloscope is connected to the output of the second detector. The receiver's channel selector switch is set to, say, channel 13, after which the sweep generator is adjusted to the band of frequencies occupied by this channel. When the overall response curve for this channel is obtained, the marker generator is set to the frequency which corresponds to the picture carrier on channel 13, or 211.25 megacycles. This will produce a pip on the high frequency side of the response curve. The receiver's fine tuning control is then swung through its range slowly and as this is done, the marker pip will change its position on the response curve. If the receiver's local oscillator has the correct tuning range, it should be possible to place the pip at the 50% point on the response curve, or point B on the response curve shown in Figure 14-41. In most cases, the oscillator will have sufficient range on the higher channels to move the pip from point A to point C. On the lower channels, the tuning range is usually not as great but it should still be possible to move the picture carrier marker approximately ten to twenty per cent. on either side of the 50% point by varying the fine tuning control. It should be pointed out that this check will not be valid unless the RF and video IF tuned circuits are correctly aligned.

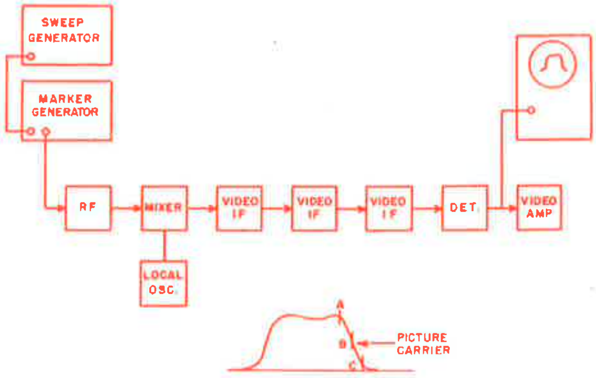

*Fig. 14-41. Checking local oscillator alignment by visual method.*

As a final test on the overall RF and IF response of the receiver, the output of the sweep generator should be slowly decreased while the vertical gain of the oscilloscope is increased, until noise or "grass" begins to show on the response curve. The receiver's gain or contrast control should be set for maximum gain. The shape of the overall response curve should not change appreciably on this very small input signal, nor should it change as the receiver's contrast control is varied over its range. Naturally, the curve will disappear into the base-line if the contrast control is set to minimum (unless the receiver employs AGC which will operate under alignment conditions), however, there should be no sudden sharp peaks or dips in the curve as either the sweep generator output control or the receiver contrast controls are varied.

**Chapter 13 which deals with Television Antennas and their installation will be published in the December issue. This will conclude "Television Principles and Practice."**