sweep and marker

GENERATORS

for

TELEVISION

and

RADIO

robert g. middleton

GERNSBACK LIBRARY NO. 55

$2.50

sweep and marker GENERATORS for TELEVISION and RADIO

robert g. middleton

published by gernsback library, inc.
new york, new york

GERNSBACK LIBRARY BOOK NO. 55

Library of Congress Catalog Card No. 55-11189
cover and book format designed by muneef alwan

contents

chapter *page*

introduction

Sweep and signal generators are standard tools of the TV service trade. Without these useful instruments, technicians would be working in the dark much of the time.

There is considerable misunderstanding in the trade concerning the capabilities and limitations of service generators, and it is the purpose of this book to clear up these points. In particular, there is especial need for clarification of fundamental principles, such as: How a beat-frequency generator operates; The nature of *flatness* (constancy) of output from a sweep generator; Harmonics and cross-beats (*spurious frequencies*) in the output; Spurious *sweep* outputs, and spurious *marker* outputs; Output voltages available on *fundamental* and *harmonic* bands; Limitations of *sum-frequency* output from beat-frequency generators; How to determine whether a sweep generator is operating properly; Accuracy requirements and calibration of signal generators.

These matters have become of increasing importance to the service technician, with the advent of color television. The foregoing considerations are also of importance in black-and-white TV service work, inasmuch as the relatively inexperienced technician may frequently be in doubt concerning whether his instrument is perhaps not all it is supposed to be, or whether he may be applying the instrument incorrectly.

For the most part this is not an applications book, but a discussion of the characteristics and construction of service generators. An understanding of the material presented here will make it possible for the technician to determine whether his instruments are operating properly; whether a given generator is adequate for the intended job, and whether a generator is "all that it is supposed to be".

The technician is often thrown upon his own resources, since service generators are not rated in many instances for voltage output on various bands for flatness of sweep output, percentage of harmonics in the output, nor are they rated for mixed or pure sweep outputs on the various bands. However, with the insight into such matters provided by this book, the technician will be in a better position to utilize his own resourcefulness in gaining an understanding of his instrument's capabilities and limitations.

The author wishes to take this opportunity of extending his sincere thanks to Martin Clifford of the Gernsback Library whose efficient interest made it possible for this book to become available to the service trade. Thanks are also due to Mel Buehring of Simpson Electric Co., for generously supplying various art work, and making available copyrighted technical data; to Bert Williams of Admiral Corp. for material supplied for this work; and to Terry Middleton, without whose assistance in organizing files and typing the manuscript, this book would not have been possible.

In conclusion, it is obligatory to extend thanks to a host of fellow engineers and TV technicians throughout the country, from whose comments and observations the writer has benefited enormously. To this group, which cannot be individually listed for practical reasons, I gratefully acknowledge my indebtedness.

ROBERT G. MIDDLETON

chapter

1

the sweep generator signal

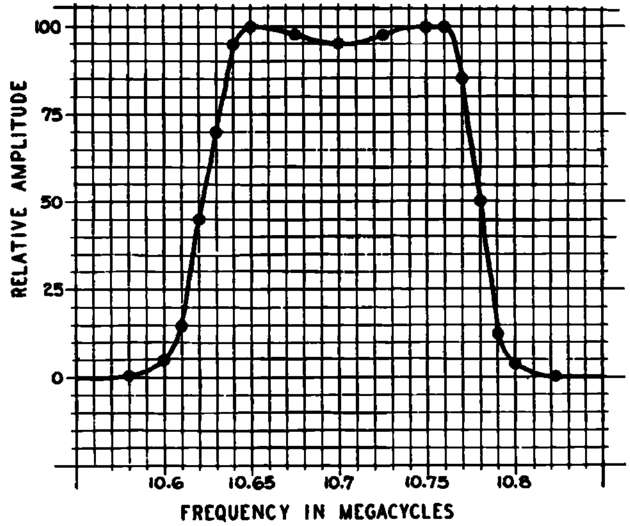
Sweep-frequency generators have been developed to eliminate tedious point-by-point measurements which would otherwise be necessary for determining the frequency response characteristics of wide-band circuits, such as TV i.f. and r.f. amplifiers, video-frequency and chrominance amplifiers, synchronous demodulators, interference filters, antennas and impedance transformers.

Fig 101 illustrates how a frequency response curve can be plotted, point-by-point, utilizing an ordinary calibrated signal generator. The plotting of a wide-band response curve requires the determination of a large number of points and consumes an excessive amount of time. When this point-by-point method is used, a signal of *constant* or *fixed voltage* is applied to the input of the circuit under test and the output voltage is measured as the generator frequency is changed in suitable steps. These measurements are recorded on graph paper and from them a curve is finally plotted. This curve is the frequency response characteristic of the circuit under test.

Much time can be saved by varying the generator frequency automatically instead of manually. The frequency variation is accomplished more rapidly and is then regarded as an FM (frequency-modulated) signal voltage. Of course, the output from a manually varied signal generator is also basically an FM signal, but the manual variation is so slow that we sometimes lose sight of the fact that we are working with an FM signal.

It is helpful to keep in mind that the output from a sweep generator is exactly the same as that from a signal generator when the dial of the signal generator is rocked back and forth. The difference is only one of "rocking speed" inasmuch as the majority of sweep generators are "rocked" at a speed of 60 times per second.

Let us return briefly to the requirement for a fixed or constant signal voltage in making a point-by-point determination. This requirement for constancy (flatness) of signal voltage holds for the sweep generator as well. Fig. 102 illustrates the distortion which results from an inconstant signal generator voltage, as compared with the true frequency response curve obtained when the generator voltage is constant. This is a very important consideration. An inconstant signal voltage can result from inadequate generator design, improper generator application or from characteristics of the circuit under test which may respond abnormally to the standard FM test signal provided by the generator.



Courtesy Simpson Electric Co.

Fig. 101. Plot of the i.f. response curve of an FM receiver. Although the curve is a relatively narrow band when compared with TV i.f. circuits, a large number of points must be determined to define the curve. A sweep generator can be used instead of an ordinary signal generator to speed up the job.

Sweep generator output

The beginner is usually surprised to discover that the frequency indications on the dial of a sweep generator are sometimes misleading. For example, the dial of a sweep generator may indicate

"23 mc," and, although this frequency is present, other frequencies are also simultaneously present in many cases, such as 75 mc, 173 mc, harmonics of these frequencies and still other frequencies termed *cross-beats.*

In other instances, this same output will be found present on a higher band, with the dial scale calibrated in terms of the harmonic output previously noted. How is it possible to use a mixed output of this nature on different bands of the generator? It is possible because the tuned circuits under test are usually effective as filters which serve to remove all of the signals except the output for which the particular scale is calibrated. But the mixed output from a sweep generator of this type will mislead the beginner who attempts to test the characteristics of a very wide-band device, such as an interference filter or an antenna. These matters will be considered in greater detail when the signal-generating arrangements of beat-frequency instruments are discussed.

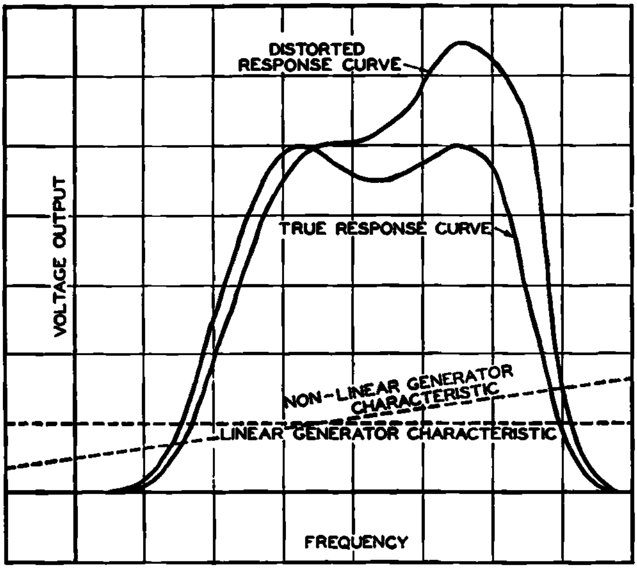


Fig. 102. Nature of the distortion in display of the frequency-response curve when the generator output is not flat.

Another common misconception concerns the appearance of false markers in the output of some sweep generators. Such markers are sometimes the result of the presence of spurious sweep voltages and are at other times the result of the presence of spurious signal voltages which are fixed in frequency. Such markers are sometimes only misleading; in other cases they may seriously impair the accuracy of test.

Amount of output

Still another misunderstanding concerning sweep generator outputs involves the signal voltage which may be available from the generator on various bands. It might be supposed that, because 1 volt of signal is measured by a high-frequency v.t.v.m. on the lower bands of some generators, this much test signal is actually present. You will sometimes find that this total voltage may be the sum of many spurious outputs and that the value of the signal indicated by the tuning dial may be only a small fraction of this 1 volt.

It is clear, furthermore, that if a sweep generator operates on the second harmonic to cover a higher-frequency band, such as 150 to 240 mc, the fundamental of 75 to 120 mc is not only present in the output but is much stronger than the second harmonic and will therefore cause a misleading indication of output voltage when the generator output is measured with a voltmeter.

Misconceptions are also prevalent concerning methods of testing the sweep output for flatness with a demodulator probe and scope. The same considerations apply here just as they do for v.t.v.m. measurements of sweep output, in addition to the necessity of using special test setups to avoid misleading indications at higher frequencies.

To avoid the consequences of such mistaken ideas, it is first necessary to observe the construction of the sweep generator to determine the signal factors to be contended with and, second, to select a suitable test setup to apply or check the available signal.

Required output voltage

The required output voltage from a sweep generator can be stated as (1) the minimum and (2) the desirable requirement. To illustrate the difference between these, consider a sweep test of a video amplifier in a black-and-white TV receiver. The video amplifier in normal operation receives a signal (from the picture detector) which has a value between 1 and 2 peak-to-peak volts. The video amplifier steps up this signal to a value of 35 to 50 peak-to-peak volts for driving the cathode or the control grid of the picture tube.

It is necessary, of course, to adjust the video amplifier circuits so that full gain is obtained from frequencies of 15 kc to 4 mc. This adjustment is made with the aid of the sweep generator. To determine the minimum generator signal required to obtain satisfactory deflection on the scope screen, keep these facts in mind:

1. The gain of the video amplifier is approximately 50 times.
2. The gain of the scope used in the test is typically .05 peak-to-peak volt per inch.
3. The insertion loss of the half-wave demodulator probe used in a test of this type is typically 90%.

If a deflection of 3 inches on the scope screen is considered satisfactory, the probe must supply 0.15 peak-to-peak volt to the scope. However, since the probe is only 10% efficient as a demodulator, the video amplifier must supply 1.5 peak-to-peak volts to the probe. Because the gain of the video amplifier is 50 times, the sweep generator need apply only .03 peak-to-peak volt to the input of the video amplifier. This, then, is the minimum generator output requirement.

Next, to determine the desirable generator signal requirement, note these operating factors:

1. The video amplifier should be able to develop full gain without overload.
2. The shape of the frequency response curve should not change with applied signal level.
3. The output voltage should be proportional to the input voltage over the entire operating range (amplitude linearity).

To meet these requirements, the sweep generator must be able to apply a signal voltage equal to the normal output from the picture detector to the video amplifier; i.e., an output voltage of approximately 2 peak-to-peak volts is necessary. Since service instruments are not customarily designed to meet this demand, expedients are required to make the tests we have described. For example, a utility video (booster) amplifier may be used between the sweep generator and the receiver under check. In other cases, amplitude linearity and overload characteristics are determined in a separate test by use of an audio oscillator.

The required output from an r.f. sweep generator is approximately 0.1 volts r.m.s. This value (100,000 microvolts) exceeds the normal input to the receiver and also provides ample deflection on the scope screen. Although some service sweep generators provide this desirable output level, some do not—principally those sweep generators which make use of harmonic output to cover the high r.f. channels.

I.f. amplifier tests, including stage-by-stage work, can be satisfactorily made with the same sweep output voltage as for r.f. testing, that is, 0.1 volt r.m.s. In the testing of chrominance amplifiers, synchronous demodulators and matrices in color TV receivers, 0.1 r.m.s. volt of video-frequency output is only a minimum requirement because the video-frequency amplifiers in color TV receivers usually have considerably less gain than their counterparts in a black-and-white receiver. A video-frequency output of 0.25 volt is the approximate minimum value which will be found necessary to check all the video-frequency circuits in a color receiver.

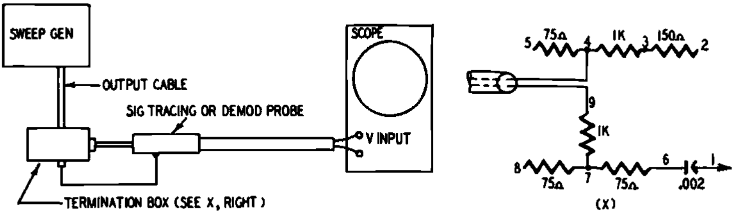
Frequency requirements

Present-day sweep generator frequency requirements are as follows:

1. I.f. circuits from 4 to 50 mc.
2. R.f. circuits from 50 to 220 mc.
3. U.h.f. circuits from 480 to 890 mc.
4. Color circuits from 15 kc to 4.5 mc.

Service sweep generators are available to provide this complete range of frequencies either on fundamentals or filtered beat fundamentals. Usually, service equipment does not give fundamental coverage in one instrument, and it is customary to provide coverage of the u.h.f. channels in a separate unit. However some instruments are available which will provide filtered beat fundamentals up to 50 or 100 mc, fundamentals up to approximately 250 mc and harmonic coverage through the u.h.f. band. Harmonic output is relatively weak, which restricts the u.h.f. tests which can be made.

Some service sweep generators provide unfiltered beat fundamentals on lower frequency bands. Since the unfiltered output contains various frequencies not indicated on the generator dial, such instruments cannot be used to make tests in which the circuit does not provide adequate filtering action. For example, checks of an antenna impedance match must be made by means of expedients when the sweep generator provides unfiltered beat fundamentals. The same observation applies to service generators which may provide harmonic coverage on higher bands, for the harmonic output is accompanied by a considerably larger fundamental output. Again expedients must be used in such cases to make antenna impedance checks and related tests. It is worth noting that the provision of *harmonic coverage* is not always expressed explicitly by some manufacturers, or the harmonic coverage may be stated by the manufacturer for only one or two bands when in fact *other* bands are also covered harmonically. In case of doubt the best procedure for the technician to follow is to check this type of generator for himself. Table 1 lists the application and characteristics of the sweep generator signal.



TERMINATION BOX CONNECTIONS

TERMINATION	CONNECTIONS	
300 ohms	Jumper 7-8-9-5	Jumper 3-4
300 ohms with pad*	Jumper 3-8	Jumper 5-9
75 ohms	Jumper 6-7-8-9-5	Jumper 2-3-4
75 ohms with pad*	Jumper 6-7, Jumper 2-3-8	Jumper 5-9
Open termination	Jumper 2-3-4	Jumper 6-7-8-9
Series capacitor	No Jumper 1-6	Use in addition to terminations indicated above. *The use of a pad provides 1000 ohms in series with each side of the line
Resistance coupling, no series capacitor	Jumper 1-6	

Fig. 103. The illustration shows a good practical test arrangement for checking flatness of output from a sweep generator. Details of the termination box are shown at the right. The numbers correspond to termination box connections listed beneath the drawing. The tabulation gives the various impedances which may be obtained by connecting the indicated terminals.

Flatness of sweep generator output

Fig. 102 shows that the shape of a response curve becomes distorted in a point-by-point plot if the signal-generator output is not constant. Evidently, if the sweep output is not uniform, the same distortion will be encountered when a sweep generator is utilized. The reasons for lack of uniform output will be discussed later in some detail—here we will note the practical results of nonuniform output and how to determine whether the output is flat.

Table 1 — SWEEP-GENERATOR SIGNAL

Signal	Characteristics	Application	How Tested
FM; pure fundamental output from the sweep oscillator.	Constant voltage over swept band (such as from 180 to 190 mc, at 0.1 volt). Negligible harmonics or other spurious frequencies.	Alignment of tuned circuits such as front ends, checking antenna characteristics, tracing feedback loops.	Output from sweep generator applied to demodulator probe, and in turn applied to vertical input terminals of scope.
FM; beat-fundamental output from a sweep and a fixed oscillator.	Difference frequency customarily utilized and indicated by generator tuning dial. Spurious frequencies filtered by built-in lowpass filter.	Same as Above	Same as Above
FM; beat-fundamental output from a sweep and a fixed oscillator.	Spurious frequencies (sum of beat and feed-through frequencies) present with the difference frequency due to lack of lowpass filter in generator. Dial calibrated in terms of the difference frequency.	Alignment of tuned circuits. Impedance checks must be made by means of expedients to avoid misleading indication due to spurious outputs.	Output from sweep generator applied to lowpass filter, thence to demodulator probe, and finally to vertical input terminals of scope.
FM; beat-fundamental output from a sweep and a fixed oscillator.	Sum frequency utilized; generator dial calibrated in terms of sum frequency. The sum beat is less desirable because it is contaminated with harmonics and other spurious outputs.	Alignment of tuned circuits in which maximum accuracy is not a requirement. Impedance checks must be made by means of expedients.	Output from sweep generator applied to bandpass filter, thence to demodulator probe, and finally to vertical input terminals of scope.
FM; harmonic output from a pure or from a beat fundamental.	Generator dial calibrated in terms of the harmonic frequency; output is weak and contaminated with strong fundamental.	Alignment of tuned circuits where weak signal suffices and grid of input stage is not overdriven by the strong spurious outputs.	Same as Above
FM; beat-fundamental output from an external non linear mixer, driven by r.f. outputs from a sweep generator and a signal generator.	Very-low-frequency sweep output obtained; 15 kc to 4.5 mc as a difference beat. Generator dial usually not calibrated for direct reading of sweep frequency.	Checking and adjustment of color circuits, such as chroma amplifier, synchronous demodulators, matrices, Y and color video amplifiers.	Direct application of sweep signal to vertical input terminals of scope; scope can respond directly to the low-frequency FM signal. Vertical amplifier also filters sum and feed-through frequencies, providing valid flatness test.

Fig. 103 shows how a demodulator probe and scope are customarily used to determine flatness of output from a sweep generator. Either 60-cycle sawtooth or sine-wave sweep can be used for horizontal deflection of the scope beam. Unless you are experienced in the construction of demodulator probes, it is best to utilize the commercial probe supplied by the equipment manufacturer or to follow the manufacturer's recommendations concerning a suitable probe. This simple and effective arrangement, is applicable *only* on generator bands which provide pure fundamental output. For example, if this simple test is made on an unfiltered beat band of the sweep generator, other frequencies than the frequency for which the dial is calibrated are present; there will exist a difference, a sum, and various feed-through frequencies. Hence, the indication is mixed and the various component voltages cannot be distinguished in the pattern. However, on a pure fundamental band of the sweep generator, the test is very informative. A typical result of this test is shown in Fig. 104. This pattern shows that the output is not flat but varies approximately 6 db over a 10-mc sweep width. The lack of flatness of this sweep output makes it unsatisfactory for TV alignment work.

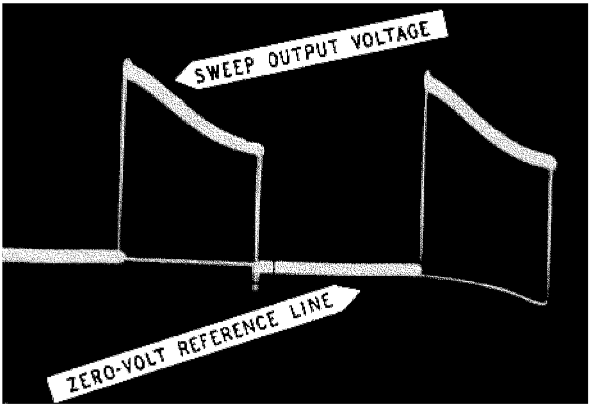


Fig. 104. Typical result of test depicted in Fig. 103, using 30-cycle sawtooth sweep for horizontal deflection of the scope beam.

The display shown in Fig. 104 is a check of the r.f. output from a sweep generator. The lower horizontal line is the zero-volt reference line and the upper horizontal line is the swept trace. The height of the swept trace above the zero-volt reference line is proportional to the sweep output voltage from the generator. The pattern shows the sweep output voltage decreasing substantially toward the right-hand (higher-frequency) end of the sweep.

The sweep width is 10 mc and the center frequency is 60 mc, as in usual circuit alignment work. Note that if a 60-cycle sine-wave sweep were used for horizontal deflection of the scope beam, the swept trace would appear *above* the zero-volt reference line and a rectangular type of pattern would be obtained. Either sawtooth or sine-wave sweep provides the same basic information.

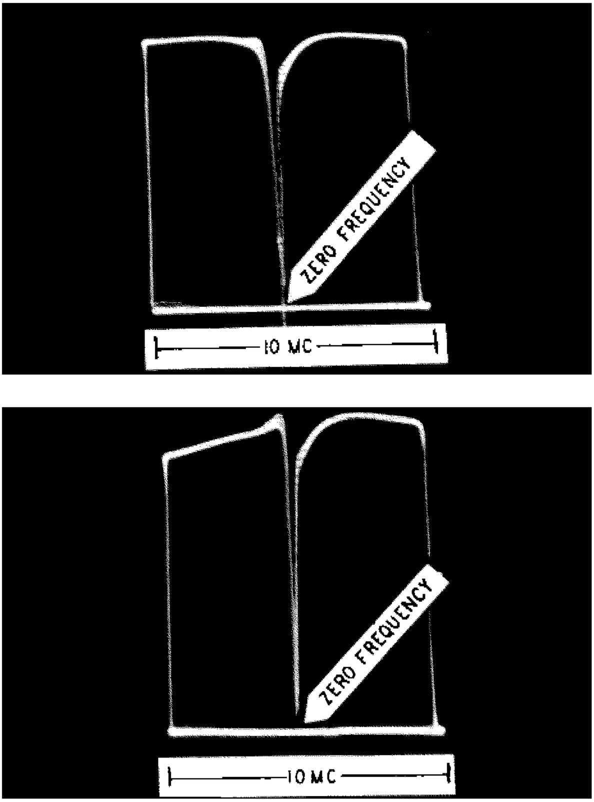


Fig. 105. Sweep-flatness test of video-frequency range of sweep generator. The output of the generator contains a low-pass filter which eliminates all but the difference frequency from the output. The attenuator is not distortionless; above, attenuator at maximum setting; below, attenuator near minimum setting, scope gain advanced. Zero frequency appears in center of pattern. Sweep width is 10 mc or ±5 mc either side of zero frequency.

Most service sweep generators used today have provisions for blanking the return trace and converting it into a zero-volt reference line. In the event that the upper and lower horizontal lines in Fig. 104 were exactly parallel with each other, the sweep output voltage would be perfectly flat.

The display shown in Fig. 105 is the same as before, except that the sweep generator is now tuned to the video-frequency band and is sweeping ±5 mc on either side of zero frequency. The zero-frequency point appears in the center of the display. The sweep frequency extends to 5 mc on either end of the pattern since the sweep-width control of the generator is set to 10 mc. The technician may be puzzled to note that the sweep flatness is impaired at low settings of the attenuator in the generator; this will be discussed later in detail.

Note that the tests illustrated in Figs. 104 and 105 were made at a sweep width of 10 mc. The operator sometimes falls into error because he fails to note the setting of the sweep-width control of the generator when making such tests. For example, if the sweep-width control is set to 1 mc when making a flatness test, the sweep output may look very flat. But, since such small sweep widths are not used in r.f. and i.f. alignment work, the test is valid only when made at sweep widths of approximately 10 mc as used in actual applications.

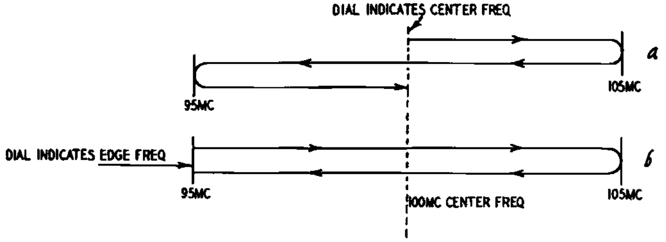


Fig. 106-a,-b. Distinction between center-frequency and edge-frequency indications.

The meaning of center frequency

As shown in Fig. 106, an FM signal is deviated both above and below a central frequency point, appropriately termed the center frequency of the signal. In Fig. 106-a the dial on the test instrument indicates the center frequency. The sweep starts at the frequency shown on the dial, increases to the high edge, sweeps back to center frequency, continues to sweep to low edge and then returns to center-frequency value. In Fig. 106-b the dial indicates edge frequency (95 mc for the example shown). Sweep starts at this low edge, sweeps through to high edge, returning to the low edge.

The photo shown in Fig. 105 illustrates this principle in practice. The video-frequency output signal is clearly sweeping from a given frequency (5 mc) at the left-hand end of the pattern, decreasing to zero frequency in the center of the pattern and again increasing to 5 mc at the right-hand end. In this case, it is stated that the center frequency of the sweep is zero frequency.

Of course, the center frequency can have any value, and the center frequency of the FM signal is *usually* the frequency indicated by the sweep generator dial. However, this is *not always* true. Instruments are in use which indicate the edge frequency of the sweep, as shown in Fig. 106. When the dial indicates the edge frequency, the center frequency necessarily changes as the setting of the sweep-width control is changed. For example, if the dial of an edge-frequency instrument indicates 23 mc, and the sweep width control is set to 6 mc, the generator will sweep from 23 to 29 mc. But if the sweep-width control is set to 10 mc, the generator will sweep from 23 to 33 mc. This change is a shift in center frequency from 26 mc to 28 mc.

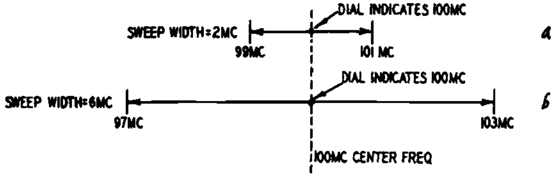


Fig. 107-a,-b. When the sweep-generator dial indicates center frequency, the sweep-width control does not change the dial indication because equal frequency excursions occur above and below center frequency.

These considerations are clarified by inspection of Figs. 107 and 108, which show that the center frequency remains independent of the setting of the sweep-width control when the generator dial indicates center frequency. But the center frequency becomes dependent upon the setting of the sweep-width control when the generator dial indicates edge frequency. In Fig. 107-a the dial indicates 100 mc. This is the center frequency of the 2-mc sweep width or ±1-mc sweep width. In Fig. 107-b the dial indicates 100 mc, the center frequency of the 6-mc sweep width or ±3-mc sweep width. In Fig. 108-a the dial indicates 100 mc, the edge frequency of the 2-mc sweep; center frequency is 101 mc. In Fig 108-b the dial indicates 100 mc, the edge frequency of the 6-mc sweep; center frequency is now 103 mc.

Actually, close calibration of the sweep generator dial is far less important than is generally supposed by the beginner, inasmuch as practically no service operations depend upon close reading of the sweep generator dial. The value of close sweep calibration is further lessened by the difficulty of keeping beat-frequency instruments in good calibration, especially at lower operating frequencies, where a 1% drift in the frequency of one oscillator may cause a drift of 50% in the frequency of the beat output, and also because of the practical difficulties of obtaining accurate horizontal linearity. Sweep generator dials are often closely calibrated only because the service technician *thinks* he needs it—not because he can actually use it!

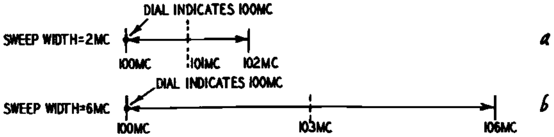


Fig. 108-a,-b. When the sweep-generator dial indicates edge frequency, the sweep-width control causes a shift of center frequency when reset, because the deviation is not a plus-and-minus excursion about center frequency.

Continuous-frequency and skip-band coverage

The frequency ranges provided by service sweep generators are sometimes continuous, but may also be stepped or skip type ranges. As an example of these differences, the following tabulation is helpful:

Type 1	Type 2	Type 3
8 kc to 4.5 mc	2 mc to 50 mc	3 mc to 42 mc
2 mc to 120 mc	54 mc to 88 mc	37 mc to 80 mc
142 mc to 260 mc	174 mc to 216 mc	75 mc to 120 mc
480 mc to 890 mc		110 mc to 160 mc
		150 mc to 240 mc

Type 4	Type 5
4 mc to 110 mc 170 mc to 220 mc	50 kc to 50 mc step-switched frequencies: Channels 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13.

Generators of type 1 provide continuous coverage of the ranges required in TV and FM receiver service, but skip the frequencies from 120 to 142 mc and from 260 to 480 mc, normally of no interest in service. Generators of type 2 provide continuous coverage over the video and i.f. ranges, but provide step-switch output for the v.h.f. channels. Generators of type 5 provide continuous-frequency coverage from the lower i.f. through the upper r.f. ranges.

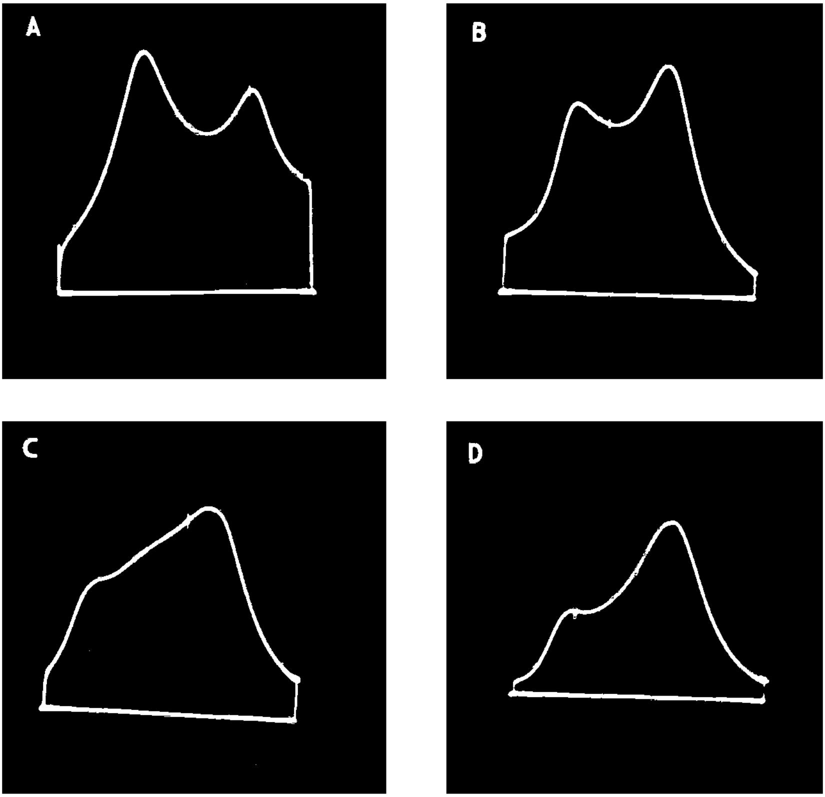


Fig. 109-a,-b,-c,-d. Front-end response curves for v.h.f. television bands, displayed on a sweep width of 12 megacycles. (a) channel 2; (b) channel 3; (c) channel 4; (d) channel 5. These curves depart considerably from the receiver manufacturer's specifications and require attention.

Type 3 and 4 generators are variants of the types discussed. Table 2 gives a comparison of various service sweep generators. Although continuous-frequency coverage has an appeal to the uninitiated, there are other considerations which may reduce its value or eliminate it completely. For example, the user first asks himself what he is going to use the continuous-frequency coverage for—perhaps he contemplates doing communications receiver service in the 152-mc to 162-mc band. But, if so, he must consider the fact that service sweep generators cannot be kept in sufficiently accurate calibration to accomplish communications receiver service, that the sweep function of the generator is largely useless for such work and that a medium-priced AM signal generator will come closer to meeting his needs.

Technicians sometimes suppose that, because a service sweep generator has a closely calibrated dial, the sweep generator will serve adequately as a signal generator when the sweep-width control is turned to zero. This is an unfortunate misconception for the following reasons: A sweep generator commonly operates on the beat-frequency principle for low-band coverage—a small error in operating frequency of either of the beat oscillators causes a large error in the output frequency. Furthermore, most service

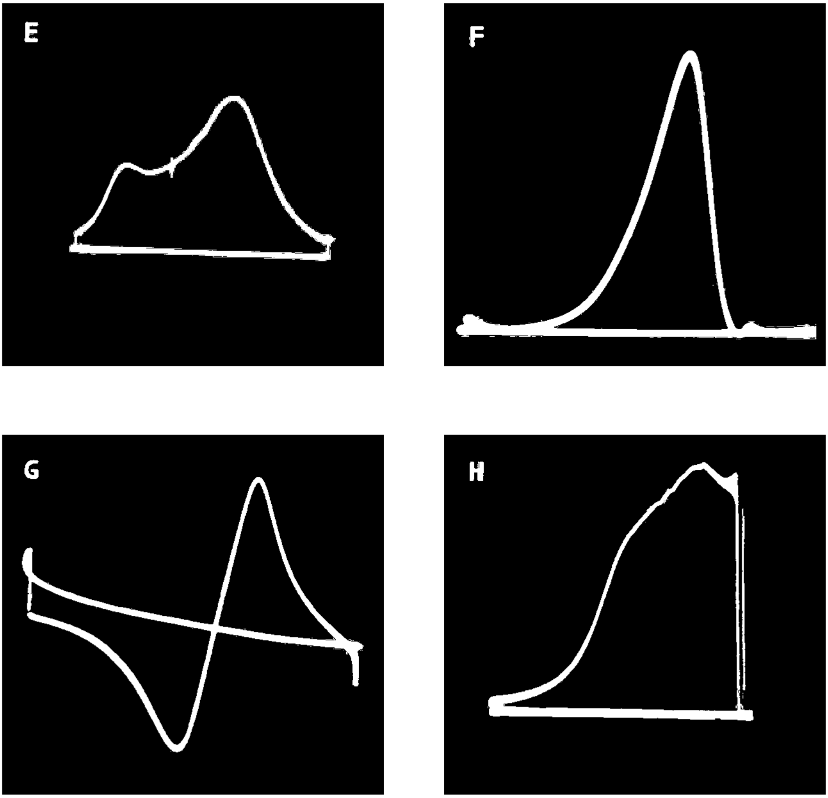


Fig. 109-e,-f,-g,-h. In (e) above, we have the front-end response for channel 6. (f) an i.f. response curve; a sweep width of 8 mc is adequate; (g) ratio-detector response curve; sweep width of 1 or 2 mc; (h) green video-amplifier response curve in color TV receiver; sweep width is 6 mc.

Table 2 —
COMPARISON OF SERVICE TYPE SWEEP GENERATORS

Brand	Fundamental Ranges	Harmonic Ranges	Special Features	Accessories
"A"	FM: 2–120 mc on beat fundamentals; 142–260 mc on pure fundamentals (contains some second and third harmonics).	480 - 890 mc	V.h.f. and u.h.f. channels marked on generator dial. Output rated flat within 0.2 db per mc of sweep width with at least 0.1-volt output at any frequency (except u.h.f.).	External mixer device for obtaining video-frequency sweep from 8 kc to 4.5 mc for color TV service. Peak-to-peak demodulator probe also available.
"B"	FM: 50 kc to 50 mc on filtered beat fundamentals; 54 – 88 mc, 174-216 mc on pure fundamentals (slight harmonic content).	None	Balanced r.f. output; single-ended i.f. and video output. Output rated flat within 0.1 db per mc of sweep width, with output of 0.1 volt minimum.	External absorption marker box available for color TV service.
"C"	FM: 4–110 mc on filtered beat fundamentals; 170–220 mc on pure fundamentals (contains some second and third harmonics).	480 - 890 mc	Balun output termination available for converting single-ended to double-ended output. Output rated flat within 0.1 db per mc of sweep width. Minimum output of 0.1 volt on any non–harmonic frequency.	External low-pass filter provided for obtaining filtered beat-fundamental output on first band.
"D"	FM: 3–80 mc on unfiltered beat fundamentals; 75–120 mc on pure fundamentals (harmonic content relatively large); 110–150 mc on beat fundamentals (sum frequency); 150–240 mc on harmonics.	V.h.f.: 150 -240 mc on second harmonic. U.h.f.: 480 - 890 mc on fourth harmonic.	Socket provided on front panel for crystal; 2-mc and 4.5-mc crystals supplied. No claims for flatness of output or for signal voltage on various bands.	None

sweep generators make use of a vibrator arrangement for obtaining frequency-modulated output. The operation of this unit vibrates the components in the generator and causes much more rapid frequency drift than in the case of typical signal generators. In addition, the vibrator adjustment tends to drift somewhat in operation, because of fatigue of the vibrator support. And even though the vibrator is at rest, it will not always come to rest in exactly the same position.

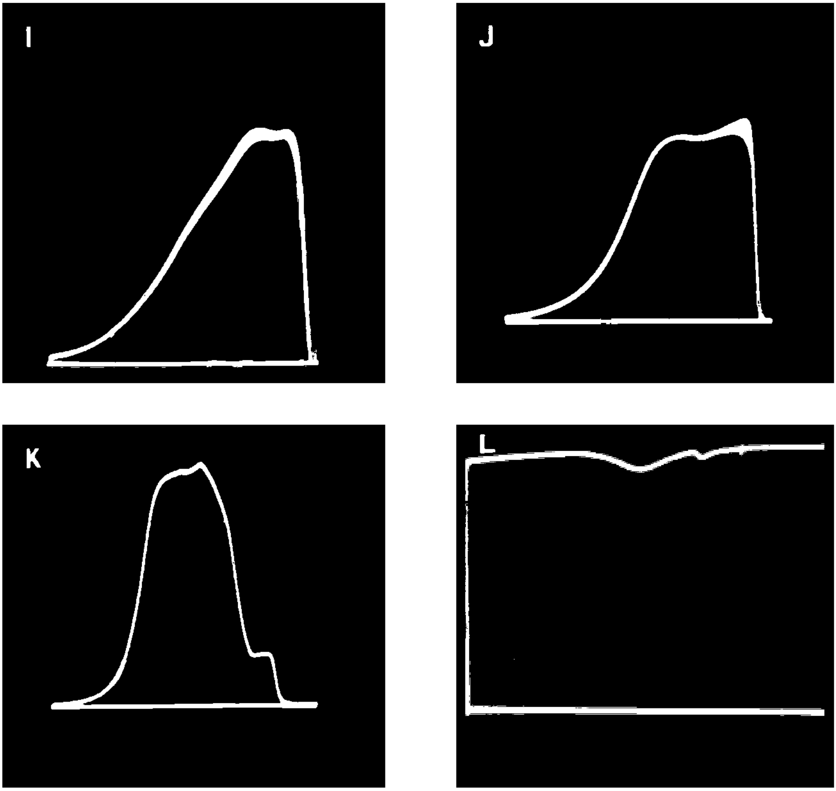


Fig. 109-i,-j,-k,-l. In (i) we have a Q demodulator response curve: sweep width of 3 mc is adequate; (j) frequency response of I video amplifier, sweep width, 6 mc; (k) frequency response of a chroma amplifier; sweep width of 5 or 6 mc is sufficient and (l) impedance check of an antenna and lead-in; maximum sweep width should be used. 12 to 15 mc is satisfactory.

Generally it is a mistake to try and make a sweep generator serve also as an AM signal generator.

Sweep-width requirements

Service sweep generators provide sweep widths from zero or from a few kilocycles up to 10 mc or 15 mc. Such a range is quite adequate for service applications, and Fig. 109 (a to l, inclusive) shows some of the everyday situations in this respect.

Antenna characteristic checks need maximum sweep width, inasmuch as the maxima and minima in the standing-wave ratio (SWR) pattern are separated by a half-wavelength. However, a sweep width of 12 or 15 mc is found ample for such checks. Since most sweep generators provide a zero-volt reference line, any inadequacy of sweep width can be circumvented by means of rocking the generator dial back and forth, to bring in the maximum and the minimum response points. With the zero-volt line present, the maximum and minimum voltages can be read, even when the generator dial is turned as required.

Sound i.f. tests and certain color-circuit tests require relatively small sweep widths, as shown in Fig. 109, hence it is essential that the sweep generator provide a range of sweep-width control from less than 1 mc to the maximum requirement of 12 or 15 mc.

When the output from the sweep generator extends down to a low frequency, such as utilized in color TV circuit testing, it is possible to apply the output from the sweep generator directly to the vertical input terminals of a scope, as shown in Fig. 110. This very informative test, shows the actual FM voltage from the generator. It also reveals the flatness of the FM voltage. This is a low-frequency sweep as used in testing color TV circuits.

In Fig. 110, the swept output appears above the zero-volt reference line (later to be explained in detail) and the frequency increases progressively from left to right. The sweep width utilized is quite small and the waveform exhibited is quite flat down to 7,500 c.p.s. At this frequency, the residual coupling between the two beating oscillators in the sweep generator (explained in later chapters) causes the oscillators to pull and lock in at frequencies below 7,500 cycles, so that the sweep does not extend down to zero frequency as might be expected upon the basis of elementary considerations.

It is seen that the output becomes abruptly attenuated below 7,500 cycles, with nil output from 7,500 cycles down to zero frequency. The display shown in Fig. 110 is obtained by utilizing a horizontal sweep rate in the scope of 60 cycles per second. This is the standard sweep rate utilized in practical alignment work.

R.f. in scope input

Whenever you make a test involving a sweep generator, a receiver, and a scope, what you are really interested in is the reaction of the receiver, or some circuit in the receiver, to the injected signal. There is no advantage in having any part of the r.f. of the generator present at the input terminals of the scope, and actually such r.f. can produce patterns on the scope screen that are wholly misleading. It is commonly thought that this is no problem since the output of nearly all generators at radio frequencies is usually so very small. In nearly all cases, however, the sweep signal is fed into some circuit of the receiver in which amplification takes place and with the scope ordinarily connected at the point of greatest signal gain.

Under the circumstances we have just described, it is entirely possible for a strengthened r.f. signal to get into the vertical-amplifier section of the scope. Further amplification of some part of the r.f. signal will take place in the vertical amplifier. It is entirely possible that such r.f. voltage, over and beyond the desired signal voltage, will overload the vertical amplifier, distorting the signal voltage waveform. While it is true that the undesired voltage is r.f., yet it can drive the vertical amplifier tube (or tubes) into a nonlinear region. The tube will then act as a combined amplifier-detector. The resulting voltage consisting of a combination of desired signal plus rectified r.f., will produce a pattern on the scope screen that has little or no resemblance to the curve of the actual wave.

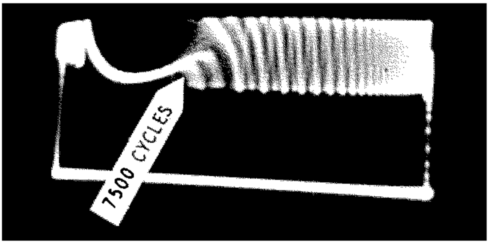


Fig. 110. *Sweep output of this generator is essentially flat down to 7,500 cycles.*

The detector probe

The signal that is supplied by your sweep generator is r.f. It is not a single frequency, but rather a rapid succession of frequencies. In an ideal case the amplitude of each of these frequencies is the same. For example, a sweep signal having a range of 20 mc to 23 mc sent into a TV circuit may be considered as an AM generator whose dial is being rapidly rotated back and forth between these frequencies. When we sweep a circuit with such a signal, all we are interested in is the reaction of the circuit to the signal. We want to know if the circuit will amplify equally all of the frequencies in the range between 20 mc and 23 mc, or if it will favor some frequencies, attenuate or weaken others, or reject them. If the output of our generator is flat (uniform) then observation of the waveform on the scope screen will give us the desired information about circuit behavior.

Note that the only part of the wave we are interested in is the peak amplitude. The situation can be compared to an r.f. signal modulated by an audio wave. The audio wave modulates the r.f. carrier, changing its amplitude. It is this variation in instantaneous r.f. amplitude that we call the envelope and it is this signal that ultimately feeds the control grid of the audio amplifier.

When a sweep signal of constant amplitude throughout its frequency range is fed into a circuit, the amplitude of the signal will be modified at various frequency points. We do not ordinarily refer to this as modulation, yet the effect is just the same as though we had modulated the wave. Since we are only concerned with amplitude changes, all we need do to observe such changes is to insert a detector probe between the scope and the test point in the receiver.

The detector probe will rectify the signal in a manner similar to detector action in a receiver. A properly designed probe will pass only the outline or the envelope of the wave, will bypass any r.f. appearing in the output of the probe, keeping the r.f. out of the scope input.

chapter 2

generating a sweep signal

An AM signal generator will operate in the same general manner as a sweep generator if the operator "rocks" the tuning dial of the signal generator back and forth. This procedure, of course, produces a signal output which varies in frequency as the dial is turned; that is, a frequency-modulated signal is produced.

In the case of a conventional sweep generator, the frequency-modulated output is obtained by varying the frequency of the oscillator automatically. Fig. 201-a shows an oscillator arrangement in which the frequency is swept back and forth by means of a capacitor shunted across the grid tank and varied in value by means of a vibrator. Sometimes the vibrator consists of a loudspeaker unit with a capacitor plate cemented to the cone. Another arrangement utilizes a variable capacitor with cylindrical plates, vibrated by a rugged type of meter movement. Fig. 201-b

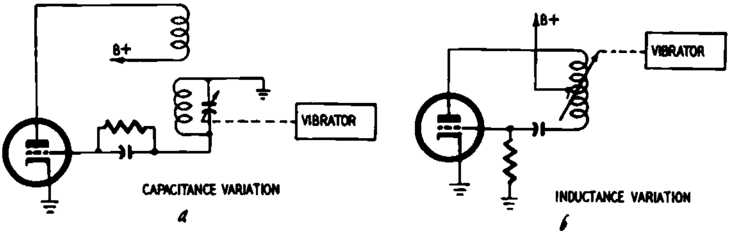


Fig. 201-a,-b. Two techniques for obtaining a sweep frequency. (a) capacitance variation and (b) inductance variation.

illustrates an oscillator arrangement in which the frequency is swept back and forth by means of a powdered-iron core which is inserted into the grid tank and vibrated by means of a loudspeaker motor or similar device. The vibrator (sometimes called an electromechanical modulator) is usually driven by 60-cycle power-line voltage. This is not only the most economical source of driving voltage but the 60-cycle repetition rate is sufficiently low to accommodate most service applications. However, there are some applications which require a lower repetition rate than 60 cycles.

Sine-wave sweep

Because the power-line voltage has a sine rather than a sawtooth waveform, we may wonder whether it is possible to develop a distortionless curve display without the use of sawtooth sweep deviation. A distortionless display is obtained because the 60-cycle sine-wave voltage is used also to drive the horizontal sweep circuit in the scope, thereby keeping the output frequency from the sweep generator and the position of the scope beam "in step." It is true that the horizontal motion of the scope beam will be slower near the ends of the trace and faster in the center, but the rate of change of *frequency* across the scope screen is constant, as shown in Fig. 202-a,-b. Arrangements other than those shown in Fig. 201 are used to obtain frequency-modulated output from an oscillator. For example, the "losser" method shown in Fig. 203 has been widely utilized. An aluminum or brass disc placed in the field of a pancake coil intercepts lines of force, which are partially dissipated as eddy currents in the metal disc. If the disc approaches the coil (due to motion of the vibrator), more lines of force are intercepted and the frequency rises. It is necessary to shape the disc

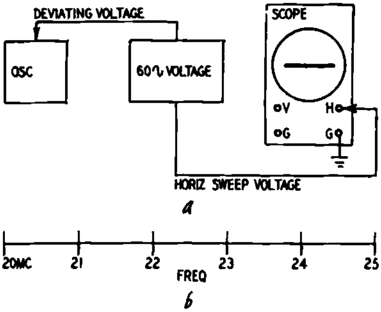


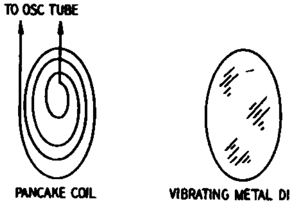
Fig. 202-a,-b. When a 60-cycle sine-wave voltage (a) is used to drive the vibrator in the sweep-oscillator circuit and the same sine-wave voltage deflects the scope beam horizontally, a linear frequency sweep is obtained. (if properly designed) equal horizontal intervals correspond to equal frequency increments. (b)

and coil properly in order to obtain a reasonably linear horizontal sweep of frequency.

In the case of the vibrating capacitor (Fig. 201-a), it is apparent that the capacitor plates can be shaped as required to obtain a straight-line frequency characteristic. The better manufacturers endeavor to obtain as linear a horizontal sweep of frequency as is practical. The vibrating inductor core also provides satisfactorily, linear horizontal sweep of frequency when the geometry of the system is properly proportioned.

The result of a nonlinear horizontal sweep is shown in Fig. 204-a,-b. The service technician is sometimes unduly alarmed by the presence of substantial horizontal nonlinearity but these points are worth noting:

Fig. 203. Another arrangement for sweeping the oscillator in a service sweep generator. A "losser" method is used in which an aluminum disc is mounted near the oscillator coil and vibrated by a loudspeaker motor or similar device.



1. Horizontal nonlinearity has the effect of expanding the curve on one side and compressing it on the other.
2. Although the curve "looks" different, it will be found that a marker placed at the 50% point on an undistorted curve, for example, will also appear at the 50% point on the curve which has been distorted horizontally.
3. If the operator makes extensive use of markers in the alignment procedure, he can do just as good a job with a generator which has substantial horizontal nonlinearity, although somewhat more time may be required.

Inductance variation of the sweep oscillator is not always accomplished by means of a vibrating powdered-iron core. In some cases, the powdered-iron core remains fixed in position in the coil, and the permeability of the core material is varied by means of a 60-cycle saturating field, as shown in Fig. 205. The sweep oscillator utilizes a powdered-iron core in the field of the oscillator tank circuit.A 60-cycle winding is also placed over the powdered-iron core, and the magnetic flux from current flow in this saturating winding causes the oscillator to vary in frequency in accordance with the magnetic saturation of the core material produced by the 60-cycle current. This method eliminates mechanical vibration from the unit and provides somewhat wider sweep widths than can be obtained from reactance-tube sweep arrangements. The output from the variable-permeability arrangement shown in Fig. 205 is not satisfactorily flat (output voltage not satisfactorily constant) unless a feedback control circuit is utilized. The feedback control typically samples the voltage across the oscillator grid leak, amplifies this voltage and uses it to control the conductance of a plate-voltage regulator tube for the oscillator plate-voltage supply. In this manner, the output voltage can be kept quite constant over the swept band.

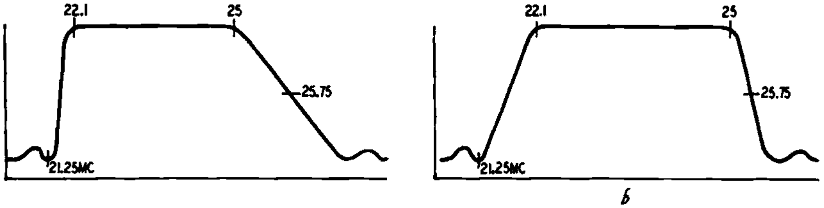


Fig. 204-a,-b. Typical response curve (a) displayed on scope screen when sweep-frequency output from generator has good horizontal linearity. Nonlinear sweep-frequency (horizontal nonlinearity) expands curve (b) on left-hand side, compresses curve on right-hand side. Note that markers appear at the same level on both curves.

The reactance-tube type of sweep generator is not common in wide-sweeping generators for TV service. The sweep modulator in a service sweep generator is customarily designed to provide a maximum sweep width of 15 mc. That is, if the low end of the sweep occurs at 20 mc, the high end of the sweep will then occur at 35 mc. It is difficult to obtain such wide sweeps with reactance-tube modulators without incurring substantial horizontal nonlinearity. However, if a beat-frequency principal is utilized (to be discussed later), and the center frequency of the swept oscillator is relatively high, wide sweeps of satisfactory horizontal linearity can be secured.

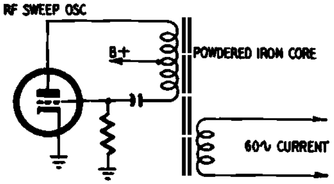


Fig. 205. Circuit of a variable-permeability sweep oscillator. The 60-cycle current varies the inductance of the powdered-iron core, changing the inductance between plate and control grid of the oscillator, resulting in a periodic frequency variation.

Double-ended output

In some cases, a push pull oscillator is frequency-modulated, as shown in Fig. 206. This arrangement has the advantage of providing double-ended output for sweeping double-ended circuits such as TV front ends. However, it must not be supposed that pushpull oscillators represent the only method of obtaining balanced output. Line-section baluns, high-frequency transformers and even long pads will effectively accomplish the conversion of single-ended output to double-ended.

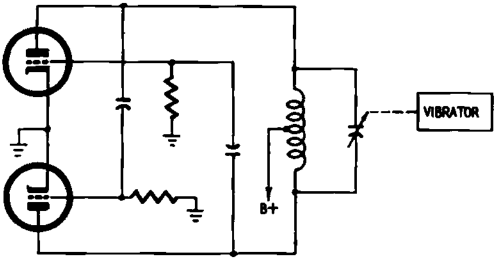


Fig. 206. Push-pull oscillator is sometimes frequency modulated. A double-ended output is provided, useful in checking balanced receiver circuits such as TV front ends.

Double-ended output is also useful for checking the characteristics of balanced devices such as antennas, interference filters and stubs. However, it is always possible to convert the output from a single-ended sweep generator to double-ended output by means of external accessories.

Flatness of output

The chief consideration in designing a sweep oscillator is to obtain an output which is constant or flat. This property of a sweep voltage (FM) is sometimes referred to as the amount of amplitude modulation (AM) in the output. However, such terms refer to

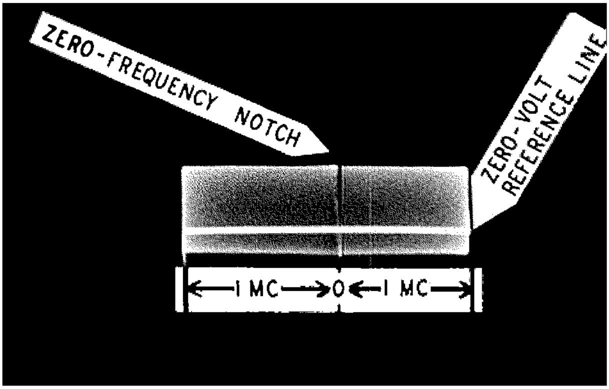


Fig. 207. Frequency-modulated voltage seen on scope screen. The essential quality of this sweep voltage is its constancy or flatness over the desired band of frequencies.

the extent to which the output voltage from the sweep generator remains constant over the swept band. This consideration is best clarified by reference to Fig. 207. Here is seen the output from a sweep generator, such as is used in color TV service, as displayed on a scope screen when the output from the sweep generator is applied directly to the vertical input terminals of the scope.

It is clear that the pattern is a frequency-modulated voltage, with the zero-frequency "notch" appearing in the center region of the pattern and with the frequency increasing to the left and to the right of the "notch." In the example shown in Fig. 207, the sweep width of the generator is set to 2 mc, so that each end of the frequency excursion occurs at approximately 1 mc. The horizontal line cutting through the FM voltage is the zero-volt reference line which is developed by the blanking function of the sweep generator. The sweep oscillator is keyed off and on by a 60-cycle square-wave voltage, so that the sweep oscillator is inoperative for one-half the total time. This keying voltage converts the return trace in an alignment curve to a zero-volt reference line—a great convenience in practical work. The zero-volt reference line does not cut exactly halfway through the FM voltage in the display of Fig. 207. This downward displacement of the zero-volt reference line is caused by a spurious voltage in the generator output, which will be examined more closely later. You should note the essential constancy of the output voltage displayed in Fig. 207. This constancy is referred to as "flatness" of the generator output voltage. In this illustration we see the FM output from a color TV generator.

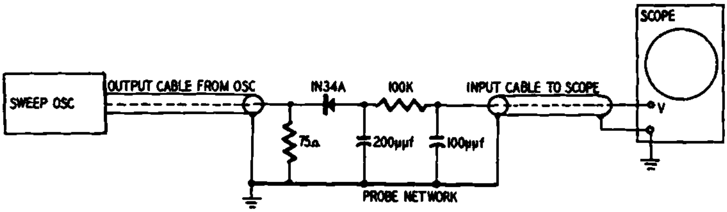


Fig. 208. Circuit of demodulator probe used to connect sweep generator to scope input.

The type of display seen in Fig. 207 can be obtained only at low frequencies within the frequency response range of the vertical amplifier in the scope. At higher frequencies, the constancy of output from the sweep oscillator must be obtained with the aid of a suitable demodulator probe, as shown in Fig. 208. The output cable from the sweep oscillator serves the fundamental function of transferring the high-frequency voltage from the oscillator to a desired point of application without distortion and practically without loss. This distortionless transfer is realized, however, only if the output cable is terminated in its own characteristic impedance (in this instance, 75 ohms). The demodulator probe is of the series type, which shunts minimum capacitance across the output cable termination. The two fixed capacitors and the 100,000-ohm resistor comprise a lowpass filter to restrict the flow of r.f. to the input side of the probe network and to keep r.f. voltage out of the scope amplifier (where it can cause trouble). The input cable to the scope carries only the demodulated signal. The result of such a "flatness" test with a demodulator probe is shown in Fig. 209. This test was made at a sweep width of 12 mc, using a good service sweep generator. The high-frequency output, though not entirely flat, would be considered adequate for service work. Many service sweep generators cannot provide this degree of flatness.

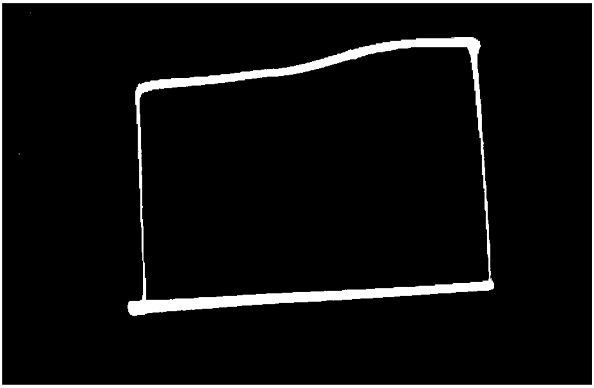


Fig. 209. Here we have the waveform seen on the scope as a result of the test setup illustrated in Fig. 208.

It is worth observing that a blocking capacitor is sometimes provided with the sweep output cable termination, as shown in Fig. 210, to avoid drainoff of d.c. voltage from the circuit under test. For example, if the cable were applied at the grid of a tube, the grid bias would be drained off if a blocking capacitor were not used. But in the test shown in Fig. 209 it is not possible to use the blocking capacitor, since there would then be no d.c. ground return for the probe circuit. In other words, the blocking capacitor shown in the arrangement of Fig. 211 must be eliminated or the desired test cannot be obtained.

The beat-frequency principle

To obtain wide sweep widths at relatively low frequencies, service sweep generators customarily make use of the beat-frequency principle. A beat-frequency arrangement is seen in Fig. 212, wherein the output from a sweep oscillator is mixed with the output from a fixed-frequency oscillator through a nonlinear mixing network (in this example, a 1N82A crystal diode). It is essential at the outset of this discussion to distinguish clearly between *linear* and *nonlinear* mixing. In Fig. 212, linear mixing takes place up to the crystal diode. In other words, the outputs from the two generators are mixed in connecting wires which have a linear resistance. Linear resistance means that the ohmic value of the conductors is the same whether little or much voltage is applied.

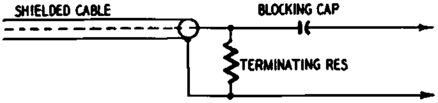


Fig. 210. The blocking capacitor keeps circuit d.c. from entering the generator or appearing across the terminating resistor.

In the linear mixing of two frequencies, no new frequencies are generated. The two signals are simply added together in the same circuit and can be recovered by means of suitably tuned circuits or filters without any change in the original signals and without the generation of any new frequencies.

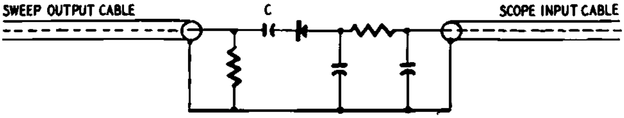


Fig. 211. The blocking capacitor, C, must be removed before the probe will function properly. Note that when the crystal diode conducts, flow of d.c. is blocked so that there is no d.c. return path through the sweep-output cable termination, and the arrangement becomes unworkable.

However, when these two signals pass through the crystal diode, nonlinear mixing takes place, because the crystal diode is a nonlinear resistance. In other words, the resistance value of a crystal diode depends upon the value of applied voltage: the crystal diode is a rectifier. Typical static characteristics of a crystal diode are given in Fig. 213. When the outputs from the sweep oscillator and from the fixed-frequency oscillator are passed through the crystal diode, the output from the diode contains new frequencies which were *not* present in the input. The principal new frequencies obtained in the output are the *difference* frequency between the fixed and sweep oscillator frequencies and the *sum* frequency of the fixed and sweep oscillator frequencies. It is perhaps apparent

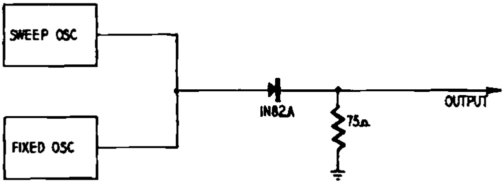
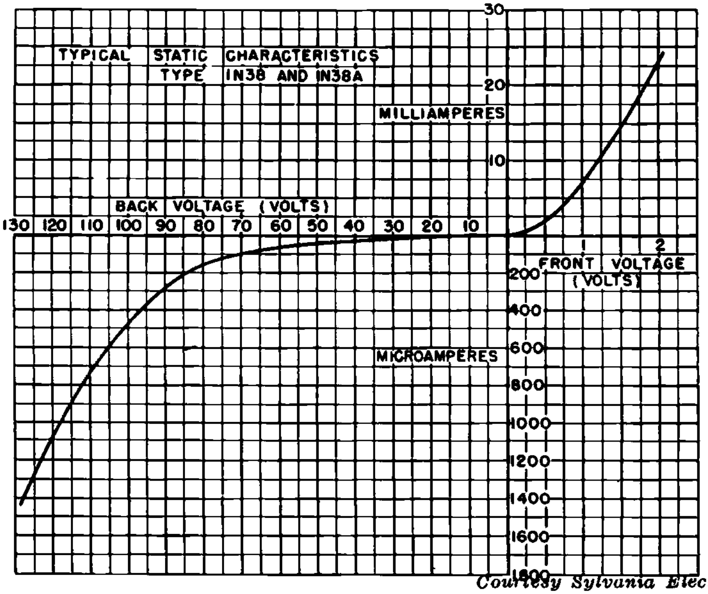


Fig. 212. Principle of a beat-frequency oscillator. Nonlinear mixing takes place in the crystal diode. Sum and difference frequencies appear across the 75-ohm load resistor.



Courtesy Sylvania Electric Co.

Fig. 213. Typical characteristic curvature of a crystal diode. Since the radius of curvature of the characteristic is not constant, the nature of the mixing action depends upon the operating point (determined by the d.c. bias on the crystal), and also upon the amplitude of the applied a.c. voltage. If the operation of the mixer is essentially square-law, no harmonics higher than the second are generated.

that the applied frequencies from the two oscillators will also "feed through" the crystal diode in attenuated form. Harmonics are also usually present in the diode output. Fig. 214 shows a probe circuit whose design is based on the nonlinear characteristics of crystal diodes.

To give a practical example, a service sweep generator may operate on the beat-frequency principle to develop a frequency of 23 mc. The fixed oscillator may work at 75 mc, and the sweep oscillator then operates at 98 mc. The difference frequency of 23 mc (98 mc — 75 mc) then becomes available in the diode output. The other undesired frequencies present in the diode output are the sum frequency of 173 mc (98 mc + 75 mc) and the feedthrough frequencies of 75 and 98 mc. In most cases, harmonics of 150 (2 × 75) and 176 mc (2 × 98 mc) will also be present in the diode output. The suppression of these undesirable spurious frequencies in the diode output is often of vital importance in service applications. This problem is treated in some detail at a later point.

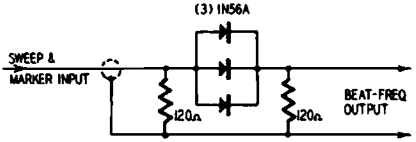


Fig. 214. Practical arrangement for using the beat-frequency principle. Circuit has three crystal diodes to match the low impedance of the sweep output system.

Reference to Fig. 215-a,-b shows that beat-frequency generators may be arranged to sweep either the fixed oscillator or the variable-frequency (tunable) oscillator. There is an advantage to sweeping the fixed oscillator, for the sweep width remains constant when the fixed oscillator is swept. The sweep width is not constant when the tunable oscillator is swept, because the L-to-C ratio of the tunable oscillator varies as the tuning dial is set to various positions. The sweep width decreases at the low-frequency settings of the tuning dial. However, the tunable oscillator is often swept in service generators because the design of the generator is somewhat simplified thereby.

Let us take a practical example: Suppose we wish to use a 140-mc fixed-frequency oscillator and a sweep tunable oscillator to cover as wide a frequency range as possible. It is possible to vary the tunable oscillator from approximately 140 to 260 mc. Now, by beating the output from the 140-mc fixed oscillator with the output from the tunable oscillator, the difference frequency of 0 to 120 mc can be obtained on one band. Next, if the fixed-frequency output is switched off, the direct output from the sweep tunable oscillator will provide coverage from 140 to 260 mc. So the output from this arrangement is as follows:

First band: 0 to 120 mc
Second band: 140 to 260 mc

Actually, the output cannot be extended down to zero frequency because of the tendency of the two oscillators to "pull" and "lock." A lower-frequency limit of 50 kc is typical, although some service sweep facilities have extended low-frequency coverage down to 15 kc.

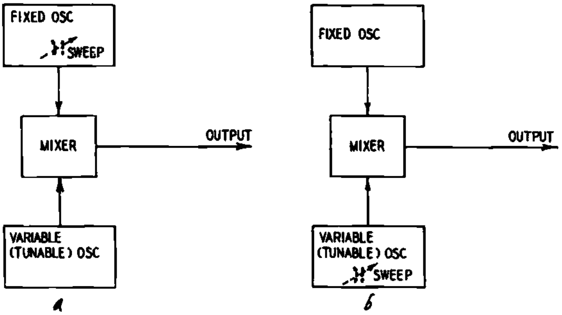


Fig. 215-a,-b. Beat-frequency sweep generators may be arranged to sweep the fixed-frequency oscillator (a) or may be designed to sweep the tunable (variable frequency) oscillator (b).

Let us now continue with our example: Suppose that, instead of sweeping the tunable oscillator, we sweep the fixed oscillator. Now, the tunable oscillator can be beat with a swept 140-mc signal over an output range from (nominally) 0 to 120 mc. But no output is available above 120 mc until another tunable oscillator is provided. So the output from this arrangement is as follows:

First band: 0 to 120 mc

Of course, another tunable oscillator range could be provided—from 260 to 400 mc. This additional tunable oscillator would then provide another beat output from 120 to 260 mc. But since another tunable oscillator would be required, the designer of service equipment usually utilizes a swept tunable oscillator, in spite of the fact that the sweep width does not remain constant from one end of the tunable oscillator range to the other end.

You may have observed that the output from a beat-frequency mixer contains the sum frequency in addition to the difference frequency, and you may have wondered why the sum frequency is not utilized. The sum frequency is discarded by most designers because it contains an excessive number of spurious outputs, principally harmonics and feed-through frequencies. However, very-low-priced sweep generators sometimes utilize the sum frequency to further simplify the construction of the instrument.

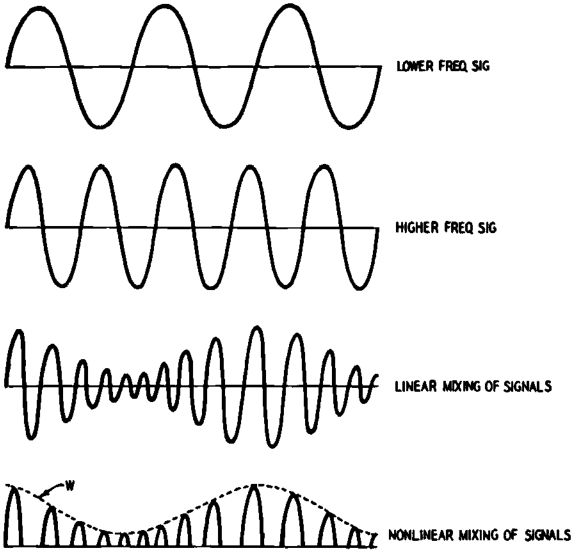


Fig. 216. How a beat-frequency generator works. At top is the sine-wave output of the lower-frequency oscillator; next is seen the sine-wave output of the higher-frequency oscillator; in the third portion we have the result of mixing these two voltages linearly. Although the waveform rises and falls, its average value is zero and the envelope frequency cannot be extracted. The last illustration shows the waveform after it passes through the nonlinear mixer. Now the average value of the wave envelope (W) or difference frequencies is not zero and this envelope difference frequency can be extracted by a tuned circuit or filter.

To clarify further the nature of the signal developed by a beat-frequency generator, refer to Fig. 216. Here is seen a low-frequency signal voltage which is first mixed with a high-frequency signal voltage. Before the mixture arrives at the crystal diode, linear mixing takes place in a resistive circuit, as shown in the third part of the illustration. Finally, the linear mixture is applied to the nonlinear crystal-diode mixer, and a difference frequency is generated, as shown in the fourth part of the illustration.

The difference frequency is represented by the wave envelope W and the sum frequency by the inherent distortion of the higher-frequency component of the wave.

It is clear that the unfiltered output from a beat-frequency generator must contain numerous components, such as shown in Fig. 217. The first three components will be recognized on the basis of the former discussion, but the fourth will not. The fourth component is a modulation of the sum-frequency component by the difference-frequency component and is an additional spurious output which is sometimes obtained when a vacuum-tube mixer is improperly operated or when an amplifier following the mixer is improperly operated.

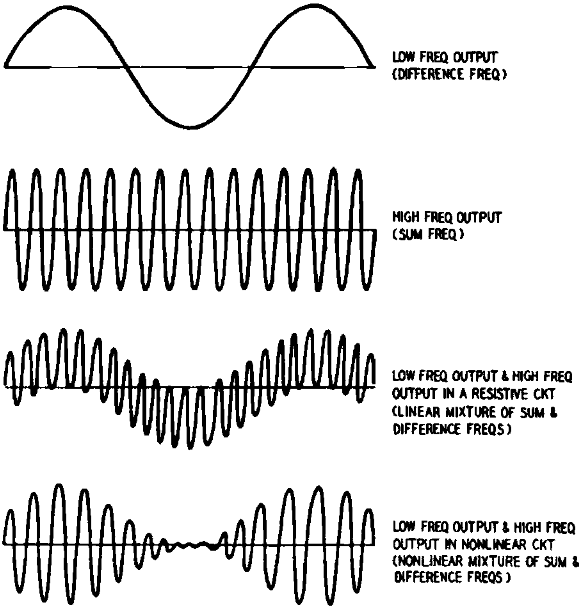


Fig. 217. Some fundamental types of signal voltages which may be present simultaneously in the output of elementary types of beat-frequency sweep generators.

Of course, harmonics are present in the output. In fact, the dials of some service sweep generators are calibrated in terms of such harmonics to provide some sort of high-frequency coverage without adding components to the unit. Harmonics are generated by the beating oscillators, unless suitable oscillator circuits are utilized which have a good sine-wave output. The mixer also generates harmonics unless circuit means are taken to suppress them.

Fig. 218 shows typical displays obtained when the sum frequency is used for one of the bands on a beat-frequency generator. Spurious response here is caused by the frequency of the fixed oscillator falling in the swept band. The harmonic of the fixed oscillator falling in the swept band also produces a similar but lesser disturbance. Curve 1 is obtained when the demodulator probe has a relatively short time constant. Curve 2 is obtained when the demodulator probe has a relatively long time constant.

In Fig. 219 we see how a spurious sweep output is developed by oscillator harmonics. In a, we have the nominal 20- to 30-mc output from the sweep generator. Illustration b indicates the feed-through frequencies of 70 to 80 mc (and also 100 mc) which are

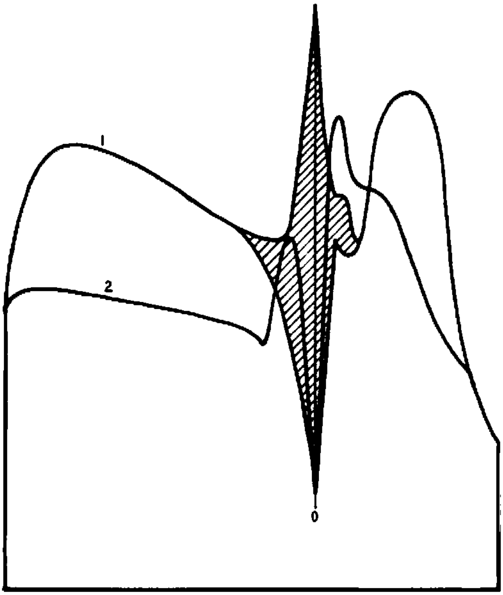


Fig. 218. *Spurious response in output of beat-frequency type sweep generator.*

present in the output. Drawing c shows the third harmonic of the oscillator which sweeps from 210 to 240 mc. Finally, in d we see how the 210- to 240-mc sweep beats with the fixed-oscillator frequency of 100 mc to produce a spurious sweep from 10 to 40 mc in the output. This spurious sweep impairs the flatness of the output and illustrates why the harmonic output of the beating oscillators should be maintained at a low level.

Beat-frequency mixers are not always in the form of crystal diodes. The majority of beat-frequency mixers are of the vacuum-tube type in which the tube is operated either at zero bias or at a grid bias which provides nonlinear operation. Crystal-diode mixers are also suitably biased in some cases to provide an optimum operating point on the curved portion of the voltage-current characteristic. The important point to observe here is that the nature of the mixing process and the number and intensity of spurious outputs obtained from a mixer depend in part upon the bias applied to the mixer. When the output current from a mixer is proportional to the square of the input voltage, we say that the mixer is a square-law device. Square-law mixers are often utilized in beat-frequency mixer circuits. Incorrect bias on the mixer can cause the generation of a disconcerting number of spurious outputs.

It is quite essential to avoid double conversion, because the outputs from the first conversion (or mixing) process will all cross-beat with one another in the second conversion process to generate an alarming number of spurious outputs. A tube mixer can develop double conversion when over driven as rectification in the grid circuit may then be supplemented by rectification in the plate circuit.

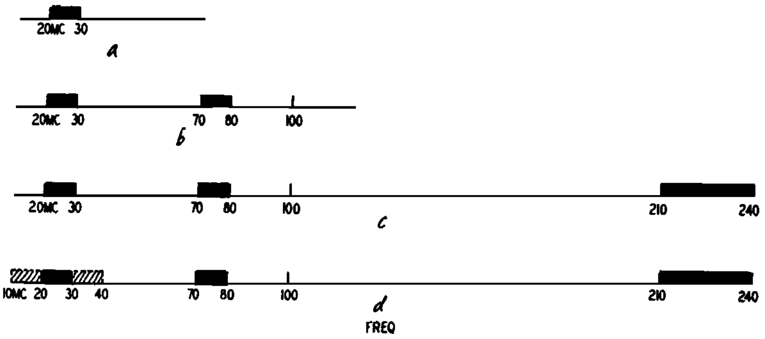


Fig. 219-a,-b,-c,-d. Spurious sweep output can be produced through the interaction of oscillator harmonics.

The relative voltages from the fixed-frequency oscillator and from the sweep oscillator, which are applied to the mixer, are a matter of considerable importance. They determine, in part, the flatness of output which is obtained from the mixer. The reason for this dependence is as follows: Consider an example of mixing in an intercarrier television receiver, by way of illustration. We know that when the sound carrier is permitted to fall too high up on the response curve the receiver starts to buzz annoyingly—the sync buzz is caused by the impression of the vertical sync pulse from the picture signal into the beat output obtained from the picture detector (mixer).

But if the sound signal is placed no higher than 5% on the response curve, with the picture carrier at 50%, then the 4.5-mc beat-frequency output from the picture detector is practically free from buzz—the vertical sync pulse from the picture signal is no longer impressed into the 4.5-mc beat-frequency output. Why should this be so? Note that in the intercarrier receiver, the picture signal is operating as a fixed-frequency oscillator. The FM sound signal is operating as the sweep oscillator—as transmitted, the FM sound signal is free from amplitude variation (is flat), but after beating with the picture signal through the picture detector, the AM of the picture signal becomes impressed upon this beat-frequency output, unless the sound signal has a relatively low voltage at the mixer input.

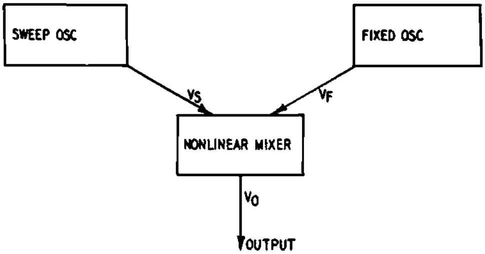


Fig. 220. When the output voltage V_s from the sweep oscillator is much larger than the output voltage V_f from the fixed oscillator, the beat frequency output V_0 is flattest (has least amplitude variation). But if V_f is larger than V_s, changes in V_s will appear in output. By making V_s very large and V_f very small the variation in output voltage can actually be made much less than that present in V_s.

This behavior gives us the clue to the relative voltages from the fixed-frequency and sweep oscillators in a beat-frequency generator which should be applied to the mixer in order to realize the maximum flatness of beat-frequency output. The points under consideration are susceptible to mathematical demonstration likewise, but this latter is scarcely necessary in view of the vivid example provided by operation of the intercarrier receiver. Now, in the case of the beat-frequency sweep generator, the output from the fixed oscillator is quite constant, inasmuch as this signal is obtained from an independent and unmodulated oscillator. On the other hand, the output from the sweep oscillator often departs more or less from flatness, depending upon the design of the sweep-oscillator circuit and the FM modulator arrangement. Hence, these two voltages from the oscillators are to be proportioned in such ratio that the beat-frequency output from the mixer will be dominated in flatness by the characteristic of the fixed oscillator output rather than by the characteristic of the sweep oscillator output. This condition is obtained, in line with the intercarrier-receiver discussion, when the output voltage from the sweep oscillator is made very much larger than the output voltage from the fixed oscillator. It is true that this relationship "looks wrong," but the careful reader can quickly demonstrate the truth of the matter for himself.

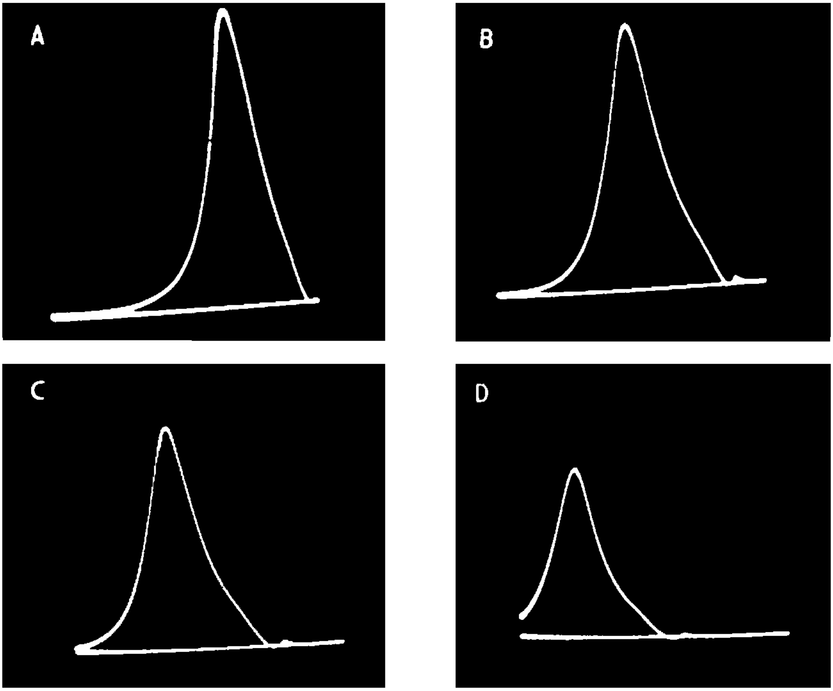


Fig. 221. Illustrations of the variations in height of an i.f. response curve as the tuning control of the sweeper is varied from one end of the base line to the other. This is caused by change of the L-to-C ratio in the fixed oscillator tank as the tuning capacitor is rotated. A flatness check with a demodulator probe will show that the output is flat over the swept band.

This requirement, illustrated in Fig. 220, is met by all well-designed beat-frequency sweep generators.

When the output from a beat-frequency sweep generator is tested for flatness with a demodulator probe, the output voltage over the swept band may appear quite flat. Yet when an i.f. response curve is viewed on the scope screen, as shown in Fig 221, the height of the curve may vary as the center frequency of the sweep is changed. You may sometimes find it difficult or impossible to reconcile these two forms of apparently conflicting test results. However, the explanation is actually simple and is based on the variation of output from the fixed oscillator in the beat-frequency arrangement, due to change of L-to-C ratio in the fixed-oscillator tank as the generator tuning dial is varied.

Of course, when the arrangement shown in Fig. 215-b is utilized, the situation shown in Fig. 221 is accompanied by a lack of flatness over the swept band. This is worth noting as there often is considerable confusion concerning this point.

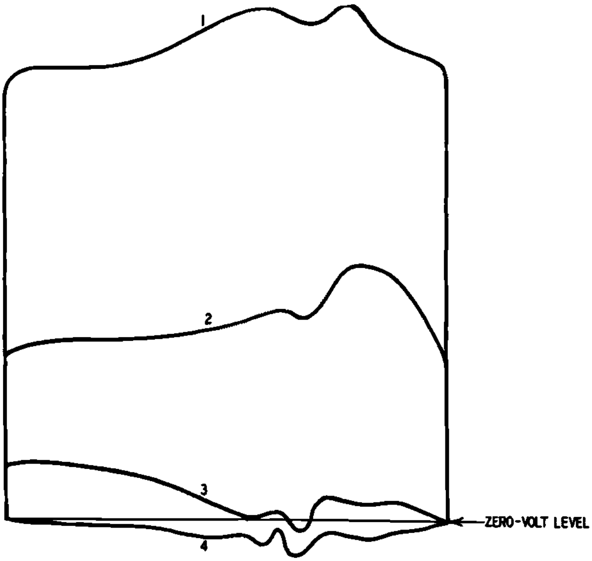


Fig. 222. Effect of attenuator setting on voltage level of sweep-frequency output.

You must not suppose that the foregoing treatment is complete, however, since the flatness of the output is also affected by the output system of the sweep generator. As an introduction, you may note Fig. 222 which shows the variation in shape of the output and the departure from flatness obtained in a typical situation as the attenuator of a sweep-frequency generator is varied. At 1 is seen the output voltage variation for maximum output, with progressive changes in the swept trace as the output voltage is reduced in steps to 4. Note that both 3 and 4 show an apparent reversal in polarity of output from the demodulator probe. This puzzling undershoot of the base line by the swept trace is caused by a displacement of the zero-volt reference line, combined with out-of-phase beats of desired and spurious outputs from the generator in the swept trace.

Filtering beat-output signals

Since it is undesirable in various service tests to have spurious frequencies present in the output from a sweep generator, it is becoming more common practice to provide filtering arrangements so that only the difference frequency from the mixer passes through to the output. For this purpose, a lowpass network is used, as shown in Fig. 223-a,-b,-c. The filter is generally provided between the attenuator of the generator and the input end of the output cable. When more sections are used, a sharper cutoff frequency is obtained. The sharpness of the required cutoff frequency is determined by the amount of separation between the desired difference frequency and the undesired spurious outputs from the mixer. For example, consider a typical situation in which the fixed oscillator operates at 140 mc and the variable oscillator is tunable from 140 to 260 mc. The difference frequency will range from (nominally) zero to 120 mc. Since there is only 20-mc separation between the desired 120-mc output and the undesired 140-mc feed-through frequency, three filter sections must be used, as shown in Fig. 223-c, to obtain a satisfactory pass at 120 mc while providing good rejection at 140 mc.

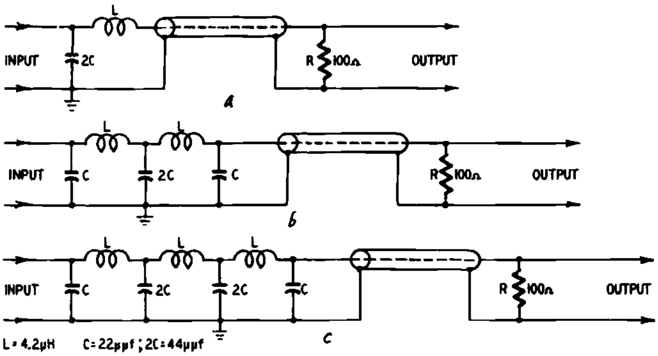


Fig. 223-a,-b,-c. Lowpass filter networks inserted between the output cable and the sweep generator.

It is customary to use the constant-k type of filter, as adequate filtering action is obtained without going to the more complex networks such as the M-derived. The values of L and C are chosen, not only to obtain the desired cutoff frequency, but also to provide a suitable characteristic impedance of the filter to match the impedance of the output cable. This is an essential consideration, inasmuch as the filter characteristic is distorted if the filter is improperly terminated. You should note that, when the output cable, shown in Fig. 223, is properly terminated by resistance R, this same value of R is reflected to the input end of the cable—in effect, the filter is terminated by R. In the event that substantial inductance or capacitance should be shunted across the cable termination during a test, the filter is then no longer terminated properly and distortion of the output will occur (flatness of sweep voltage will be impaired).

The lowpass filter is usually inserted in the output system as shown in Fig. 224, but the filter may be either removable or fixed in place, depending upon the necessity of removal for operation on other than the beat band. For example, if the variable-frequency oscillator is swept and the output from this sweep oscillator is used for high-band output, then the lowpass filter must be removed during high-band operation to avoid suppression of the desired frequencies. In such case, either the manufacturer supplies the lowpass filter as a separate unit with connectors for inserting the filter in series with the sweep output cable or the lowpass filter may be built into the sweep generator, being switched in or out, as required, by a separate deck on the bandswitch.

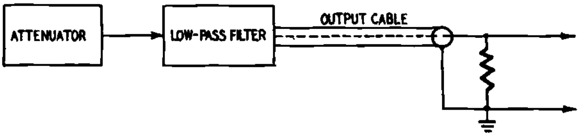


Fig. 224. Location of the low-pass filter in the sweep-generator output system. The filter may be "built in" or constructed as a plug-in form. In some cases the filter can be switched in or out by means of a switch on the generator.

When i.f. and r.f. output cables are provided on the sweep generator, the lowpass filter can be installed permanently in series with the i.f. output cable, since r.f. output is not obtained through the filtered cable. In any case, the technician will find a suitable lowpass filter valuable in obtaining the full use of a beat-frequency sweep generator.

Converting the retrace into a zero-volt line

A response curve can be displayed on *sawtooth sweep,* as shown in Fig. 225. The three illustrations are typical displays obtained by the use of 60-cycle sawtooth sweep for horizontal deflection of the scope beam. The first curve (top) is normal, but the second and third curves show progressive degrees of overload due to use

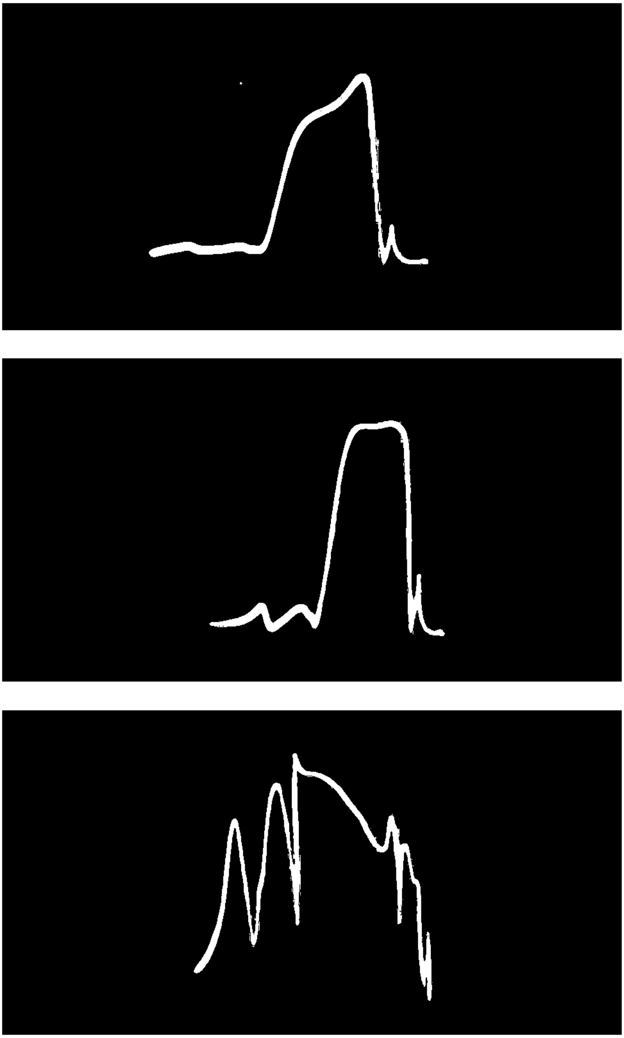


Fig. 225. Representative curve displays obtained by use of 60-cycle sawtooth sweep. Note the complete absence of a retrace waveform. Compare these curves with those shown in Fig. 226.

of too high a setting of the attenuator in the sweep generator. Note that there is no retrace problem when sawtooth sweep is used; however, there is often a synchronizing and centering problem.

Technicians usually prefer to display a response curve on 60-

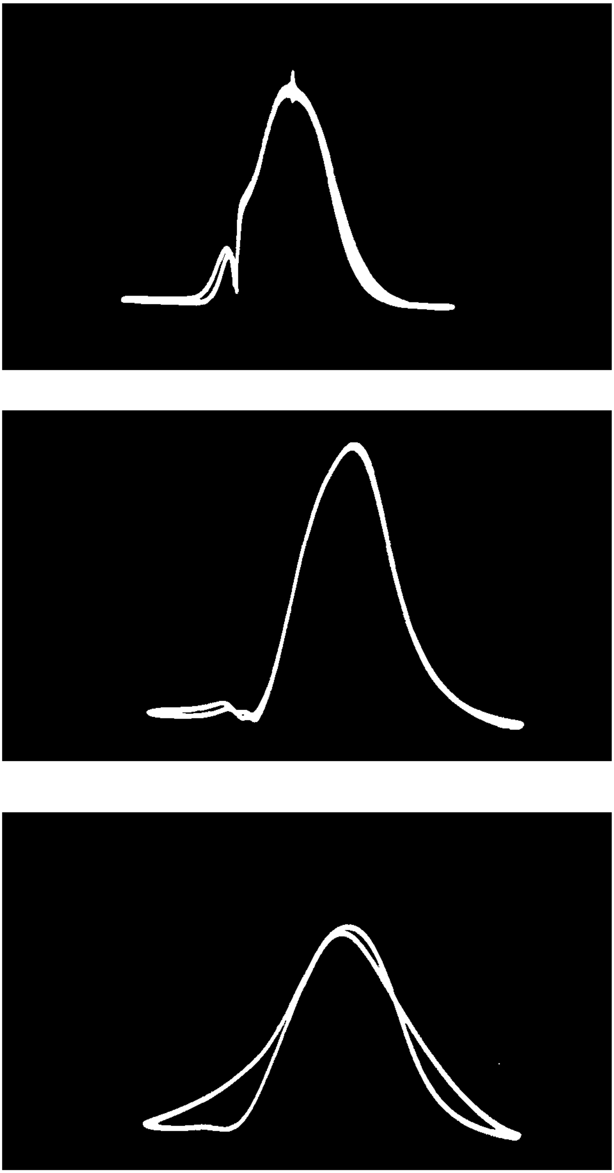


Fig. 226. Curves obtained by use of 60-cycle sine-wave sweep. Note lack of exact layover of trace and retrace. This problem is best met by a retrace blanker.

cycle *sine-wave sweep,* as shown in Fig. 226. There are some good reasons for this preference:

1. The FM sweep modulator is operated by 60-cycle sine-wave voltage. If the modulator is properly designed, use of 60-cycle sine-wave sweep for horizontal deflection in the scope provides better horizontal linearity.
2. There is no synchronizing problem when the display is made with 60-cycle sine-wave sweep, and the pattern is more stable on the screen.
3. Centering of the pattern on the base line is a relatively simple operation when 60-cycle sine-wave sweep is used, inasmuch as the pattern is automatically centered when the generator is adjusted to the correct center frequency and the horizontal phasing control of the scope is adjusted for proper layover of trace and retrace.

The blanking network of the sweep generator can convert the retrace of the scope beam into a zero-volt reference line. In the case of wide-band response, the sweep width of the generator may be inadequate to display the points at which the skirts of the curve meet the zero-volt level. In such an instance, the zero-volt reference line provides very useful information to the technician in evaluating the response curve.

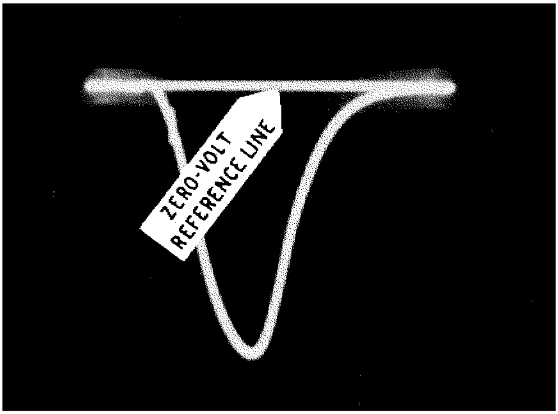


Fig. 227. Formation of zero-volt reference line by blanking network of sweep generator.

To obtain retrace blanking and development of a zero-volt reference line, as seen in Figs. 227 and 228, a 60-cycle square wave is applied as bias (also known as keying voltage) to the sweep oscillator. In Fig. 228 we see that the bandwidth of the circuit is too great to be completely displayed with the available sweep width from the sweep generator. Although the points at which the skirts of the response curve meet the zero-volt level are not apparent, nevertheless the zero-volt reference line shows the location of this zero-volt level. This is very valuable in checking wide-band circuits.

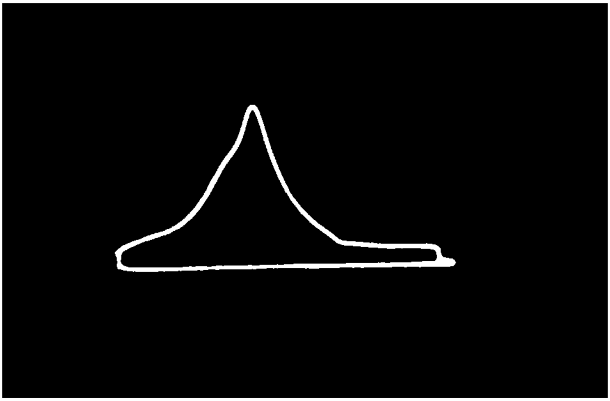


Fig. 228. Bandwidth of circuit is too great to permit full display.

When a 60-cycle square wave is used to bias the grid of the sweep oscillator (see Fig. 229), the oscillator is permitted to operate only half the total time. Consequently the output is zero during the retrace interval and the zero-volt level is accordingly indicated on the scope screen. The phase of the blanking voltage must be in step with the FM modulating voltage. Sometimes this phasing is automatically provided in the generator network and sometimes the phase of the blanking voltage is under the manual control of the operator.

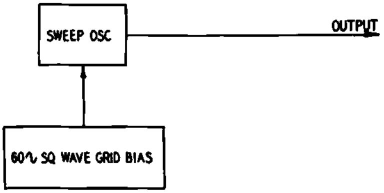


Fig. 229. The 60-cycle square wave bias drives the sweep oscillator to cutoff for one-half the operating time. During retrace the sweep-generator output is zero.

A typical square-wave voltage of this type is illustrated in Fig. 230. Such square-wave voltages are readily obtained by applying a large 60-cycle voltage to a limiter diode or triode. However, the keying voltage used in service sweep oscillators is more often of the form shown in Fig. 231, in which only one excursion of the 60-cycle sine-wave is clipped flat. The reason for this is that uniformity of the keying voltage is required only during the key-on interval, and the clipper circuitry is simplified by permitting the negative excursion of the waveform to retain its original shape. The arrangement of the wave-shaping circuit is usually such that the sweep oscillator operates for a somewhat shorter interval than when it is disabled.

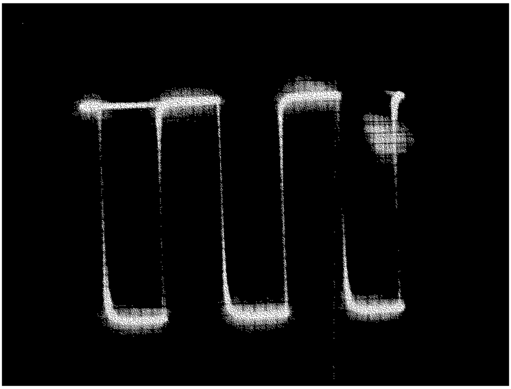


Fig. 230. A 60-cycle square-wave voltage which can be utilized for keying the control grid of the sweep oscillator to develop a zero-volt reference line.

The use of this particular keying waveform, instead of a true square wave, makes the key-on and key-off intervals somewhat unequal, with the result that, when the output from the sweep generator is tested with a demodulator probe and scope, the rectangular pattern obtained does not extend equally above and below the resting position of the scope beam (scope base line), as shown in Fig. 232-a, -b. However, the inequality of key-on and key-off periods does not affect the utility of the result in practical

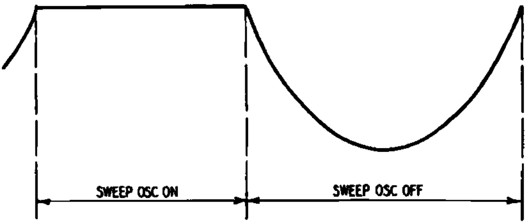


Fig. 231. Keying waveform of voltage often applied to grid of sweep oscillator to develop a zero-volt reference line. Only the "on" portion of the voltage need be clipped since the oscillator does not respond to changes in grid bias during the time it is cut off.

service work. The point is stressed only to clarify the lack of vertical centering of the rectangular pattern, which the technician may observe during use of the generator.

To provide a better understanding of the lack of vertical centering in this situation, note that the resting position of the scope beam in an a.c. scope (scope base line) is the dividing line between the positive and negative portions of the pattern displayed on the scope screen. The forward trace is accomplished faster than the return trace when the keying voltage is rectangular, instead of square. Hence the positive and negative areas displayed on the scope screen are unequal. There is, of course, just as much positive as negative electricity displayed in this a.c. waveform. But because one excursion is accomplished *more rapidly* than the other, the screen areas are not directly proportional to electrical quantity: hence the failure of the display shown in Fig. 232 to rest symmetrically with respect to the scope base line.

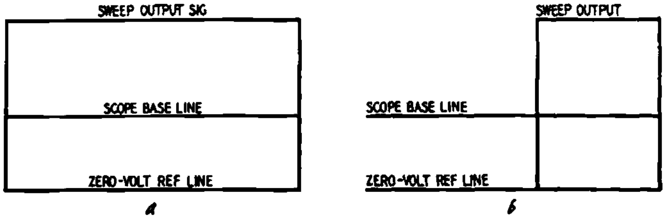


Fig. 232-a,-b. The sweep signal and zero-volt reference line (a) are unequally spaced above and below the scope base line (resting position of the scope beam) when the sweep time is less than the zero-volt reference time. This is caused by inequality of keying periods. When the keyed output from the sweep generator is displayed on sawtooth sweep (b) the relative on-and-off times are readily apparent.

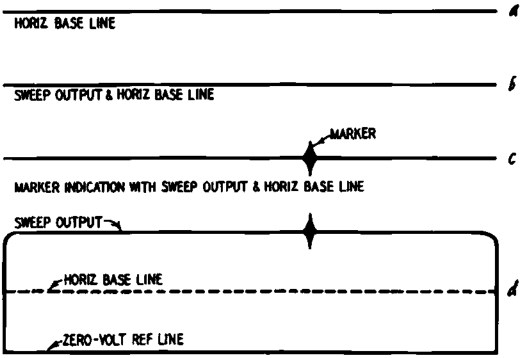


Fig. 233. Positioning of marker with reference to sweep output and zero-volt reference line.

You should understand that the resting position of the beam in an a.c. scope is the a.c. voltage level, and the position of the zero-volt reference line developed by the sweep generator is the d.c. voltage level, as shown in Fig. 233. If a d.c. scope were used to test the output from a sweep generator, the resting position of the beam and the zero-volt reference line would coincide, since both indicate the d.c. zero-volt level. In Fig. 233-a we have the resting position of the beam in an a.c. scope with no signal applied. In the next illustration (b) a demodulator probe is used to display the sweep generator output with no zero-volt reference level provided by the generator. No change is noted in the base line if the sweep output is flat. When marker voltage is added as in Fig. 233-c, the marker extends on either side of the sweep trace and the base line. When the zero-volt reference line (Fig. 233-d) is developed by the sweep generator, the sweep output level and the marker rise above the base line and the zero-volt level falls below the base line.

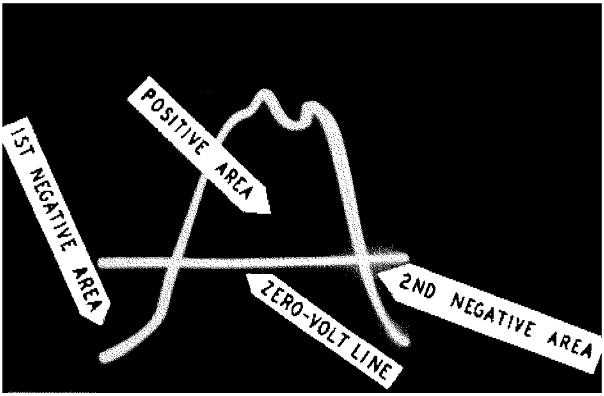


Fig. 234. When a waveform is developed by use of 60-cycle sine-wave sweep, the spot moves fast over the center, but slowly at the ends of the pattern. The spot takes longer to traverse the negative excursion of the waveform, hence the time axis is compressed at the ends. Because the spot travels faster in the central region, the positive area of the pattern is larger than the sum of the negative areas.

Fig. 234 is a double exposure which shows the resting position of the beam in an a.c. scope (zero-volt line for a.c.) and the manner in which a response curve distributes itself about the a.c. zero level when swept by a 60-cycle sine-wave voltage. Since the spot velocity is not constant in a sine-wave sweep, the algebraic sum of the positive and negative areas in the pattern is not zero, as would be the case with sawtooth sweep. However, since the amount of positive electricity is necessarily exactly equal to the amount of negative electricity, it is apparent that we are concerned basically with the product of *time* and *voltage.* In the event, however, that the sweep is linear in time, areas and electrical *quantities* are proportional—otherwise, they are not.

A service sweep generator may utilize two bands, as shown in Fig. 235, wherein the output from a sweep variable oscillator is utilized for high-band output and a fixed-frequency oscillator is switched into the circuit for low-band output. In such case, the nonlinear mixer is often left in the circuit for high-band as well as low-band operation, since this simplification reduces switching requirements. However, the use of the mixer on the high-band operation produces waveform distortion and generation of harmonics. For best output waveform, the mixer should be switched out on the high-band operation.

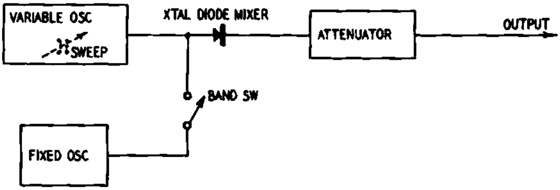


Fig. 235. A two-band sweep-generator arrangement in which the variable sweep oscillator drives the mixer at all times. For low-band operation a fixed-frequency oscillator is switched into the mixer circuit.

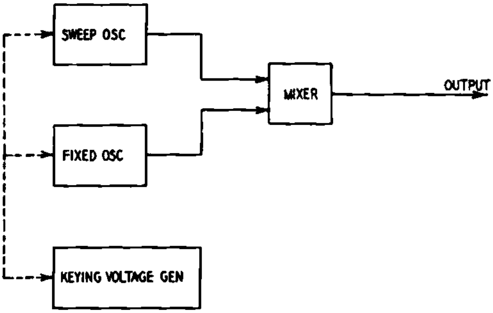


Fig. 236. Here the keying voltage is applied to both the fixed-frequency and sweep oscillators. This ensures zero output from the sweep generator during the zero-volt interval.

For low-band operation, a fixed-frequency oscillator is switched into the mixer circuit, as indicated in Fig. 235. The difference beat between the two oscillators is then used for low-band output.

Now, the keying voltage for zero-reference blanking may be applied to the sweep oscillator only (as shown in Fig. 229) or the keying voltage may be applied to both the fixed and swept oscillators (as shown in Fig. 236).

The output from the beat-frequency sweep generator will not be zero volt during the supposed zero-volt interval (see Fig. 237) if the keying voltage is applied only to the sweep oscillator. But if the keying voltage is applied to both the fixed and sweep oscillators, then the output from the sweep generator will be zero volt during the key-off interval.

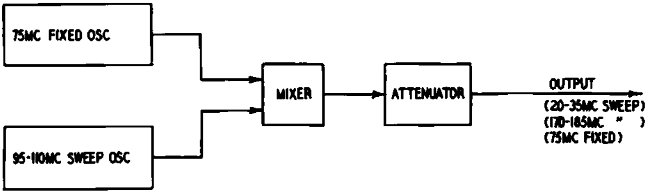


Fig. 237. Unfiltered output results in large numbers of undesired frequencies in the output.

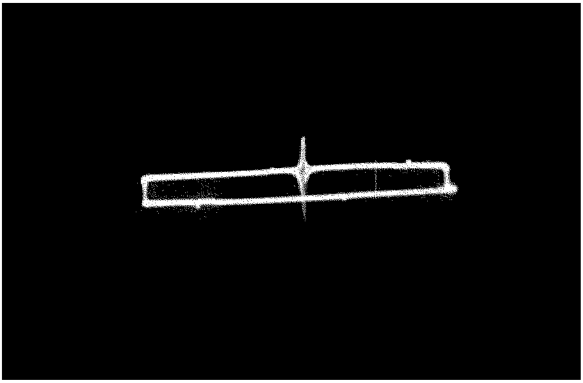


Fig. 238. Undershooting of the zero-volt reference line by a marker placed on the sweep output from a beat-frequency generator. The display is obtained through the use of a demodulator probe. The zero-volt reference line is displaced upward by feedthrough of the fixed oscillator during the key-off period. The sweep trace is displaced downward by out-of-phase beats of the marker with one or more of the spurious outputs present during the key-on period. The result is undershoot of the zero line by the marker.

To illustrate this further, when the output from a beat-frequency generator is unfiltered, there are large numbers of undesired or spurious frequencies present in the output. For example, when the voltage from a 75-mc fixed-frequency oscillator is mixed with the voltage from a 95-110 mc sweep oscillator (see Fig. 237) the output from the mixer contains a difference frequency of 20-35 mc, a sum frequency of 170-185 mc, and the fixed-oscillator frequency of 75 mc. Also present will be the 95-110 mc signal which feeds through with the 75-mc signal with har-

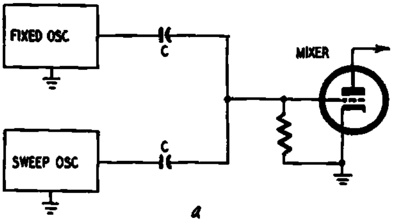


Fig. 239-a. The fixed and sweep oscillators are comparatively closely coupled by capacitors marked by letter C. The low-frequency output is considerably limited by the extensive residual coupling.

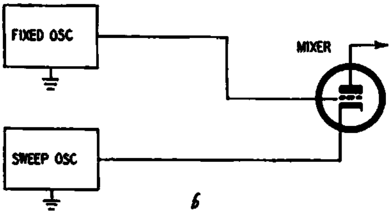


Fig. 239-b. The fixed and sweep oscillators are less extensively coupled by the cathode-follower type of mixer. Since the cathode "follows" the grid, the grid-cathode capacitance is effectively quite small. More extended low-frequency response can be obtained.

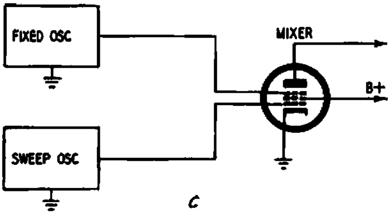


Fig. 239-c. The fixed and sweep oscillators are still less extensively coupled due to still smaller effective capacitance between the suppressor and control grids. Still more extended low-frequency response can be obtained.

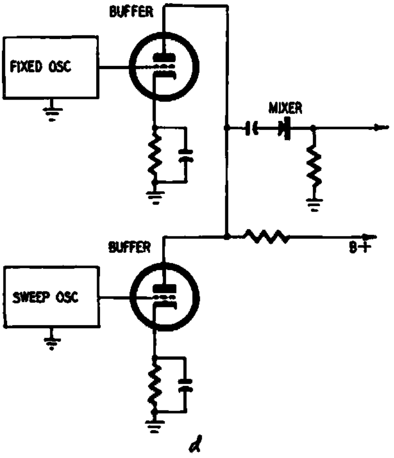


Fig. 239-d. The fixed and sweep oscillators are further decoupled by use of buffer stages. Low-frequency response down into the audio range can be secured due to very small value of residual coupling.

monics from the oscillators and from the mixer action. When keying voltage is applied only to the 95-110 mc sweep oscillator, the feedthrough from the 75-mc fixed oscillator is still present in the mixer output during the zero-volt reference-line interval. In other words, the output from the sweep generator *is not zero* during the key-off interval if the keying voltage is applied only to the sweep oscillator.

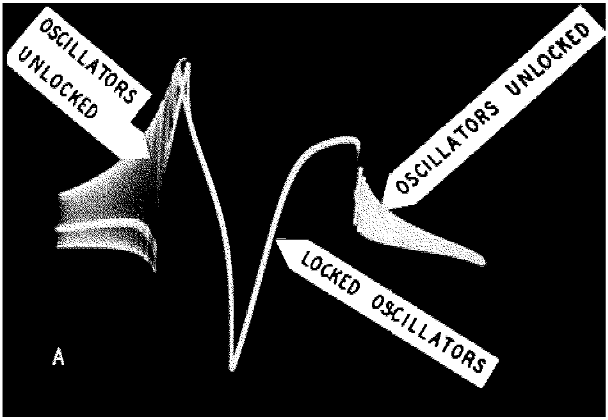


Fig. 240-a. The low-frequency notch may define the low-frequency limitation of the beat-frequency sweep generator or the low-frequency limitation of the demodulator probe utilized in the test, whichever is the greater. To check the generator output with certainty, apply the output of the generator directly to the vertical-input terminals of the scope. The illustration above shows the oscillators locked below 1 mc.

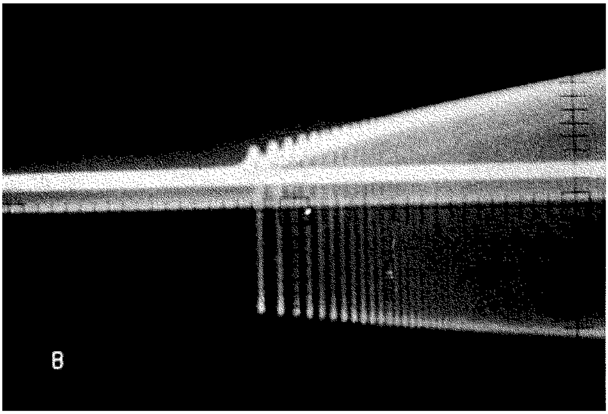


Fig. 240-b. Photograph shows oscillators locked below 100 kc.

Undershoot

It is this practice of keying off only the sweep oscillator which causes the sweep trace to undershoot *occasionally* the zero-volt reference line, as illustrated in Fig. 222. Another example of this situation is shown in Fig. 238 in which a marker on the sweep response, when tested with a demodulator probe, apparently falls below zero volt. It will be perceived that the feed through output from the fixed oscillator during the key-off interval is displacing the zero-volt reference line upward. Also the marker voltage is beating out of phase with one or more of the spurious outputs during the key-on interval, causing a downward displacement of the supposed difference-frequency level and an undershooting of the displaced zero-volt reference line. Undershooting of the zero-volt reference line does not occur when both the fixed-frequency and sweep oscillators are keyed, *but* this does not mean that spurious frequencies are not present during the forward-trace interval. The only way that these spurious frequencies can be eliminated is by use of a suitable lowpass filter in the output circuit of the generator, as previously discussed.

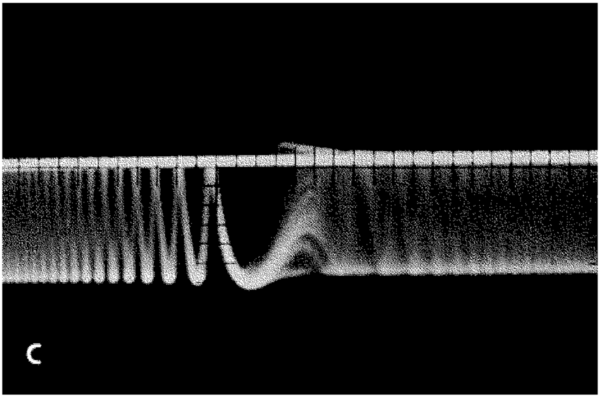


Fig. 240-c. Condition in which the oscillators are locked in below 7 kc.

Limitations of low-frequency output from beat-frequency generator

For color TV tests, it is desirable to have the output from a sweep generator down to 15 kc or lower. It might be supposed that this would be an easy requirement to meet with a beat-frequency sweep generator, inasmuch as the output theoretically extends down to zero frequency (d.c.) as the frequency of the sweep oscillator sweeps through the frequency of the fixed-frequency oscillator. However, theory and practice diverge because of the interaction of the sweep and fixed oscillators in the form of *pulling* and *locking*. The lowest frequency which can be obtained from a beat-frequency sweep generator is determined by the amount of residual coupling between the sweep oscillator and the fixed oscillator. At some lower frequency, this coupling between the two oscillators causes both to pull in to the same frequency and to oscillate together at the *same* frequency over a band which is called the *locking interval*. It is the reduction of this locking interval to a suitably low range that makes a beat-frequency sweep generator useful for color TV service.

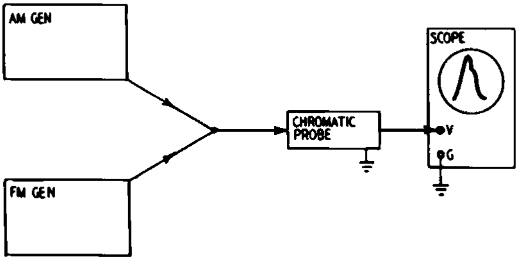


Fig. 241. Typical service sweep arrangement for obtaining very low-frequency sweep output for checking color TV circuits being tested by direct application of the sweep voltage to the vertical-input terminals of the scope.

To obtain an understanding of residual coupling between sweep and fixed oscillators, refer to Fig. 239 which shows some of the various methods used to apply the outputs from sweep and fixed oscillators to the mixer. The methods are shown in the order by which the residual coupling is lessened and which makes possible the realization of a lower-frequency sweep output.

When the low-frequency output from a beat-frequency sweep generator is tested with a demodulator probe and scope, the low-frequency "notch" is as shown in Fig. 240-a,-b,-c. The operator may be misled in evaluating the low-frequency capability of the generator in such case, because there is a definite low-frequency limit to the probe response which may impose a limitation in turn on the validity of the test. Hence, it is necessary to apply the output from the low-frequency band of the generator directly to the vertical input terminals of the scope, as illustrated in Fig. 241, with a resulting display as shown in Fig. 207. This is the type of display obtained when the low-frequency output extends down to a very low value, such as 8 kc. In the event that the sweep and the fixed oscillators of the generator are not quite so extensively decoupled, you will find that the low-frequency notch is much wider.

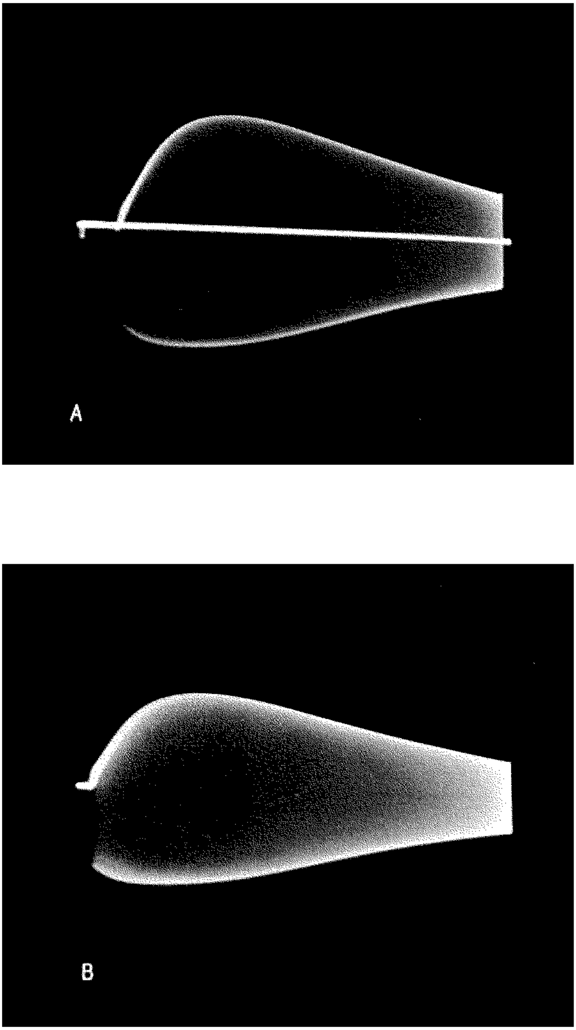


Fig. 242-a,-b. Dissymmetry caused by waveform error from generator. Display of output (a) of video sweep-generator when zero-volt reference line is used. Display of video-sweep generator output (b) applied directly to input terminals of scope.

Figs. 242-a,-b, 243-a,-b, and 244 are instructive. They show that if the sweep and fixed oscillators are not extensively decoupled, the low-frequency notch is wider. It also shows that the sweep and fixed oscillators "pull" prior to locking and that the "pulling"

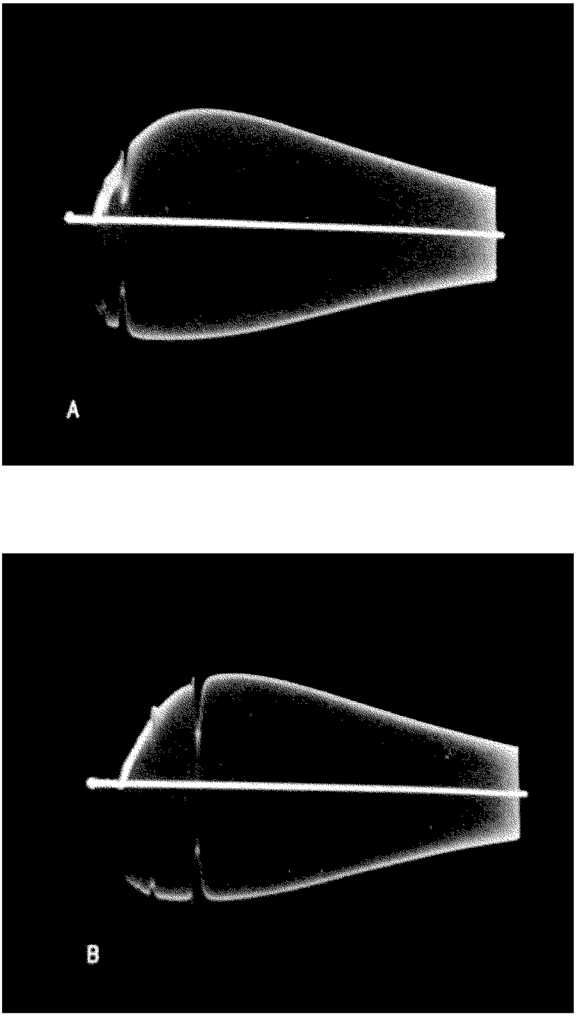


Fig. 243-a,-b. Marker at 100 kc (a) and at 200 kc (b). Marker disturbances are caused by spurious outputs from the generator. For example, the intended absorption marker is illustrated above in the photo (b) at 200 kc. An undesired harmonic causes a smaller spurious marker to appear at the left in the sweep waveform at the 100 kc point.

process introduces even-harmonic distortion, with the result that the positive and negative excursions of the sweep voltage are unequal in the "pulling" region. It also shows that the sweep width of the generator must be kept within the frequency response range of the vertical amplifier in the scope or high-frequency attenuation will be apparent, which is caused by limitations of the scope vertical amplifier. Fig. 240 also shows that spurious sweeps may be present in the output, and will cause spurious markers to appear, even when the absorption type of marker is used. If the spurious sweep is caused by the presence of a second harmonic, the spurious output will then sweep through the band twice as fast as the fundamental, so that the second-harmonic spurious indication falls halfway between the fundamental indication and zero frequency. Absorption markers are usually preferred in video-frequency sweep work inasmuch as they give rise to far fewer spurious markers than does beat-marker indication, as shown in Fig. 245. The detailed discussion of marker arrangements is reserved for a later chapter.

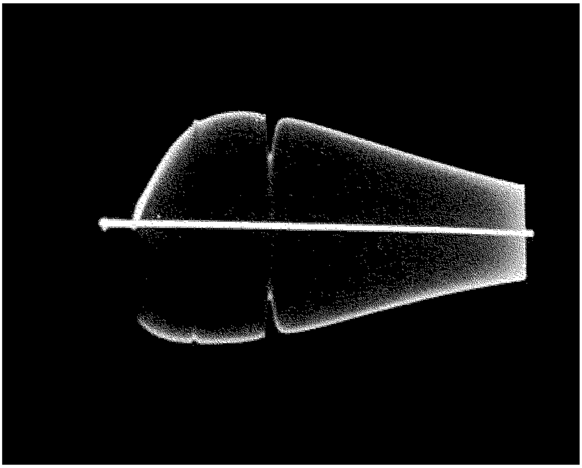


Fig. 244. The illustration above clearly shows the positioning of the absorption marker at 300 kc on the sweep output waveform.

The reactance of blocking capacitors increases rapidly at low sweep frequencies. Hence the blocking capacitors in the output system of the sweep generator (if used) must be sufficiently large in value to pass these low frequencies without attenuation. Compare, for example, Fig. 240 with Fig. 246: the only difference between these two sweep outputs is the use of a relatively small blocking capacitor in Fig. 246. Of course the output system must have sufficient bandwidth to pass without objectionable attenuation the highest r.f. frequency provided by the generator. These considerations will become clearer after the next chapter.

Irregularities in generated sweep signal

Sometimes you will find that there are certain irregularities present in the sweep output signal. These may be puzzling when their cause is not recognized. For example, it may be observed that the width of the response curve fluctuates horizontally in an irregular and unpredictable manner. Sometimes this difficulty appears only at maximum setting of the sweep-width control, while at other times the difficulty may appear at all settings of the sweep-width control. The fluctuation in horizontal width of the curve

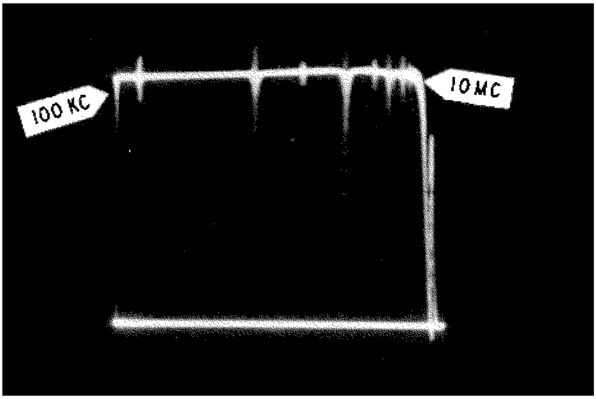


Fig. 245. The advantage of an absorption marker is that it results in fewer spurious pips on the sweep waveform. Note the large number of pips produced by beat markers.

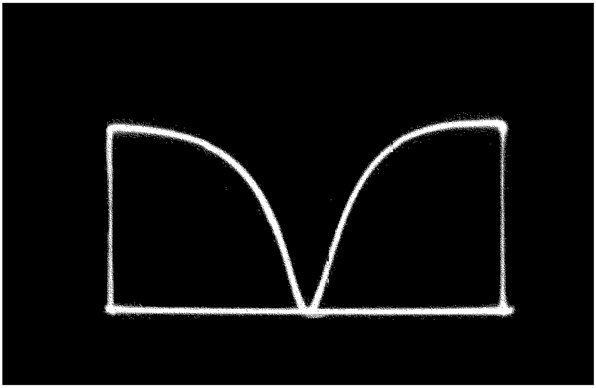


Fig. 246. This illustration shows the effect on the sweep waveform of using a relatively small blocking capacitor.

is annoying and makes it difficult to use the sweep generator effectively.

Such horizontal fluctuation is usually caused by a poor contact of the sweep motor with the source of driving voltage. For example, the sweep motor may be energized through flexible strips, pigtail leads or hairsprings. In any case, lack of a solid mechanical connection to the connecting leads, especially under the condition of vibration which is present, will cause the driving voltage to the motor to vary in an erratic manner. This variation evidences itself as fluctuation in horizontal sweep width, causing the response curve to widen and narrow rapidly and erratically.

Another problem sometimes encountered appears as large bursts of noise on the response curve when the tuning dial of the sweep generator is turned. This difficulty is also caused by poor electrical contact to the tuning capacitor or tuning inductor and can be remedied by attention to this point.

Severe fluctuation of line voltage can also cause irregular operation of the sweep generator. If difficulty is encountered from this source, an automatic line-voltage regulating transformer will serve to stabilize the output from the sweep generator.

attenuating the output

After the sweep signal has been generated it then becomes necessary to bring the signal from the output of the mixer to the point of application in the circuit under test (see Fig. 301) and likewise to control the signal level without distortion. A properly terminated cable, as shown in Fig. 302, is used as the link between the generator and the circuit under test. When the shielded output cable is terminated in its own characteristic impedance, the input of the cable "looks like" the terminating resistor so that there is no reactance present at the input of the cable to distort the sweep signal. The losses in a properly constructed cable are negligible, so that the sweep signal can thus be transported from the point of generation to the point of application essentially without loss.

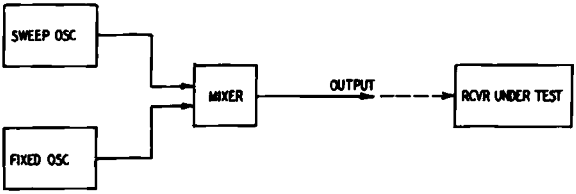


Fig. 301. The first problem in application of the sweep signal to the circuit under test is to provide an output-cable arrangement which will transport the signal without distortion and essentially without loss.

However it is usually undesirable to transport the sweep signal without loss since the unattenuated signal will usually overload the circuit under test. Hence, suitably designed attenuators must be utilized to lower the signal voltage to the desired value without distortion of the sweep voltage (without loss of flatness). The design of high-frequency attenuators is not a simple matter. Attenuators which are satisfactory at lower frequencies of operation become unsuitable at higher frequencies because of the *residual reactance* in the attenuator construction and *impedance irregularities* introduced by the attenuator. However, as will be seen, adequate answers for these problems exist.

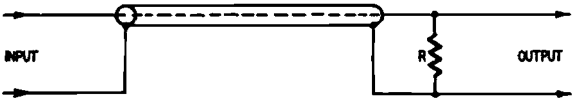


Fig. 302. In a low-loss coaxial cable the characteristic impedance is purely resistive and the cable can be terminated by a resistance R.

Types of attenuators

Fig. 303 shows a simple potentiometer which serves very well at audio frequencies for signal attenuation. The stray capacitance of the potentiometer does not affect its operation. However, as the operating frequency is raised, the influence of the stray capacitances becomes greater and greater, since the reactance of the capacitance decreases at higher frequencies. To maintain proper control of the output, and also to avoid disturbances due to the introduction of substantial capacitive reactance into the system, it

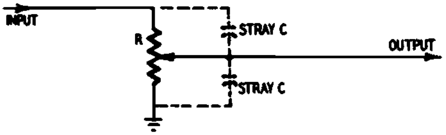


Fig. 303. Stray capacitance, C, shunts the output potentiometer.

becomes necessary to reduce the value of the potentiometer to a very low value. A typical resistance value for a potentiometer used in a sweep output system is 50 to 100 ohms.

While it is not desirable to utilize low-impedance output systems in a sweep generator arrangement, there is a very definite upper limit to the output impedance which can be tolerated because of the influence of stray capacitances as has just been noted. In addition, there is also the consideration of the capacitance which may be present at the point of signal application in the circuit under test. Unless the output system has a low impedance, the effect of such circuit capacitances will impair the flatness of the output and the generator will be unsuitable for practical work. Hence, the impedance of typical sweep output systems is limited to the range of 50 to 100 ohms.

A potentiometer such as shown in Fig. 303 may be used either at the input or output end of the cable, (Fig. 304-a,-b), either method being satisfactory in application. Both arrangements shown in the illustration are utilized in service sweep generators. In either case, it is essential that the resistance at the output end of the cable comprise a proper termination to avoid reflections of the sweep voltage. In other instances, two potentiometers are connected in parallel as shown in Fig. 305. This latter arrangement must be maintained at very low impedance and constructed with care if excessive reactance is to be avoided from the cascading. By arranging the two potentiometers in cascade (series) it is possible to obtain greater attenuation than with only one potentiometer.

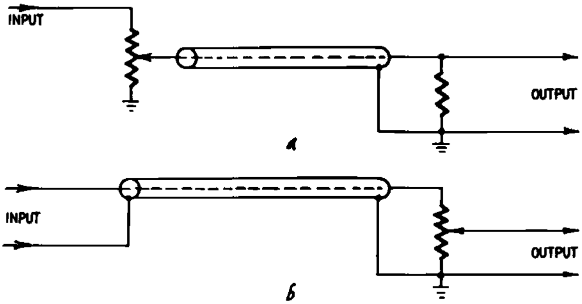


Fig. 304-a,-b. A potentiometer-type attenuator may be placed at the input (a) or at the output end (b) of the cable.

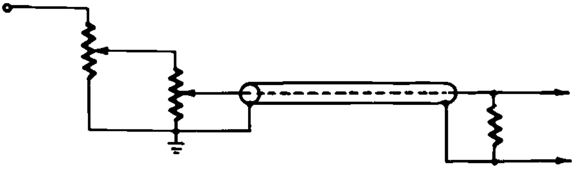


Fig. 305. Cascaded attenuators make it difficult to avoid sweep-voltage reflections. Unit must operate at very low impedance and be constructed with shortest possible leads.

In most resistive attenuating systems, a step type attenuator is used in addition to the continuous potentiometer form of attenuator, as shown in Fig. 306. A properly constructed ladder attenuator of this sort makes it possible to attenuate the output down to a very small value to meet all service requirements. To function properly, the ladder attenuator must have a low impedance and must be extensively shielded in such a manner as to maintain a reasonable value of characteristic impedance throughout. Substantial irregularities in characteristic impedance cause reflections of voltage and may impair the flatness of output.

It is interesting in passing to observe why a high-impedance output system would be desirable, if it were practical. Suppose that the mixer delivers 0.5 volt into an impedance of 1,000 ohms. The electrical relationship here can be stated: $W=E^2/R$ or the mixer delivers 0.25 milliwatt into the attenuator impedance. The power output from the mixer remains constant, no matter what attenuator impedance is utilized. If the attenuator impedance is made equal to 100 ohms, 0.5 volt output is no longer available, but only 0.15 volt. Hence, the lower the output impedance, the greater the amount of output voltage which must be foregone.

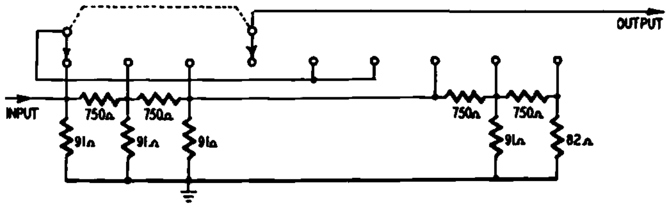


Fig. 306. Typical step-type attenuator. The network is a ladder construction, provides reasonably constant impedance at each step.

Stray capacitance

The effect of stray capacitance C in attenuating high-frequency signals in a resistive attenuator arrangement R-R is shown in Fig. 307. The occurrence of shunt capacitance along a resistive circuit has the effect of introducing an integrating circuit, or lowpass filter action, which progressively attenuates the higher frequencies. This situation of *lumped* capacitance must not be confused with the *distributed* capacitance of the output cable. Because the shunt capacitance in a cable is *uniformly* distributed along the length of the cable, it reacts with the distributed inductance of the cable conductors to "look like" a pure resistance equal in value to the characteristic resistance of the cable. Of course, the cable presents a pure resistance only when properly terminated. In the case of the network shown in Fig. 307 the high-frequency response can be improved by lowering as far as possible the values of both R and C.

Residual leakage

All attenuators used in service generators tend to exhibit residual leakage when set for minimum output. This does not hamper the operator, provided the leakage voltage is sufficiently low. An illustration of the cause of residual leakage is shown in Fig. 308. The capacitance from one switch contact to the next affords a reactive path for escape of sweep voltage to the output. The higher the frequency, the greater the leakage. This can be reduced by adding sections to the attenuator or by using a lower-impedance attenuator.

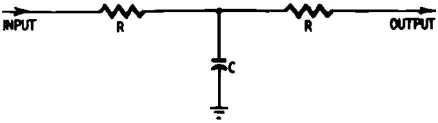


Fig. 307. Stray capacitance (C) causes high-frequency attenuation.

Reflections

The problem of reflections due to impedance discontinuities in the attenuator is a serious one at higher frequencies, and suitable means must be taken to eliminate the influence of these reflections upon the flatness of the swept output. The general nature of the problem is illustrated in Fig. 309, which regards the output system of the sweep generator as a continuous coaxial cable, with exception of the impedance discontinuity C, introduced by the attenuator. Reflections of sweep voltage occur at C and form standing waves on the line between the "Input" and "C". These standing waves form interference patterns with the output sweep voltage and impair the flatness.

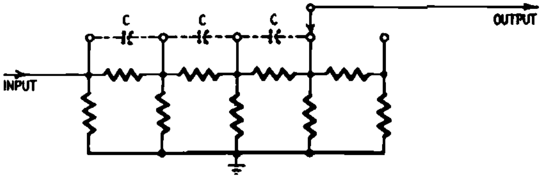


Fig. 308. One of the causes for leakage from a sweep generator. There is a certain small value of capacitance from one switch contact to the next (and from one lead to the next) providing a path for flow of high-frequency currents.

To overcome this difficulty, two precautions are commonly taken in the construction of the instrument. First, the attenuator is located as close as possible to the sweep oscillator (or mixer), so that there is a minimum length of cable or lead on which to develop standing waves. Second, the attenuator is tapped down approximately 50% on the output load resistor, as shown in Fig. 310, so that reflected voltages will be effectively absorbed in the resistive padding (R/2 and R/2) thus provided. By observing these two precautions in the instrument construction, loss of flatness due to attenuator reflections can be largely avoided.

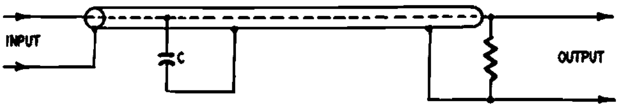


Fig. 309. The output of the generator should have a constant impedance to avoid reflections which cause lack of flatness. The capacitive reactance in the attenuator is represented here as a capacitor C shunted across an intermediate point of the cable.

In addition to reflections which may occur within the attenuator, there is also the possibility of reflections occurring back from the output cable termination to the attenuator, as illustrated in Fig. 311. The output cable is properly terminated by R. The impedance of the cable is chosen sufficiently low so that quite a wide tolerance of Z (impedance of circuit under test) is permissible before the effective value of R is appreciably lowered. However, there are some test conditions which the operator may employ, such as injection of sweep voltage by the chassis ground-current method, which places a very low impedance Z across R and results in improper cable termination. In such case, standing waves develop on the output cable between the attenuator and R and impair the flatness of the sweep voltage. However, the seriousness of such reflections can be minimized by designing the attenuator so that it presents a match to the input end of the cable.

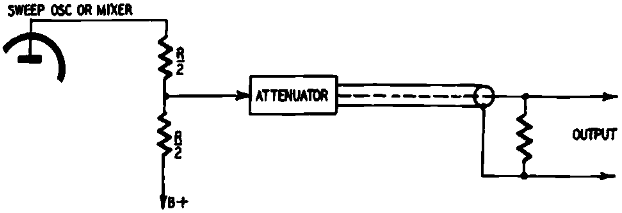


Fig. 310. When the attenuator does not have a constant impedance for all settings, reflections can be minimized by resistive padding. The attenuator is connected as closely to the sweep source as possible, and is tapped approximately 50% down on the output load resistor. Reflections from the attenuator are then substantially absorbed in R/2 and R/2.

Ladder attenuators in service sweepers are usually constructed around wafer switches. Laboratory type instruments, however, generally utilize a more expensive type of construction in which the ladder attenuator is assembled in a metal casting, designed so that leakage and impedance irregularities are minimized.

The electronic attenuator

Another type of continuous attenuator is sometimes provided to give a vernier control between the steps of a ladder attenuator, as illustrated in Fig. 312. The electronic attenuator is a very simple form in which the output from the sweep oscillator is varied by changing the plate voltage. The range of the electronic attenuator is somewhat limited. The method operates quite satisfactorily as a vernier control, but is not suitable as a primary control of output. The sweep oscillator will suddenly "drop out" at some critical setting of the plate voltage. Hence, an electronic attenuator of this type must always be supplemented by a primary attenuator, such as a ladder network. A sufficient number of steps must be provided on the ladder so that continuous control of output is provided by the electronic attenuator between steps of the ladder.

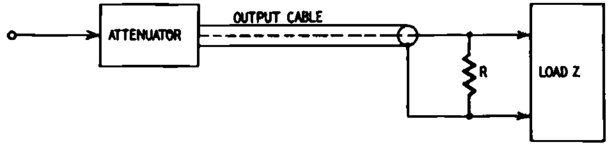


Fig. 311. Low values of Z can result in reflections of sweep voltage back to the attenuator.

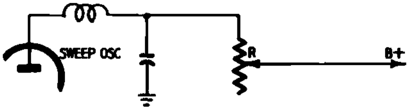


Fig. 312. Electronic attenuator used for vernier control of the sweep voltage. Potentiometer R varies the plate voltage of the sweep-oscillator tube. This attenuator must be used with some other type, such as a ladder network.

Another form of electronic attenuator is shown in Fig. 313, in which the bias voltage on the mixer tube is varied. This attenuator has a wide range compared with the circuit shown in Fig. 312. This principle is used in some of the top service sweepers. It will be seen from Fig. 313 that the mixer characteristic can be changed from linear to nonlinear operation, with all in-between characteristics, as potentiometer R is varied. When the mixer is operating on a linear portion of its characteristic, no conversion takes place and the frequencies of the fixed and sweep oscillators merely feed through, producing no difference frequency. However, when the mixer is operating on a nonlinear portion of its characteristic, the frequencies of both the fixed and sweep oscillators heterodyne to develop the difference frequency, which then appears in the output. When the potentiometer is set to produce a very small curvature of the tube characteristic, a very small difference frequency appears in the output. But when the potentiometer is set to produce a substantial curvature of the tube characteristic, a large difference frequency appears in the output. Hence the range of output voltage which can be obtained from this arrangement is much

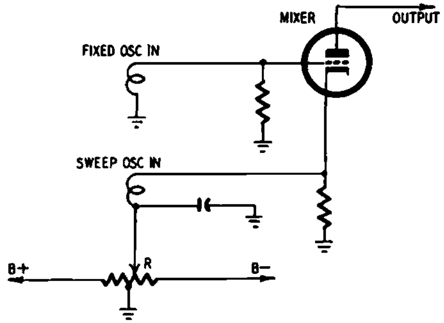


Fig. 313. This attenuator utilizes the principle of biasing the mixer tube for various degrees of nonlinear mixing.

greater than in the case of plate-voltage variation of the sweep oscillator, and this arrangement operates satisfactorily as the primary attenuator unit. The application of the mixer-bias attenuator is usually limited to the beat-frequency ranges of the sweeper, since it is preferable not to pass the output from the sweep oscillator through a nonlinear circuit for utilization; although beat fundamentals have good waveform when the constants of the mixer are suitable, it is not possible to maintain good waveform of feed-through frequencies, which suffer considerable even-harmonic distortion in passage through the nonlinear circuit.

It is desirable, of course, to eliminate any feed-through frequencies from the output of the mixer illustrated in Fig. 313, and this is readily accomplished by use of a lowpass filter, as shown in Fig. 314. The combination of the mixer-bias attenuator arrangement and lowpass filter provides pure fundamental output from the mixer and also a wide attenuation range. It is essential, of course, that the lowpass filter be terminated in its own characteristic impedance by resistor R to obtain proper filter action.

Any lead carrying high-frequency current must be properly terminated, if it is a substantial fraction of a wavelength, to avoid reflections and impairment of flatness due to standing waves. In other words, the precautions which have been observed with respect to termination of output cables apply equally to generator wiring which conducts high-frequency currents. For example, Fig. 315 shows how a lead which is to connect the sweep oscillator to the mixer may be designed for flatness of response, in the event that the lead is sufficiently long to cause trouble otherwise. The low-impedance link is coupled to the tank of the sweep oscillator and in turn energizes a coaxial lead which is properly terminated by a resistor R at the mixer tube. The mixer tube receives a flat sweep voltage no matter how long the coaxial lead may be.

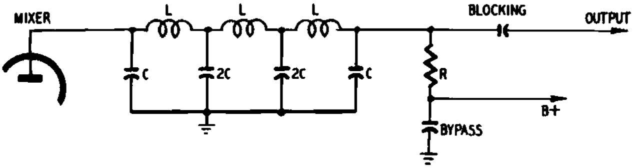


Fig. 314. When the mixer is followed by a low-pass filter, only the difference frequency is passed to the output.

The critical nature of sweep generator wiring may be better appreciated if it is recognized that even ½ inch of lead at 200 mc exhibits substantial reactance. However, the 200-mc signal can travel a yard in a properly terminated coaxial cable without encountering reactance or appreciable loss.

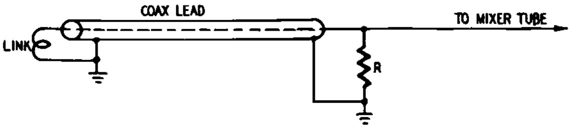


Fig. 315. The wiring of the high-frequency section of a sweep generator presents standing-wave problems. Above is shown an effective method of utilizing a long lead without impairing sweep-voltage flatness.

The waveguide attenuator

One of the best attenuators for use at radio frequencies or u.h.f. is the waveguide type, as illustrated in Fig. 316-a, -b. Such an attenuator provides continuous control of the output voltage as well as a very wide range of attenuation. The one attenuator thus serves for complete control of the output.

The sweep voltage is launched into the waveguide tube by means of a hairpin link if electromagnetic coupling is used or by means of a probe pin if electrostatic coupling is used. The waveguide tube has a relatively small diameter with respect to the operating wavelength, so that in effect the attenuator is a section of waveguide operating below cutoff. When operated below the cutoff frequency, the rate of attenuation of the fields in the waveguide is very rapid and falls off exponentially from the source.

Attenuation is accomplished by use of a sliding pickup link or probe pin, as the case may be, inside the waveguide tube. The pickup element need slide only 3 or 4 inches in a typical attenuator to reduce the sweep signal from full output voltage to a point below the noise level where it is no longer usable.

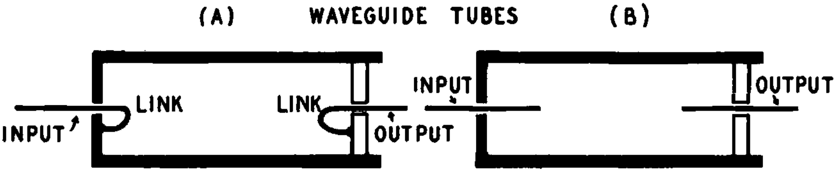


Fig. 316-a,b. Two forms of waveguide attenuator. Electromagnetic type (a) in which the input sweep voltage launches an electromagnetic field into the waveguide tube through a coupling link. A second coupling link is mounted on a sliding plunger to pick up the field. The lower illustration (b) is the same except that the input voltage launches an electrostatic field into the waveguide by means of a probe pin.

The link or probe at the input end of the waveguide attenuator does not necessarily provide a constant impedance over the complete range of frequencies to be accommodated and, accordingly, some degree of reflection may be obtained from the attenuator. To avoid impairment of flatness, the input of the attenuator may obtain its signal from a resistive pad, as has been noted earlier, in order to absorb any reflections which may be present. The output link or probe may be used to energize a coaxial output cable directly. No padding is needed at this point since reflections along the output cable are caused only by improper termination of the cable—not by improper source resistance. Of course, when the source resistance matches the characteristic impedance of the cable, maximum energy transfer is obtained.

Some of the more elaborate sweep generators provide double-ended output on the v.h.f. and u.h.f. channels to test balanced circuits such as front ends and antennas under normal operating conditions. To develop the balanced signal, a pushpull sweep oscillator is utilized. The attenuator system is also double-ended in such case, as illustrated in Fig. 317. The pushpull oscillator develops a double-ended output which may be controlled by a dual waveguide attenuator. Resistors R/2 provide absorptive padding. The two attenuators are operated by a common control and deliver their output to a twin-conductor coaxial cable. Resistor R terminates the cable in its own characteristic impedance. When the waveguide type of attenuator is used, it is possible to obtain balanced attenuation in a single waveguide tube by launching suitable forms of field into the tube from a double-ended probe arrangement. Table 3 is a listing of the attenuating methods used in service sweep generators.

Attenuator calibration

Service sweep generators do not commonly utilize calibrated attenuators. Service work can usually be accomplished satisfactorily without knowing how many microvolts of signal are being applied to the circuit under test. The cost of the instrument is considerably reduced by eliminating the added circuitry and refinements of construction which are required to obtain calibrated output. However, there are available to the service trade specialized types of signal generators having calibrated output and a somewhat limited frequency range, which are used primarily for testing receiver sensitivity. An elaborate waveguide attenuator, constructed as a bellows, and a carrier-level meter are used to determine the output level in microvolts. By limiting the range of generator operation to the low end of the v.h.f. range, its cost is kept in line with other service generators.

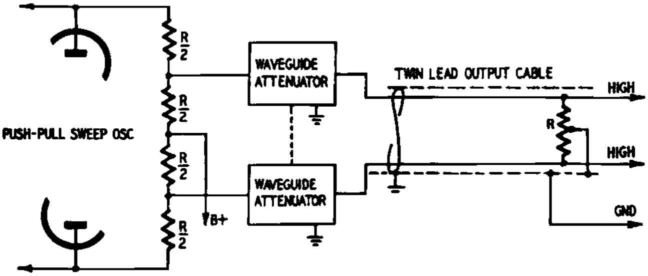


Fig. 317. A double-ended output arrangement for more efficient testing of balanced circuits such as front ends, antenna systems, etc.

When the technician needs to know the number of microvolts being applied by a conventional generator to the receiver under

Table 3 —
ATTENUATING METHODS FOR SERVICE SWEEP GENERATORS

Method	Control Provided	Advantages	Disadvantages
Potentiometer voltage divider.	Inserted in series with r.f. output lead or cable; in some cases used as termination for sweep-output cable.	Low cost, simplicity.	Must operate at very low impedance to avoid impairment of flatness at r.f. Does not provide the freedom from feed-through afforded by various other attenuator arrangements.
Dual-potentiometer voltage divider (cascaded potentiometers).	Inserted in series with r.f. output lead or cable.	Relatively low cost and simplicity.	Must operate at lower impedance than the single potentiometer arrangement to avoid impairment of sweep flatness at r.f.
Resistive ladder step attenuator.	Inserted in series with r.f. output lead or cable.	Smoothness of impedance when properly constructed; same source resistance as characteristic impedance of output cable.	Output variation is stepped, and ladder must be supplemented by a vernier attenuator. Costly when designed for top performance.
Electronic attenuation by control of mixer grid bias.	Transition from linear to nonlinear operation of mixer tube.	Low cost, simplicity, adequate attenuation range.	Does not provide control of other than beat-frequency bands.
Electronic attenuation by control of plate voltage of sweep oscillator.	Amplitude control of sweep-oscillator output.	Low cost, simplicity.	Limited range; oscillator "drops out" if plate voltage is reduced excessively. In beat operation, does not maintain proper ratio of voltages from sweep and fixed oscillators.
Waveguide type of attenuator.	Inserted in series with r.f. output lead or cable.	Wide attenuation range obtained without supplementary attenuators.	Relatively high cost; operates to best advantage over v.h.f. and u.h.f. ranges (attenuation too extreme at i.f. and video frequencies).
Resistive H-pad arrangement.	Inserted between terminated output cable and point of application in circuit under test.	Low cost, simplicity, and conversion of single-ended to double-ended output. Operates as absorption pad in critical applications.	Provides only rough control of signal level. Time consuming to connect or disconnect. Double-ended output obtained at expense of severe signal attenuation.

test, it is sometimes possible to use a field-strength meter to measure the generator output. Whether the field-strength meter will be satisfactory for the application depends upon the confidence which can be placed in its calibration. In case the meter is sufficiently accurate, the output cable from the generator can be applied to the terminals of the field-strength meter and the generator output adjusted to obtain the desired number of microvolts. Then the output cable can be disconnected from the field-strength meter, and connected to the input terminals of the receiver under test.

Attenuation is sometimes obtained at the termination of the sweep output cable, as shown in Fig. 318. For example, when the 1,000-ohm resistors are used to pad each side of the line, a 75- or 300-ohm impedance may be presented to the circuit under test, with the resistive padding and attenuation afforded by the series 1,000-ohm resistors. The cable itself is properly terminated by another 75-ohm resistor.

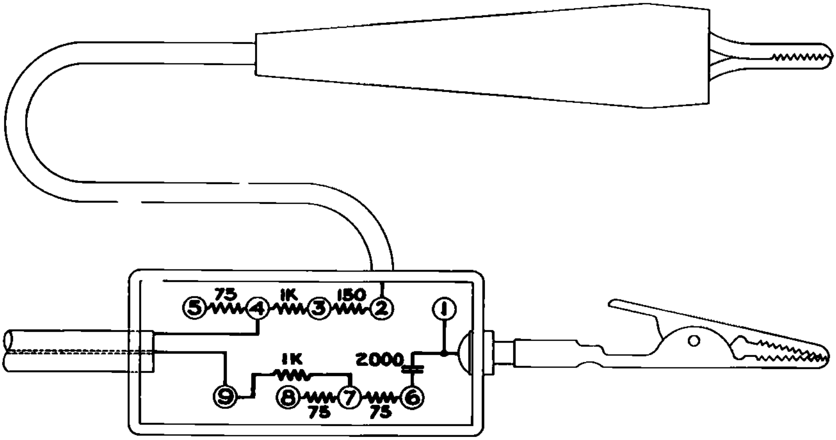


Fig. 318. Sweep-output termination box for a typical generator. See the chart on page 13 for a tabulation of the various impedances available.

Another property of this H-pad at the end of the cable is the conversion of single-ended to double-ended output, as shown in Fig. 319-a,-b. The H-pad is shown in conventional form at a, and is redrawn at b to illustrate how both sides of the output appear above ground, with a voltage drop between the two output terminals. A loss of 29/30 of the output voltage occurs, but the conversion from single-ended to double-ended output is practically complete.

Expedients are sometimes used by the operator to obtain attenuation beyond the value provided in the attenuating system, such as operation on the second or third harmonic.

Change of generated frequency with attenuator setting

It is desirable that the output frequency from the generator be independent of the attenuator setting. In other words, to cite a practical example, once the operator has adjusted the generator output to 4.5 mc and has centered the S-curve display of a ratio detector on the scope screen, it should be possible to set the attenuator to any desired level without moving the S curve along the base line or off-screen. However, it does not always happen that service generators are so stable.

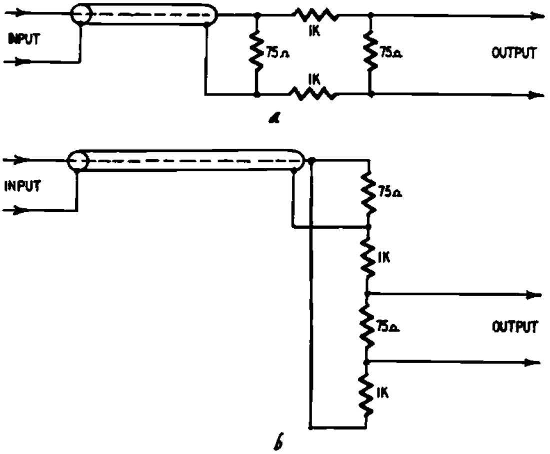


Fig. 319-a,-b. The use of the resistive H pad (a) also provides conversion of single-ended to double-ended output at the expense of voltage attenuation. This principle is clearer from the redrawn circuit (b). Note that both sides of the output are now above ground and although an attenuation of approximately 30 times is incurred, an effectively balanced output is provided.

The reason for change of the generated frequency with change of attenuator setting is shown in Fig. 320. In this example, the output from a Hartley oscillator is capacitively coupled to the grid of a buffer tube through a small coupling capacitance (3 μμf). The attenuator consists of a potentiometer in the cathode circuit of the buffer stage. This is a representative arrangement, and the principles to be discussed apply also to other attenuating arrangements.

In many practical situations, a buffer does not provide *complete* isolation. In the arrangement shown in Fig. 320, there is residual stray capacitance C1 from grid to cathode of the buffer as well as residual stray capacitance C2 from the cathode of the buffer to the wiper arm of the potentiometer. These stray capacitances are comprised of wiring and terminal capacitances and residual interelectrode capacitance between grid and cathode of the buffer stage.

As a practical result of this situation, the 3-μμf coupling capacitor is effectively in series with C1 and C2. Thus when C2 is varied by changing the attenuator setting, the tuning capacitance across the oscillator tank is also varied somewhat. This change in tuning capacitance causes a change in the generated frequency. To avoid this difficulty, it is necessary to provide sufficient isolation between the oscillator and the attenuator so that negligible capacitance change is reflected into the oscillator tank as a result of change in attenuator setting.

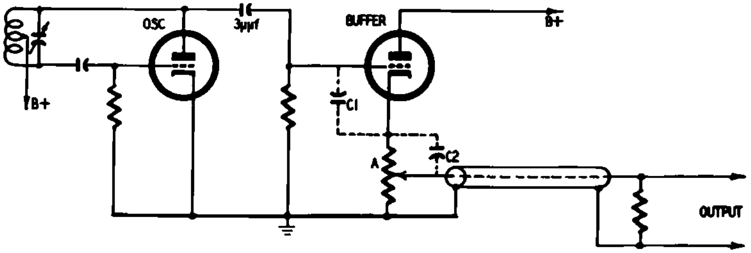


Fig. 320. A change in the setting of the attenuator can result in a shift of the output frequency.

Attenuating action is sometimes obtained incidentally with devices which are utilized with other purposes in mind; e.g., since the output impedance of typical service generators is usually low (in the order of 50 to 100 ohms), resistive pads are often utilized to provide a match of generator output to circuit input impedance. Consider a situation in which the output from a 75-ohm generator output system is to be applied to the input terminals of a television receiver having an impedance of 300 ohms. In such case, it is common practice to connect a 125-ohm resistor in each side of the generator output cable, thereby providing an impedance step-up of 250 ohms; this 250 ohms is added to the 75-ohm termination of the generator cable which is in turn connected in parallel to the cable, making an effective total impedance of 287.5 ohms, as "seen" by the input terminals of the television receiver. The shunting effect of 250 ohms plus 300 ohms (total of 550 ohms) does not significantly reduce the effective value of the 75-ohm resistor which terminates the generator output cable, so that the generator cable still "sees" practically 75 ohms.

Thus, it is apparent that the pad serves its primary purpose, viz., that of providing a proper termination for the generator output cable, and also of providing a proper source resistance to the input terminals of the television receiver under test. Next, let us investigate the incidental attenuating action which is imposed by this pad arrangement. The terminal voltage across the cable output drops across a total pad resistance of 250 ohms, as well as across the 300-ohm input impedance of the receiver. Hence, approximately 50% of the available output voltage from the generator is dissipated in the insertion loss of the pad.

An attenuation of 50% in the available output voltage from the generator might seem to be a small price to pay for proper matching of system impedances—but it must be clearly recognized that the output from some low-priced sweep and signal (marker) generators is marginal. Practically no loss of available signal can be tolerated in tests such as front-end sweep checks, especially on high channels. Let us review a typical situation, in which the problem is not one of attenuating the output from the generators, but indeed, one of obtaining a usable amount of signal voltage. A service signal generator which provides channel 13 coverage on the fourth harmonic for marking, and a service sweep generator which provides channel 13 coverage on the second harmonic for sweeping, were connected to the antenna input terminals of a TV receiver through an impedance-match pad. A sensitive scope was connected to the test point provided on the front end of the receiver. A small amount of deflection was obtained on the scope screen, showing the shape of the front-end response on channel 13; however, no marker indication was visible.

Next, the impedance-matching pad was removed, and the generator output applied directly to the antenna-input terminals. This arrangement permitted the output from the sweep generator to be reduced to approximately half its former value, and with the signal (marker) generator operating "wide open" a small marker became visible on top of the response curve. The shape of the curve was not changed seriously by the lack of proper impedance matching, but the incidental *attenuator action* which was thereby eliminated made possible a test which otherwise could not be accomplished with generators having insufficient output.

chapter 4

shielding the output

In theory, sweep voltage is available from a generator only at the termination of the output cable. In practice, the r.f. voltage may be found on the tuning dial, the front panel, the power cord or the outside of the generator cable. The better the equipment is designed and constructed, the less do sweep voltages develop at points other than the cable termination.

Leakage and standing waves

Undesired output is caused either by leakage or by launching of standing waves on the output cable due to improper termination. To distinguish between the two situations, the output cable may be removed from the instrument and the output connector capped. A TV receiver, communications receiver, heterodyne-frequency meter or field-strength meter may then be utilized to determine the extent of leakage from the generator case. A small exploratory loop antenna is commonly used for this test, which should show negligible leakage from the interior of the sweep generator. The power cord is a source of high leakage in some low-priced instruments.

Minimizing leakage

The leakage from a sweep generator can be made less troublesome in many cases by providing a good r.f. ground. This serves to dissipate and distribute the leaking energy and prevents its radiating as extensively through the work space. The best remedy for leakage is to provide an additional shield box for the generator so that internal fields are properly confined.

If the leakage from the sweep generator is satisfactorily low, or after excessive leakage has been corrected, you may next proceed to determine whether the sweep output cable is properly terminated, as shown in Fig. 401. If the sweep output cable is properly terminated, all of the sweep energy coming down the cable is absorbed by the terminating resistor and dissipated as heat. On the other hand, if the cable is improperly terminated, a fraction of the incoming energy will be reflected, and in this process, it often occurs also that standing waves are launched on the outside of the cable. To determine whether standing waves are present on the outside of the generator cable, a scope and crystal probe may be used. *No connection* is made to the termination, and the probe is removed from the vicinity of the termination. However, the two shielded cables are placed closely together, and the vertical gain of the scope is advanced to maximum. If observable deflection occurs on the scope screen, it is an indication that the generator cable is improperly terminated.

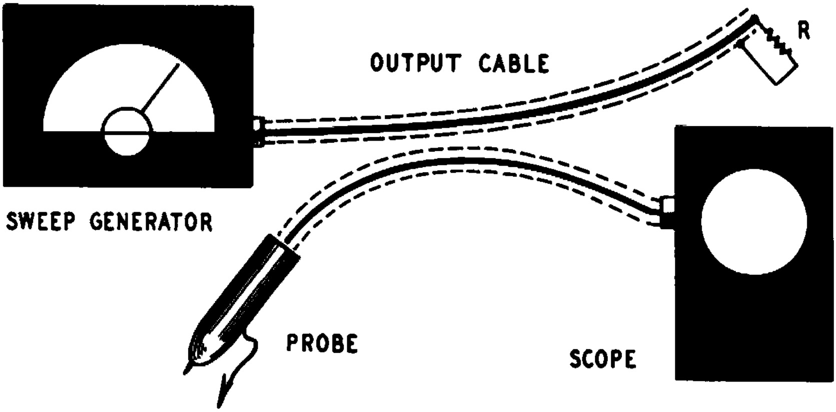


Fig. 401. The output cable from the sweep generator is terminated by the resistor R. In case deflection is obtained on the scope screen when the scope cable (with crystal probe) is brought near the output cable, it shows that the termination has not been made properly.

The principle of this test involves the capacitive transfer of standing-wave voltage from the sweep output cable to the scope input cable. Any transferred energy proceeds to the end of the scope input cable, where it is conducted by the probe tip to the probe network, from which point the scope becomes energized in normal fashion.

It may be a puzzling fact that sometimes a sweep output cable remains improperly terminated, no matter what value of terminating resistance is utilized. The difficulty is due, not to an improper *value* of termination, but to an improper *method* of termination. The terminating resistor must be connected with the shortest possible leads, as close as possible to the exposed end conductors of the output cable. Connecting leads of substantial length between the end of the cable and the terminating resistor will launch standing waves on the outside of the cable because of the lead reactance. Note that, although the dial of the sweep generator may indicate a low frequency, an unfiltered output may contain high-frequency harmonics.

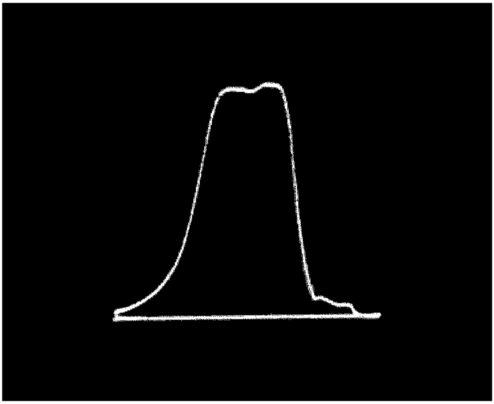


Fig. 402. Typical bandpass response of the chroma amplifier in a color TV receiver.

The more philosophical type of technician is sometimes inclined to observe that everything under the sun has its uses. This can be applied even to considerations of sweep generator leakage. For example, consider the chroma bandpass amplifier response shown in Fig. 402; this is a typical video-frequency response curve of a color TV receiver circuit, having a pass band from 2.1 to 4.2 mc. The zero-frequency point does not appear in the display, being off-screen. In one method of marking the curve the technician will find it useful to locate the zero-frequency point. This can be quickly accomplished by taking advantage of the residual leakage from the sweep generator.

When the display is first obtained, the response of the bandpass amplifier appears as shown in Fig. 403. Zero frequency appears in the center of the stop band and is not indicated by a low-frequency "notch" such as observed earlier in video-frequency displays. Hence it is necessary (or at least convenient) for the technician to mark initially the zero-frequency point along the base line, since that point is not explicit in the display. This zero-frequency point is very useful as a reference in certain marking procedures. To locate the zero-frequency point in a stop-band pattern, such as shown in Fig. 403, it is necessary only to hold the sweep output and input cables together temporarily. The small residual leakage which is usually present then serves to develop a marker at the zero-frequency point along the base line.

Of course, in the event that there is little or no leakage from the generator, the same effect can be obtained if the operator runs a test lead from the sweep output cable and holds it near the tip of the demodulator probe. This expedient serves to illustrate the occasional utility of what is generally regarded as a fault.

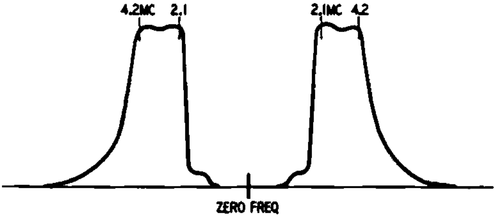


Fig. 403. In this illustration, the sweep generator is tuned to a center frequency of approximately zero. To locate the zero-frequency point accurately, hold the generator output and scope input cables together. Residual leakage is often sufficient to place a marker on the base line at the zero-frequency point.

Other leakage sources

Leakage from a sweep generator shows up in other ways. For example, connectors are often provided on the front panel of a sweep generator for other cables—marker cables, scope cables or external modulation leads. In theory, there is no sweep-voltage leakage into such auxiliary connectors. In practice, the technician may find that the response curve on the scope screen will change in shape when a marker generator cable is connected or disconnected from the sweep generator. Or he may find that the response curve changes its shape when the attenuator of the associated marker generator is varied. The nature of this difficulty is illustrated in Fig. 404. In this arrangement, a twin triode is utilized to mix the signal from an auxiliary marker generator with the sweep signal from the FM oscillator tank. The output from the FM oscillator is coupled into the grid of V1 and the output from the auxiliary marker generator into the grid of V2. The cathode circuits of V1 and V2 are connected in common, so that the mixed signals are obtained in the cathode output circuit. In theory, the dual triode V1-V2 decouples the FM oscillator tank from the marker-input cable circuit while providing a mixed sweep and marker signal from the cathode output circuit of the tube.

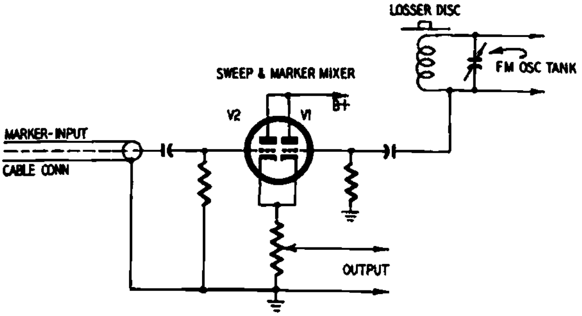


Fig. 404. Theoretically, the dual triode decouples the FM oscillator tank from the marker input cable, while providing mixed sweep and marker signal from the cathode output. In practice various stray coupling permits sweep voltage to back up into the marker input cable. This impairs flatness of sweep voltage.

Difficulty with leakage of sweep voltage into the marker input branch of the circuit occurs when the grid of V1 is not sufficiently isolated or decoupled from the grid of V2. This stray coupling is

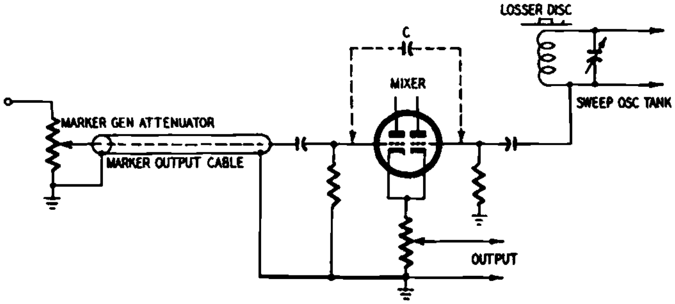


Fig. 405. When sweep voltage is coupled into the marker output cable by stray coupling (represented in the aggregate as C), standing waves will develop when the marker-generator attenuator does not match the impedance of the marker-output cable. Hence, the shape of an i.f. or r.f. response curve may be observed to change when the marker output cable is connected or disconnected; also when the marker-generator attenuator is varied.

the result of capacitance between tube electrodes, socket terminals, circuit leads, circulating ground currents and standing waves along the inside surface of the case and the chassis. However, such stray coupling can be practically eliminated by proper design and construction of the mixing arrangement and its associated branch circuits.

Fig. 405 shows how the setting of the attenuator in the marker generator may distort the sweep output when such stray coupling exists between the sweep oscillator and the marker input circuit. FM voltage from the sweep oscillator proceeds via stray capacitance C to the marker input cable, which is in effect terminated with respect to the coupled sweep voltage by the attenuator resistance. As the setting of the attenuator is varied, the termination of the marker output cable is changed and the standing-wave pattern of sweep voltage which develops along the marker output cable is altered correspondingly. This standing wave of sweep voltage represents a nonlinear sweep output voltage, which is delivered in part to the cathode output circuit of the mixer. Hence, the shape of the response curve may be observed to change as the setting of the marker-generator attenuator is varied.

You will also see upon occasion that the form of a high-frequency response curve will change its basic shape as the setting of the sweep-width control is varied. The reason for this distortion is shown in Fig. 406. A typical modulating system is shown in which a losser disc is vibrated at a 60-cycle rate in the field of the FM tank coil. The connecting leads to the vibrator electromagnet (or loudspeaker movement, which is often used), are powered via a stepdown transformer and a variable resistor which operates as a sweep-width control. The sweep-width control is commonly in the form of a wirewound resistor. Since the connecting leads to the vibrator electromagnet are often in a strong field from the FM tank, stray coupling may exist between the FM tank and the sweep-width control (which is inductive because of its wirewound

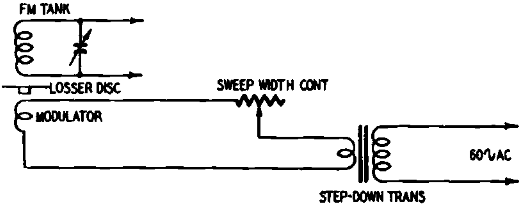


Fig. 406. If the leads from the modulator electromagnet fall in a strong r.f. field from the FM tank, the high-frequency voltage will be coupled into the sweep-width control.

construction). Accordingly, various values of reactance are reflected into the FM tank as the sweep-width control is varied. As a result, changes in the setting of the sweep-width control may not only produce desired variation of curve width, but can also give various distortions in the basic shape of the response curve. The flatness of the sweep voltage is impaired when the sweep-width control introduces some type of reactance back into the tuned circuit forming the FM tank.

This source of distortion can be avoided by arranging the modulator so that the leads to the electromagnet are not in a strong portion of the field from the FM tank, and also by suitably decoupling these leads and the sweep-width control for high-frequency currents.

Having seen how stray couplings in the generator circuit arrangement cause unexpected distortions of sweep signal output, due to leakage of the sweep voltage into associated circuits, you will understand how the same general situation leads to various curve distortions as the result of plugging external modulation leads into the sweep generator terminals, plugging and unplugging marker crystals from the crystal holder on the front panel of the sweep generator, operating such switches as external modulation, marker crystal, and external marker. Of course, a properly designed sweep generator is free from such objectionable distortions.

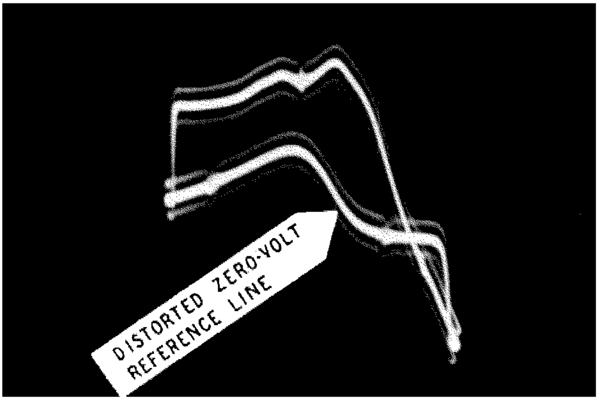


Fig. 407. Result of testing the output from a sweep generator with a demodulator probe and scope when there is leakage from the sweep oscillator into the fixed oscillator circuit. A zero-volt reference line exhibits curvature under these conditions when the output from the fixed oscillator is not flat.

Base-line curvature

Closely related to curve distortions caused by sweep-voltage leakage is base-line curvature, as seen in Fig. 407. This is a disconcerting condition which the operator may sometimes encounter when the output from a beat-frequency sweep generator is tested with a demodulator probe and scope. The upper trace in the pattern is the sweep output from the generator and the lower trace the zero-volt reference line. Not only does the sweep trace depart seriously from flatness, but the zero-volt reference line is badly kinked. To understand the meaning of this pattern, it is first necessary to return to some earlier points which have been made. It will be recalled that it is often customary practice in beat-frequency sweep generator design to key only the sweep oscillator. Under this condition, the fixed oscillator continues in operation during the zero-volt reference-line interval. Accordingly, the zero-volt reference line will be displaced up toward the sweep trace in broad-band tests such as a flatness check.

It will also be recalled that it is possible for the sweep trace to undershoot such a displaced zero-volt reference line, if components in the mixed output from the beat-frequency instrument happen to combine out-of-phase with each other in such manner that the voltage of the sweep output is less than the voltage displacing the zero-reference line. This situation is responsible for the crossover of the swept trace and "zero-volt" reference line seen in Fig. 407.

The kinking or curvature of the sweep trace, of course, results from lack of a resistive output (reactive output circuit) which impairs the flatness of the sweep voltage. The kinking of the zero-volt reference line arises from leakage of the sweep generator voltage into the fixed oscillator tank circuit, and vice versa, as shown in Fig. 408. This leakage is indicated by the stray coupling capacitance C. As a result of this leakage between the two oscillator circuits, two distortions become apparent in the output:

1. The fixed oscillator does not develop a fixed frequency, but an output which is frequency-modulated to the extent that the stray coupling introduces the action of the sweep modulator into the fixed oscillator circuit.
2. The sweep oscillator does not develop a flat output, due to the coupled reactance of the fixed oscillator circuit into the FM tank circuit.

The leakage between the two beat oscillator circuits causes the fixed oscillator to become frequency-modulated to some extent, as is clearly apparent from Fig. 407. A marker on the upper sweep trace is accompanied by two marker indications on the lower zero-reference trace, showing the frequency modulation of the output from the "fixed" oscillator. As the operating frequencies of the fixed oscillator and the sweep oscillator are brought closer, it is clear that this leakage couples stray reactance from each circuit into the other, impairing the flatness of the output. It is a necessary consequence, likewise, that the horizontal linearity of the sweep output is impaired.

In case both the fixed and sweep oscillators are keyed, the curvature of the zero-volt reference line will not become apparent, although the frequency modulation of the fixed oscillator will still be present and the flatness of the sweep trace will still be impaired. By keying both the fixed and sweep oscillators, the output from the generator is caused to become true zero during the zero-reference interval. This improves the appearance of the zero-volt reference line but fails to remove the basic fault which impairs the sweep flatness.

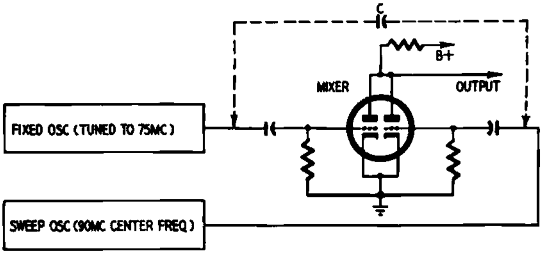


Fig. 408. When leakage occurs via stray capacitance C, the FM modulator not only varies the sweep oscillator, but also the fixed oscillator to some degree. The sweep output is not flat and if the sweep oscillator is keyed, the resulting zero-volt reference line exhibits kinking.

Likewise, if a lowpass filter is used in the output circuit of the sweep generator, the curvature of the zero-volt reference line will no longer be apparent in the pattern because the lowpass filter eliminates the voltage of the fixed oscillator from the generator output during the key-off interval. Again, the use of a lowpass filter does not remove the basic fault in the generator arrangement which continues to impair the flatness of the sweep trace.

Stray coupling between various circuits of the generator may be caused by flow of high-frequency energy along heater lines, B plus lines and similar inadequately decoupled leads. It is often desirable to place the sweep oscillator section in a separately shielded compartment and to bring the ingoing and outgoing leads through the shield walls by means of feed-through capacitors. High-frequency currents may be conducted out of the compartment by coaxial cable.

Leakage characteristics

To illustrate some important and interesting points which may be encountered in testing the leakage characteristics of a beat-frequency sweep generator, please refer to Fig. 409. In this illustration, the output from a video-frequency sweep generator is applied directly to the vertical input terminals of a scope. Several characteristics of the display immediately command our attention. At low frequencies (left-hand end of the display) the excursion of the output is much greater in the positive than in the negative direction. This difference is caused by leakage between the fixed and sweep beating oscillators in the generator. This gives rise to waveform error in which the output waveform departs from a sinusoid and becomes unsymmetrical in the positive and negative directions. This type of dissymmetry is associated with the development of strong even harmonics in the output.

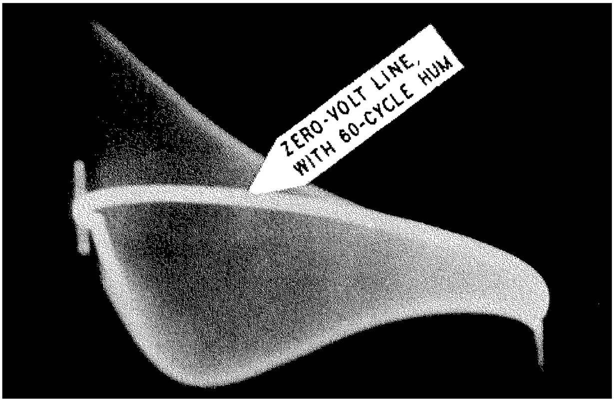


Fig. 409. Leakage between sweep and fixed oscillators in the beat-frequency generator causes substantial even-harmonic distortion at low frequencies. The curvature of the zero-volt reference line and sweep output is due to the presence of 60-cycle hum voltage in the generator output system.

If a demodulator probe is used in making the test, the pattern will change in shape when the crystal diode is reversed in polarity, as shown in Fig. 410-a,-b. The crystal, of course, rectifies the sweep voltage and displays either the envelope of the positive excursion or that of the negative excursion, depending upon which way the crystal diode is wired into the probe circuit.

It is sometimes assumed that the crystal diode output is the same whether or not the crystal is reversed. Fig. 410-a shows the output for negative polarity while Fig. 410-b shows the output waveform when the crystal diode is reversed. By superimposing the two waveforms on each other, as shown in Fig. 411, you can readily see the difference in output.

The attenuation of the high-frequency end of the sweep output noted in Fig. 409 is not caused entirely by deficiency of generator

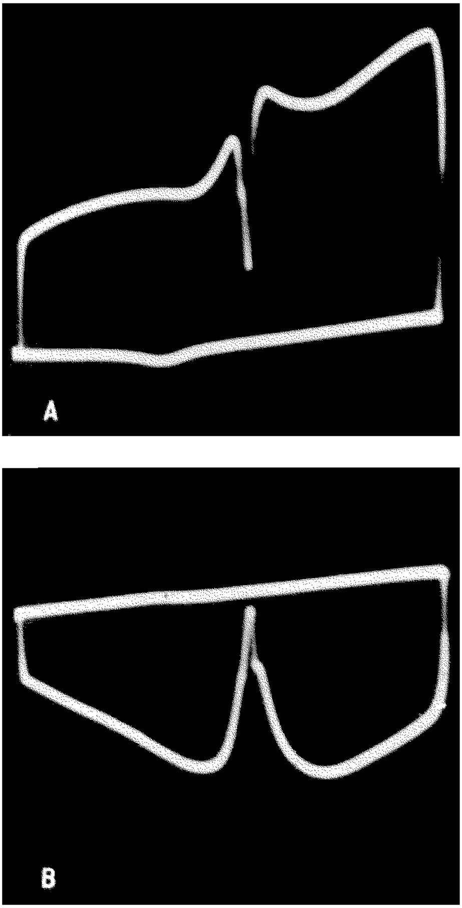


Fig. 410-a,-b. When the crystal diode is reversed in a demodulator probe, waveform error in the form of even-harmonic distortion will cause the sweep trace to change.

output in this region, but also by a dropoff of frequency response in the vertical amplifier of the scope used in the test. This is a point which the operator must keep in mind when the output from a generator is applied directly to the scope—the frequency output of the generator must not exceed the frequency capability of the scope amplifier if the test is to be a valid one.

The curvature which is apparent in both the zero-volt reference line and in the sweep output displayed in Fig. 409 is caused by the presence of 60-cycle hum in the output system of the sweep generator. This hum is usually the result of heater-cathode leakage in a generator tube, but may also be picked up by exposed test leads to the scope. Shielded cables should be used in all such tests.

In running receiver response curves, you will sometimes find that the receiver will overload, despite the fact that the output cable from the sweep generator is removed completely. This, of course, is caused by excessive leakage from the generator and is often due to conduction and radiation of sweep voltage by the power cord of the generator. A lowpass line filter such as shown in Fig. 412 will eliminate the sweep voltage from the power cord.

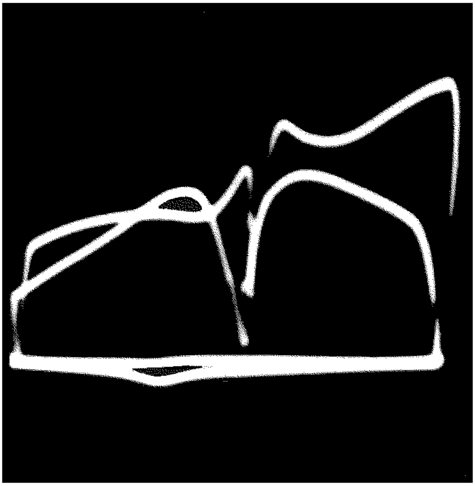


Fig. 411. Here we have the waveforms of Fig. 410-a and -b superimposed. Note the small kink in the zero-volt reference line caused by spurious frequency modulation of the fixed oscillator in the beat arrangement.

Upon occasion the tuning dial of the generator is found to radiate excessive sweep voltage, this voltage being conducted to the dial via the shaft from the tuning capacitor. In such case it is sometimes helpful to utilize a wiper spring between the front panel of the instrument and the tuning dial, as indicated in Fig. 413. It is even more effective to provide a friction box between the shaft and the front panel so that a tight seal is maintained between shaft and case.

Radiation is always greater on higher frequencies; hence it might be supposed that this would be a greater problem on the harmonic frequencies in the output. However, the reverse is usually observed, the harmonic voltages in the output being weaker than the fundamental voltages. The greater radiation of the harmonics still does not come up to the radiation level of the stronger fundamentals. When it is impossible to use the fundamental output from a sweep generator because of leakage and radiation, the technician can sometimes operate satisfactorily by tuning the generator to half or third frequency, thereby using the second or the third harmonic.

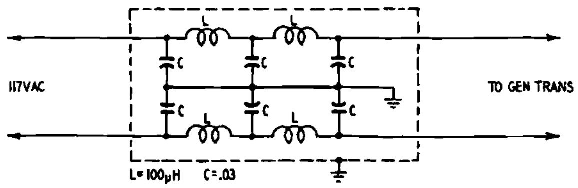


Fig. 412. Leakage of sweep voltage into the line cord is prevented by use of a lowpass line filter. It is often advantageous to shield the filter.

Operators of inadequately designed sweep and signal generators often complain that they "can get any shape of curve there is" by moving cables about or by shifting the instruments slightly, and that the generators are hence "of no use to them." It must be said in all justice that there is a great deal which is valid in such complaints, and in such cases the only solution is to obsolete the inadequate equipment and to install properly designed generators. In other instances, however, the difficulty may be described as "cockpit trouble," due to an insufficient amount of experience with the techniques of high-frequency test work.

It is true that poorly designed generators are offered on the service market, and it is also true that well-designed generators sometimes fail to provide the expected results, because the operator is attempting to apply the principles of d.c. electricity to situations which involve high-frequency a.c. In the event that the operator is inexperienced with the principles of high-frequency test work, he must rely upon the service manual provided with the instrument. Sometimes such manuals are well prepared by men who know what they are doing, but there have been cases in which instrument manuals are written by persons who have never really used the instrument in service, and who do not know what the requirements actually are. Such situations, of course, only compound confusion, and tend to throw suspicion upon all service instruments.

The writer, who has had many years of specialized experience with service instruments, would offer the following advice to the ambitious TV technician: As rapidly as possible, expand your knowledge of high-frequency test work, and learn to fall back with confidence upon your own resources. This ability is acquired by asking yourself the *reasons* for everything that you observe during your daily work at the bench. After you think you have stated the reason for a given distortion, such as changing curve shape when the power-cord of the generator is grasped, *prove* your reason; for example, for the problem we have just cited, install an r.f. filter in the power-cord circuit of the instrument, and see whether the trouble is eliminated.

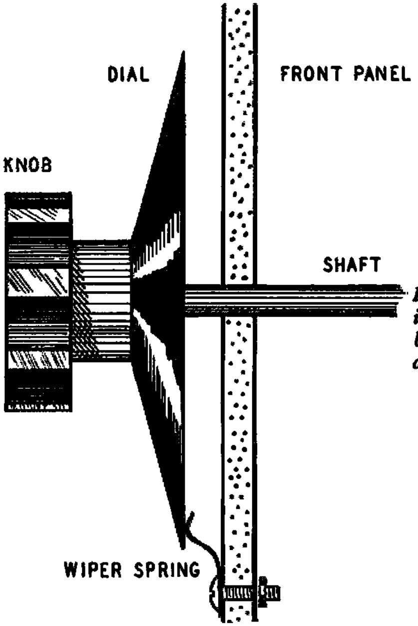


Fig. 413. Excessive radiation from the tuning dial of a sweep generator can sometimes be reduced to a satisfactory level by use of a grounding spring between the panel and dial.

chapter

5

aspects of sweep output

We have observed in foregoing sections that spurious markers sometimes appear in the output from a sweep generator and are undesirable byproducts in that they tend to cause confusion with reference to desired frequency markers. The frequency of a false marker can be determined as indicated in Fig. 501. The output from a marker generator can be mixed with the output from a sweep generator, and a demodulated display on the scope screen will show a marker pip from the marker generator, in addition to the spurious marker. The spurious marker remains fixed in position, but the generator marker travels along the sweep trace as the tuning dial of the marker generator is turned. In Fig. 501-a we have the sweep trace (demodulated output) with the spurious marker present. The next illustration, Fig. 501-b, shows the additional marker introduced by mixing the output from a marker generator with the output from the sweep generator. When the generator marker (Fig. 501-c) is tuned near the frequency of the spurious marker, a difference beat appears along the sweep trace and the zero-volt reference line.

As the generator marker is tuned to superimpose on the spurious marker on the sweep trace, you will usually observe that the beat between the two markers becomes evident as a "fuzzing" of the sweep trace and the zero-volt line. The frequency of this fuzzy disturbance is the difference between the two marker frequencies. By carefully tuning the marker generator, the frequency of the fuzzy disturbance can be brought to zero beat. At this point, the two markers are in exact coincidence, and the frequency of the spurious marker can be considered equal to the frequency indicated on the marker generator dial.

However, you will sometimes find that, when the marker from marker generator is superimposed on the spurious marker, no difference beat (fuzzy disturbance) occurs. This absence of difference beat is caused by the fact that the spurious marker has

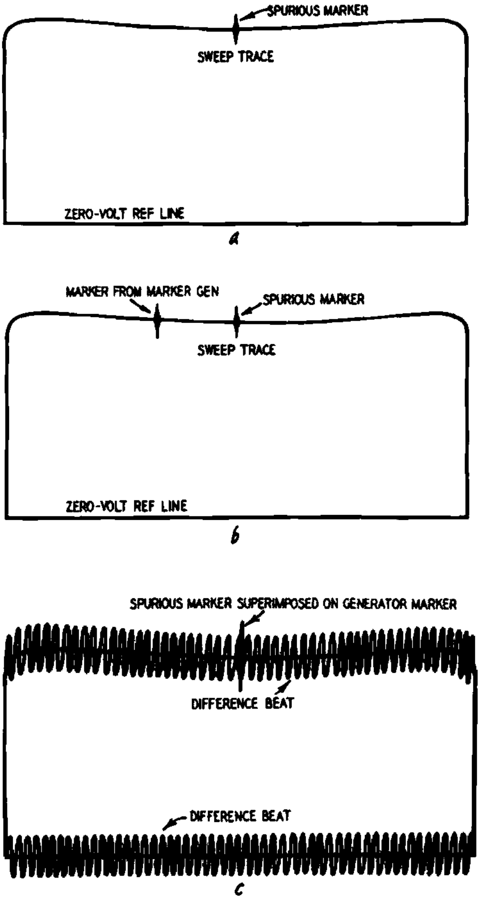


Fig. 501-*a,-b,-c. Effect of interaction between spurious marker and signal output of the marker generator.*

been previously demodulated in the sweep generator circuits and only the envelope of the marker is present in the output as an audio-frequency waveform. This causes the sweep output to depart abruptly from flatness in the vicinity of the demodulated marker envelope. The wavy departure from flatness appears very much like a conventional marker and is quite often the source of a considerable amount of confusion when non-beating markers are observed on the screen of the scope.

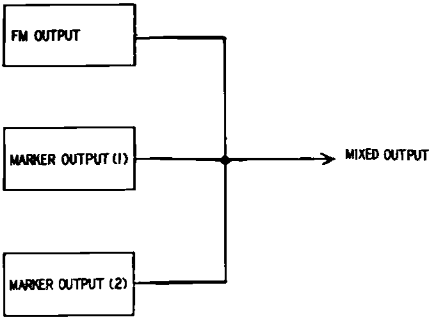


Fig. 502. Technique for producing a pair of markers on the sweep trace.

Fig. 502 shows a typical arrangement which develops *beating* markers. This arrangement is characterized by the presence of three *high-frequency* outputs in the same circuit, namely, an FM output, marker output 1 and marker output 2. When the output from an FM generator is mixed with the outputs from two marker generators, a pair of markers will appear on the sweep trace. These markers will beat (heterodyne) when superimposed. On the other hand, Fig. 503 shows a typical arrangement which develops *non-beating* markers. When the output from an FM gen-

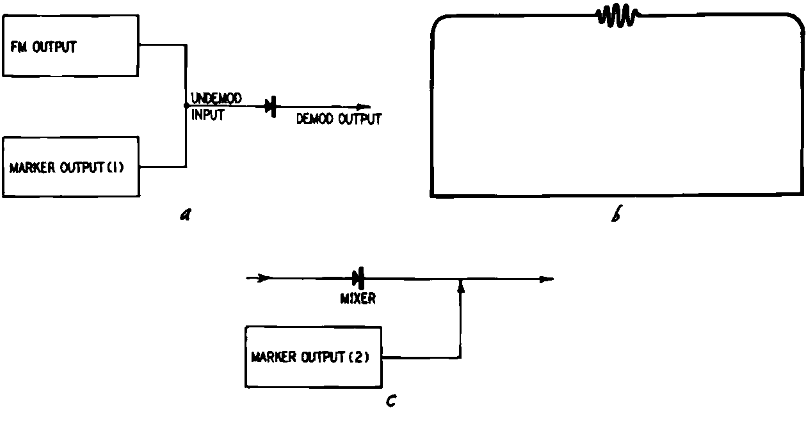


Fig. 503-a,-b,-c. Detection of beat signal (a) is shown graphically in (b). Insertion of second marker (c) after the crystal mixer prevents beating of the two markers.

erator (Fig. 503-a) and a marker generator are passed through a nonlinear circuit element such as a crystal diode, the mixed outputs are demodulated (detected). The envelope (low) frequencies then appear in the output. The demodulated marker has the form shown in Fig. 503-b. Here we see that the beating of the FM voltage and the marker voltage is now a rapid disturbance of the sweep trace. Now, if a second marker voltage is introduced *after* the mixer as shown in Fig. 503-c, it is clear that the two marker indications cannot beat inasmuch as marker output 2 is present only with the FM sweep output which contains a sudden departure from flatness produced by demodulated marker 1. This arrangement does not give rise to beating markers.

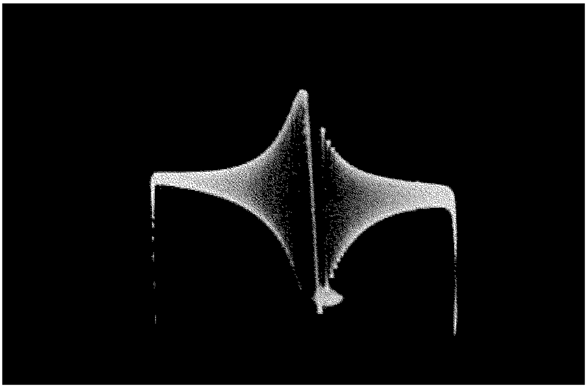


Fig. 504. Demodulated waveform obtained by passing FM sweep waveform and marker generator voltage through a germanium crystal used as a nonlinear mixer. It can readily be seen that the sweep voltage is not uniform over the sweep range.

In Fig. 504 we see the detail of marker indication developed by demodulation of the FM and marker voltages through the demodulator probe. You can see that this envelope waveshape represents sudden departures from flatness in the FM signal. You cannot decide just by looking at this display whether the demodulation has taken place in the probe or in the heterodyne mixer section of the sweep generator. However, this point can be determined by applying another marker generator signal to the input of the probe. In this way you will learn whether this is a *beating* or a *non-beating* marker.

The marker generators may be conventional generators, but it is also clear that they may be represented by harmonics of the beating oscillators in the sweep generator. For example, consider a beat-frequency sweep generator in which the outputs from a 100-mc sweep oscillator and from a 75-mc fixed oscillator are applied to a heterodyne mixer. In the event that the third harmonic of the fixed oscillator and the fourth harmonic of the sweep oscillator are sufficiently strong to produce a spurious marker indication, a demodulated spurious marker must appear on the sweep trace at 25 mc. However, since this 25-mc spurious marker is a demodulated marker, it is a non-beating marker. If a 25-mc voltage from a marker generator is mixed with the sweep voltage, the new marker thus produced will not beat with the demodulated spurious marker.

Obtaining flat output from external mixer

To develop the low-frequency sweep output desired for checking color TV receiver circuits, the arrangement shown in Fig. 505 can be used. The outputs from an FM generator and from a signal generator are heterodyned in a suitable low-impedance triple-diode mixer arrangement to develop a low-frequency *difference* output. An arrangement of this type is capable of providing very-low-frequency sweeps, because of the extensive decoupling which is afforded. The two generators are isolated in separate cases, and the two outputs are also isolated by the output networks of the two instruments.

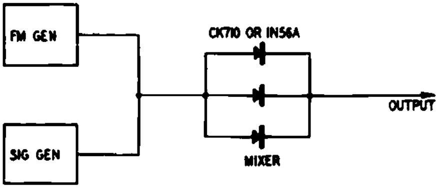


Fig. 505. Here we have the use of three crystal diodes in parallel acting as a low-impedance mixing circuit. The FM generator must supply a pure fundamental output otherwise cross beats will take place in the mixer, resulting in spurious markers.

However, unless the frequency ranges of the two generators are properly chosen, the sweep output may vary considerably from flatness. In particular, if a beat output from the FM generator is utilized, considerable departures from flatness and numerous spurious markers may be observed in the output from the mixer. This situation is understandable in terms of the principles of nonlinear mixing which have now been established. Any two frequencies applied to the input of the heterodyne mixer must cross-beat to generate new sum and difference frequencies in the output.

Since the output from an unfiltered beat-frequency generator contains both sum and difference frequencies, plus feed-through frequencies and harmonics, it is clear that an arrangement such as shown in Fig. 505 may operate with a half-dozen various frequencies applied to the input of the mixer. The output from the mixer, under such conditions, must contain numerous spurious sweeps and markers. The spurious sweeps cause the desired output to depart from flatness, and the spurious markers cause misleading frequency indications when the technician attempts to mark the curve.

However, these difficulties can be avoided by applying a pure fundamental FM voltage to the input of the mixer. A pure fundamental output can usually be obtained from a service sweep generator by use of a suitable frequency band. At least one of the frequency bands is usually derived as the direct output from the sweep oscillator. Such a band should be used in this arrangement to avoid the difficulties we have noted.

Of course, any lack of flatness in the pure fundamental output from the FM generator in the arrangement shown in Fig. 505 will appear in the mixer output as a corresponding lack of flatness. Hence, you should check the flatness of the output before proceeding with tests, and you should also tune the FM generator to a center frequency which provides *maximum* flatness of output. This procedure is possible since the departure from flatness will vary over the given sweep generator band and some portion of the band will exhibit a maximum flatness. As long as the signal generator is tuned to the same frequency as the center frequency of the sweep generator, the external mixer operates in the desired manner. Hence, by use of such an external mixing device, the operator can obtain a sweep flatness which usually exceeds the rated accuracy of the sweep generator alone.

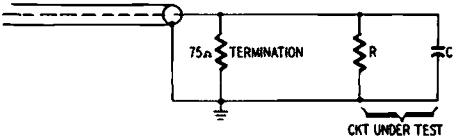


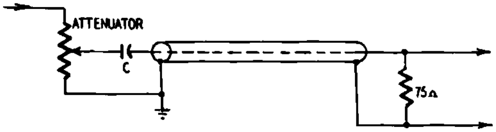
Fig. 506. Flatness of sweep output is dependent upon the output impedance of the generator and circuit loading.

Bandwidth of sweep generator output system

It is clear that the bandwidth of the sweep generator output system must accommodate the range of frequencies utilized. For example, if the generator is to provide frequencies up to 250 mc, the output system of the generator must not attenuate voltages up to this frequency. To obtain full bandwidth of the generator output system at high frequencies is one of the chief reasons for using a *low-impedance* output circuit. An output impedance of 75 ohms is typical. This permits application of a flat sweep voltage to the circuit under test, even when the input impedance of the circuit has a substantial capacitive component. As shown in Fig. 506, the circuit under test can usually be represented by a relatively high resistance R and a shunt capacitance C. Unless the internal resistance of the sweep source is low (75 ohms), the shunting effect of C will become noticeable at higher frequencies and flatness of sweep output cannot be maintained. In general, the output impedance of a generator is made at least 10 times smaller than the capacitive reactance of any circuit which might be subjected to test.

Capacitive reactance, of course, has the effect of shunting the higher frequencies progressively. If the internal impedance of the source is kept low (75 ohms in this case), the effective shunting of the capacitance can be reduced to a negligible value.

Fig. 507. Bandwidth of sweep output (at low-frequency end) is governed by capacitive reactance of blocking capacitor C.



There is another aspect to the consideration of generator output-system bandwidth which becomes of equal importance when low-frequency circuits such as chroma circuits of color TV receivers are to be tested. The bandwidth of the generator output system must also provide full transmission of *low-frequency* sweep signals down to 15 kc. The low-frequency limitation in the sweep generator output system is usually determined by the value of the blocking capacitor, as shown in Fig. 507. Unless this blocking capacitor has negligible reactance at the lowest output frequency desired, low-frequency attenuation will be observed in the sweep output. By making C sufficiently large, the output system shown may be designed to pass as low a frequency as may be desired.

A practical example of this situation is illustrated in Fig. 508, which shows the sweep output from a beat-frequency sweep generator which is unsuitable for low-frequency sweep tests. As indicated, the center frequency of the generator is tuned to place the zero-frequency point approximately in the center of the demodulated display on the scope screen. The sweep width of the generator is set to 8 mc. You can see that low-frequency response from 0 to 2 mc is severely attenuated. This attenuation is caused by too small a value of blocking capacitor in the output circuit of the sweep generator.

The generator output also rises to a maximum at approximately 2 mc and then drops off severely from 2 to 4 mc. This dropoff is caused by high-frequency resonances and cross-beating of resonant-rising voltages in the heterodyne mixer circuit of the sweep generator. It is apparent that a sweep output which departs so severely from flatness is not of practical use in test work.

Marker may appear unsymmetrical

In checking sweep generator outputs, the operator is sometimes puzzled by the appearance of unsymmetrical markers (whether spurious or desired), as shown in Fig. 509, in which the positive peak value of the marker is greater than the negative peak value or vice versa. The dissymmetry of the marker is caused by nonlinear detector action—either of the heterodyne mixer in the beat-frequency sweep generator (in the case of a spurious marker) or of the crystal diode in the demodulator probe (in the case of a desired marker) or in circuit test work, of the picture detector in the receiver. This nonlinearity means that the high-frequency input voltage is not proportional to the low-frequency output voltage. It must not be confused with the rectifying action of the

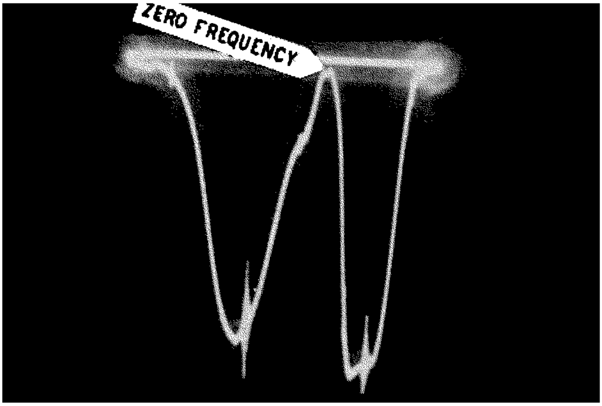


Fig. 508. Low-frequency flatness test of a poor beat-frequency sweep generator. Zero frequency is located approximately in the center of the display. A severe fall-off of output starts at 2 mc (marker points) and proceeds progressively within the low-frequency region of the sweep. Another dropoff starts at 2 mc and proceeds progressively to 4 mc. The dropoff at frequencies below 2 mc is caused by use of too small a value of blocking capacitor in the mixer output circuit.

mixer or detector. To provide a more familiar example of this situation, the technician may find when testing the sensitivity of a TV receiver that although 1/2-volt output can be obtained from the picture detector for an input of 500 microvolts, that 1-volt output can be obtained for an input of only 800 microvolts.

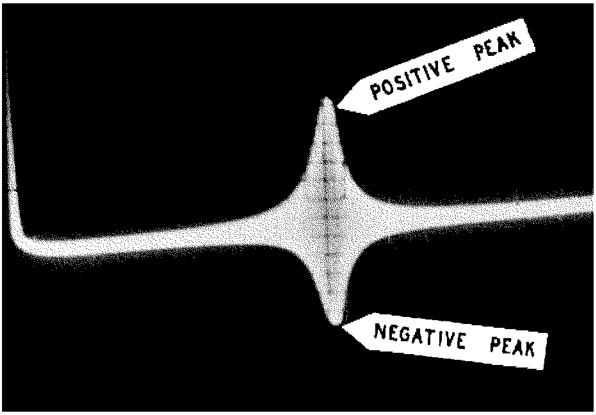


Fig. 509. Photo shows existence of dissymmetry in the positive and negative peaks of the marker.

The same principle applies to the operation of heterodyne mixers and nonlinear devices in general.

Frequency progression of FM output

As shown in Fig. 510, the FM output from a sweep generator may appear with the low-frequency end at the left of the sweep

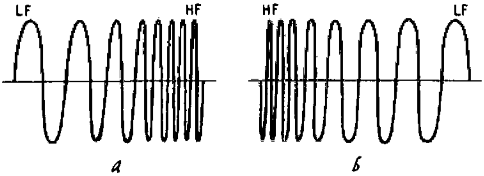


Fig. 510-a,-b. FM output from the sweep generator increasing in frequency (a) from left to right and decreasing (b) from right to left.

trace and the high-frequency end at the right or vice versa. Since most frequency response curves supplied by receiver manufacturers in service notes show the curves with the low-frequency end at the left of the display, the technician usually prefers to obtain the sweep output in this manner. In some cases, however, the curves may be shown with the high-frequency end at the left, so that the technician may wish to have control of the output accordingly.

Reversal of the frequency progression of the FM output from the sweep generator can easily be accomplished by reversing the phase of the driving voltage to the electromechanical modulator of the sweep unit. The electromechanical modulator is energized or driven by an electromagnet which is energized by a 60-cycle current, as shown in Fig. 511. This reversal may be accomplished by means of a reversing switch or similar arrangement. It is worth noting that the *apparent* frequency progression of the output may depend upon the particular application of the sweep generator. For example, if a front-end response curve is developed and the frequency progression increases from left to right, this is the true progression of the sweep output. You should note that, when the overall r.f.–i.f. response curve of the receiver is displayed, the apparent progression may now be reversed with the frequencies decreasing from left to right. This reversal is the consequence of the heterodyne action in the front end, when the local oscillator operates on the high side of the sweep signal, as is very often the case.

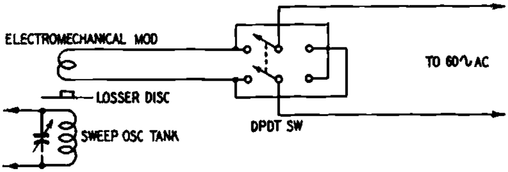


Fig. 511. *Electromechanical modulation of oscillator circuit.*

Auxiliary functions of sweep generators

The simplest beat-frequency sweep generators with unfiltered output sometimes do not have a bandswitch, despite the fact that the dial may be calibrated for several bands of operation. The reason for this omission is shown in Fig. 512 from which it is seen that the unfiltered output contains feed-through frequencies, their harmonics, a sum frequency and a difference frequency. Since the tuned circuit under test filters out all but the desired band of frequencies, a bandswitch is not needed in a simple beat arrangement of this kind. The mixed output, however, is unsuitable for very-wide-band tests, and the sum frequency will usually be rather badly contaminated.

An auxiliary function sometimes provided in a sweep generator of this type is shown in Fig. 513. This is the addition of a bandswitch to the arrangement shown in Fig. 512 in which the fixed oscillator is switched out of the circuit when operation is desired on the sweep oscillator frequency. The bandswitch has a definite advantage in that it provides one band of operation free from a mixed output. As we have noted earlier, the availability of even one band of pure fundamental output is occasionally of considerable value in practical test work. While this band is not actually a pure fundamental band since the sweep oscillator usually generates harmonics (and because the passage of the oscillator output through the mixer generates additional harmonics), it is much more usable in various test arrangements than when mixed with strong spurious outputs generated by the unneeded output from the fixed oscillator.

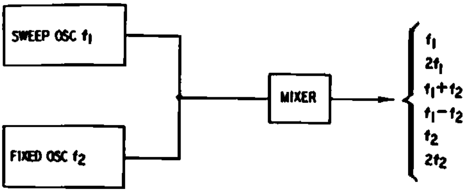


Fig. 512. The unfiltered output from a beat-frequency generator contains a wide mixture of frequencies.

The technician is sometimes disconcerted when using the arrangement shown in Fig. 513 to check an r.f. or i.f. circuit to discover that the shape of the response curve changes shape when the bandswitch is open or closed. Of course, theoretically no change in curve shape should take place, yet there are at least two possible causes for such change in curve shape. In some cases, the sweep oscillator tank couples back (by stray capacitance) into the bandswitch circuit. This in turn introduces reactance in the

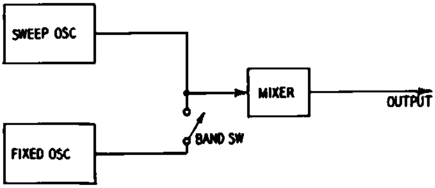


Fig. 513. A bandswitch can be used to disable the fixed oscillator so that unmixed output from the sweep oscillator can be obtained on one band.

sweep oscillator circuit, impairing the flatness of the sweep output in accordance with the change of circuit resonances in the bandswitch section.

There is also another reason for this occasional change in curve shape—the generation of spurious sweep outputs in the mixer section of the generator. The beat oscillators sometimes have a relatively strong harmonic output which may cross-beat in such a manner as to develop one or more spurious sweeps in the frequency band being utilized. These spurious sweeps impair the flatness of the output and cause the curve to change shape when the fixed oscillator is switched into or out of the mixer circuit.

Another auxiliary function sometimes provided by the bandswitch in very simple beat-frequency generators which make use of harmonic output is a reduction of the 60-cycle voltage to the sweep modulator unit on the harmonic-band position of the switch. The reason for this reduction of driving voltage to the FM modulator is as follows: If the second harmonic is being used for one of the generator bands, the deviation or sweep width of the harmonic output is greater than the sweep width of the fundamental. For example, if the generator uses the second harmonic for output on one of the bands, the sweep width on this harmonic band will be twice as big as on a fundamental band. This doubling of the sweep width causes the response curve to appear only half as wide on the scope screen when the harmonic band is in operation. Hence, to maintain uniform sweep width on harmonic operation, the bandswitch may be arranged to switch a suitable value of resistance in series with the 60-cycle driving voltage to the FM modulator unit, when the switch is turned to the harmonic-band position.

Still another auxiliary function which is provided with some sweep generators is a built-in a.g.c. override bias network. This provision is a considerable convenience in practical work. Override bias must be supplied in nearly all alignment procedures and it is less troublesome to have the necessary supply voltage available at the front panel of the sweep generator. In some cases a d.c. voltmeter is also built in the generator, so that the exact value of override bias can be read without connection of an external voltmeter.

Sweep-flatness monitoring is another auxiliary function occasionally provided by both elaborate and simple sweep generators. The important consideration in evaluating a flatness monitor is the following: "Does the monitoring arrangement check the flatness of the sweep voltage being applied to the circuit under test, or does this monitoring arrangement merely check the flatness of the output voltage from the *sweep oscillator*?" In view of the principles of sweep operation which have been developed earlier, you will appreciate that loss of flatness occurs chiefly in the circuits *following* the sweep oscillator. This means that it is useless to monitor the output from the sweep oscillator, and in turn to assume that the sweep voltage being applied to the circuit under test is equally uniform. In fact, this is a very elementary error.

Another very common auxiliary function provided by service sweep generators consists of a variable-phase 60-cycle sine-wave voltage for use in driving the horizontal amplifier of the scope used in the test setup. The chief requirement for this facility is that the phasing range should be adequate to accommodate the merging of the trace and retrace under all test conditions (this is not always realizable), and also that the phase-shifting network be designed in such manner that the harmonic content of the 60-cycle voltage is not unduly accentuated. Enhancement of harmonics by the phase-shifting network produces a nonlinear horizontal sweep and causes the forward trace to have a different shape from the return trace. The difficulty is aggravated, of course, in case the line voltage itself has poor waveform, as may be the case in heavy factory areas.

Still another auxiliary function provided by some beat-frequency sweep generators is a vernier scale for very accurate setting of the frequency of the output. This is a function of no utility in so far as sweep output is concerned, but some generators of this type provide means for switching off the FM modulator, so that the output becomes that of a conventional signal generator. In such case, it might be supposed that a vernier scale might be of some utility. But you will find that beat-frequency sweep generators sometimes have far less stability than standard signal generators, so that the vernier scale is of less value than might be supposed. For example, the user of such a generator might suppose that when the FM function is turned off, the CW signal which is delivered might serve for use in aligning communication receivers. However, inaccuracy and extensive drift usually disqualify the beat-frequency generator for these more critical applications. This auxiliary function is better placed in the class of "sales features" calculated to make an instrument appear attractive to inexperienced users without necessarily increasing the practical utility of the instrument.

The need for providing such auxiliary "sales features" is becoming less and less, as the service trade gains a better understanding of what various generators can and cannot do. Only a minority of present-day technicians attempt to make a beat-frequency generator serve the purpose of a standard signal generator.

Leakage problems and zero-line undershoot

A puzzling problem which often arises in testing of service sweep generators is the undershooting of the zero-volt reference line, as shown in Fig. 514. For example, when the output of the sweep generator is tested for flatness with a signal-tracing or demodulator probe, at some frequencies of test, the sweep trace undershoots the zero-volt reference line. Or, the undershoot may be encountered only at certain settings of the attenuator, or may be observed only when the operator grasps the output cable from the sweep generator at certain points.

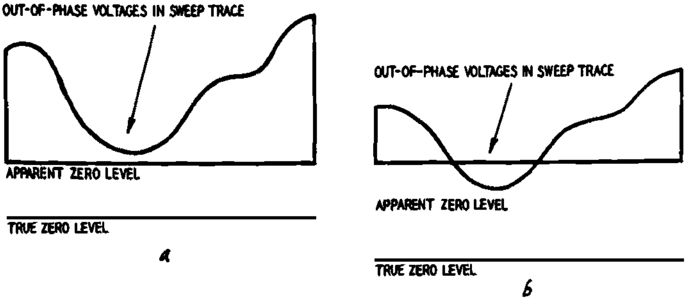


Fig. 514. Because the sweep oscillator is only keyed during the zero-volt reference-line interval, output from the fixed oscillator is present at all times. This produces a displacement (a) of tne reference line from true no-signal level. When there is leakage through the attenuator via stray capacitance (b), two output signals appear at low attenuator settings. One is the regular signal, the other is leakage. At certain attenuator settings, these two signals arrive out of phase, produce cancellation and undershoot of the zero-volt reference line.

Most of the conditions causing undershoot of the zero-volt line are the result of leakage. Consider, for example, a situation in which the sweep trace appears as in Fig. 514-a at high settings of the attenuator, but which undershoots the zero-volt line at lower settings of the attenuator, as shown in Fig. 514-b. In such case, the attenuator is often leaky. Some of the energy passes through the resistive network of the attenuator, but another portion of the energy leaks through the attenuator via stray capacitance, as shown in Fig. 515. The stray capacitance, of course, causes a phase shift of the leakage energy, which cancels all or a part of the intended output at certain settings of the attenuator. However, the output from the fixed oscillator in the beat-frequency sweep generator is not similarly affected for the fixed oscillator operates at a frequency other than that of the sweep output. But, during the zero-volt reference-line interval, the fixed oscillator continues to operate, since only the sweep oscillator is conventionally keyed. Thus, the output from the fixed oscillator during the zero-volt reference-line interval causes an upward displacement of the zero-volt line, as shown in Fig. 514-a, while the sweep trace is subjected to downward displacement as a result of attenuator leakage and cancellation of the output signal during the sweep-trace interval. Hence, with sufficient sweep cancellation, the technician observes undershoot.

As an example of this condition, consider the dual potentiometer arrangement (see Fig. 515) sometimes used in service sweep

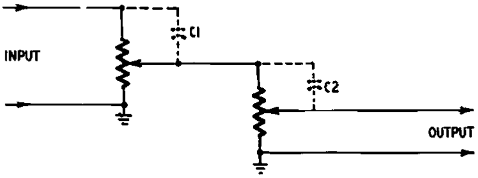


Fig. 515. Stray capacitances appear across the dual potentiometer.

generators to attenuate the output. Unless the potentiometers are of suitable construction, there is stray capacitance between terminals. This is shown in the illustration as C1 and C2. It is apparent that these stray capacitances permit exit of a portion of the input voltage to the output. Likewise, another portion of the input voltage finds its way out through the resistive elements of the potentiometers. The stray capacitances C1 and C2 introduce a phase shift at certain operating frequencies. This causes cancellation to take place in the combined output and is the basis of zero-line undershoot as shown in Fig. 514-b.

With this basis of understanding, it is likewise clear why undershoot of the zero-volt line may be seen upon occasion when we grasp the output cable of the sweep generator. In such cases, standing waves are present on the outside of the cable. The distribution of the standing-wave voltage is changed by grasping the cable. The output at the terminal end of the cable becomes a combined output, consisting of the normal flow of energy from the central conductor of the cable to which is added the standing-wave energy present on the outside of the cable. When the phases of these two sources cancel, you will see undershooting of the zero-volt line.

Standing waves on the outside of the sweep output cable are sometimes caused by leakage of energy from the front-panel connector, but may also be caused by excessively long ground leads at the terminal end of the cable. In the latter case, the long r.f. ground lead serves to launch standing waves back up the cable. These are reflected at the panel of the generator, returning once again to the terminal end of the output cable. For example, if the signal-tracing or demodulator probe which is being used to test the flatness of the sweep has too long a ground lead, the sweep output cable may become "hot" and undershooting may be observed at certain operating frequencies.

The leakage of signal energy via stray capacitance of the attenuator is also responsible for another puzzling aspect of attenuator operation in certain sweep generators. For example, when tested with a sensitive voltmeter device, such as a field-strength meter, you will sometimes observe that the output from the generator decreases as the attenuator setting is reduced, up to a certain point. Beyond this point, the output from the generator starts to increase as the attenuator setting is further reduced. This condition is also caused by out-of-phase leakage through the stray capacitances of the attenuator network. Only improved design can eliminate this source of difficulty.

Stray capacitance filters high-frequency harmonics

Sometimes the output from a service sweep generator may have a high percentage of harmonics at frequencies below 200 mc, with only a small percentage of harmonics at frequencies much in excess of that value. In these cases, the high-frequency harmonic output is effectively filtered by the stray shunt capacitance of the generator wiring and stray capacitances of the generator components.

As a practical example of this, you may sometimes encounter difficulty in attempting to beat the outputs from an r.f. sweep generator and from an r.f. signal generator through the picture detector to develop a low-frequency difference beat to sweep the video amplifier. The difficulty is due to the cross-beats of the harmonics from the sweep generator and from the signal generator. These cross-beats cause the video response curve to exhibit various distortions as the generator output frequencies are varied.

However, this difficulty is met only when the generators are operated at a frequency below 200 mc. In case the generators are set to a high frequency, such as 225 mc, the low-frequency difference beat becomes free of harmonic cross-beats from the generators. This elimination of cross-beat distortion is due to the increased filtering effect of the stray wiring capacitance in the generators, which effectively shunts the higher-frequency harmonics to ground.

This is the same general type of difficulty which you will find in mixer operation of a beat-frequency generator when the outputs from the fixed and sweep oscillators contain an abnormally high harmonic content. The strong harmonics develop strong spurious sweeps through the mixer tube of the sweep generator, producing a beat output which departs substantially from flatness. At least one manufacturer of service sweep generators utilizes the filtering effect of stray wiring capacitances to minimize harmonic output from the fixed and sweep oscillators. These oscillators are operated at a fundamental frequency of approximately 200 mc, so that the stray wiring capacitances in the generator circuits effectively filter the harmonic frequencies of 400 mc, 600 mc, etc.

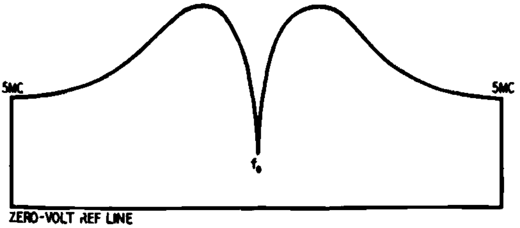


Fig. 516. When the output from a sweep generator contains strong harmonics and this output is utilized to produce a heterodyned output from a Chromatic probe, the low-frequency region of the sweep signal from the probe develops abnormally high voltage.

When the voltages from a signal and a sweep generator are applied to a Chromatic Probe, the output from the probe consists of a low-frequency beat-difference signal. The output from the probe is flat, provided the sweep output from the generator is flat. The harmonic output from the sweep generator must be relatively small to obtain a flat output. In the event that the sweep generator contains a strong harmonic output, the low-frequency region of the probe output is "bumped up," as illustrated in Fig. 516.

This type of distortion is caused by the increased deviation (sweep width) of the harmonics, as compared with the sweep width of the fundamental. For example, the sweep width of the second harmonic is twice as great as the sweep width of the fundamental; the sweep width of the third harmonic is three times as great as the sweep width of the fundamental, etc. It is clear that when the output from a sweep generator contains strong harmonics, and this output is applied to a Chromatic Probe, the second and third harmonics must sweep out of limits *before* the fundamental. The limit of sweep is usually determined by the amount of stray capacitance in the probe construction.

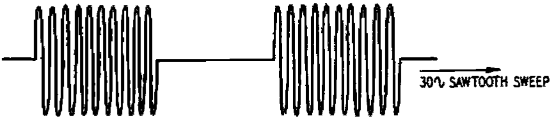


Fig. 517. Output from a sweep generator modulated by a 60-cycle square wave.

The result of the multiple beating with the harmonics sweeping progressively out of probe response limits is the development of a sweep which has abnormal voltage in the low-frequency region. It is apparent that the output from the Chromatic Probe contains spurious sweeps, in such case, just as the output from the sweep generator contains spurious sweeps. This is illustrated for us in Fig. 516. Note the abnormally high voltage in the low-frequency sweep region in the probe output. Zero frequency is at f_0. The sweep is through 5 mc left and 5 mc right.

Keying voltage modulates sweep output

The keying voltage applied to the grid of the sweep oscillator in a sweep generator produces a modulated output which appears on a wide-band scope as illustrated in Fig. 517. If the sweep width of the generator is reduced to a small value or to zero, this output becomes useful for checking the response of signal circuits to 60-cycle square-wave modulation. The illustration shows the output from a sweep generator modulated by a 60-cycle square-wave voltage. This type of output is obtained by utilizing the zero-volt reference-line blanking function of the generator.

marker generators

The FM output from a sweep generator displays the frequency response curve of the circuit under test on a scope screen, but does not usually provide complete information concerning the location of specific frequency points along the curve. To locate a given frequency point on a response curve, the output from a CW generator is often mixed with the output from the sweep generator and demodulated to form a beat pattern, as shown in Fig. 601. At the point where the frequency of the FM generator

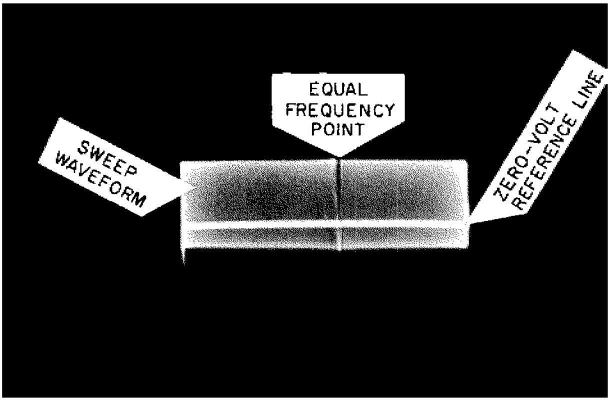


Fig. 601. When the outputs from FM and CW generators are heterodyned, demodulated, and displayed on the screen of a wide-band scope, the display is marked by a small gap at the zero-beat point. At this point the frequencies of the two generators are instantaneously equal.

is instantaneously equal to the frequency of the CW generator, a small break is noted in the beat pattern. This is termed *zero beat.* The zero-beat point is called the *marking point.* Likewise, the CW generator is termed a *marker generator.*

A display such as shown in Fig. 601 is obtained only when the combined output from the two generators is displayed on a wide-band scope. When a narrow-band scope is used, the marker display has a bandwidth equal to that of the scope and appears typically as seen in Fig. 602. Both types of marker displays will be encountered upon occasion in tests of color TV circuits, for example, hence you should be familiar with both types.

The practical considerations concerning the output from a marker generator are:

1. Accuracy of the marker frequency
2. Voltage of the marker frequency
3. Purity of the marker output
4. Ease of setting marker dial to desired frequency

Accuracy of the marker

The accuracy of the marker frequency is determined by the calibrating facilities which are provided, in the case of crystal-calibrated generators, or by the inherent stability of the oscillator in the case of generators which are not crystal-calibrated. The accuracy of a quartz-crystal oscillator is generally ±.05%. It does not follow, however, that the frequency of a marker generator can be set to this same accuracy by beating against the crystal harmonics, for the following reasons:

1. The zero-beat point can be determined with considerable accuracy, but the zero-beat point is seldom the specific marking frequency desired.
2. The specific marking frequency which is wanted must be determined by interpolation or some equivalent procedure. This considerably lessens the accuracy of the determination.

Typical accuracy of the oscillator in a marker generator is in the order of ± 1%. To gain an understanding of what this value of accuracy means, note that ± 1% is equivalent to ± 1 mc in 100 mc. That is, if a front end is being aligned at 100 mc, a marker frequency with an accuracy of ± 1% corresponds to a possible error of marker setting from 99 mc to 101 mc. But an accuracy of ± .05% corresponds to a possible error in marker setting from 99.95 mc to 100.05 mc. Although an accuracy of ± 1% is adequate for aligning r.f. and mixer circuits, for example, a somewhat higher accuracy is usually required for setting local oscillator tuning adjustments.

Crystal calibration of a marker generator requires frequent rechecking in many cases because of the tendency of the oscillator to drift. Drifting becomes more noticeable as the operating frequency is raised. Although drift may be almost negligible at 20 mc, it may become quite evident at 200 mc. Drift is most severe during the warmup period of the marker generator before thermal equilibrium has been established.

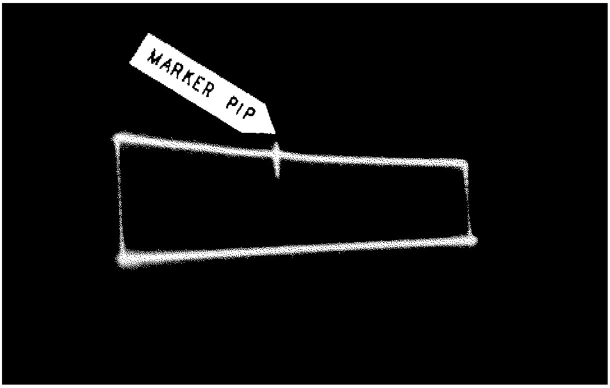


Fig. 602. When the output from an FM generator is mixed with the output from a CW generator, demodulated, and displayed on the screen of a narrow-band scope, the display is marked by a pip at the zero-beat point. The pip has the same bandwidth as the scope.

Oscillator stability

Some types of oscillator arrangements are inherently more stable and have less tendency to drift than do other types. For example, the beat-frequency oscillator arrangement is very susceptible to drift, especially at relatively low difference frequencies. This is one of the reasons why the beat-frequency circuit is seldom used in marker generator design. Simple oscillator arrangements, such as a triode Hartley circuit, are capable of relatively good inherent stability when suitable components are utilized in a favorable layout. The stability of such oscillators is further increased by use of temperature-compensated padding capacitors. These considerations concern only the inherent accuracy of the oscillator and do not include the frequency change which may take place due to load or line-voltage variations.

Generator dial errors

Considerations of accuracy also includes the distribution of error along the generator dial. To clarify this matter, a dial might read 1% low at 20 mc, but 1% high at 30 mc, and perhaps read exactly correct at 25 mc. This variation in magnitude and sign of the frequency error is termed the *distribution of the error.* Such a distribution is evidently difficult to work with since you cannot add or subtract a definite amount from the dial indication to compensate for the error. Distributions vary from one type of instrument to another and also from one instrument to another *of the same type.*

Percentage accuracy and absolute accuracy

A distinction must be made between *percentage accuracy* and *absolute accuracy.* The distinction becomes readily apparent when you note that a marker generator having an accuracy of ±1% will have a possible error of ±0.2 mc at a frequency of 20 mc, but will have a possible error of ±2 mc at a frequency of 200 mc. Although the percentage accuracy is the same in the two cases, the *absolute error* is 0.2 mc in the first case and 2 mc in the second case, or the absolute error is 10 times as great in the second case while the *percentage error* remains constant.

Various applications require marker accuracy in terms of percentage accuracy, while others require it in terms of absolute accuracy. The alignment of r.f. and mixer circuits, for example, can be conducted satisfactorily upon the basis of percentage accuracy. On the other hand, the adjustment of local oscillator circuits must be conducted upon the basis of absolute accuracy. The distinction between the two situations is this: although an increased absolute error is incurred from channel 2 to channel 13 when r.f. and mixer circuits are aligned upon the basis of percentage marker accuracy, the total absolute error at 200 mc is ±2 mc. Since the bandwidth of the r.f. and mixer circuits is quite considerable, an absolute error of 2 mc in marker location can be tolerated without serious consequences to quality of reception.

The tuning range of the fine-tuning control in many TV receivers, on the other hand, may be somewhat limited; accordingly, the local oscillator frequency must be adjusted on the basis of absolute accuracy—particularly on the higher channels. In this respect, crystal calibration of the marker generator serves to provide the required absolute accuracy for such applications.

Let us now consider the procedure used in a typical situation for determining tunable frequencies with high accuracy, using harmonics of a crystal oscillator for calibrating the variable-frequency oscillator in a representative service generator. Our instrument has two precision vernier dials: one is used with the marker (AM) generator and the other is used with the sweep (FM) generator. The marker generator has a basic accuracy better than 1% (output frequency within ±1% of the dial indication), but, as we have mentioned earlier, a higher degree of accuracy is sometimes required in practical applications. For this reason, the instrument is provided with a crystal oscillator having a basic accuracy of .05% or better. It is through the use of the crystal standard and the logging scale of the instrument that any desired frequency can be established to crystal oscillator accuracy.

When the function switch of the instrument is set to the CALIBRATE position, the outputs from the marker generator and from the crystal oscillator are combined and passed through a simple detector. This develops the difference beat frequency. It is this beat voltage that is applied to the scope. As the dial of the marker generator is slowly rotated, a sine-wave pattern is observed on the scope screen at certain dial settings. First, the technician will see a high-frequency sine-wave beat pattern. This decreases in frequency as the tuning dial is brought near the zero-beat point. At the exact zero-beat point, the pattern collapses, rising again abruptly to full height as the zero-beat point is passed through. The crystal oscillator in our instrument has a fundamental frequency of 5 mc, hence the strongest beat patterns are found at 5-mc intervals along the marker dial.

The point at which the pattern is reduced to zero frequency (zero beat) is the point at which the marker generator and the crystal oscillator have identical frequencies. This zero-beat point is easily identified by the fact that the slightest movement of the marker dial in either direction will cause the pattern suddenly to jump up in height and to increase in frequency as the dial is moved from the zero-beat position. At zero beat, the pattern is essentially a straight line. Adjustment for zero beat becomes more critical as higher operating frequencies are utilized. At the highest frequencies it may be found almost impossible to set the marker

BAND A				BAND B				BAND C			
Fundamental Megacycles	2nd Harmonic Megacycles	Var. Osc. Harm.	Xtl. Osc. Harm.	Fundamental Megacycles	2nd Harmonic Megacycles	Var. Osc. Harm.	Xtl. Osc. Harm.	Fundamental Megacycles	2nd Harmonic Megacycles	Var. Osc. Harm.	Xtl. Osc. Harm.
*3.33	*6.67	3	2	*15.00	*30.00	1	3	*70.0	*140	1	14
3.46	6.92	13	9	15.83	31.66	6	19	72.5	145	2	29
3.50	7.00	10	7	16.00	32.00	5	16	*75.0	*150	1	15
3.57	7.14	7	5	16.25	32.50	4	13	77.5	155	2	31
3.64	7.28	11	8	*16.67	*33.34	3	10	*80.0	*160	1	16
*3.75	*7.50	4	3	17.00	34.00	5	17	82.5	165	2	33
3.89	7.78	9	7	*17.50	*35.00	2	7	*85.0	*170	1	17
*4.00	*8.00	5	4	18.00	36.00	5	18	87.5	175	2	35
4.09	8.18	11	9	*18.33	*36.66	3	11	*90.0	*180	1	18
*4.17	*8.34	6	5	18.75	37.50	4	15	92.5	185	2	37
4.29	8.58	7	6	19.00	38.00	5	19	*95.0	*190	1	19
4.38	8.76	8	7	*20.00	*40.00	1	4	97.5	195	2	39
*4.44	*8.88	9	8	21.00	42.00	5	21	*100.0	*200	1	20
4.50	9.00	10	9	21.25	42.50	4	17	102.5	205	2	41
4.55	9.10	11	10	*21.67	*43.34	3	13	*105.0	*210	1	21
4.58	9.17	12	11	22.00	44.00	5	22	107.5	215	2	43
*5.00	*10.00	1	1	*22.50	*45.00	2	9	*110.0	*220	1	22
5.63	11.26	8	9	23.00	46.00	5	23	112.5	225	2	45
*5.71	*11.42	7	8	*23.33	*46.66	3	14	*115.0	*230	1	23
5.83	11.66	6	7	23.75	47.50	4	19	117.5	235	2	47
6.00	12.00	5	6	24.00	48.00	5	24	*120.0	*240	1	24
*6.25	*12.50	4	5	*25.00	*50.00	1	5	122.5	245	2	49
6.43	12.86	7	9	26.25	52.50	4	21	*125.0	*250	1	25
*6.67	*13.34	3	4	26.67	53.34	3	16				
6.87	13.74	8	11	*27.50	*55.00	2	11				
*7.00	*14.00	5	7	28.33	56.66	3	17				
7.14	14.28	7	10	28.75	57.50	4	23				
7.22	14.44	9	13	*30.00	*60.00	1	6				
*7.50	*15.00	2	3	31.67	63.34	3	19				
7.72	15.44	11	17	*32.50	*65.00	2	13				
7.78	15.56	9	14	33.33	66.66	3	20				
*8.00	*16.00	5	8	*35.00	*70.00	1	7				
				36.67	73.34	3	22				
				*37.50	*75.00	2	15				
Asterisk (*) indicates the stronger calibration points											

Fig. 603. When the output from a 5-mc crystal oscillator is mixed with the output from a variable-frequency oscillator, both oscillator outputs contain harmonics with the result that observable beats are obtained according to the tabulation above.

dial closely enough to bring the pattern to exact zero beat. However, when operating at 200 mc, the dial is set to high accuracy if the beat pattern is within 200 or 300 cycles of zero beat.

Although the user of a crystal calibrating arrangement such as we have described might expect to find beat patterns only at 5-mc points on the marker dial (since a 5-mc calibrating crystal is used in the example cited), he will actually observe that beat patterns are obtained at other than the 5-mc points, although these intermediate steps are weaker than the 5-mc beats. The intermediate beats are generated from harmonics of both oscillators. Fig. 603 shows the various beats which are obtained in practice; the stronger beats are marked with an asterisk.

Reading a vernier scale

It is not sufficient, of course, to determine a calibration point

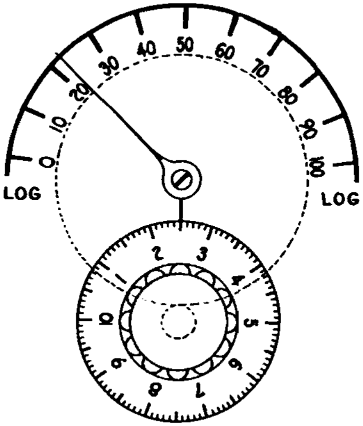


Fig. 604. Typical vernier or logging scale for interpolation of crystal calibration check points to desired marker frequencies.

accurately. For purposes of practical application, the calibration points must be interpolated to desired frequencies suitable for the job in hand. This interpolation is usually accomplished by means of some form of vernier scale, a typical example appearing in Fig. 604. The upper arc of the dial is divided into 10 equal divisions which are marked from 0 to 100. Another dial (marked off in 100 divisions) is mounted on a rotatable shaft. The gear ratio between the knob shaft and pointer is such that one complete revolution of the knob shaft moves the pointer through one of its 10 divisions. Thus, each division of the logging scale is effectively divided into 100 parts and the entire arc into 1,000 parts. The minor divisions may be divided visually to increase further the effective number of logging points and the terminal accuracy of the interpolation procedure. For example, the reading on the logging scale in Fig. 604 is 22.5. The main pointer shows that the setting is 20 plus some additional amount, and the dial on the knob shaft shows that the additional amount is 2.5. If the knob were turned slightly counterclockwise, so that the dial setting were halfway between 2.5 and 2.6, it could then be read as 2.55; and the indicated setting would be 22.55 divisions. By taking advantage of visual division in this manner, the technician can effectively increase the accuracy of a vernier scale to 2,000 or more scale divisions.

There are two methods by which you can interpolate a desired frequency with a vernier scale of this type. The two are similar, but one method is faster while the other method yields more accurate values. The first method is less accurate, but produces acceptable results for all but the most critical alignment applications. This process consists of first determining the number of logging-scale divisions which correspond to a 1-mc frequency difference (this determination being made to include the desired frequency to minimize the possibility of distribution error). Second, the technician mathematically figures the number of logging-scale divisions that the desired frequency falls from a crystal check point (as found in Fig. 603). Third, the technician tunes to the crystal check point and observes the reading on the logging scale, and, fourth, he adds or subtracts the determined number of scale divisions to or from the reading observed at the crystal check point. When the logging scale is set to the reading obtained in the fourth step, the generator will deliver the desired frequency with considerable accuracy.

A step-by-step example of this first method is as follows: Assume that a frequency of 20.75 mc is desired for marker application. Note that the table of Fig. 603 shows a strong calibration check point at 20 mc. First, set the scale pointer on the main tuning dial of the marker generator exactly over the 20-mc point on the scale. The logging dial will then show some arbitrary indication, such as 36.0. Next, set the scale pointer on the main tuning dial exactly over the 21-mc point on the scale, and again note the indication of the logging scale, which is now some other arbitrary indication, such as 40.45. Then, subtract the first logging scale reading from the second to obtain the number of scale divisions which correspond to 1 mc. For the example cited, this difference is 40.45 – 36.0 = 4.45 divisions on the logging scale.

In the next step, the technician determines the frequency difference, in megacycles, between the desired frequency and a check point near by, as found from the tabulation in Fig. 603. Then he multiplies this difference by the number of divisions on the logging scale as found above (4.45 divisions for the example cited). The desired frequency is 20.75 mc, which is 0.75 mc away from the strong calibration point at 20 mc. Since we have determined that a change of 4.45 logging-scale divisions corresponds to a change of 1 mc in frequency, the operator multiplies 0.75 × 4.45 to obtain 3.33 logging-scale divisions to the desired frequency setting.

Using the beat indication on the scope screen, the marker generator is then tuned to zero-beat at 20 mc, and the resulting arbitrary indication of the logging scale is noted, such as 36.2. Finally, the 3.33 divisions must be added or subtracted to the 36.2 setting of the logging scale. If the check-point frequency is lower than the desired frequency, the 3.33 divisions are added to 36.2, and vice versa. This sum or difference is the setting of the logging scale which provides the desired frequency output from the marker generator with a high order of accuracy. In the example under consideration, the two values are added, because the check point is below 20.75 mc. That is, the logging scale is set to 3.33 + 36.2 or 39.53. At this setting (39.53) the marker generator delivers a very accurate 20.75-mc output.

A second method of interpolation can be accomplished with a vernier scale, different from the method just described only in the fact that *two crystal check points* are used instead of the two scale indications. To use this alternate method, first determine the number of logging-scale divisions which correspond to the frequency difference between two crystal check points which include the desired frequency between them. Secondly, figure mathematically the number of logging-scale divisions that the desired frequency is away from one of the check-point frequencies. Third, add or subtract the determined number of scale divisions to or from the crystal check point. The quantity is added if the lower check point is the reference and subtracted if the higher check point is the reference. When the logging scale is set to the reading obtained in the third step, the desired frequency is obtained with an accuracy of better than 0.1%.

Here is a step-by-step example of this second method: Assume that a frequency of 20.75 mc is wanted from the marker generator to a high degree of accuracy. Note that the two nearest strong crystal check points are 20.0 and 21.67 mc in the tabulation of Fig. 603. There are weak check points at 21.0 and at 21.25 mc, but these would not be so useful because they are close together and difficult to identify. Using the beat-pattern indications on the scope screen, tune the marker generator for zero-beat indication at 20 mc. Record the corresponding indication of the logging scale, such as 36.2. Then, retune the marker generator for zero-beat indication at 21.67 mc. The reading on the logging scale is again recorded, such as 43.3. The first and second readings are subtracted giving $43.3 - 36.2 = 7.1$ divisions on the logging scale.

Now determine the frequency difference between the desired frequency and either of the check-point frequencies noted above. In this example, the desired frequency (20.75 mc) is 0.75 mc above the lower check point and is 0.92 mc $(21.67 - 20.75)$ below the upper check point. The difference between the two is 1.67 mc, $(21.67 - 20)$. By proportion, the frequency deviations can be determined in terms of logging-scale divisions: $D_1/D_2 = F_1/F_2$ or $D_1 = D_2(F_1/F_2)$, where D_1 = logging-scale divisions from one check point to the desired frequency, D_2 = logging-scale divisions between two check points, F_1 = frequency difference between the same check point (see D_1 above) and the desired frequency, and F_2 = frequency difference between the two check points.

If the lower check point is used to determine D_1, then D_1 is added to the logging-scale setting for this check point. If the higher check point is used to determine D_1, subtract D_1 from the logging-scale setting for this check point. The result will be the logging-scale setting for the desired frequency. In the example cited, add 3.19 to 36.2 to obtain 39.39 divisions, which is the required 20.75-mc setting to a very high degree of accuracy.

In some cases, a vernier scale is not used on a marker generator, but instead the dial scale is rotatable through a small arc. In this method of calibration, the generator will be zero-beat at some crystal harmonic frequency in the vicinity of the desired frequency. The dial scale is then rotated by means of a control to make the scale indication read exactly correct with respect to the pointer. The scale is graduated in fine intervals, and the operator may then set the pointer to any frequency in the vicinity of the calibration point with a high degree of accuracy.

Marker output voltage

It is by such means that calibration of a marker generator is provided to obtain the absolute accuracy which is sometimes required in critical applications. But in addition to accuracy, it is also necessary that the marker generator provide sufficient output voltage. Unless ample output voltage is available, satisfactorily large and visible beat markers may not be obtained when the sweep-voltage output is relatively high, such as in front-end alignment procedures. It is evident that harmonic output from a marker generator must necessarily be weaker than fundamental output, hence the more expensive and elaborate marker generators provide complete coverage on fundamentals. On the other hand, the least costly marker generators may depend on harmonic coverage for the majority of the ranges, and it is not unknown for the fourth harmonic to be used to obtain coverage on channel 13.

In general, it is more difficult to obtain a large marker display in r.f. work than in i.f. work, because the gain of the r.f. circuits is relatively low and a strong sweep voltage must be used, which reduces the visibility of the marker. In addition, when a higher harmonic is being used to mark the r.f. response curve, still further attenuation occurs and it may be very difficult to see a harmonic marker at all on the higher TV channels.

The reverse situation is often encountered in marking curves at lower frequencies, namely the inability to attenuate the marker sufficiently to avoid overload of the response. The difficulty is aggravated by use of high gain in the receiver circuits. Tests of circuit response with very low values of a.g.c. over-ride bias therefore require the ability to attenuate the marker voltage to a very small value. Such attenuation of a signal which is sufficiently strong to provide adequate markers on low-gain responses must usually be accomplished by a combination of step and vernier attenuation, plus extensive shielding of the marker generator components.

In addition to a wide-range attenuating system, the marker generator should preferably operate with a terminated output cable. Such termination is needed since standing waves in the output cable can cause very large rises and falls of output voltage at frequencies for which the cable becomes resonant, thereby defeating the purpose of the attenuating network.

Attenuation of an extreme degree may be encountered due to low gain in the circuit under test. For example, the marking of sound traps by means of beat-marker indication is a typical problem. This difficulty is overcome in the higher-priced marker generators by use of a heterodyne marker-adding network, whereby the beat marker is developed in a special mixing circuit apart from the circuit under test and applied to the scope input terminals directly. This avoids passage and attenuation of the marker voltage through the circuit under test.

Purity of output waveform

Another consideration of importance for the technician is the purity of the output from the marker generator. In the ideal situation, an output having a true sine waveform free of harmonics and spurious frequencies would be obtained from the generator. In practical generator design, however, harmonic output is always present to some extent, although few marker generators now in use develop spurious outputs, such as cross-beat frequencies. Unless a marker generator has negligible harmonic output, it is usually unsatisfactory for video-frequency marking, inasmuch as the harmonics of the marker often fall within the pass band to develop spurious markers, as shown in Fig. 605. In fact, the problem is frequently aggravated by the presence of harmonic sweep voltages, so that beat marking is abandoned in such cases.

It is interesting to note that this is a general type of problem. It is sometimes encountered in the operation of a marker generator in which the marker is developed in a separate mixer network in order to provide full-sized markers in sound traps. The indication is sometimes confused by the presence of spurious markers, which in some cases are larger than the desired marker. Two measures are possible to minimize the cross-beats: (1) the levels of the input signal voltages to the separate mixer network should be no greater than required to produce a full-sized marker (attenuation of the marker should be effected prior to mixing, instead of subsequently), and (2) the mixer should be biased for minimum output of cross-beats.

The marker dial

Finally, considerations concerning ease of marker-dial setting should be briefly noted. It is understood that a generator is a utility instrument and should provide ease of application. Large and easily read frequency indications on the dial are desirable, plus finely divided calibrations so that the need of estimating an odd frequency is minimized. The pointer should run sufficiently close to the scale so that errors of parallax will not be excessive in normal use. The scale divisions should be spread out extensively rather than crowded, so that a very small movement of the tuning dial does not result in a relatively large frequency change. This latter requirement is difficult to meet in harmonically operated instruments, since the scale calibrations are twice as crowded on the second harmonic as on the fundamental, three times as crowded on the third harmonic and four times as crowded on the fourth harmonic. Backlash should be virtually eliminated, so that the setting and resetting of the dial are appropriate to the inherent accuracy of the generator oscillator. The amount of backlash present in generator dial gearing is a purely mechanical problem.

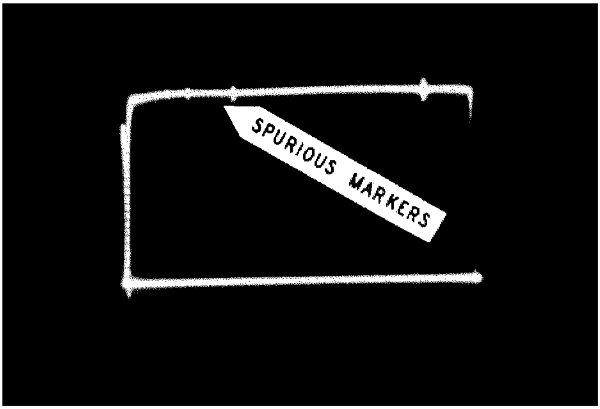


Fig. 605. Output from video-frequency FM generator combined with output from low-frequency marker generator, demodulated, and applied to scope shows development of harmonic marker pips.

Modulating the marker

It is often of assistance in practical applications to have provision for modulating the output from a signal or marker generator. One technique is to provide plate modulation of the marker signal when the SIGNAL switch is set to the MOD R.F. position. A modulated output is sometimes desired for setting traps, peaking stagger-tuned stages, adjusting ratio-detector circuits or for signal-tracing operations. Most generators provide for a fixed modulating frequency, such as 400 cycles. The percentage of modulation which is obtained may be fixed (such as 30% modulation) or may be adjustable for values ranging from 0 to 100% modulation.

Fig. 606-a shows the r.f. output from a signal generator modulated 100% by an audio-frequency sine wave (usually a 400-cycle wave). When modulated 100%, the average or unmodulated carrier voltage is caused to increase to twice its average value at the modulation peaks and to fall just to zero at the modulation troughs. The modulating sine wave is shown in Fig. 606-b. You should clearly understand that a sine-wave modulation represents an idealized condition which is usually approached but not attained by service instruments. In some instances, the approach is good, in others poor.

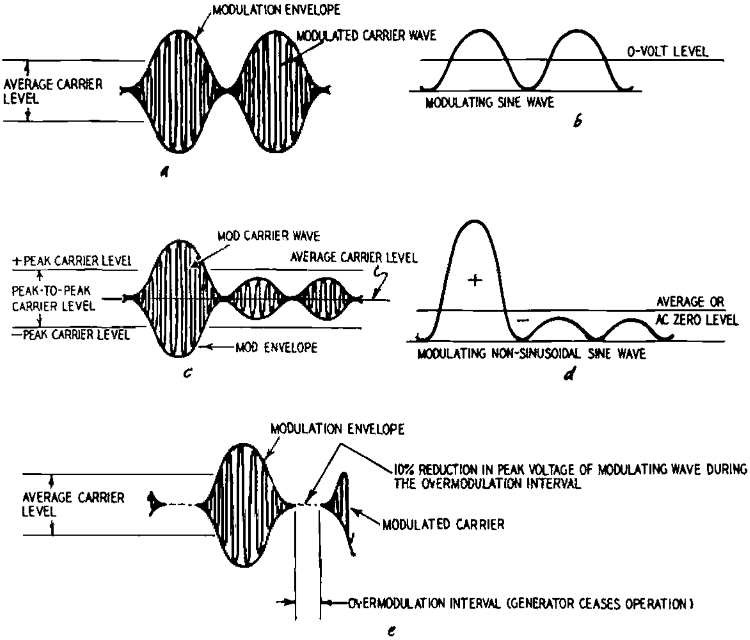


Fig. 606 (a to e). An illustration of 100% modulation (a) of an r.f. carrier. The modulating sine wave (b) represents an ideal condition. An illustration of 100% downward modulation but 300% upward modulation (c) of an r.f. carrier wave by a nonsinusoidal audio-frequency wave. The modulating waveform (d) is characteristic of some signal generators. Overmodulation (e) of an r.f. carrier wave.

Fig. 606-c shows how the output from a signal generator may be 100% modulated in a *downward* direction but modulated 300% in an *upward* direction when a nonsinusoidal modulating

wave is generated, as shown in Fig. 606-d. It is, of course, possible for the output from the generator to be *overmodulated,* as shown in Fig. 606-e. Overmodulation may be produced either by a sine wave or by nonsinusoidal wave. Overmodulation causes the output waveform to become abruptly distorted in the region of overmodulation and also generates excessive numbers of harmonics.

The envelope of the modulated wave can be easily checked by applying the output from the signal or marker generator to a signal-tracing or demodulator probe and feeding the output from the probe to a scope.

Signal generators vs. marker generators

There is sometimes a misunderstanding concerning the meaning of the term "marker generator" as compared with the words "signal generator". Use of a description such as "AM generator" also tends to add to the confusion. To set the matter straight, any source of a.c. voltage is a generator; if used to mark a response curve, the operator regards the instrument as a *marker generator.* In case the instrument is used to check circuit response by itself, without the use of a sweep generator, the term *signal generator* is applied, although the same instrument may be used in both applications. The term *AM generator* is ordinarily applied to instruments for testing radio receiver circuits over the AM broadcast band (550 kc to 1600 kc).

The first generators offered for service work were designed to provide output from 550 kc to 1600 kc. When FM broadcasting became the concern of the service technician, two modifications of generators appeared: new generators having higher frequency output (up to 125 mc or 150 mc); and, the older AM generators in some cases were calibrated with harmonic bands up through the third or fourth harmonic to cover the new requirements. Of course, the output on higher harmonics was necessarily weak.

When TV broadcasting made its advent, only the low channels were utilized at first, covering frequencies up to approximately 90 mc; hence existing generators served reasonably well in the new application except that accuracy became a somewhat more pressing requirement for setting of traps and discriminators, as well as local-oscillator circuits. As the higher channels opened up, covering frequencies up to approximately 220 mc, the older generators were in many cases no longer adequate. New higher-priced instruments then appeared, providing fundamental output through channel 13, with crystal-calibration facilities. Lower-priced instruments in some cases made more extensive use of harmonics; some of the medium-priced instruments raised the top fundamental coverage to 50 or 75 mc, relying on harmonics to obtain tests on the high channels; unmodified instruments gradually became recognized as obsolete for TV, and were relegated to the radio service bench.

An expanding requirement of this type produces great confusion in the mind of the technician. When it was realized that many of the older AM generators were inadequate for TV service work, some technicians came to the conclusion that TV receivers could not be completely and properly aligned by means of service generators, and that the only way to obtain acceptable reception was to wait for a suitable TV station signal to become available. It is obligatory to relate that the situation was somewhat aggravated by the misconception of some service instrument manufacturers that front-end and oscillator alignment was of little or no importance, and that only i.f. amplifier alignment was required to service a TV receiver adequately.

Today, it is generally recognized that marker generators for TV service work must have suitable coverage for r.f. and oscillator checks through channel 13, and must have sufficient accuracy of output at these frequencies—to such an extent that when the local oscillator is adjusted on the basis of the generator signal, proper reception will be obtained within the range of the fine-tuning control when the receiver is tuned to a TV station transmission.

chapter
7

marker signal generation

The chief consideration in the design of an oscillator for a marker generator is the frequency stability which can be realized at the price for which the generator is to sell. That is, a very low-priced generator may provide an accuracy of ±5% or even less, while a relatively high-priced generator may provide an accuracy of ±1%. The accuracy rating for the instrument may be furnished in two ways:

1. Accuracy over the entire range of the tuning dial
2. Accuracy over a portion of the tuning range

In the second instance, the accuracy limitation is not usually set forth explicitly.

Frequency stability

The frequency stability which is realized from such circuits depends upon suitable positioning of the components, so that thermal equilibrium is reached as soon as possible after turning on the oscillator. All oscillators tend to drift rather rapidly immediately after power is applied, but the better arrangements soon settle down to a relatively stable output frequency. To illustrate the necessity for judicious positioning of components, consider a situation in which the tank coil might be placed next to the tube envelope. The coil would slowly heat and expand over a long period of time until thermal equilibrium would ultimately be reached, accompanied by a prolonged period of frequency drift. The coil, of course, should be mounted in such a position that it does not receive excessive heat from the tube. Furthermore, by suitable attention to the geometry of the coil, it is possible to obtain relative immunity to reasonable temperature changes.

To stabilize further the frequency output, fixed temperature-compensating capacitors can be connected suitably in the inductor branch of the circuit and physically mounted with respect to the tube or tube terminals so that the compensation provided by the change in capacitance cancels the thermal drift of the overall arrangement. It will be apparent that the problem of temperature compensation is not entirely straightforward. Different sections of the oscillator tend to reach thermal equilibrium at different rates, hence several temperature-compensating capacitors in several different locations would be required to closely compensate for the resultant drift.

The L-to-C ratio of the oscillator tuning circuit varies for different settings of the tuning dial. This means that complete compensation is difficult to obtain at both the high end and low ends of the band. Hence, temperature compensation in practical situations is somewhat of a compromise between conflicting factors.

Brand-new oscillator tubes tend to drift more than tubes which have been "aged" by operation for an appreciable length of time and which have attained stable operating characteristics. Some tubes will be encountered which are troublesome "drifters" and cannot be satisfactorily aged. Any of the simpler oscillator circuits change frequency to some extent as the oscillator tube nears the end of its useful life and as the g_m of the tube falls excessively.

Because the values of the tube characteristics change with plate voltage (and to a lesser extent with variation of heater voltage), most marker generators tend to vary in output frequency with variation of line voltage. Marked improvement in stability can be realized by the use of plate-supply voltage regulation.

The various oscillator circuits shown in Fig. 701 are suitable for use in marker generators. Any of these arrangements is capable of providing satisfactory accuracy for marker applications when the components are properly chosen and positioned.

Fig. 701-a shows a commonly used oscillator arrangement for a marker generator in which the feedback coil is placed in the cathode circuit. In Fig. 701-b we have an alternative arrangement in which the feedback coil is inserted in the plate circuit. Fig. 701-c illustrates a circuit in which the feedback coil is not physi-

cally separate from the grid coil. This is a basic Colpitts oscillator in which the high-frequency ground return is made to the capacitors instead of the coil. The next circuit (Fig. 701-d) is a modification of the Colpitts. Here the plate-cathode and grid-cathode capacitances of the tube provide the high-frequency ground return.

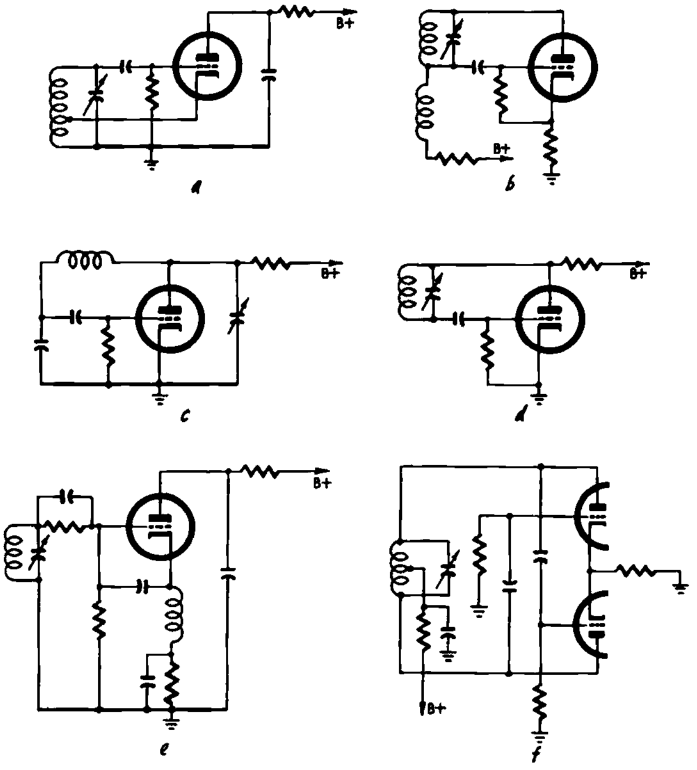


Fig. 701 (a to f). Quite often marker generators use an oscillator circuit (a) in which the feedback coil forms part of the cathode circuit. An alternative arrangement (b) shows the feedback coil in the plate circuit. It is not necessary to have a separate feedback coil. In the basic Colpitts (c) the high-frequency ground return is made to the capacitors instead of to the coil. A modification of the Colpitts (d) uses the plate-cathode and grid-cathode interelectrode capacitances to provide the high-frequency ground return. This is then known as the ultra-audion circuit. The feedback coil can be placed in the cathode (e) and capacitively coupled to the grid coil instead of using inductive coupling. We can get a higher frequency (f) by using a push-pull oscillator circuit. In this arrangement less total capacitance is shunted across the coil terminals by the oscillator tube.

This arrangement is termed the ultra-audion circuit. In Fig. 701-e we see that the feedback coil is placed in the cathode circuit, but is capacitively coupled to the grid coil instead of being inductively coupled. Fig. 701-f illustrates a pushpull oscillator circuit.

Generation of harmonics

All simple oscillator circuits generate harmonics in addition to the fundamental frequency. In fact, the lower-priced types of marker generators often rely upon harmonic output to provide high-frequency coverage. The harmonic outputs from various oscillator arrangements differ, although a rough rule of thumb sometimes used states that the voltage of an oscillator harmonic is proportional to the order of the harmonic. In other words, the second harmonic is half as great as the fundamental, the third harmonic one-third as great, the fourth harmonic one-fourth as great, etc. However, looser coupling between the feedback coil and the tank serves to reduce greatly the harmonic output. In some cases, waveform-distorting output circuits are utilized to enhance the harmonic voltages, so that more bands can be calibrated in terms of harmonics. For example, when the output from the oscillator is taken from the plate circuit in an electron-coupled oscillator circuit, the plate circuit, being untuned, receives plate current in the form of pulses from the class C grid-cathode oscillator circuit, and these output pulses are rich in harmonics. Some marker generators of this type are harmonically calibrated through the fourth harmonic.

In general, the better types of marker generators are operated in such manner as to minimize the harmonic output, since service tests are sometimes confused or made impractical if the generator has excessive harmonic output. For example, the test of a video amplifier response at 1 mc would be impractical in case the generator had 50% output at 2 mc and 30% output at 3 mc. For such broad-band tests, the second-harmonic output should be less than 10% in any case.

It is sometimes supposed that even-harmonic distortion is minimized by use of a pushpull oscillator circuit, but this is seldom realized due to lack of circuit balance. To eliminate even-harmonic distortion from the output, each tube section and its associated components in the pushpull circuit must have identical characteristics. Stray and residual impedances in the oscillator arrangement cause the positive half-cycle of output to differ somewhat from the negative half-cycle. The result is that even harmonics can usually be found in the ouput.

Harmonics are *minimized* in the output of an oscillator by taking the output voltage from across the tuned tank, rather than from the tube current, as shown in Fig. 702. In the arrangement of Fig. 702-a the plate circuit is nonresonant and receives pulses of current which have a high harmonic content. However, in the circuit of Fig. 702-b, the output is taken from approximate midpoint of the shunt-feed resistor to the pushpull oscillator. This provides isolation of the output circuit from the oscillator tank as well as much better waveform than the first arrangement. Effectively, the take-off shown in Fig. 701-b is coupled to the "flywheel" tank circuit, in which the electrical energy surges in essentially sine-wave form. The basic operation of such oscillators may be compared with that of a pendulum which oscillates smoothly and uniformly in spite of the fact that the escapement "pulses" the pendulum briefly during each cycle. In a similar fashion, the tube current in a class C oscillator pulses the tuned tank coil, which nevertheless oscillates smoothly and uniformly. When the signal is taken from the "escapement," the output has a pulse form; when taken from the "pendulum," the output has a sine waveform.

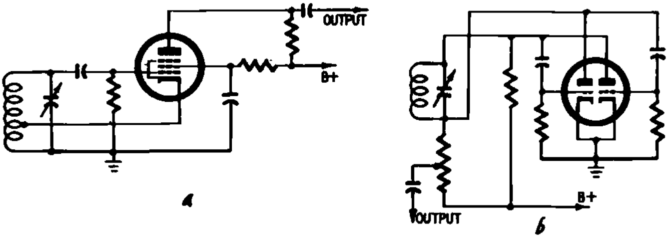


Fig. 702-a,-b. Electron-coupled oscillator arrangment (a) used in the marker generator relies upon harmonic output for the higher frequency bands. The output circuit is coupled to the space current in the tube and is driven by highly distorted pulses. In the push-pull oscillator (b) with the output circuit coupled to the tuned tank coil, harmonic output is minimized.

The higher the Q of the tank circuit, the more nearly does the output approach a true sine wave. The Q of the circuit is the ratio of its inductive reactance to resistance. At high frequencies of operation, the resistance rises due to greater surface losses, higher absorption losses and heavier loading by the tube due to finite transit time of the electron stream. The tank circuit is also loaded, of course, by the take-off arrangement, which must not impose so much coupling upon the tank that the frequency is noticeably affected by attenuator variations. It is sometimes found that the frequency of very low-priced marker generators tends to change as the attenuator setting is varied. However, all of the higher-priced generators are free from this source of inaccuracy.

Marker output

The maximum output of a typical marker generator is approximately 0.1 r.m.s. volt, while the terminal voltage of the tank coil may be from 15 to 100. The difference between these two voltages is an indication of the looseness of coupling utilized between the tank and the output circuit. Although an output of 0.1 volt may seem to be a rather small value, you will find that, provided this amount of output is available on all bands, all usual service requirements can be met. However, there are applications in color television service, for example, in which a higher output is required. For example, some receiver manufacturers specify alignment of the chrominance circuits with a 3.58-mc AM signal having a level of 1 volt. Although it is usually impractical to provide such a high level of output directly from the marker generator, a booster amplifier such as shown in Fig. 703 serves to raise the level from a conventional service generator to a suitable level for specialized tests of this type.

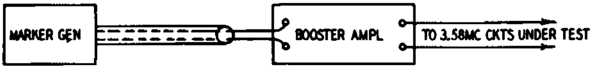


Fig. 703. Here we see the use of a booster to increase marker generator output.

Amplifiers used with signal generators

The arrangement shown in Fig. 703 can be used to increase the output level from a generator to meet the requirements of specialized tests. However, there are certain precautions which must be observed in practice to avoid difficulties. If the circuit under test requires a 3.58-mc signal, for example, it is essential to utilize a booster amplifier which provides the required gain at this frequency. It should be noted in this regard that most scope preamplifiers do not provide substantial gain at 3.58 mc; however, there are some preamplifiers available which have full gain at this frequency.

Preamplifiers which have full gain at such frequencies may be *load-sensitive;* in other words, the amplifier may not operate properly unless it is working into a specified load. A typical example: an amplifier* which is particularly designed to drive a voltage doubler demodulator probe having an input capacitance of

---

*Simpson Chromatic Amplifier

approximately 8 μμf. With a load having this value of capacitance, the amplifier develops full gain at 3.58 mc, but higher values of load capacitance cause rapid attenuation of the output. Hence, if this amplifier were to be used as a generator output booster, an 8-μμf capacitor would usually be connected in series with the amplifier and the circuit under test.

A capacitance of 8 μμf has a reactance of approximately 6,000 ohms at 3.58 mc. This may drop a substantial portion of the output voltage if the boosted output from the amplifier is applied to a low-impedance circuit point. Keep this point in mind when using a load-sensitive booster amplifier. It is usually possible to apply such a signal at a high-impedance circuit point, such as the grid of the chroma amplifier or the grid of a video amplifier.

In case a load-sensitive amplifier is supplemented by a cathode follower, these considerations do not apply and the low-impedance output which is made available by the cathode follower can be applied at any convenient circuit point without impairing the gain of the booster amplifier.

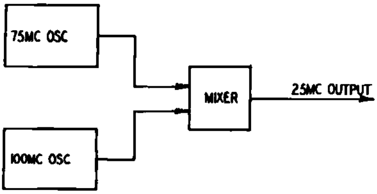


Fig. 704. The beat-frequency method of marker signal generation, now largely abandoned. The output from the mixer must be filtered to avoid generation of spurious markers.

Beat-frequency marker generation

In the past, signal and marker generators which operated on the beat-frequency principle have occasionally been offered to the service trade. The output frequency in such instruments is obtained in a manner similar to that which we explained earlier for beat-frequency sweep generators. Although it is possible to filter the output from a beat-frequency signal or marker generator to obtain a pure output (in the same manner that the output from a beat-frequency sweep generator is filtered), such generators have lost favor because of the difficulty in maintaining accurate calibration.

A simple example will illustrate this calibration difficulty. Consider a 75-mc oscillator beating against a 100-mc oscillator, as shown in Fig. 704, to develop a 25-mc output. It is difficult to hold the oscillators in service instruments to an accuracy of better than 1%. In case the 100-mc oscillator drifts 1% off frequency to 101 mc, the output frequency (obtained as the difference frequency between the two oscillators) changes from 25 mc to 26 mc. This is an effective drift of 4%. In case the 75-mc oscillator drifts 1% off frequency also to 74.25 mc, the output frequency changes to 26.75 mc. This is an effective drift of 7%. Hence, a drift of the two beating oscillators beomes apparent in the output as a much larger effective drift, and this difficulty becomes greater as the output frequency is reduced. At 4.5 mc, for example, a small drift in the frequency of a beating oscillator appears as a very large drift in the difference frequency. Hence, such methods of marker-signal generation have been largely abandoned.

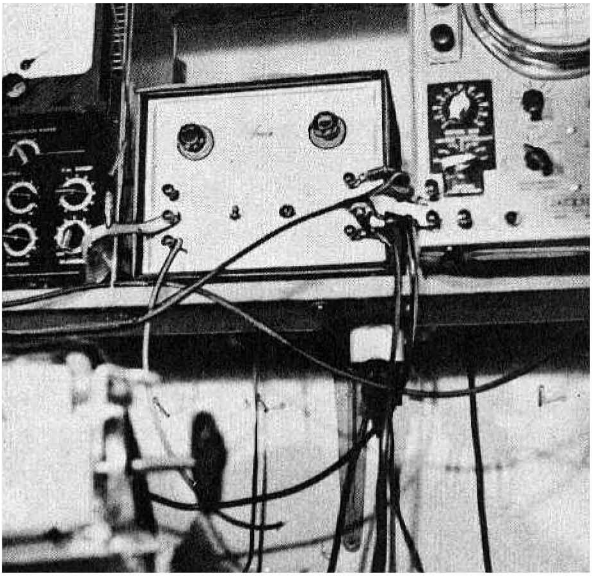


Fig. 705. Photograph shows a setup using a typical dual-marker generator.

Dual-marker generation

Marker modulators are available which generate sideband markers when the output from a conventional marker generator is applied. A typical dual-marker generator is shown in Fig. 705. The principle of operation of the unit is illustrated in Fig. 706-a. The output from a crystal oscillator which is contained in the dual-marker generator is used to modulate the marker signal from a marker generator. The result of this modulation is the generation of a pair of sidebands on either side of the marker frequency.

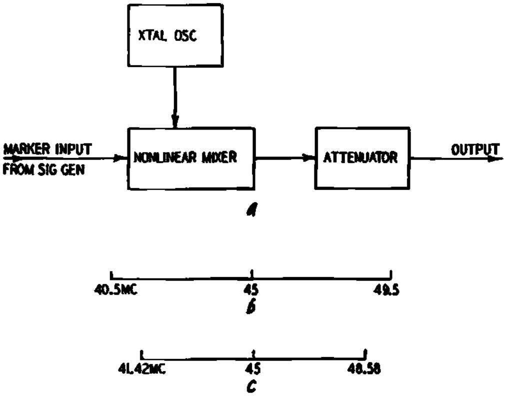


Fig. 706-a,-b,-c. Basic arrangement (a) of a dual-marker generator. The output from a built-in crystal oscillator modulates the output from a conventional marker or signal generator to add sideband frequencies to the output. When the marker signal (b) is set to 45 mc, with a 4.5-mc crystal oscillator, the sideband frequencies added are 40.5 mc and 49.5 mc. When the marker signal is set to 45 mc (c) with a 3.58-mc crystal oscillator, sideband frequencies are added at 41.42 mc and at 48.58 mc.

These are used to indicate the carrier-frequency points on a response curve. For example, if a 4.5-mc crystal is used in the dual-marker generator and the applied signal from the marker generator has a frequency of 45 mc, the output from the dual-marker generator will contain three frequencies: 40.5, 45 and 49.5 mc. (See Fig. 706-b.) When this output is utilized to mark an i.f. response curve in which the picture-carrier frequency is 45 mc, either the 40.5- or 49.5-mc marker will fall in the sound trap on the curve. Whether the one marker or the other will mark the sound-carrier frequency depends upon whether the local oscillator in the receiver operates above or below the channel. In either case, a sideband marker is available so that the picture-carrier and sound-carrier frequencies are marked simultaneously.

As another example, if a 3.58-mc crystal is used in the dual-marker generator and the applied signal from the marker generator has a frequency of 45 mc, the output from the dual-marker generator will contain three frequencies: 41.42, 45 and 48.58 mc, as shown in Fig. 706-c. When this output is utilized to mark an i.f. response curve in which the picture-carrier frequency is 45 mc, either the 41.42-mc marker or the 48.58-mc marker will fall at the color-subcarrier point on the response curve. Whether the one or the other of the two markers is utilized depends upon whether the local oscillator operates above or below the channel. But in either case, a sideband marker is available so that the picture-carrier frequency and the color-subcarrier frequency are marked simultaneously.

Of course, it is not necessary that the output signal from the marker generator have a 45-mc frequency; this frequency is only chosen in the examples for purposes of illustration. It is possible to utilize a marker signal having a frequency of 25 or 35 mc, and the output from the dual marker generator in either case will contain sideband markers above and below the applied marker signal frequency. It is also possible to use other crystal frequencies in a dual-marker generator. For example, a 1.5-mc crystal can be utilized, and in such case multiple markers will appear along the response curve, each marker being separated by 1.5 mc from the marker next adjacent.

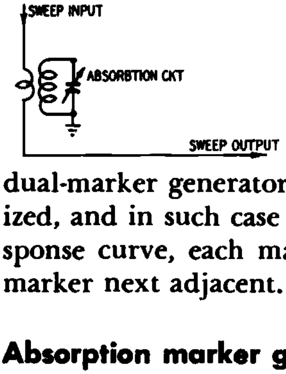


Fig. 707. Typical circuit used for producing an absorption type marker in the sweep output waveform. The name "absorption circuit" is somewhat misleading since the circuit does not absorb energy, but reflects a high impedance into the sweep output circuit at the resonant frequency of the absorption circuit.

Absorption marker generation

Marker generators often operate on the absorption principle, as illustrated in Fig. 707, to avoid harmonic difficulties. The term "absorption marker" is somewhat of a misnomer, inasmuch as the absorption marking circuit has a very high Q in most instances and actually absorbs a very negligible amount of current. The absorption marker operates in exactly the same manner as a sound trap or a color-subcarrier trap and causes an attenuation at the marker frequency by reflecting a high value of reactance back into the coupled circuit (in the case of Fig. 707, the reactance is reflected back into the link). The link provides the necessary coefficient of coupling to develop a small sharp dip in the sweep output. The frequency of this dip is determined by the tuning of the absorption circuit. This coupled reactance operates as if a high impedance had been inserted in series with the coupled circuit at the marker frequency. The output voltage passing through the coupled circuit is attenuated at the marker frequency, causing a dip to appear in the marked response, as shown in Fig. 708. Here, a deep dip is imposed upon the Y-channel response curve at 3.58 mc. Absorption markers are usually preferred in checking the color circuits of a TV receiver.

It is possible to obtain dual or multiple absorption markers, just as dual or multiple beat markers may be generated. By utilizing several absorption circuits in cascade, a succession of absorption markers may be placed on a response curve. This type of indication is commonly utilized in color TV servicing, in which it is deemed more convenient to provide several absorption markers of fixed frequency rather than a tunable absorption marker. In marking i.f. response curves with an absorption marker, however, it is more customary to provide continuous tuning of the absorption circuits. The difference between the two types of applications is based upon the use of standard response frequencies in the case of chrominance circuits, as against the arbitrary response frequencies utilized in i.f. amplifiers.

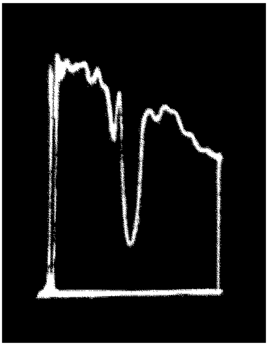


Fig. 708. Dip at center of waveform is caused by absorption marker circuit. The dip is prominent.

The principal reason for utilizing an absorption type of marker in color TV circuit work is to avoid the appearance of harmonic markers, as shown in Fig. 709. Harmonics and cross-beats in the sweep voltage and harmonics in the marker voltage combine to develop confusing spurious marker indications in many instances when video-frequency circuits are under test. The use of absorption marker indication largely minimizes the difficulty of spurious markers. Another advantage of the absorption type of marker indication is that it appears to considerable advantage upon an undemodulated sweep display, as shown in Fig. 710. Undemodulated sweep displays are commonly used to check the extreme low-frequency response of chrominance circuits in color TV receivers. The utility of an absorption marker in working with an undemodulated sweep display is readily apparent in Fig. 710. A beat marker indication becomes very difficult to see since the amplitude of the response is not changed at the marker point and only variations in the individual cycles of frequency modulation are apparent. However, the absorption marker produces a prominent dip in the amplitude of the sweep signal.

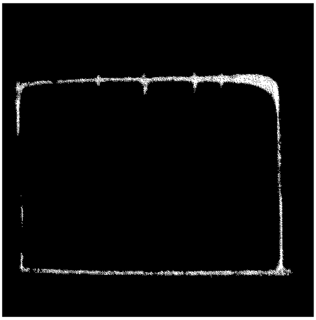


Fig. 709. Waveform shows spurious marker indications. Such markers are confusing.

Frequency bands utilized in marker generators

The frequency coverage of a typical instrument is from 2 to 260 mc obtained from three basic bands. However, each alternate band is provided as the second-harmonic output of the next adjacent lower band. Thus, the first band is covered on fundamentals, the second band on the second harmonic, the third band on fundamentals, the fourth band on the second harmonic, etc. Accordingly, three switch positions provide six bands. Since the output from the marker oscillators is relatively high, satisfactory marker indication is obtained on the harmonic bands.

Less-expensive marker generators may operate on higher harmonics and are calibrated as high as the fourth harmonic in some cases. The output voltage on such higher harmonics is relatively weak, so that special marker-injection methods may be required to obtain visible marker indication on third and fourth harmonic bands.

The most costly marker generators operate on fundamentals over their complete range and typically provide a total of six switch positions. A lesser number of bands could be used to cover the required frequency range if an individual oscillator tank could be operated over a sufficiently wide frequency range. But, as students of radio circuits are well aware, it is impractical to de sign an oscillator to cover a frequency range much greater than 3 to 1. In fact, when higher frequency oscillators are tuned, the stray capacitances become much more troublesome and it may be impossible to obtain a 3-to-1 coverage. For example, a representative instrument has a range from 150 to 260 mc on the highest band, which represents a ratio of less than 2 to 1.

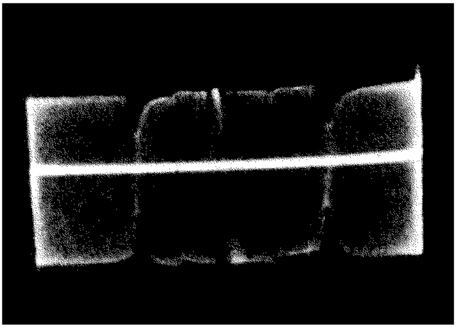


Fig. 710. The utility of an absorption marker in working with an undemodulated sweep display is readily apparent from the illustration above.

Higher harmonics through the eighth may be used to cover the principal u.h.f. channels by conventional v.h.f. marker generators, as shown in Fig. 711. The frequencies indicated are those of the lower limit of the channel, the video-carrier frequency, the sound-carrier frequency and the upper limit of the channel. The fundamental frequency of the marker generator and the harmonic which is utilized are indicated. By taking advantage of the gain of the front end and of the i.f. amplifier in the receiver (sweeping the u.h.f. converter with the instruments and connecting the scope at the output of the video detector), useful harmonic marker indication through the eighth harmonic can be obtained in this typical case.

Utilization of harmonic marker indication in this manner evidently multiplies the effective number of bands on the marker generator many times and provides a much wider field of application for the instrument. However, there are some u.h.f. alignment problems which cannot be met with the arrangement herein described. The principal limitation is lack of sufficient voltage in the harmonic output to provide a satisfactory marker above 800 mc. However, this frequency is the lower limit of channel 69, and there are very few station assignments which use these highest frequencies. In the event, however, that marking of u.h.f. channels above channel 69 is required the technician will usually require a separate u.h.f. marker generator, instead of making use of the higher harmonics of his v.h.f. generator.

CHANNEL		FREQUENCY (MC.)	FUNDAMENTAL FREQ.	HARMONIC
14	LOWER LIMIT	470	117.50	4
	VIDEO CARR.	471.25	117.81	4
	SOUND CARR.	475.75	118.94	4
	UPPER LIMIT	476	119.00	4
15	L L	476	119.00	4
	V C	477.25	119.31	4
	S C	481.75	120.44	4
	U L	482	120.50	4
16	L L	482	120.50	4
	V C	483.25	120.81	4
	S C	487.75	121.94	4
	U L	488	122.00	4
81	LOWER LIMIT	872	109.00	8
	VIDEO CARR.	873.25	109.16	8
	SOUND CARR.	877.75	109.72	8
	UPPER LIMIT	878	109.75	8
82	L L	878	109.75	8
	V C	879.25	109.91	8
	S C	883.75	110.47	8
	U L	884	110.50	8
83	L L	884	110.50	8
	V C	885.25	110.66	8
	S C	889.75	111.22	8
	U L	890	111.25	8

Courtesy Simpson Electric Co.

Fig. 711. Harmonics up to the eighth may be utilized from some generators. The tabulation shown above indicates the relationship between the generator fundamental and harmonics useful for running checks on receivers working in the u.h.f. bands.

chapter
8

marker signal calibration

Although crystal calibration of the marker frequency is not required for all applications, there are certain procedures which can be carried out effectively only with the accuracy provided by crystal calibration. For example, the alignment of a stagger-tuned i.f. amplifier does not usually require crystal calibration of the marker, provided the dial accuracy of the marker generator is reasonably good. With 1% accuracy of dial indication, the technician will gain no advantage in utilizing crystal calibration to perform a stagger-tuned i.f. alignment.

On the other hand, consider the alignment of a 4.5-mc sound i.f. channel and ratio detector. The accuracy of the 4.5-mc marker must be held within a few kilocycles to obtain proper circuit performance, and here the technician requires crystal calibration of the marker: 1% of 4.5 mc is equal to 45 kc. This is too large a tolerance on the marker accuracy for this application. Again, consider the adjustment of the local oscillator in a front end. Here also the accuracy requirements (in view of the limited tuning range on many fine-tuning controls) impose the necessity of crystal calibration of the marker frequency.

In the alignment of color TV receivers, the placement of the color subcarrier on the overall response curve is critical with respect to the placement of the sound carrier and once more the technician will often find it advantageous to utilize crystal calibration of the marker frequency. Still another example is provided by the necessity for correlation of sound traps and sound i.f. amplifier circuits in the split-sound type of receiver.

The block-diagram arrangement of a representative combination sweep and marker generator, providing crystal calibration of the marker frequency, is shown in Fig. 801. By means of a switch, plate voltage can be removed from the sweep oscillator to stop its operation. This is the CALIBRATE position of the switch; it permits operation of the AM (marker) generator and also applies plate voltage to the crystal oscillator, thereby placing the crystal oscillator in operation. The quartz crystal used in the generator has a fundamental frequency of 5 mc and also develops numerous harmonics having less voltage than the fundamental. The crystal-oscillator circuit is of the tuned-plate tuned-grid type, with a fixed coil providing the necessary plate-load impedance. Output from the crystal oscillator is taken from across a cathode load resistor and is applied to a mixer crystal. The mixer is a germanium diode which operates as a nonlinear heterodyne mixer to develop beat-difference signals with respect to the output from the AM generator.

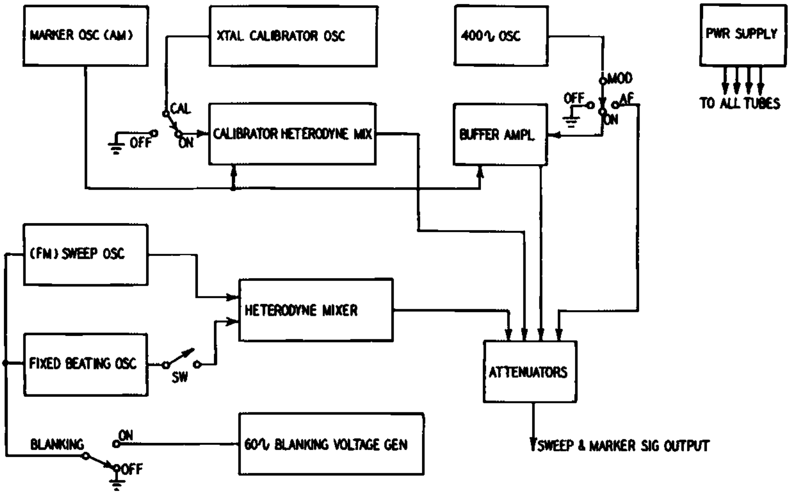


Fig. 801. A typical AM-FM generator arrangement for service applications, including a crystal-calibrator oscillator which beats with the AM marker oscillator output through the calibrator heterodyne mixer to deliver the difference-frequency beat pattern to the output. Calibrating beat patterns can be observed on the screen of a scope.

The output from the AM generator is also applied to the same germanium diode and beats with the output from the crystal oscillator to deliver a difference frequency. From here the signal voltage goes to the generator output terminals.

Calibration is commonly carried out utilizing 60-cycle horizontal sweep for the scope with the result that when zero beat is obtained, as illustrated in Fig. 802, the AM generator frequency is within 60 cycles of the crystal-oscillator frequency. This is a minor point but of some interest because service technicians sometimes suppose that, when a zero-beat pattern is obtained on the scope screen with an arrangement of this type, the AM generator and crystal oscillator then are operating at exactly the same frequency. Actually there is a difference of 60 cycles between them. Fig. 802-a shows the screen pattern obtained on a scope when the generator is far off zero beat. In Fig. 802-b the generator is *near* zero beat while in Fig. 802-c the generator is in a zero-beat condition with the horizontal sweep of the scope. The type of pattern obtained depends on the phase of the two beating voltages.

To have the two frequencies coincident at the zero-beat indication, one frequency has to be applied to the vertical input circuit

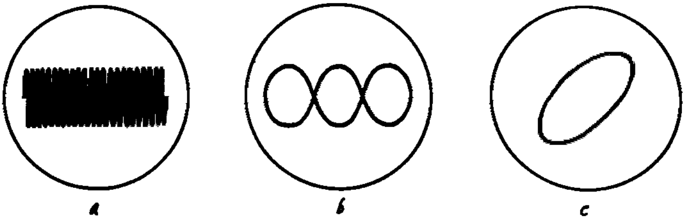


Fig. 802-a,-b,-c. Screen pattern obtained on scope (a) when generator is far off zero beat. The Lissajous figure (b) when the generator is near zero beat and (c) generator zero-beat with horizontal sweep of scope; frequency coincident within 60 cycles. This zero-beat pattern may vary from a straight line through an ellipse to a circle, depending upon the phase relations of the beating voltages.

of the scope, while the other frequency is applied to the horizontal input circuit of the scope, as shown in Fig. 803. However, when we are dealing with frequencies in the order of 20, 50 or 100 mc, a zero-beat indication within 60 cycles represents a negligible error and far exceeds the accuracy of the crystal itself. A quartz crystal used in an instrument such as that of Fig. 801 has a typical accuracy of .01%, or 500 cycles out of 5 mc. It is apparent that a difference of 60 cycles in 500 cycles can be neglected in practical work.

The zero-beat indication obtained may be a straight line across the scope screen, or it may consist of an ellipse, a slanted line or a circle. The type of zero-beat indication which is obtained depends upon the phase relation of the 60-cycle output from the heterodyne mixer with respect to the 60-cycle horizontal sweep voltage of the scope. Often the zero-beat indication is observed to assume rapidly shapes such as a line, ellipse and circle in succession. Such rapid variation of zero-beat pattern is the result of varying phase from the heterodyne mixer, due to slight instabilities of the beating oscillators.

When calibration is carried out at lower frequencies, such as 5, 10 and 15 mc, etc., you may often observe that the zero-beat indication is quite stable and consists of a horizontal straight line across the scope screen. In fact, the dial of the marker generator may sometimes be turned through several kilocycles before the zero-beat line suddenly breaks into a Lissajous figure. This perhaps unexpected behavior is the result of pulling and locking between the crystal and marker oscillators. When the frequency of the marker oscillator is the same as the fundamental frequency of the crystal oscillator, or when the frequency of the marker oscillator is the same as one of the lower-harmonic frequencies of the crystal oscillator, the tendency to lock and pull becomes most evident. On the other hand, when calibration is being carried out by beating one of the higher harmonics of the crystal oscillator against the fundamental of the marker oscillator, the pulling and locking tendency may be negligible.

It is quite possible, of course, for harmonics of the crystal oscillator to beat with harmonics of the marker oscillator. However, these interharmonic beats are much weaker than the beats involving fundamental frequencies of one of the oscillators. To equalize more nearly the amplitude of the beats obtained on the crystal fundamental and the beats obtained on the crystal harmonics, the inductance of the oscillator plate load may be suitably chosen to provide a greater impedance at harmonic frequencies of the crystal than at the fundamental frequency. More elaborate devices can be employed such as clipping of the harmonics to a uniform voltage to provide a constant beat amplitude at all check frequencies.

Calibration accuracy is less than crystal accuracy

It is sometimes supposed that the calibration accuracy which is obtained in such arrangements is equal to the accuracy of the crystal. Actually, this is not the case, because of observational and interpolation inaccuracies. Thus, although the crystal may be ground to an accuracy of .01%, the accuracy to which the marker dial may be certainly set may be in the order of only 0.1%. Here are the reasons for this loss of accuracy in the calibrating procedure: First, the marker dial must be beat against the crystal oscillator, and this zero-beat point read. Reading of the zero-beat point involves a certain error due to parallax as well as human judgment. Use of an auxiliary logging scale will minimize this source of error, but cannot eliminate it completely. Next, the marker dial must be beat against the crystal oscillator at the next higher beat point, and this next zero-beat point read. If a logging scale is utilized (as is desirable), there is a small inherent error in the running of the scale as the mechanical movement is never completely free of geometrical error. A subtraction is then made between these two readings and proportional parts are taken. Unless incorrect calculations are made, this portion of the procedure is free from error. Finally, the logging dial must be set to the value

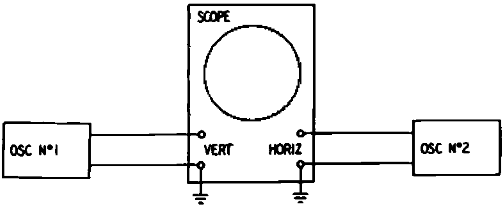


Fig. 803. For absolute zero beat, the output from one oscillator must be applied to the vertical input of the scope, while the output from the other oscillator is connected to the horizontal input. This arrangement works quite well when audio frequencies are used, but is impractical for i.f. and r.f. testing since vertical and horizontal amplifiers of most scopes do not extend into the i.f. and r.f. range.

obtained in the calculation, and a third source of error, similar to that previously noted, is again encountered. Moreover, the marker dial itself is usually not entirely linear. This introduces a small error because of the inapplicability of the proportional-parts calculation to the slightly nonlinear situation. In consequence, the end result may have a certain accuracy of only 0.1%, while the crystal unit itself could very readily have an accuracy in the order of .01%.

The meaning of calibration accuracy is sometimes misunderstood by the technician who may fail to recognize the difference between percentage accuracy and absolute accuracy. The following examples will make the distinction clear: Consider a marker generator having a dial calibrated to an accuracy of ±1%. At an operating frequency of 5 mc, this accuracy figure corresponds to an absolute accuracy of 5 mc ±.05 mc, or to a range of frequencies from 4.95 to 5.05 mc, encompassing a band of 100 kc. However, at an operating frequency of 200 mc, this accuracy figure of ±1% corresponds to an absolute accuracy of 200 mc ±2 mc, or to a range of frequencies from 198 to 202 mc, encompassing a band of 4 mc.

When an accuracy figure is given as 1%, it is almost always implied that the marker accuracy is equal to ±1%, or a total possible spread of 2% of the operating frequency. This is the possible extent of uncertainty implied by the accuracy rating. While the accuracy of a given dial setting might be better than the rating, the operator may be certain that the inaccuracy of the setting will never exceed the rating, provided, of course, that the rating is correct.

Interharmonic beats

Beats may occur between harmonics of the marker generator and harmonics of the crystal oscillator. Fig. 603 (Chapter 6) shows the practical situation which is encountered in a typical case. The number of interharmonic beats which are observed on the scope screen will depend upon the gain which is used in the vertical amplifier. At full gain, all of the beat points noted in Fig. 603 will be observed. If the gain is reduced to such a value that only the largest beats produce a readily visible deflection on the scope screen, then the only beats observed by the operator will occur at multiples of 5 mc, viz., 5, 10, 15, 20, 25, 30, 35 mc, etc. As these beats of the fundamental output from the marker generator are checked at higher and higher harmonics of the crystal oscillator, the beat patterns grow weaker and weaker until visible indication is no longer obtained. The vertical amplifier gain control of the scope must then be advanced somewhat, and visible beats will again be noted at 5-mc intervals, such as 40, 45, 50, 55, 60, 65 mc, etc. In this manner, it is possible to work with evenly spaced beats only, and to suppress the interharmonic beats.

The interharmonic beats are not evenly spaced because only the crystal oscillator generates evenly spaced harmonics. The harmonics from the marker generator may occur at uneven intervals, as illustrated by the following example:

Crystal oscillator: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, etc.

Marker oscillator: 8, 16, 24, 32, 40, 48, 56, 64, 72, 80, 88, 96, 104. etc.

Hence, when the marker dial is set to 8 mc, the fifth harmonic of the marker oscillator has a frequency equal to the eighth harmonic of the crystal oscillator, and an interharmonic beat appears. Thus, the interharmonic beats which are encountered are not evenly spaced. These interharmonic beats are also weaker than fundamental beats since the harmonic voltages are less than the fundamental voltages.

The array of interharmonic beats which is encountered is very complex. For this reason, in the event that the output from the marker generator should contain other components besides harmonics, the beat patterns may become so complex that they are no longer usable for calibration purposes. Consider, for example, the arrangement shown in Fig. 804. This is a beat-frequency arrangement which has been used to a limited extent in the past to obtain a wide-range output with minimum complication of the generator and to reduce the cost of the instrument. An arrangement of this type generates a large number of output frequencies other than the frequency indicated on the tuning dial. Hence, it is almost impossible in many cases to calibrate such a generator against a crystal oscillator. Not only are interharmonic beats present, but also a perplexing array of cross-beats from the spurious outputs. Some of these spurious outputs may be considerably stronger than the desired output, making calibration a next to impossible job.

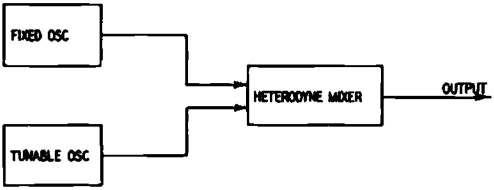


Fig. 804. Some marker generators use a beat-frequency arrangement to get wide frequency coverage with minimum complications. Circuit-wise this cannot be successfully calibrated against a crystal oscillator because of the excessive number of confusing cross beats which result.

When the output from a beat-frequency generator is to be calibrated, you will get best results by using a fundamental calibrating frequency instead of a harmonic calibrating frequency. This can be accomplished by use of an auxiliary generator which is not of the beat variety. The auxiliary generator may first be calibrated at the same frequency at which the beat-frequency generator is to be calibrated. Then, the output from the auxiliary generator may be used to calibrate the output from the beat-frequency generator. In this manner, the number of confusing cross-beats is minimized by developing a relatively large beat indication at the calibrating frequency.

Calibration against standard transmissions

The picture-carrier frequencies of television transmitters are held to high accuracy and provide convenient calibration frequencies for marker generators. To calibrate a marker generator in this manner, the output from the generator is loosely coupled to the lead-in of a TV receiver which is tuned to a TV station. As the frequency of the marker generator is brought near the picture-carrier frequency of the TV station, a bar pattern appears on the screen of the picture tube. When the frequency of the generator is identical with the frequency of the picture carrier, a large single wavy bar is observed as the zero-beat point.

In this procedure, you will note that certain spurious responses are obtained due to harmonics of the marker generator, the local-oscillator frequency and its harmonics, and also because of the sound carrier of the TV transmitter. However, these spurious responses usually cause small difficulty, and the operator has little trouble in identifying the desired zero-beat point.

The same general procedure can be utilized to calibrate signal generators in the broadcast range by beating the output from the signal generator with the carrier of a radio station through a broadcast receiver. In this test, of course, the zero-beat point is obtained audibly instead of visually. The indication is similar to that which is obtained from conventional heterodyne frequency meters.

Receivers can be used as zero-beat indicators in this manner, utilizing two oscillators feeding separately into the receiver. For example, if a marker generator does not have facilities for crystal calibration, a separate crystal oscillator may be utilized by feeding the output from the crystal oscillator into a TV receiver and also feeding the output from the marker generator into it. When the receiver is tuned to accept the output from the marker generator and the dial of the marker generator is turned to vary the output frequency of the generator through the receiver channel, zero-beat patterns will be observed on the screen of the picture tube at harmonic frequencies of the crystal oscillator which fall in the receiver channel.

The chief difficulty which is encountered in the foregoing procedure is the problem of identifying the harmonic of the crystal oscillator being utilized. For this reason, it is advisable to use a crystal having a high fundamental frequency, such as 5 or 10 mc, instead of a crystal having a low fundamental frequency, such as 1 or 2 mc.

Adjusting the oscillator frequency

When the marker generator is found to be out of calibration, the operator must adjust the trimmers in the oscillator tank circuit to bring the operating frequency to the correct point. As shown in Fig. 805, the tank usually provides both inductive and capacitive adjustments. The inductive adjustment affects principally the low-frequency end while the capacitive adjustment affects principally the high-frequency end of the band. This is because tuning of the tank is usually accomplished by means of a variable tuning capacitor having substantial capacitance. As a result, when the plates of the tuning capacitor are fully meshed, any variation of the trimmer capacitor has a relatively small effect percentage-wise on the total circuit capacitance. Doubling the value of the trimmer capacitance does not then double the L-C product. However, when the plates of the tuning capacitor are fully unmeshed, any variation of the trimmer capacitor has a relatively large effect percentage-wise on the total circuit capacitance: now, doubling the value of the trimmer capacitance will greatly increase the L-C product. (The resonant frequency is inversely proportional to the square root of the L-C product.)

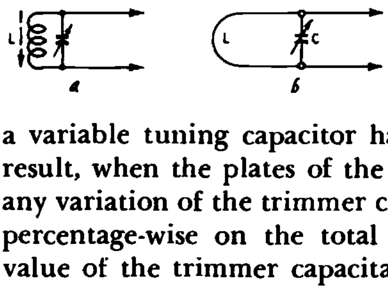


Fig. 805-a,-b. Marker oscillator tank arrangements. Large inductors (a) may be trimmed by a slug or small inductors (b) may be formed like a hairpin with adjustable length.

Next, considering the effect of the slug (inductance) adjustment with the plates of the tuning capacitor meshed and unmeshed, it is apparent that since the frequency of the circuit is determined by the product of both L and C, the amount of frequency change caused by a given variation in L will be greater when C is large than when C is small. Hence, inductance trimming has its greatest effect at the low-frequency end of the band.

In the case of large tank inductors having many turns, a tuning slug may be provided for inductance variation. In the case of small tank inductors consisting of a single hairpin loop, the mounting for the loop may be arranged so that the ends of the loop can be slid through the securing terminals in order to obtain inductance trimming. Small inductors having relatively few turns may be wound with several spaced turns at the end; inductance trimming may be accomplished by squeezing the turns closer together or by spreading them farther apart.

To make the dial track exactly at all points, it is necessary to utilize a tuning capacitor construction having a segmented plate, so that the segments can be bent as may be required to correct the dial indication at various intermediate points. The chief limitation to this latter procedure is the desirability of obtaining reasonably good tracking on *all* of the generator bands.

chapter 9

receiver alignment

The three signal sections of a superheterodyne receiver are shown in Fig. 901; the r.f. circuits, which resonate at the station frequency; the i.f. circuits, which are at a fixed frequency at all times, and the converter circuits working at the r.f. circuit frequency plus the intermediate frequency. It is evident that the r.f. and converter circuits must *track*—in other words, the r.f. and converter tuning capacitors are ganged on a single shaft. As the tuning dial of the receiver is rotated, the resonant frequencies of the two sections must remain separated by the value of the intermediate frequency.

Fig. 901. The three signal sections in a superheterodyne receiver.

The sequence and relationship of the signal frequencies in a superheterodyne receiver is indicated in Fig. 902. The r.f. amplifier operates at station frequency f_s; the local-oscillator tuning capacitor is ganged with the r.f. tuning capacitor and operates at a frequency of $f_s + f_{i.f}$ where $f_{i.f}$ is the intermediate frequency. The intermediate frequency is always lower than the lowest frequency to which the radio-frequency amplifier can be tuned.

Briefly then, the converter circuit contains an oscillator and a mixer section. The mixer section is tuned to the radio frequency in the grid circuit and to the intermediate frequency in the plate circuit; the oscillator section is tuned to the sum of the radio and intermediate frequencies. (In some rare instances the oscillator is tuned to the difference between the i.f. and r.f.) Note that this portion of the receiver may utilize a separate oscillator tube and a separate mixer tube, as illustrated in Fig. 903, or, very

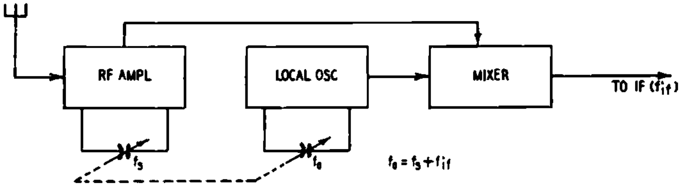


Fig. 902. The mixer circuit receives signals from two sources. One of these signals is that picked up by the antenna; the other is produced by a generator (local oscillator) in the receiver.

often, may employ a multigrid tube as a combination oscillator-mixer, as shown in Fig. 904, which is then termed a converter. The technician should not become confused by such variations in circuitry if the basic principle of operation is kept in mind. The use of a separate oscillator tube results in greater stability of operation at higher frequencies.

In the converter tube system of heterodyne operation a multigrid tube is utilized as a combination oscillator and mixer. The mixer section of a superheterodyne always operates as a *nonlinear*

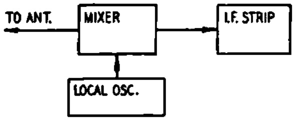


Fig. 903. A superheterodyne receiver can use a converter or a mixer and local oscillator to get the i.f. The mixer and local oscillator combination has better frequency stability.

device, sometimes called the *first detector.* The output meter can be energized from the first detector in aligning r.f. circuits and from the second detector in aligning the i.f.

It might be supposed that alignment of a superheterodyne receiver could logically start with the r.f. input circuits and continue progressively to the second detector. However, this method has certain disadvantages and is not often utilized. Instead, experienced technicians almost invariably start with alignment of the i.f. amplifier.

The reader will recognize the fact that the i.f. section of the receiver is least dependent upon the frequency relationships of the other sections, since the i.f. amplifier operates at only one frequency (more accurately, over only one band of frequencies—

the passband of the i.f. amplifier). This is not to imply that the i.f. amplifier can be aligned at *any* frequency, since the r.f., local oscillator and mixer circuits are designed to work into an i.f. amplifier having certain limits of center frequency. Nevertheless, since the i.f. amplifier is not too widely tunable, its alignment to the specified i.f. peak frequency is fairly simple.

At this point it is well to emphasize the fact that the converter (or mixer) plate is the first i.f. circuit in the receiver. Technicians sometimes overlook this and get into difficulties from either disregarding this tuned plate circuit or by loading it down and killing its resonant response by applying the generator output cable at the grid of the first i.f. tube. It is essential to apply the generator output cable at the grid of the convertor (or mixer) tube.

It is also well to emphasize that, if the i.f. amplifier is aligned very carefully with a weak signal, that the sensitivity of the receiver will be very good for weak-signal reception. But it is possible that the selectivity may be impaired for strong signals, since the frequency response of the i.f. amplifier in some receivers changes with grid bias. We also have the reverse situation. If the receiver is aligned very carefully with a strong signal, it is possible that the sensitivity may be impaired for weak signals. Hence, the technician should make a practice of deciding at the outset whether selective reception of strong signals or sensitive reception of weak signals is desired. Of course, if the receiver is quite stable in its operation, both objectives can be achieved.

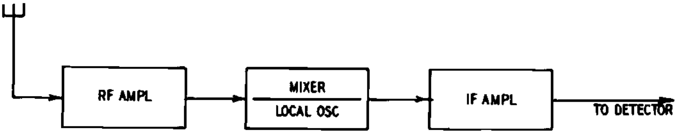


Fig. 904. A multigrid tube is often utilized as a combination mixer and local oscillator. The mixer always acts as a nonlinear device.

Ground connection

Many small receivers are of the a.c.-d.c. type with one side of the power line connected to the chassis of the receiver. Such receivers always impose a hazard on the service bench unless a line-isolation transformer is used. It is necessary to distinguish in this regard between a line-isolation *transformer* and a line-isolation *autotransformer*. Fig. 905-a shows a transformer arrangement which provides isolation of the receiver from the line as well as adjustable output voltage. In Fig. 905-b we have an autotransformer setup which does *not* supply isolation from the line, although it does give adjustable output voltage. Either type of device provides variation of supply voltage, *but only the transformer type provides line isolation and prevents shock.* This is the only type that should be used in the alignment of a.c.-d.c. receivers.

Before the alignment procedure is started, the technician should also make certain that he has located the d.c. ground as well as the r.f. ground in the receiver. Sometimes the power line and the B-supply return are not made to chassis in an a.c.–d.c. receiver, but are made instead to a common bus or a false chassis within the physical chassis. In such case, it will be found that the physical chassis will serve as an r.f. ground for the signal generator, but will not serve as a d.c. or low-frequency ground for the output meter which requires connection to the false chassis or to the power-supply bus. In this regard, likewise, it is well to note that the chassis is sometimes used as the system ground, but brackets are provided for mounting in the cabinet which are insulated from the chassis—if the technician tries to make either r.f. or d.c. ground returns to these brackets, he will obtain no response from the receiver. This is a point worth noting. Close inspection or an ohmmeter test may be required to establish the fact clearly that the brackets are not connected to the chassis.

The great majority of superheterodyne receivers utilize a peaked response in the i.f. amplifier, so that alignment is a relatively simple matter. Only a very few (high-fidelity) receivers make use of a double-humped response. The peaking frequency utilized is commonly 455 kc, although other i.f.'s will be encountered, such as 175, 262, 370, 456 and 465 kc.

A point which often perplexes the technician is that an amplifier aligned for proper response at 455 kc also responds when the signal generator is tuned to 227.5 or 151.6 kc. The reason for these responses is that service signal generators usually have strong harmonic output. This must be taken into consideration in various applications. In the alignment of an i.f. amplifier, the tuned circuits of the receiver filter the unwanted harmonic frequencies so that they may be disregarded. However, other tests can be made successfully only with the aid of a generator having low harmonic output—these are broad-band tests, in which the second or third harmonic from the generator is *not* filtered by the circuits under test.

Since the i.f. amplifier (for AM receivers) has narrow-band response and because there is usually considerable feedthrough from the antenna input terminals of the receiver into the i.f. amplifier (unconverted signal passage), most technicians do not bother to couple the output from the signal generator to the grid of the converter but merely apply the i.f. test signal to the antenna input terminals of the receiver. However, since some receivers provide an *i.f. trap* in the input section of the receiver, it may attenuate the generator signal to such an extent that a satisfactory indication cannot be obtained on the output meter. In such case, the trap may be shorted temporarily by means of a short clip lead. If an adequate signal still does not pass into the i.f. amplifier, it then becomes necessary to couple the output from the generator to the grid of the mixer or converter tube. Sufficient coupling is often obtained merely by clipping the output cable to the insulation of the signal-grid lead or it may be found desirable to use a small coupling capacitor of approximately 47 μμf to the signal-grid terminal.

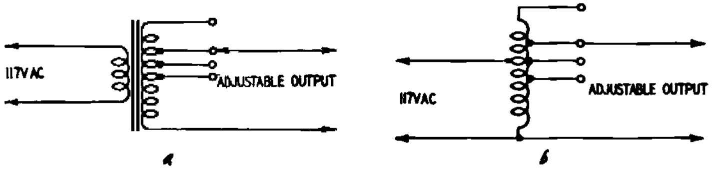


Fig. 905-a,-b. Techniques for increasing or decreasing the line voltage. The transformer type (a) provides line isolation but the autotransformer (b) does not.

Unsatisfactory output

Failure to obtain satisfactory deflection on the output meter in this procedure may be due to one of the following situations:

1. When the output is taken from across the voice-coil leads of the speaker, the a.g.c. should be overridden—but the override bias must *not* be set too high.

2. Output from across the voice-coil leads will be indicated only when the v.t.v.m. or v.o.m. is set to the a.c. function—*not* to the d.c. function. The "output" function is satisfactory.

3. When the output is taken from across the a.v.c. bus, the a.v.c. should *not* be overridden—if override bias is used, the meter will not respond to signal changes.

4. Output from across the a.v.c. bus will be indicated only when the v.t.v.m. or v.o.m. is set to the d.c. function.

5. The i.f. circuits may be so far out of proper adjustment that no signal is able to arrive at the detector until rough alignment

has been made—possibly a rough initial stage-by-stage adjustment of the tuned circuits.

At this point in the procedure, it is good practice to "stop" the local oscillator in the receiver by using a clip lead to short across the plates of the oscillator tuning capacitor. This precaution is necessary because many service signal generators have strong harmonic output, which may beat with the local oscillator voltage to produce false responses and mistuning of the i.f. amplifier.

In the case of the usual receiver, the operator then proceeds to peak-align the i.f. stages for maximum response, and this portion of the procedure is then complete. However, situations sometimes arise in which a high-fidelity i.f. strip cannot be aligned in such simple manner, because of the use of a double-humped or flat-topped response. Such response curves are commonly utilized also by FM receivers. In such case, alignment should be made by the visual method.

After the i.f. section of the superheterodyne receiver has been properly aligned, the usual procedure is to remove the shorting lead from the local-oscillator tuning capacitor and to align the local-oscillator circuit. Note particularly that, once the i.f. amplifier has been aligned, the indicated frequency on the receiver dial will depend only on the operation of the local oscillator—it makes no difference whether the r.f. circuits are in or out of alignment insofar as the receiver dial indication is concerned. Of course, if the r.f. circuits are out of alignment, the signal will be relatively weak, but the dial indication is unaffected.

Tracking

In the adjustment of the local-oscillator circuit, it will be noted that the receiver sometimes provides two trimmers, but usually only one. The plates of the oscillator tuning capacitor may be slotted to provide more accurate adjustment at various dial points. Fig. 906 shows an oscillator tuning arrangement utilized when the oscillator tuning capacitor has the same area of plates as the r.f. tuning capacitor. The main tuning capacitor is shown at C and the padding capacitor at C_3. This padding capacitor is used to track the oscillator at the low-frequency end of the band, while padding capacitor C_2 serves the same purpose at the high-frequency end of the band. Fixed capacitor C_1 usually has a capacitance considerably greater than the maximum capacitance of C.

In many cases, the plates of the oscillator tuning capacitor are specially shaped to minimize the external circuitry required to obtain satisfactory tracking. In another arrangement utilized to some extent in higher priced receivers, a ferromagnetic core is inserted in the oscillator coil for tracking adjustment at the low-frequency end of the band.

Tracking refers to the ability of the local oscillator to maintain a frequency separation from the r.f. amplifier exactly equal to the value of the i.f. at all positions on the receiver tuning dial. In practice, perfect tracking is not obtained. In the better receivers, a rather high accuracy of tracking is realizable. *Poor tracking,* of course, results in reduced sensitivity and selectivity.

When the oscillator trimmer adjustments are properly made, the tuning dial of the receiver will usually read correctly over its complete range. It is possible that there may be a fault in the tuning system. This should be corrected before oscillator alignment is attempted. The better manufacturers often specify reference checks, such as the frequency of maximum response when the tuning capacitor is set to either maximum or minimum capacitance. This is helpful because it minimizes the chance of error due to mechanical faults in the tuning system.

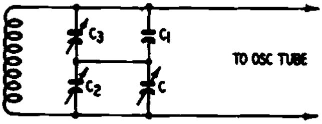


Fig. 906. One type of oscillator tracking circuit. In other systems, the plates of the oscillator tuning capacitor can have a special shape or be slotted. Sometimes the inductance of the oscillator coil is made variable by means of a poly-iron slug.

Oscillator adjustment

To check the oscillator adjustment, a signal is applied through a dummy antenna (or coupling loop) to the input of the receiver and the tuning dial is turned to the high-frequency end. If the manufacturer specifies this check with the tuning capacitor set to minimum capacitance, this is the setting used. Otherwise, the tuning dial is set to the high-frequency end of the band, such as 1400 kc. The signal generator is set to 1400 kc (or to the frequency specified in the service notes), and the output is observed on the output meter. The high-frequency trimmer capacitor is then adjusted to make the output meter indication rise to a maximum.

Next, the tuning capacitor plates are set for maximum capacitance (or the tuning is set to the low-frequency end of the band) and the output from the signal generator is set to 600 kc (or other frequency specified for this adjustment). The indication of the output meter is observed and the low-frequency trimmer or slug is adjusted to maximum indication. Finally, the setting of the high-frequency trimmer should be rechecked, since there is sometimes noticeable interaction between the two trimmers.

It should be understood that the low-frequency trimmer in some receivers is in the form of a slug, which must be adjusted for maximum low-frequency output and that in others the low-frequency response is adjusted by means of slotted plates in the oscillator tuning capacitor. In the simpler receivers there may be no provision at all for low-frequency trimming. Thus the technician must seek a suitable compromise between high-and low-frequency response with the one available trimmer.

At this point, the tracking of the receiver should be satisfactory, as indicated by the agreement of the tuning dials of the receiver and the signal generator as various points along the band are checked for response on the output meter. Of course, the selectivity and sensitivity of the receiver may still be poor, since the r.f. section of the receiver remains to be aligned.

It is perhaps well to repeat here that the signal generator used in the alignment procedure should have good accuracy, so that the circuits are not misadjusted by the operator in unwittingly compensating for the inaccuracy of the generator. Spot checks of the generator calibration can be easily accomplished by heterodyning the output from the generator with the signal from a broadcast station whose carrier frequency is known. This calibration may be accomplished conveniently in the receiver under test.

R.f. and mixer alignment

Alignment of the r.f. and mixer circuits usually starts at the high-frequency end of the band. For example, the tuning dials of both signal generator and receiver may be set to 1500 kc and the high-frequency trimmers adjusted for maximum indication on the output meter. Next, the operation may be checked at 550 kc (low frequency end of the band) by setting both signal generator and receiver tuning dials to 550 kc. The adjustment at the low-frequency end of the band may consist of slotted plates, a tuning slug or a padding capacitor. In the simpler types of receivers it is quite possible that there is no adjustment at the low end.

Rocking the tuning dial is a procedure utilized to obtain the best tracking of the local oscillator with the r.f. and mixer circuits.

To make this adjustment, the signal generator and receiver are tuned to the low-frequency end of the band. The output is maintained at a very low level, since this is primarily an adjustment to achieve good receiver sensitivity. The low-frequency trimmer of the *oscillator* is adjusted slightly one way or the other and the receiver dial is rocked back and forth through the point of maximum response. The technician notes the reading on the output meter to find the point of maximum sensitivity by trial and error.

After the receiver has been rocked in, it is good practice to recheck the setting of the high-frequency trimmers, as they may have been affected slightly. As a result of aligning the receiver for best possible reception, the technician may discover that the receiver tuning dial does not indicate the exact frequency of reception over some region of the tuning dial. This is due to manufacturing tolerances and does not indicate faulty receiver operation.

Shortwave receiver alignment

Receivers which provide shortwave in addition to standard broadcast reception require additional attention during alignment procedures. At the outset, you should recognize that the efficiency of shortwave reception is usually sacrificed to some extent in such receivers to reduce manufacturing costs. For example, instead of providing separate tuning circuits for the shortwave bands, the same inductors may be utilized on the broadcast band, but with suitable sections shorted by the band switch. Likewise, instead of providing separate and smaller tuning capacitors, the same gang may be used for both broadcast and shortwave reception.

A separate trimmer capacitor is usually supplied in the oscillator circuit for alignment on shortwave, but it should be noted that only one trimmer capacitor may be provided for two or three separate shortwave bands. Thus, a compromise alignment procedure is often required. The oscillator trimmer is adjusted by rocking; that is, the shortwave trimmer is adjusted while turning the tuning dial back and forth through resonance, watching the output meter for maximum response. The trimming adjustment is usually made at the low-frequency end of the shortwave band being aligned. If only one oscillator trimmer is provided, and more than one shortwave band is to be aligned, this procedure is repeated on the other bands, and any variation in the setting of the trimmer is noted. Then "split" the difference in settings to obtain a compromise alignment on the other shortwave bands.

Image response

All superheterodyne receivers are subject to *image response*. In some cases, however, it is so small that it can be completely disregarded; in other instances the image response is a problem. Image response results from the fact that the i.f. frequency can be obtained by operating the local oscillator either above or below the station frequency. To give an example, consider a broadcast station operating at 1000 kc. If the i.f. amplifier of the receiver operates at 455 kc, the local oscillator may be aligned at *either* 1455 or 545 kc. In other words, the local oscillator may operate *above* or *below* the station frequency by the value of the intermediate frequency. In either case, the *difference* between the station and the local-oscillator frequencies is equal to the intermediate frequency so the receiver is equally operative.

The image-response problem now becomes apparent. Consider a situation in which the local oscillator is set to 1045 kc. If a station frequency of 1500 kc is present, the difference frequency is 455 kc, which is accepted by the i.f. amplifier. If a station frequency of 590 kc is also present, the difference frequency is again 455 kc, and this station signal will also pass into the i.f. amplifier. If the receiver is designed to respond to 1500 kc when the oscillator is operating at 1045 kc, then 590 kc is termed the *image frequency*. On the other hand, if the receiver is designed to respond to 590 kc when the oscillator is operating at 1045 kc, then 1500 kc is termed the *image frequency*.

The manner in which one frequency or the other is made the image frequency is to tune the r.f. amplifier to the desired frequency. For example, consider the following tabulation:

Oscillator frequency	1045 kc
Intermediate frequency	455 kc
Radio frequency	1500 kc
Image frequency	590 kc

Conversely, consider this tabulation:

Oscillator frequency	1045 kc
Intermediate frequency	455 kc
Radio frequency	590 kc
Image frequency	1500 kc

The difference between these two listings is that, in the first example, the image frequency is equal to the radio frequency *minus* twice the intermediate frequency [1500 kc − (2 × 455 kc) = 590 kc]. In the second example, the image frequency is equal to twice the intermediate frequency *plus* the radio frequency [(2 × 455 kc) + 590 kc = 1500 kc].

The mixer is made nonresponsive to the image frequency by tuning the r.f. amplifier and mixer circuits to the desired response, thus rejecting the other response. Obviously, the more r.f. stages provided and the more selective they are made, the better will be the rejection of image interference. Receivers which have no preselection are most subject to image interference because only the selectivity of the mixer circuit is then operative in suppressing image interference. *Image interference is often a confusing factor in alignment, particularly to those who may not have a clear picture of the circuit relationships.*

When a shortwave receiver operates into a low-frequency i.f. circuit, such as a 455-kc amplifier, the image-interference problem is greatly aggravated. An example will make this point clear: Consider a receiver operating on the shortwave band and tuned for 20-mc reception. The tabulation becomes as follows:

Oscillator frequency	20.455 mc
Intermediate frequency	455 kc
Radio frequency	20.000 mc
Image frequency	19.545 mc

It is apparent that the image frequency is separated only 2½% from the response frequency, when the receiver is operating at 20 mc. Compare this situation with that of operation on the standard broadcast band (first tabulation). When the receiver is operating at 1500 kc, the image frequency is separated by 60%. It is not difficult to see that the front end will be much more immune to image-frequency interference when the image frequency is separated from the desired response by 60% of the desired frequency, rather than by 2½%. This is another of the compromises made in many cases when a shortwave receiver is combined with a standard broadcast receiver. It makes for difficulties in alignment, because often you will find that the output meter indicates almost the same output on the image frequency as on the desired frequency, particularly when aligning the shortwave bands.

Again, the best insurance against this type of alignment difficulty is a clear understanding of the factors involved, plus a careful study of the circuit diagram of the receiver before alignment is started. It is essential also to determine from the receiver service manual whether the local oscillator is designed to operate *above* or *below* the radio frequency on the various bands.

The trimmers for the broadcast band are usually mounted directly on the tuning capacitors, while the trimmers for the shortwave bands are connected at the individual coils. If the shortwave coils are switched completely in or out of the circuit by the bandswitch, it will make little difference whether the low- or high-frequency bands are aligned first. However, as noted previously, the shortwave bands may be tuned by short-circuiting a portion of the inductors used primarily for standard broadcast reception or the various coils may be arranged in series with a shorting switch, as shown in Fig. 907. In any series arrangement, it is good practice to align the highest-frequency band first and to proceed in order to the lowest frequency. In this manner, the least back-and-forth maneuvering will be required.

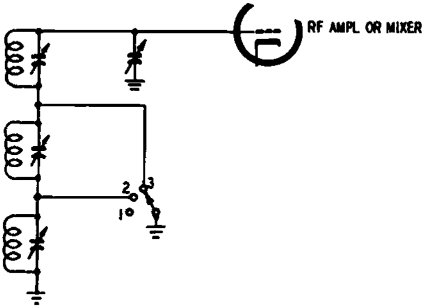


Fig. 907. Circuit arrangement for a multi-band receiver. The shorting switch provides three-band operation.

In the event that the receiver has an i.f. wavetrap in the front end, this circuit is aligned by applying a signal at intermediate frequency (such as 455 kc) to the antenna input terminals of the receiver and aligning the trap for minimum response on the output meter. The trap prevents interference at or near the intermediate frequency from feeding through the receiver system.

Point-by-point alignment

FM receivers of the better type have wide-band response as illustrated in Fig. 908. It is apparent that such circuits cannot be aligned by means of a simple peaking procedure. Most beginners, as well as some careless experienced men, attempt to align such circuits upon the basis of peak response, thereby impairing the fidelity of the receiver. Peaking of such circuits causes a reduction in the bandwidth, with a loss of the higher frequencies in the transmission.

In the point-by-point method, the technician records or plots the readings of the output meter as the dial of the signal generator is moved a given amount each time, such as 0.1 or 0.2 mc. A dozen or so readings serve to outline the curve definitely, as seen in Fig. 908. The plot obtained is then compared with the response curve provided in the receiver service manual, and any necessary remedial steps are taken to bring the response curve into proper form. FM receivers of the better type use a flat-topped or double-humped response. Such circuits cannot be aligned by means of a peaking procedure. Instead, the technician must use a point-by-point method if a simple signal generator is utilized.

It might be asked why double-humped curves are acceptable, since the voltage is higher at the ends of the top portion. A flat-topped curve would appear to be more acceptable because the output voltage is then uniform over the top portion of the curve. However, in practice, it will be found that the double-humped curve is quite as satisfactory as the flat-topped one, provided the double humps are not extreme. The reason for this is that FM receivers often utilize a *limiter* which has the effect of slicing off the top of the curve, making the output voltage uniform under usual operating conditions. Thus, the limiter has the effect of making a flat-topped curve out of a double-humped one. The limiter, however, has very little effect in improving the *bandwidth* of the curve, so that it is essential for the technician to align the tuned circuits for proper bandwidth if high-fidelity response is to be obtained. The bandwidth is usually defined as the number

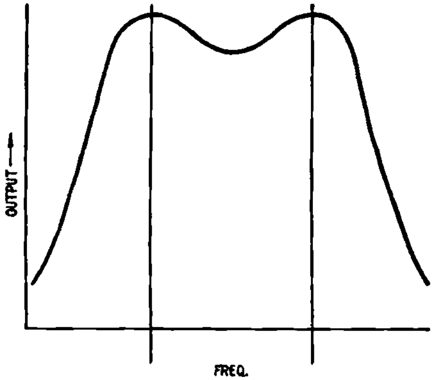


Fig. 908. Double-humped response of the i.f. section of an FM receiver. A limiter stage or ratio detector following the i.f. will flatten the top of the curve.

of kc (or mc) between the half-power points (70.7% voltage points).

Uniform output from signal generator

The reader will perceive that a new signal generator requirement has now been introduced; that is, the generator must provide substantially uniform output voltage over the passband of the circuit under alignment. It is clear that if the generator has twice as much output at the low-frequency end of the channel as it has at the high-frequency end, the technician will unknowingly misalign the circuits. In this way, *the requirements for an FM signal generator are more strict than for an AM unit.*

The reader may ask, "What is the most common cause of non-uniformity (lack of flatness) in the output from an FM signal generator?" Here it must be noted that chief among these is the use of a long and unterminated output cable for the generator. All signal generators of the laboratory type are provided with an output cable having a resistor across the end. This resistor has a value equal to the characteristic impedance of the cable and avoids the development of standing waves. However, few service generators of the AM and FM type provide such a resistor; in most cases the cable is left unterminated. (Of course, the user can *supply* the resistor, as long as he is aware of the requirement.)

Now, it must not be supposed that all unterminated cables are distortion-makers in FM receiver alignment—whether the unterminated cable will cause trouble depends entirely upon the *length* of the cable. If the cable is kept quite short (2 feet), not much inaccuracy will be introduced into alignment of the FM i.f. circuits (operating at approximately 10 mc). But if the cable is made 6 feet long, the technician will very likely run into rather serious trouble.

Again, the seriousness of an undetermined cable depends upon the operating frequency of the FM signal generator. An unterminated cable that produces negligible distortion over the FM i.f. band can cause intolerable distortion over the FM r.f. band (88–107.9 mc). For this reason, the careful technician always makes certain that the output cable from the FM signal generator is properly terminated before work is started. The better types of generators are provided with terminated output cables by the manufacturer.

If the characteristic impedance of the output cable is unknown, it is possible to measure its value, although the measurement is sometimes difficult for the relatively inexperienced technician to make properly.

Note particularly that the output meter cannot be connected across the voice coil because many FM receivers make use of a limiter stage before the detector. Even a relatively small input signal will saturate the limiter, after which no further rise in output occurs. For this reason, the output meter must be connected across the limiter load resistor, as shown in Fig. 909. The voltage drop across the limiter load resistor is d.c. and hence the d.c. ranges of the v.t.v.m. or v.o.m. are utilized.

With the foregoing considerations in mind, alignment of the circuits up to the FM detector is carried out in much the same manner as for AM receivers. Of course, considerably more time is required to align the tuned circuits properly, since they are not simple peaked circuits.

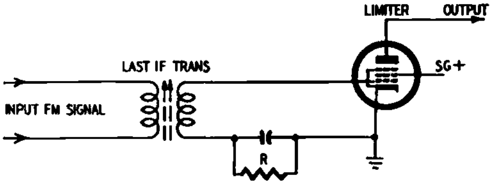


Fig. 909. The output meter is placed across limiter resistor R to indicate r.f. and i.f. alignment.

The limiter arrangement shown in Fig. 909 is basically a class-C amplifier operated under overload conditions. The output waveform is, of course, severely distorted and a wide spectrum of harmonics is generated. These harmonics are rejected by the subsequent ratio detector or discriminator tuned circuits and only the fundamental is utilized. This *fundamental-frequency* output remains constant in voltage over a wide range of input voltages, although the rejected harmonic output does not remain constant. Hence, the circuit serves well as a limiter.

The screen grid voltage of the limiter is maintained at a relatively low value; this reduction in voltage is required to avoid excessive space-current flow when no input signal is present, since the tube then operates at zero bias. At very low values of input signal, the limiter operates in class A or class B, and limiting action is not obtained.

The flow of grid current in normal operation damps the last i.f. transformer, so that *the frequency response curve should be determined with respect to application of the generator signal to the grid of the preceding i.f. tube.*

FM detectors

The detector in an FM receiver, as illustrated in Fig. 910, differs essentially from an AM detector in that the frequency modulation of the applied signal is converted to AM and the modulating envelope of the AM signal yielded as the detector output. The operation of this circuit is such (when properly aligned) that a signal applied to the limiter at center frequency (usually 10.7 mc), produces zero output from the discriminator. This null is usually determined upon the basis of an applied CW signal and a d.c. output meter. The meter must of course be applied at the output of the discriminator ahead of any blocking or coupling capacitor which may be present in the circuit.

A v.t.v.m. is preferred for metering the output from the discriminator, although a 20,000-or 100,000-ohms-per-volt v.o.m. will serve the purpose. The usual procedure is to apply the voltmeter across one of the discriminator load resistors (commonly called the "half-load") and to adjust the primary trimmer for maximum output. Next, the voltmeter is applied across the complete discriminator output and the secondary trimmer adjusted for a null. Note that three nulls can be obtained, and that the central null is the correct adjustment. The central null differs from the end ones in that the voltmeter pointer will swing *positive or negative* as the trimmer adjustment is rocked back and forth through the null position, whereas an end null will cause the pointer to fall to zero *without* going through zero to an opposite deflection. Most technicians use a zero-center v.t.v.m. function for this adjustment, since the polarity switch of the instrument does not need constant attention when the zero-center indication is used.

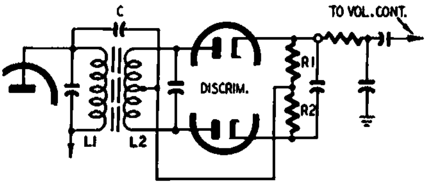


Fig. 910. Typical discriminator arrangement. The test meter is connected across R1 and L1 is adjusted for maximum output. The meter is then placed across the total diode load (R1 and R2) and L2 is adjusted to null at the i.f. center frequency.

It is good practice to recheck the adjustment of the primary trimmer after adjusting the secondary trimmer and finally to recheck the adjustment of the secondary trimmer. Note also that, unless the i.f. amplifier is in reasonably good alignment, the off-frequency response of the i.f. circuits can cause the maximum setting of the discriminator primary trimmer to shift. Hence, i.f. alignment should be completed before starting discriminator alignment.

An FM discriminator requires a preceding limiter because it is desired to have the receiver reject any spurious AM which may accompany the FM signal. A discriminator will reject AM when the signal is at center frequency, but does not reject AM when the FM signal is deviated from it. By use of a limiter, the incoming signal is clipped to a constant level.

Ratio detector adjustments

For this reason, the ratio detector (illustrated in Fig. 911) was developed so that a limiter would not be required and the last i.f. stage can be operated at full gain. It is seen that the ratio detector circuit bears some superficial resemblance to a discriminator, but that it is basically a different arrangement. The diodes are connected back to back and a large electrolytic capacitor C maintains a bias on the diodes. This bias is proportional to the average signal level on a long-time basis; that is, the electrolytic capacitor can only discharge slowly through bleeder resistors R1 and R2. The circuit action is such that the output remains at a constant level, with the electrolytic capacitor acting like a "cushion" to impulse noise and other fluctuations in signal level of an AM nature. However, some receivers using ratio detectors also use limiters.

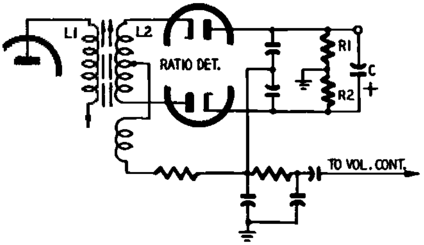


Fig. 911. Typical ratio detector. Unlike the discriminator, this circuit does not usually require the use of preceding limiter stages.

The static characteristic of a ratio detector is considerably different from its dynamic characteristic, as will be better appreciated after the discussion proceeds to visual alignment of circuits (see

Chapter 10). To align the ratio detector with a signal generator and v.t.v.m., apply the v.t.v.m. across electrolytic capacitor C and adjust the primary L1 for maximum output voltage. The v.t.v.m. is then connected across the audio-output point and secondary L2 is adjusted for a null indication. As described for the alignment of a discriminator, three nulls will be found; the central null is the correct alignment point. A zero-center v.t.v.m. is accordingly useful for alignment of the ratio detector circuit. Recheck both the primary and secondary adjustments, as there is often some degree of interaction between the circuits.

Alignment of communications receivers

The alignment of communications receivers, in general, follows the techniques utilized in aligning AM and FM broadcast receivers. However, the technician sometimes overlooks a very important requirement—the accuracy of the signal generator output. Communications receivers often operate in a very narrow band—sometimes with crystal-filter facilities, and the accuracy and stability which can be realized from much of the run-of-the-mill service equipment often leaves much to be desired. If you contemplate undertaking this type of work you should consider the acquisition of a laboratory generator in the lower-price bracket.

The technician can easily be misled since some types of generators are designed only to meet usual service requirements. Some misunderstanding has arisen in the past over this point and it is well for the technician to be selective. It is best to get full information concerning numerical specifications on frequency coverage (fundamental, beat fundamental or harmonic), numerical specifications on accuracy at any dial setting, numerical specifications of stability and drift characteristics, calibration facilities, microvolt specifications on output and attenuation range, microvolt leakage, numerical specification on harmonic distortion, modulation accuracy and distortion.

Because there are a large number of tuned circuits and wide frequency coverage in many communications receivers, the inexperienced technician in particular should not attempt to align this type of receiver upon the basis of general principles; rather, it is advisable to obtain the service notes for the receiver and to follow these carefully. Novel circuits encountered, such as beat-frequency oscillators and crystal filters, pose small difficulty when the service notes are followed.

Since accurate calibration of the signal generator is essential in this type of service work, attention is called to availability of the standard radio-and audio-frequency transmissions from WWV. These are broadcast *continuously* from Washington, D. C., on the following frequencies:

r.f. (mc)	a.f. (c.p.s.)	Power (kw)
35.0	1	0.1
30.0	1	0.1
25.0	1,440 or 600	0.1
20.0	1,440 or 600	8.5
15.0	1,440 or 600	9.0
10.0	1,440 or 600	9.0
5.0	1,440 or 600	8.0
2.5	1,440 or 600	0.7

Note that the 1-c.p.s. audio modulation is a .005-second pulse, the leading edge of which marks the beginning of each second to an accuracy of 1 part in 1,000,000. The pulse is not sent on the 59th second of each minute.

The 600-and 1,440-cycle audio-frequency signals are transmitted in alternating 5-minute periods, transmitting the 600-cycle note during the first 5-minute period of each hour.

Accuracy of the radio and audio frequencies is maintained within 1 part in 50,000,000. Audio-frequency transmissions are interrupted at exactly 1 minute before each hour and each 59 minutes thereafter. Audio-frequency transmission is started again in exactly 1 minute. During the time that the audio tones are not transmitted, GMT (Greenwich mean time) is transmitted in code and EST (Eastern standard time) by voice.

Announcement of radio-propagation conditions is transmitted in code at 19 and 49 minutes past the hour. Abbreviations utilized are as follows: W, ionospheric disturbance prevalent or anticipated; U, unstable propagation expected; N, no warning.

Generator signal strength

One of the greatest advantages supplied by a generator, whether AM, crystal marker, or sweep, is the production of a signal voltage that is under the complete control of the service technician. In nearly all cases the signal out of the generator is not an exact duplicate of that produced by the radio or TV station, nor is it even necessary that this condition exist. For example, in an AM station the audio modulation may range from a low of 100 cycles (approximately) to 5,000 cycles, or more. Most often, the modulation voltage used in generators is 400 cycles, with the percentage of modulation quite often fixed at 30%. Similarly, in the alignment of a television i.f. stage it is not necessary to inject a complete, composite video signal. By testing the bandpass of a circuit or by injecting a test signal at a fixed frequency, we can determine the way in which a circuit would behave if an actual radio or TV signal were present.

While we do not concern ourselves with actual duplication of the station signal, yet we must concern ourselves with signal amplitude. The ideal situation in working with a generator of the fixed frequency or of the sweep type is the use of an amplitude of generator voltage equal to the amount of voltage that would have been produced by the actual signal itself. Thus, if in a particular TV receiver, the input to the video detector is 2 volts, then the generator attenuator should be so adjusted that this voltage is produced at the detector input when all stages are properly aligned and operating. This is an ideal situation, not always a practical one. It is complicated by a number of variable factors. Thus, the input to the video detector depends upon the location of the receiver (whether strong signal or fringe area); upon the particular channel selected; upon the number of i.f. stages; types of tubes used, etc. However, through experience and observation of repeated measurements, the service technician can secure a generalized idea of signal strengths for circuits of different receivers in his particular location.

The output indicator

The type of output indicator used by service technicians is generally a matter of know-how. It is true that a v.t.v.m. can be used in many applications following the ideas presented in this chapter. A scope, however, has a decided advantage since you can use it as a very high impedance voltmeter, at the same time observing the condition of the waveform, checking it for flatness, presence of spurious voltages, unsuspected pulses, etc. Unfortunately, some technicians still avoid the use of the scope, probably deterred by the large number of controls, plus an inability to interpret waveforms.

chapter

10

visual-alignment methods

The technician is often confused by visual-alignment procedures. This stems chiefly from the lack of a basic understanding of what is accomplished by this technique. An understanding of visual alignment starts with a picture of the frequency response curve of a receiver circuit, as illustrated in Fig. 1001. The reader will be familiar with the procedure of determining such a response on the basis of application of a test voltage from a conventional signal generator to the circuit under test and observing the output voltage obtained at various frequencies as indicated by a v.o.m. or v.t.v.m.

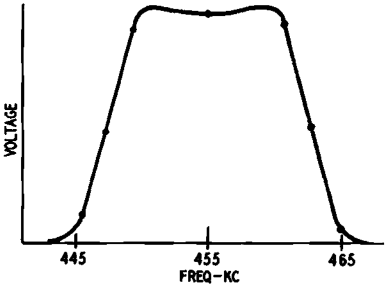


Fig. 1001. You can make a point-by-point plot of a response curve by using an AM generator. This method is tedious and time consuming. It is a far easier and certainly a much better technique to use a sweep generator for this purpose.

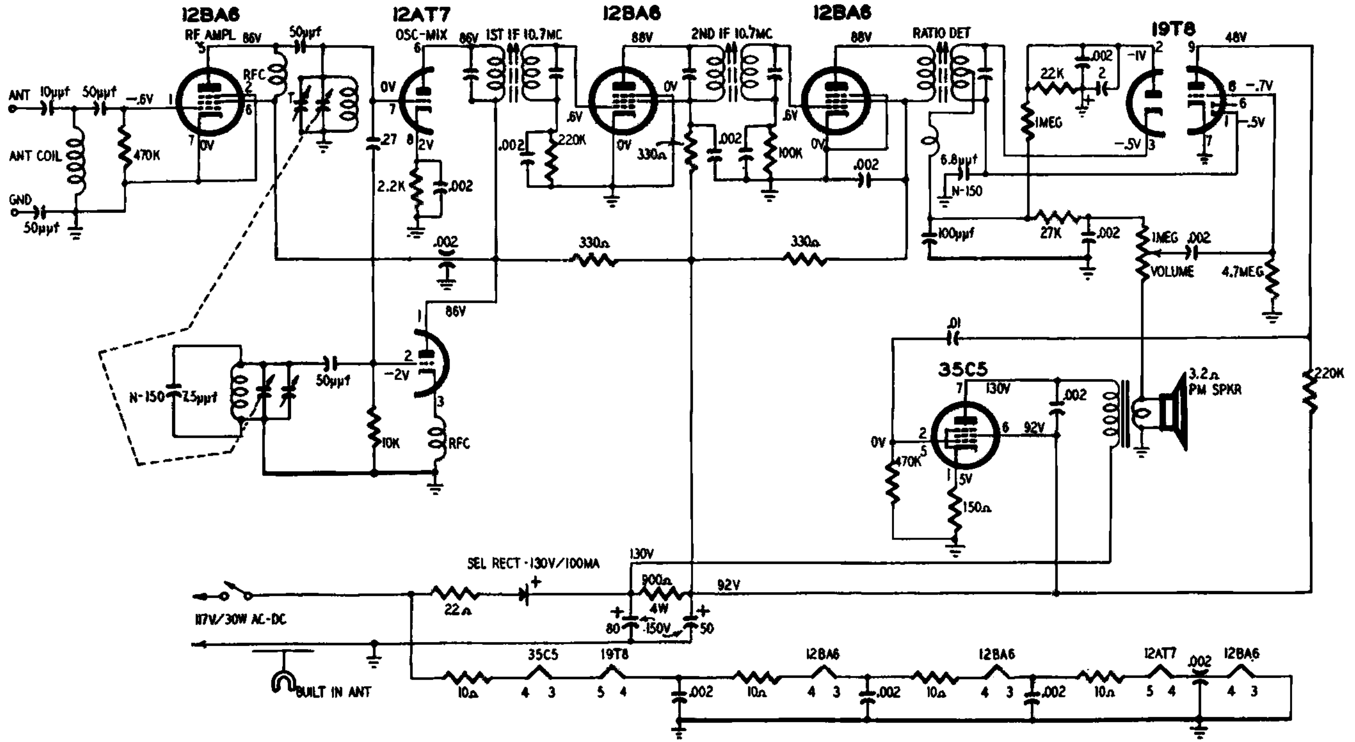


Fig. 1002. Circuit diagram of a complete FM receiver. Since the ratio detector does not give perfect limiting action, the i.f. circuits are used as combined amplifier-limiters. An AM generator can be used for point-to-point testing, but for complete alignment a sweep generator is needed.

Principles of visual alignment

Fig. 1001 shows a frequency-response curve obtained by plotting the output voltage of the receiver versus frequency, point by point, on a sheet of graph paper. The visual alignment techniques discussed in this chapter show how to obtain the curve instantaneously by use of a scope and a sweep-frequency generator. Instead of using a v.t.v.m. as the indicator, a scope is connected at the output of the circuit under test and a display of the frequency response curve is presented on the screen of the cathode-ray tube. Instead of using a conventional signal generator to energize the circuit under test, a sweep-frequency generator is utilized. It will be understood from the earlier discussion that a sweep generator provides an FM signal which is sweeping back and forth through the pass band of the circuit under test at a rate of 60 sweeps a second. Thus, the response curve is traced out so fast on the scope screen that persistence of vision causes the pattern to appear as a continuous curve, instead of a moving spot of light.

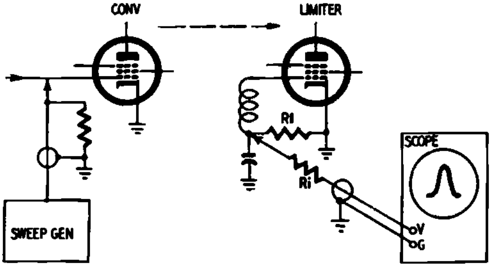


Fig. 1003. Technique for connecting sweep generator and scope for visual alignment of the i.f. amplifier in an FM receiver.

Intermediate-frequency circuits

Fig. 1002 shows the complete circuit arrangement of a typical FM receiver. Most of the selectivity and gain of the receiver are developed in the i.f. section and visual alignment checks usually start here. Hence, we shall start our discussion with the test setup shown in Fig. 1003. This description, incidentally, applies equally to sets using converters, or oscillator-mixer circuits.

The output from the sweep generator is applied to the control grid of the converter tube. In applying the sweep signal, it is good practice to terminate the sweep output cable in its own characteristic impedance. However, unless the output cable is quite long, the technician will probably note little difference in the response curve as a result of termination because the test frequency is relatively low (10.7 mc). Sometimes, the technician finds it convenient to make use of a long output cable, which must be terminated (usually with 75 ohms) to avoid cable resonances which would distort the shape of the response curve. In addition, when the front end of the receiver is being visually aligned, even a short output cable must be properly terminated to avoid distortion since the test frequency is relatively high (88 to 107.9 mc).

Because the impedance of the sweep output cable is quite low, it is not necessary to disconnect the converter coil from the control grid of the converter tube when applying the sweep signal. The low cable impedance shunts down the resonant circuit and effectively "kills" its response so that the tuned circuit does not impair the flatness of the sweep signal nor does it distort the response curve obtained on the scope screen.

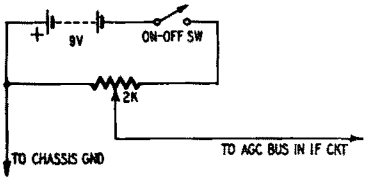


Fig. 1004. *With six cells in series you can get any bias from zero to nine volts. It is not necessary to disconnect the a.g.c. bus when override bias is used.*

Inexperienced technicians sometimes make the mistake of connecting the "hot" lead of the sweep output cable to the grid of the converter tube or the mixer tube without making any provision for a ground connection. It is essential to ground the braid of the sweep cable with a short lead to the chassis near the converter or mixer; otherwise curve distortion will often be encountered.

Fig. 1003 shows that the scope is connected across the limiter load resistor Rl through an isolating resistor Ri. The value of the isolating resistor may be approximately ¼ megohm. The "hot" lead of the scope cable is connected to the vertical input and the braid of the cable is connected to the ground terminal of the scope. The braid of the cable at the receiver end should be grounded to the receiver chassis; otherwise, strong hum interference may appear in the scope pattern.

Setting the bias

It is desirable to stabilize the bias on the grids of the i.f. amplifier tubes in the FM receiver by means of override bias, as shown in Fig. 1004. Override bias is applied by connecting a flashlight cell (or cells) between the a.g.c. bus and chassis. One flashlight

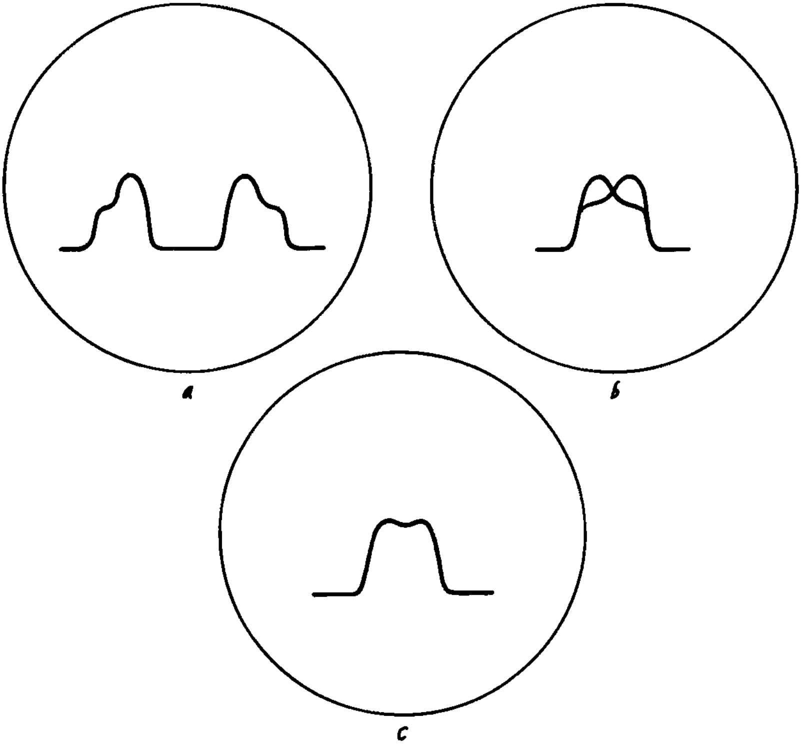


Fig. 1005-a,-b,-c. *Using 60-cycle sawtooth sweep, the illustration (a) shows the i.f. response curve when the i.f. transformers are misaligned. Increasing the sweep to 120 cycles produces the curve shown at the top right (b). Proper adjustment of the i.f. stages using 120-cycle sweep results in the curve shown in the bottom illustration (c).*

cell providing $-1\frac{1}{2}$ volts of bias is usually satisfactory; however, if difficulty is encountered in preventing amplifier overload, an override bias of -3 volts may be utilized. Note carefully that the minus side of the battery connects to the a.g.c. bus and the positive side to the receiver chassis. Technicians sometimes make the error of assuming that the a.g.c. bus must be disconnected from its source network when override bias is used, but this is not so. The reason that the battery bias may be applied without any modification of the a.g.c. circuit is that it has a very low internal resistance, while the a.g.c. circuit has a high internal resistance. Hence, when the override bias battery is merely shunted between the a.g.c. bus and chassis, the battery voltage "takes over" and establishes the bias on the line.

Unplug the detector tube during i.f. alignment to avoid distortion of the response curve. Likewise, it is essential to unplug the local-oscillator tube. Unless this is done, distortion of the i.f. response curve will occur and the shape of the curve will vary as the tuning dial of the receiver is turned.

The scope can be deflected horizontally on either 60-or 120-cycle sine-wave sweep. If sawtooth sweep is used, two curves will be observed on the scope screen, and either curve may be centered by adjustment of the horizontal centering control. Two curves are seen side by side because service sweep generators are swept by 60-cycle sine-wave voltage, and the output from the generator completes two entire sweeps in 1/60 second. *In the case of FM receiver alignment, it is better to use 120-cycle sawtooth sweep.* See Fig. 1005. The use of 120-cycle sawtooth sweep is to determine whether the i.f. response curve is *symmetrical,* as it should be. The basis of this test is as follows: The sweep generator not only completes two entire sweeps in 1/60 second, but develops the two corresponding response curves as mirror images. When the pattern is displayed on 60-cycle sawtooth sweep, the two responses corresponding to the two sweep excursions appear side-by-side. But when the pattern is displayed on 120-cycle sawtooth sweep, the beam returns to the left-hand side of the scope screen before the second curve is started, and the second curve is then scanned on top of the first curve. This type of display is a very good indication of *symmetry* of response, hence is the most useful type of horizontal deflection to use in FM i.f. alignment checks. Fig. 1005-a shows the appearance of an FM i.f. response curve on 60-cycle sawtooth sweep when the i.f. transformers are out of alignment. In Fig. 1005-b we have the FM i.f. response curve on 120-cycle sawtooth sweep when the i.f. transformers are not aligned. Fig. 1005-c is a representation of the i.f. curve on 120-cycle sawtooth sweep with the transformers properly aligned.

It may appear a simple matter to display the pattern on 120-cycle sawtooth deflection but actually there is more here than meets the eye. Synchronizing the horizontal deflection oscillator in the scope *requires a 120-cycle voltage which is locked in with the power-line voltage.* Otherwise, the technician will find it difficult to lock the pattern at the desired point on the base line and even more difficult to maintain a stable lock as the FM i.f. transformers are adjusted. For this reason, you should make use of the 120-cycle ripple voltage from the input filter capacitor in the receiver under test and apply this voltage through a 0.1-μf capacitor to the external sync terminal of the scope. Then, by adjusting the horizontal sweep speed to a suitable value and the sync amplitude control to a suitable level, the patterns shown in Figs. 1005-b, -c can be locked on the screen. This is a point which trips up many at the alignment bench.

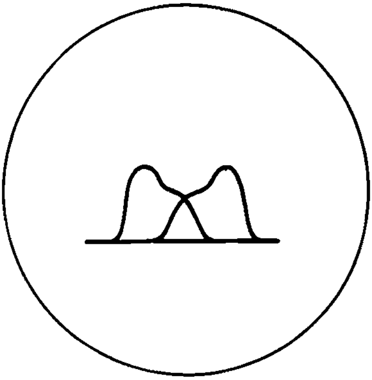


Fig. 1006. Displacement of curves can be overcome by slight adjustment of sweep generator dial.

After adjusting the horizontal sweep speed of the scope and setting the sync amplitude control to a level that locks the pattern satisfactorily, you may observe that one of the FM i.f. curves is shifted horizontally with respect to the other, as illustrated in Fig. 1006. In such case, it is necessary to turn the tuning dial of the sweep generator slightly, as required, to make the curves "lay over" properly. These procedures may appear unduly complicated at first acquaintance, but they soon become automatic.

Another common error made in FM receiver alignment is overloading the circuits under test. The gain of the i.f. amplifier is high and not much signal is required to energize the amplifier normally. An excessive signal voltage causes the response curve to be clipped, as illustrated in Fig. 1007-a. In practice, the output from the generator should be reduced until evidence of clipping disappears (Fig. 1007-b); the gain of the scope may be advanced, as the output from the generator is reduced, to maintain full-screen deflection. Clipping produces severe distortion of the curve.

Sweep width

The sweep width used is a matter of some importance and calls for some judgment. Although it is true that use of excessive sweep width does not produce distortion of the response curve, nevertheless excessive sweep width causes the curve to appear very thin and narrow (Fig. 1008-a), which makes it difficult to observe properly. A total sweep width of 0.6 mc (±0.3 mc) usually serves satisfactorily for FM i.f. alignment work. Remember that the sweep-width calibration of many service sweep generators is inadequate (Fig. 1008-b) or inaccurate and that the calibrations are intended only to serve as a rough guide. Hence, it is essential to set the sweep-width control on the basis of the scope pattern and to turn it to the point where the curve is completely swept, with a little base line showing on each side, as illustrated in Fig. 1008-c. You can easily get into trouble by taking sweep generator calibration scales too seriously.

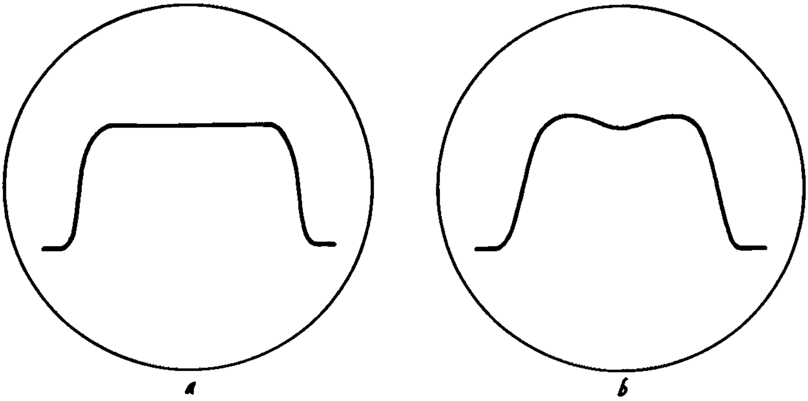


Fig. 1007-a,-b. *Top of FM i.f. response curve severely clipped (a) by excessive generator signal and clipping eliminated (b) when generator voltage is reduced.*

Dial inaccuracy

It is also worth while to emphasize the fact that the tuning dial of the sweep generator is often quite inaccurate at FM frequencies, such as 10.7 mc. The reason for this is that the sweep generator usually operates on a beat-frequency principle and develops the difference frequency between two high-frequency oscillators, such as the difference frequency between a 75- and an 85.7-mc oscillator. In consequence, a +1% drift in one oscillator and a -1% drift in the other can cause an inaccuracy of 15% in the dial calibration at 10.7 mc. Hence, the experienced technician merely turns the tuning dial until the curve is centered on the scope screen and does not concern himself with the frequency indicated on the dial.

Returning for a moment to Fig. 1003, note that the output of the sweep generator need not be applied to the grid of the converter (or mixer) tube, and, if you wish to do so, the output cable from the sweep generator may be applied at the control grid of the second i.f. stage. (It is advisable to connect a series blocking capacitor between the grid and the output cable of the generator to avoid short-circuiting the d.c. grid bias to ground through the sweep generator. A .01-µf capacitor is suitable.) This procedure, of course, results in a display of the frequency response of the second stage of the FM i.f. amplifier. The bandwidth is considerably greater than that of the complete amplifier response and the gain is also much less. Hence, more signal output must

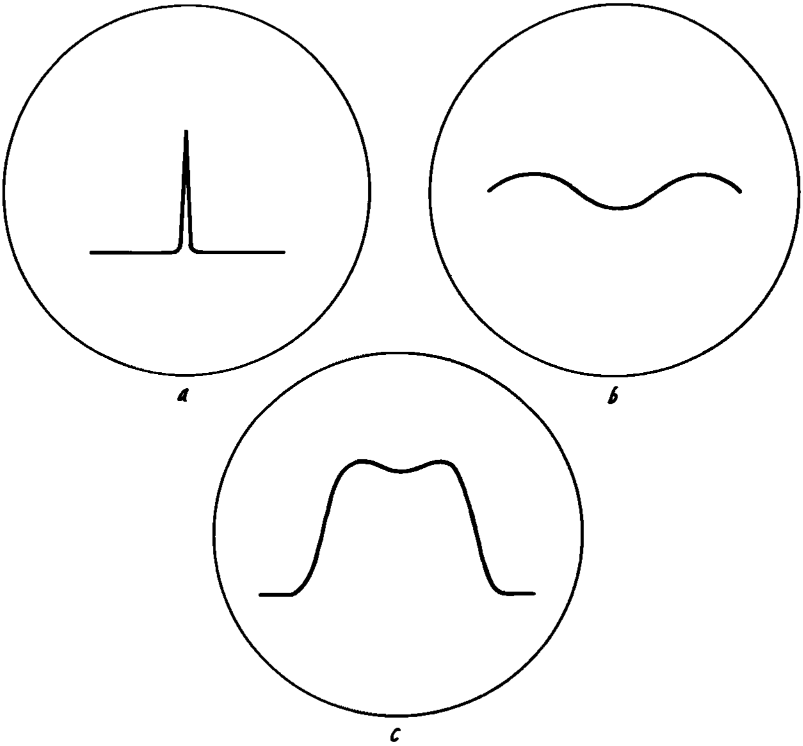


Fig. 1008-a,-b,-c. *FM i.f. response curve appears as narrow pip (a) because sweep width of generator is excessive. Only top of FM curve is seen (b) because sweep width is inadequate. Satisfactory display is seen (c) when generator sweep width is suited to bandwidth of circuits being tested.*

be used from the generator to obtain the same height of pattern on the scope screen. The waveform of the second stage of an FM i.f. amplifier is shown in Fig. 1009. This illustration shows a typical response for the second stage of an FM i.f. amplifier in a good-quality FM receiver in proper alignment. This is a single-humped type of stage response. The bandwidth is large and the sides of the curve slope slowly.

Next, the output cable and blocking capacitor can be connected to the control grid of the first i.f. stage and the response of the two stages viewed while the trimmer capacitors or slugs are adjusted as required for symmetry and agreement with the response specified in the receiver service manual. A typical response of the first and second i.f. stages is shown in Fig. 1010. A single-humped curve is still obtained in this instance. The bandwidth is less and the curve is somewhat steeper.

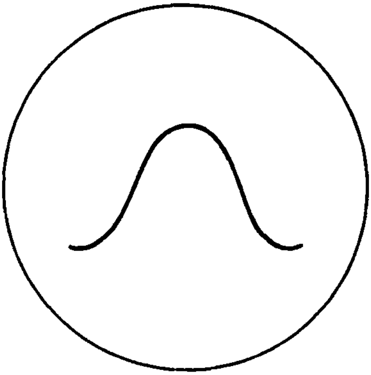


Fig. 1009. Typical response for the second stage of an FM i.f. amplifier in proper alignment. The bandwidth is large; sides of curve slope slowly.

Finally, when the complete FM i.f. amplifier is swept from the converter grid, the response displays the frequency characteristic of the converter and first and second i.f. stages. This curve has the steepest sides and flattest top (often with a small sag in the center of the curve—a double-humped response). Fig. 1011 shows a typical overall FM i.f. response curve for a good-quality receiver in proper alignment. This curve may be compared with the other typical response depicted in Fig. 1001. Fig. 1011 represents the response of the converter or mixer stage plus the first and second i.f. stages in a typical FM receiver. Note how the bandwidth has decreased. The sides of the curve have become quite steep and the top has tended to flatten.

Bandwidth

None of the responses so far illustrated shows any indication of circuit bandwidth. The most practical way to measure bandwidth (and center frequency) is by means of a beat marker. Such a marker is obtained by mixing the output from a signal generator with the output from the sweep generator, as shown in Fig. 1012. In principle, a marker is developed on the FM i.f. response curve by applying the outputs from both a sweep generator and a signal (marker) generator to the grid of the converter or mixer tube. In practice, other methods of applying the marker signal may be preferred. The result of mixing the two generator signals is a beat pattern in the output of the last i.f. stage (Fig. 1013). However because of the choking action of the scope input system the marker "bug" is seen on the FM i.f. response curve as in Fig. 1014. The i.f. circuits are aligned to place the bug on top of the curve at a frequency of 10.7 mc, and the primaries and secondaries

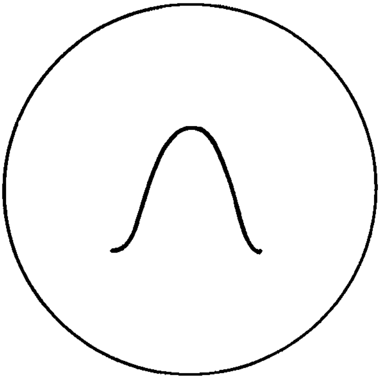


Fig. 1010. *Response of the first and second i.f. stages. Bandwidth is less than curve shown in Fig. 1009; curve is somewhat steeper.*

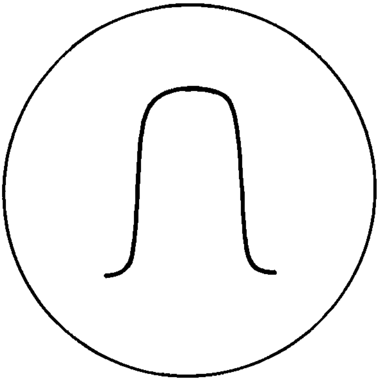


Fig. 1011. *Response of converter, first and second i.f. stages. Bandwidth has decreased, sides of the curve are steeper and top is flatter. Compare with Figs. 1009, 1010.*

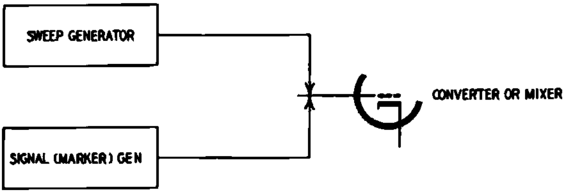


Fig. 1012. *A marker can be developed on the i.f. response curve by applying the outputs from a sweep and a signal (marker) generator to the input of the converter or mixer.*

are stagger-tuned, if required, to obtain the bandwidth specified in the receiver service manual. As shown in Fig. 1015, the bandwidth of the response curve is defined as the number of kc between the half-power (70.7% voltage) points. This is worth noting, as there is frequent misunderstanding among technicians concerning the definition of bandwidth. It is sometimes supposed that the bandwidth of the response curve is given by the points at which the curve contacts the base line, but this is not true because the response below the half-power points does not contribute much to the quality of reception.

To determine the bandwidth of a response curve, the marker is first run to the half-power point on one side of the curve by turning the dial of the marker generator as required; this reading is noted. Then, the marker is run to the half-power point on the other side, and the reading again noted. The difference between these two readings is the bandwidth of the curve and should agree with the value specified in the receiver service manual.

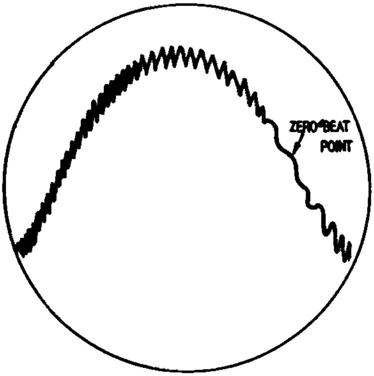


Fig. 1013. Result of mixing sweep and marker signals is to produce this beat waveform.

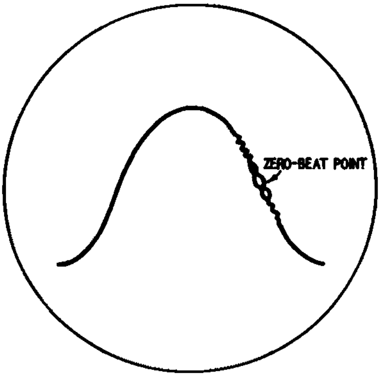


Fig. 1014. The scope input system modifies the beat seen in Fig. 1013 to the form shown above.

Applying the marker

Simple paralleling of the sweep and marker output cables may not be the most desirable way to introduce the marker voltage into the FM i.f. amplifier. If it is observed that the shape or the bandwidth of the curve changes when the cable from the marker generator is connected and disconnected from the sweep cable, it will be necessary to utilize some other method of applying the marker signal.

Sometimes a satisfactory marker indication can be obtained, with the desired degree of decoupling, by connecting the output cable from the marker generator to the antenna input terminals of the FM receiver, since there is often sufficient "feedthrough" to introduce the marker signal into the i.f. amplifier and obtain a satisfactory bug on the curve.

If the amount of feedthrough is insufficient, it is often possible to obtain a satisfactory decoupled marker by clipping the output cable from the marker generator to the insulation on the control grid lead (signal grid) of the converter tube. This method provides a loose capacitive coupling to the grid lead and will usually provide more marker voltage than the feedthrough method. Other techniques for obtaining a loosely coupled marker are occasionally utilized. The output from the marker generator may be applied to the heater line or to the a.g.c. line of the i.f. amplifier through a coupling capacitor of approximately .05 µf. This method is useful because there is often a small amount of coupling from the signal circuits into the heater and a.g.c. lines. This permits a certain amount of marker signal to enter the i.f. circuits; at the same time the coupling is sufficiently small so that connection of the generator cable in this manner does not disturb the normal operation of the FM i.f. amplifier.

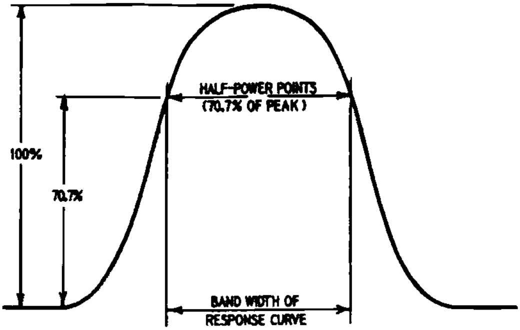


Fig. 1015. *The bandwidth of a response curve is measured between a pair of points located at 70.7% of the peak amplitude.*

Stability test

After the tuned circuits in the receiver have been properly aligned, make a check for stability of operation at various signal levels. In the stability test, the a.g.c. override bias is reduced to a small value, such as 1 volt, and the output from the generators is weakened to avoid overloading the i.f. amplifier. If the amplifier is satisfactorily stable, the response curve will not be changed in bandwidth. If the bandwidth is considerably less for a weak signal, check the various bypass capacitors for opens or leakage. The values of the cathode and screen resistors are also important in the stabilization of many FM receivers. Hence, in case of instability these should be checked with an ohmmeter.

Discriminator frequency response

The discriminator is next aligned exactly to the center frequency of the i.f. amplifier as shown in Fig. 1016. The sweep signal is injected at the control grid of the limiter tube and the scope is applied at the audio output lead from the discriminator. It is best to use the sweep generator at the same control settings

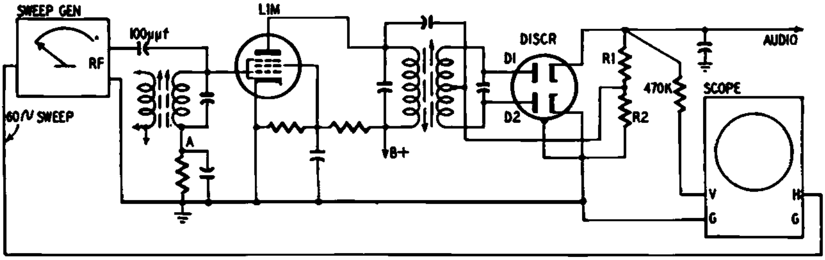


Fig. 1016. Typical sweep setup for checking the frequency response of a discriminator circuit. The 100 μμf capacitor prevents shorting of the limiter bias to ground.

as were used in aligning the i.f. amplifier. Then, the discriminator S curve (Fig. 1017-a) will occupy the same position on the base line of the scope when the discriminator is in proper alignment. Note that 120-cycle sweep can be used in aligning the discriminator circuits, just as it was used in aligning the i.f. circuits. With 120-cycle sweep, a crossover response is obtained (Fig. 1017-b). This type of display is often recommended by receiver manufacturers because it provides an accurate check of symmetry of the response.

The response of an FM detector to circuit adjustments, is sometimes bewildering because the factors of gain, symmetry and center frequency must be considered simultaneously. In addition, the difficulty of marking the FM detector response satisfactorily also makes the job seem quite difficult. It is helpful to keep the following points in mind: The height of the S curve (gain of the circuit) is determined primarily by the adjustment of the primary trimmer in the discriminator transformer. The symmetry is further determined to some extent by the primary adjustment, but much more so by tuning of the secondary. The center frequency of the S curve is determined by the settings of both the primary and secondary trimmers.

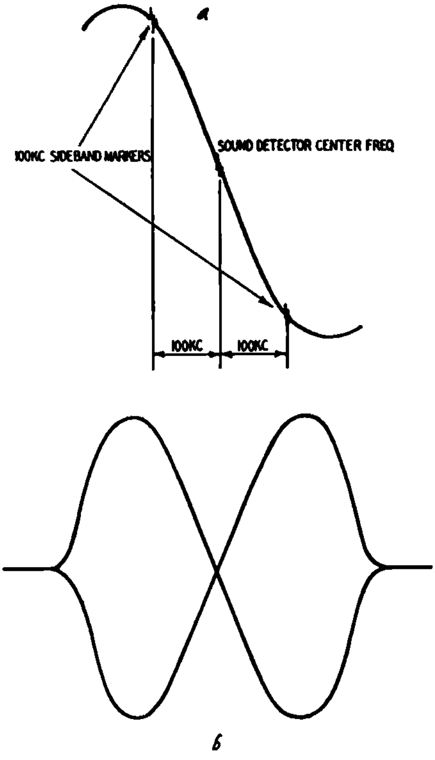


Fig. 1017-a,-b. *The discriminator S curve (a) as displayed on 60-cycle sweep, and as shown on 120-cycle sweep (b).*

Difficulty is often encountered in marking the curve because the discriminator tends to reject the marker signal. Hence, it is usually preferable to leave the sweep generator set at a point which centers the i.f. response curve on the scope screen and then to use the same sweep generator setting to run the discriminator curve. If the discriminator curve appears centered on the scope screen, the center frequency is correct.

It is helpful to remember that a marker signal may be applied in parallel with the sweep signal (if the connection does not distort the S curve). The marker will become visible when the marker generator is tuned off center frequency to run the bug to top or bottom of the S curve. By taking the difference between these two frequency indications of the marker generator, the center frequency of the S curve may be accurately determined. The reason why the marker voltage is not rejected at the top and bottom of the S curve is that the discriminator has little rejection for the marker bug at off-center frequencies but a high degree of rejection at center frequency. In these respects the response of an FM receiver detector is quite different from that of an AM unit.

Limiter sweep voltage

It is essential to apply sufficient sweep voltage to the control grid of the limiter to operate the FM detector approximately at normal level, as the shape of the S curve often changes at abnormally low-signal levels. This is a point to keep in mind, as some service sweep generators lack sufficient output to make this test satisfactorily. In such case, the output from the sweep generator may be applied at the control grid of the second i.f. tube, (or the first i.f. tube) to obtain a signal boost so that the detector may operate at normal level.

Even if ample output is available from the sweep generator, it is good practice to check the S curve finally with the sweep signal applied to the control grid of the converter to determine whether the curve has the proper shape and center frequency when driven through the FM i.f. amplifier. If the curve appears distorted, it indicates that the i.f. alignment, the discriminator alignment or both have not been performed properly. However, when both receiver sections are aligned at the correct center frequency (10.7 mc) and the bandwidths of the circuits are correct, the S curve will appear in satisfactory form no matter where the i.f. signal is injected into the amplifier circuit.

The ratio detector

Both the discriminator (which requires limiters) and the ratio detector (which does not) are to be found in FM receivers. Most TV receivers use a ratio detector in the sound channel. This choice is dictated by economy rather than actual preference of one circuit to the other.

The alignment of a ratio detector is quite similar to that of the discriminator. Both of these detector types can be adjusted by using a v.t.v.m. (as described in the preceding chapter) or with the help of a scope. The ratio detector does require somewhat more precise adjustment since you do not have any limiters to depend upon for clipping action. For this reason, the secondary of the ratio detector transformer must be balanced carefully. Briefly, the primary of the ratio-detector transformer is tuned for maximum output, while the secondary is adjusted for zero. The sweep generator, of course, is tuned to the i.f. of the receiver. For FM receivers this is 10.7 mc and in the case of intercarrier receivers is 4.5 mc. The sweep width for FM sets should not be less than 200 kc while a minimum sweep of 100 kc is satisfactory for TV. The sweep generator and scope should be connected as shown in Fig. 1018. A small capacitor (100 μμf is satisfactory) can be used in series with the generator cable to prevent d.c. drainoff of the bias.

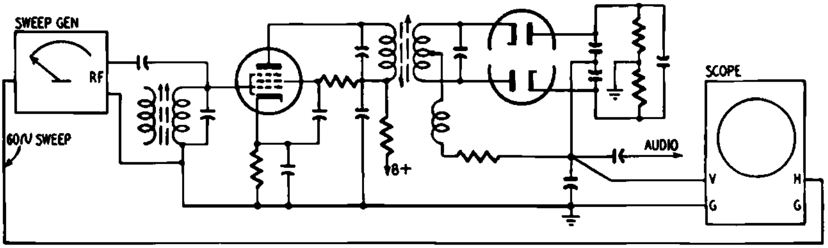


Fig. 1018. Technique for alignment of ratio detector. Note that the sweep generator is connected to the driver circuit, while the scope is across the audio output.

To align the detector, set the secondary of the ratio-detector transformer on the high-frequency side of the i.f. Do this by opening the trimmer capacitor as far as it will go, or by rotating the slug in a counterclockwise direction until it will turn no further. This will result in a complete detuning of the secondary.

The primary should be aligned so that the linear portion of the S-curve is maximum—that is, as long as possible. You can now tune the secondary for balance on either side of the center point. It is very important that you get zero output at the center frequency. Turn on the marker generator and inject the signal into the control grid of a preceding stage. The exact center point of the scope screen is a good spot to put the marker. While it is desirable to have the S curve extend equal lengths away from the zero frequency point, it is even more important to have zero output at the center of the i.f. sweep frequency.

Aligning the r.f. circuits

At this point in the procedure, only the r.f. circuits of the FM receiver remain to be aligned. The local oscillator should now be restored to operation, as accurate r.f. and mixer circuit alignment cannot be done without the local oscillator working. Alignment of the i.f. circuits and r.f. circuits differs in basic procedure. The mixer grid circuit is loaded to some extent by the flow of grid current in the mixer tube. This grid current results from local oscillator drive; hence the necessity for having the local

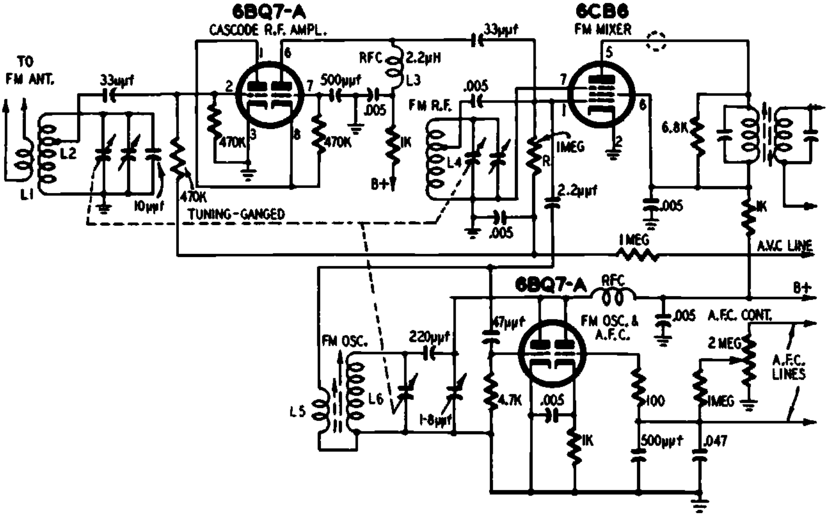


Fig. 1019. *Front end of a representative FM receiver. The use of a separate local oscillator improves frequency stability.*

oscillator in operation during alignment of the 88–107.9 mc circuits.

R.f., mixer, and local oscillator alignment

The final step in the alignment of the FM receiver concerns the r.f. mixer and local oscillator circuits. Fig. 1019 shows the circuit arrangement of the front end in a typical FM receiver. Note that there are three separate sections to be adjusted: L1 and L2 comprise the r.f. grid transformer, operating over a frequency range of 88 to 107.9 mc. The number of turns on L1 and the coupling between L1 and L2 are arranged by the receiver manufacturer to provide an input impedance at the antenna input terminals of approximately 75 ohms.

L3 and L4 constitute the r.f. plate load and mixer grid inductors; and are the impedance coupling network operating between r.f. amplifier and mixer. This circuit also operates over the FM frequency range. Resistor R is shunted across L4 to broaden its frequency response, inasmuch as an FM receiver must develop wide-band response to avoid sideband trimming and impairment of fidelity.

It must be noted in passing that various of the less-expensive FM receivers are not designed to develop the necessary wide-band response, with the result that even when carefully aligned such sets have little better fidelity than AM broadcast receivers. If the technician utilizes damping resistors and adjusts coupling to obtain the necessary wide-band response for high-fidelity reception, the usual result is sufficient loss of gain so that the receiver is useful only in the immediate vicinity of a transmitting station. Additional tubes must be supplied in such case to restore the original sensitivity of the receiver, since it is an inescapable law of nature that the product of bandwidth times gain is a constant.

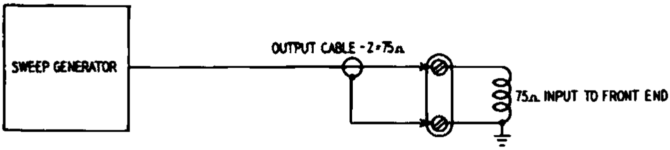


Fig. 1020. *Correct technique for connecting sweep generator to receiver input.*

L5 and L6 are the oscillator transformer coils, operating over a frequency range of 98.7 to 118.6 mc. The plates of the oscillator tuning capacitor are shaped by the manufacturer (in most cases) to provide proper tracking of the local oscillator with the r.f. and mixer circuits.

The governing consideration in the tuning of the front end is the local-oscillator frequency, since you must necessarily tune the capacitor gang to the point at which an i.f. of 10.7 mc is obtained. If tracking should be poor, selectivity and sensitivity will also be poor.

Since the input impedance across the antenna terminals is 75 ohms, the front end of the FM receiver provides a proper termination for the sweep output cable; i.e., the sweep generator signal should be applied to the receiver as shown in Fig. 1020 and *not* as in Fig. 1021. When the input circuit of an FM receiver is rated at 75 ohms, the input terminals should "look like" a 75-ohm resistor over the frequency range of the FM band. Note carefully that an ohmmeter reading across the input terminals will be much *less* than 75 ohms (actually, less than 1 ohm) because impedance ratings are based on a.c. impedance (resistance, capacitance and inductance) and not on d.c. resistance (resistance only). You should clearly recognize the importance of matching the output cable impedance to the circuit under test when working in the FM frequency range; a substantial mismatch can seriously impair the flatness of output from the sweep generator, and cause the technician actually to misalign the front-end circuits in unknowingly compensating for the signal irregularities caused by standing waves in the output system of the sweep generator. Although the technique illustrated in Fig. 1021 is *not* the correct way to apply the sweep signal to the front end of a receiver having a 75-ohm input, it is nevertheless a very common error made by some technicians. When a 75-ohm resistor is connected across the end of the sweep-output cable, the cable is actually terminated by 37.5 ohms since this resistor is in parallel with the 75-ohm input impedance of the front end.

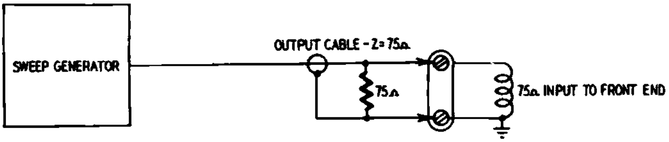


Fig. 1021. *This is not the correct way to connect the sweep generator to the receiver.*

Another common error is illustrated in Fig. 1022, which shows an incorrect method of applying the sweep signal to an unbalanced pair of input terminals; it is clear that this connection results in grounding of the sweep-input signal. Moreover, even if the output from the sweep generator can be raised to a level high enough to "spray" sufficient energy into the system to obtain a response, the extremely serious mismatch present causes an enormous variation in output signal from one frequency to another (severe loss of flatness). It is essential to connect the braid of the output cable to the *grounded* input terminal and the central conductor of the output cable to the "high" input terminal. Otherwise the sweep signal becomes grounded.

Matching pads

Some FM front ends are arranged to accommodate 75-ohm balanced-line input and, in such case, the input coil is grounded at the center, instead of the end, as shown in Fig. 1023. Since a dipole antenna has a 75-ohm impedance at its fundamental resonant frequency, it is a convenient technique to use a 75-ohm twisted pair lead-in, or 75-ohm twin lead to the input terminals of the FM receiver. The lead-in then matches the antenna, and the double-ended input thus provided has desirable noise-cancellation ability. Any voltages picked up by the lead-in produce

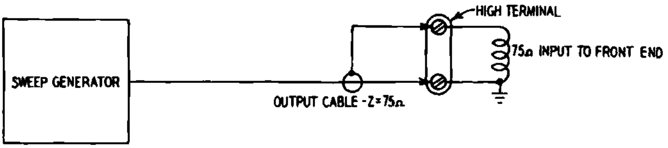


Fig. 1022. *This method of connecting the sweep generator to the receiver input is also incorrect.*

opposing currents in the balanced input coil and cancel. In this manner, the "antenna effect" of the lead-in is minimized or eliminated. However, you should not apply a single-ended sweep-output cable to the antenna input terminals of the receiver in this type of input system.

Fig. 1024 shows the *incorrect* way to apply a sweep signal to the balanced 75-ohm input circuit. This mode of connection succeeds only in shorting one-half of the antenna coil, since a ground is then present both at one end and at the center of the coil. The sweep signal should *not* be applied as depicted in Fig. 1024, since the characteristics of the front end may be disturbed

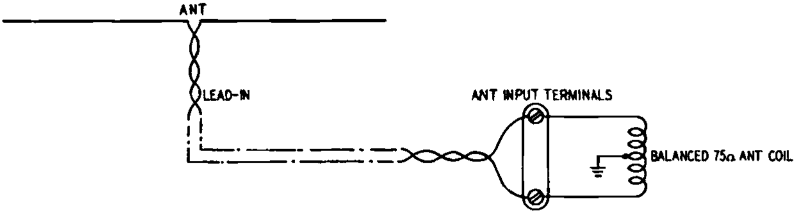


Fig. 1023. *Balanced input is obtained by grounding the electrical center of the input coil.*

by the shorted half of the input coil caused by the crossed grounds. Instead, the sweep signal should be applied through a pad, as shown in Fig. 1025. The pad provides for practical conversion of single-ended output to double-ended while maintaining proper impedance relations. The conversion is accomplished at the expense of signal attenuation; but if a reasonably sensitive scope is used in the procedure, this will not be a source of difficulty.

Other FM receiver front ends provide a 300-ohm instead of a 75-ohm input impedance. The 300-ohm front end is invariably of the balanced type and requires a suitable conversion and impedance-matching pad between the output cable of the sweep generator and the receiver's antenna input terminals. A typical arrangement is illustrated in Fig. 1026. It is quite simple if you remember that the sweep-generator output cable should be terminated in its own characteristic impedance and that the conversion pad (shown in Fig. 1026) helps provide a reasonably normal type of signal to the receiver. Aside from impedance matching, the pad, in this instance, supplies partial conversion from single-ended to double-ended output. This is a device which is often imperfectly understood. As shown in Fig. 1027, the 75-ohm sweep output cable is, first of all, properly terminated by the 75-ohm resistor. Hence, the terminal arrangement meets the initial requirement that a condition is provided which avoids the development of standing waves on the sweep output cable. Secondly, the two 125-ohm resistors are in series with the 300-ohm impedance of the front end of the FM receiver and a divider network is formed. It is the divider network which produces the insertion loss of the pad since the voltage which appears across the 75-ohm resistor must drop across the two 125-ohm resistors and the 300-ohm resistor in proportion to their values. Thus, only a fraction of the signal voltage is actually applied across the antenna input terminals.

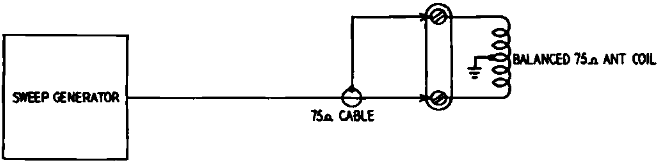


Fig. 1024. This technique for connecting unbalanced sweep generator output to balanced receiver input is not correct.

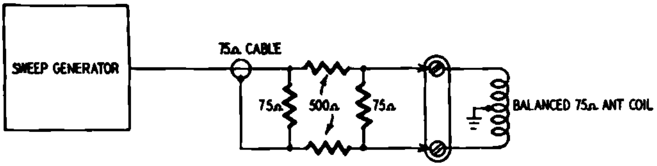


Fig. 1025. Termination pad helps convert single-ended generator output to double ended.

Actually, the sweep output cable is now terminated with slightly less than 75 ohms, because of the shunting effect of the pad and receiver, but this is relatively slight and is equal to (75 × 550)/(75 + 550) or 66 ohms instead of 75. This might seem to be a substantial reduction to some but, as a matter of fact, the match is sufficiently close for all practical purposes. A purist can make use of an 80-ohm terminating resistor, if desired, but little improvement in sweep flatness is noted.

The antenna input terminals of the FM receiver are also loaded with a slightly off-value source resistance, as may be seen from Fig. 1027 by adding 125 + 125 + 38 = 288 ohms. However, since this value is reasonably close to 300 ohms, no distortion of consequence results. The input impedance of an FM receiver is rarely equal exactly to 300 ohms and, in some cases, departs far from the rated value.

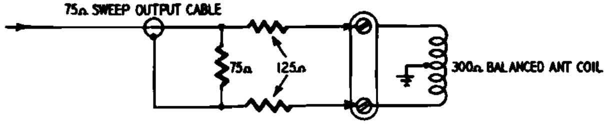


Fig. 1026. *This termination pad can be used when connecting 75-ohm generator cable to 300-ohm balanced input.*

To understand how the pad arrangement shown in Fig. 1027 effects partial conversion from a single-ended source to a double-ended one, it may be observed that roughly half of the applied voltage is dropped across the two 125-ohm resistors and that *both* of the antenna input terminals thus operate above ground. This is equivalent to the desired source conversion. The unbalance which exists is evidently greater than 2 to 1, but this is usually considered tolerable for the application. If a person wishes to split hairs in arranging a pad, the circuit shown in Fig. 1028 meets the desires of the most finicky worker. The resistance values are chosen to provide close match as well as substantially complete conversion from single-ended to double-ended source. This is accomplished by utilizing unequal values of resistors in the two arms of the pad, resulting in a better conversion from single-ended input to the double-ended output. The insertion loss is approximately the same, the 80-ohm terminating resistor giving a closer match for the cable.

The connection of the scope to the circuits under test requires consideration because of the circuit arrangements typically encountered. Always examine the circuit. For example, in some representative FM front ends, the mixer does not utilize a grid leak and capacitor. Hence, the scope cannot be connected through an isolating resistor to the mixer grid—there is no rectified sweep signal available at this point. For this reason, technicians often leave the scope connected across the limiter load resistor when making front-end frequency response checks. In the hands of an experienced operator, this method is quite satisfactory; but due to the fact that the shape and bandwidth of the overall response thus obtained are a *composite* of the r.f. mixer and i.f. response, it can be confusing.

It is quite practical to obtain the r.f. and mixer responses separately from the i.f. response. One of the readily applied techniques is to utilize a demodulator probe at the plate of the mixer tube, as shown in Fig. 1029. The demodulator probe rectifies and demodulates the i.f. signal output from the mixer. When the primary of the first i.f. transformer is damped with a 200-ohm resistor and the secondary is shorted to "kill" its trap action, the response curve displayed on the scope screen is that of the r.f. and mixer circuits. The importance of damping the primary and shorting the secondary cannot be overemphasized as a highly distorted response curve will otherwise result. Any good demodulator probe can be used in the test. Be careful only to avoid the use of a rectifier probe, such as is intended for use with a v.t.v.m. instead of a scope. If a v.t.v.m. rectifier probe is used, no pattern will be obtained on the scope screen since such probes have no demodulating action.

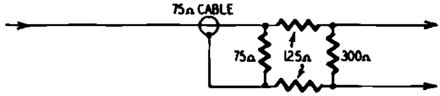


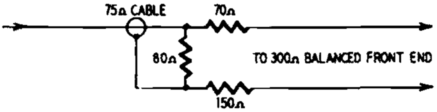
Fig. 1027. Impedance matching requirements for the sweep generator and receiver input are practically met by this arrangement.

In aligning the front end of the FM receiver, the basic problem is that of obtaining reasonably flat-topped curves with proper bandwidth and with proper center frequencies over the entire tuning range. In other words, the operator seeks to make the three tuned circuits "track" properly as well as to develop the specified bandwidth. In normal operation of the receiver the tuning of the front end is dominated by the frequency of the local oscillator. The reason for this is that the i.f. passband will accept a signal only when it has a frequency of 10.7 mc, and the signal cannot have this frequency unless the local oscillator is adjusted to a frequency equal to the incoming r.f. signal frequency + 10.7 mc. That is, the tuning of the r.f. and mixer circuits may be badly off, but the operator will still tune the gang capacitor to the same point. Of course, the selectivity and sensitivity will be greatly impaired, but the indication on the receiver tuning dial is determined only by the frequency of the local oscillator.

The situation is somewhat different, however, when using the test setup in Fig. 1029. Now the local oscillator has no effect on the tuning of the front end and only the frequency response characteristic of the r.f. and mixer circuits is displayed on the scope screen. This is a simplification which is of great assistance in obtaining proper tracking; the local oscillator is tested separately after the r.f. and mixer circuits have been brought into alignment, and tracking is checked in a separate procedure.

To align the r.f. and mixer circuits set the dial of the receiver to the low-frequency end of the band, i.e., to 88 mc. The sweep generator tuning dial is set to the same frequency and sufficient sweep width is utilized to display the response curve with a certain amount of base line at each end of the curve. In general, the sweep width will have to be somewhat greater in checking the front end than in checking the i.f. response since the i.f. circuits usually have less bandwidth than the front end. Manipulation of the controls to obtain the response curve in standard form follows exactly the procedure outlined previously for i.f. checking.

Fig. 1028. Unequal values of resistance in the pad supply better conversion from single-ended to double-ended input.



The r.f. and mixer trimmer capacitors (shown in Fig. 1019) are then adjusted to provide the maximum height of response curve on the scope screen. Although overloading is less likely in running front-end responses, it is still a possibility when using some types of sweep equipment. Make certain that the circuits are not overloaded. When the trimmers are adjusted for maximum height of curve, it may be found that the bandwidth is not sufficient. In such case, a slight stagger-tuning of the two trimmers may serve to obtain proper bandwidth at a small reduction in gain.

The local oscillator should not be disabled during these tests, because the injection voltage from the local oscillator into the mixer circuit affects the value of the mixer input conductance. This in turn determines in part the value of damping across the mixer transformer secondary. The bandwidth of the response curve will not appear correctly on the scope screen unless the local oscillator is operating. In this respect, i.f. and front-end alignment differ.

At this point in the procedure, it is necessary to check for proper center frequency of the response curve (we have selected 88 mc as the initial check frequency). For this purpose, the output from an accurate marker generator is mixed with the sweep voltage by any of the methods previously discussed for i.f. alignment applications. The marker generator is tuned to 88 mc at this point in the procedure, and the marker bug should appear at top center of the response curve. If it does not, the trimmer capacitors are readjusted to center the marker.

After these adjustments have been made, the response is next checked at the high-frequency end of the FM band. The tuning dial of the receiver, and the sweep generator are set to a center frequency of 107.9 mc. A marker is applied at the same frequency and its position on the response curve noted. In most cases, the marker bug will not appear at top center of the response curve. However, by readjustment of the receiver tuning dial, it may be brought to this position. The indication of the receiver tuning dial at this point should not be seriously in error. If it is, inspect the tuning mechanism to determine whether some fault exists.

The r.f. and mixer trimmers can now be rocked slightly on either side of the first setting to determine whether r.f. and mixer tracking are satisfactory. If they are not, it may be possible to bend the plates of the tuning capacitors slightly to improve the r.f. and mixer tracking at the ends of the band. Some receivers provide independent low- and high-end tuning adjustments which facilitate r.f. and mixer tracking. The check should be repeated in the approximate center of the r.f. band at a suitable frequency such as 98 mc. Any necessary compromises between low-end, mid-band and high-end response of the r.f. and mixer circuits can then be concluded.

Finally, it is necessary to align and check the tracking of the local oscillator. This can be easily accomplished by using the same scope input arrangement as for r.f. and mixer alignment (Fig. 1029). The sweep generator is removed from the antenna input terminals of the receiver, and the output cable from an accurate signal generator is connected instead. A matching pad is not required in this portion of the procedure.

To check the alignment of the local oscillator, the tuning dial of the receiver is set to the high-frequency end of the FM band. The output from the signal generator is advanced to maximum and the gain of the scope is also increased to maximum. The tuning dial of the signal generator is turned and the scope observed for the appearance of a zero-beat pattern. As the generator output approaches the local oscillator frequency, a "wiggle" will be seen along the scope trace. The number of cycles in the beat pattern will decrease as the generator frequency is brought closer to that of the local oscillator. At exact zero beat, the pattern will be brought to a straight line, but a slight variation on either side of the zero-beat frequency in tuning the generator will cause the wiggle to appear again. At this zero-beat point, the signal generator dial should indicate the radio frequency plus the intermediate frequency. Of course, the tuning dial of the receiver must be accurately set for this determination. In case of doubt, the sweep signal and marker can be applied initially to make certain of the r.f. and mixer response frequency.

If zero-beat occurs at some incorrect frequency, the trimmer capacitor of the local oscillator circuit (see Fig. 1019) should be adjusted to produce zero beat at the correct frequency. Although the receiver will then be operating properly at the high end, tracking remains to be checked at the low end of the band and also at mid-band. The same procedure is followed in these determinations. For example, the r.f. and mixer circuits are tuned accurately to a low frequency, such as 88 mc. The local oscillator is then checked for zero beat at 98.7 mc (88 mc + 10.7 mc). If zero beat occurs at this frequency the low-end tracking is accurate. But if you do not get zero beat then the tracking is off accordingly. It may be possible to bend the plates of the local oscillator tuning capacitor to improve the low-end tracking. Some receivers provide a low-frequency tracking adjustment. Consult the receiver manufacturer's service notes to determine the recommended procedure.

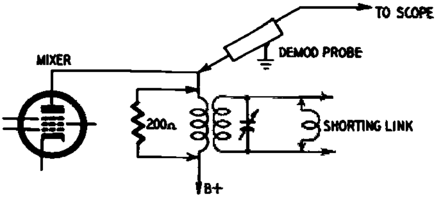


Fig. 1029. Test setup for obtaining the r.f. and mixer frequency response. A 200-ohm resistor is connected temporarily as shown. A shorting wire is placed across the secondary of the first i.f. to detune the coil and avoid a trapping action. The output of the demodulator probe is connected to the scope input.

Finally, a mid-band check of tracking is made and, if necessary, a suitable compromise worked out in the local oscillator adjustment for best tracking over the complete range.

As a final check-out of the receiver, apply the sweep-generator signal to the antenna input terminals and connect the scope to the limiter load just as for i.f. alignment. The shunt on the primary of the first i.f. transformer and the short on the secondary are removed. This test setup displays the overall response of the

FM receiver—a combination of the r.f. and i.f. characteristics. If there is no instability in the signal circuits and if the alignment has been performed correctly, the overall response curve will have the same shape as the i.f. response curve by itself and only slightly reduced bandwidth. Checks should be made at low, medium and high frequencies.

Excessive bandwidth

It is now apparent why the less-experienced technician finds it difficult to make front-end adjustments upon the basis of an overall response curve display. Most of the gain and selectivity of the receiver are developed in the i.f. amplifier with the result that excessive bandwidth in the r.f. and mixer circuits will pass unnoticed unless the operator is very experienced. Excessive bandwidth leads to poor sensitivity, poor selectivity and high noise level.

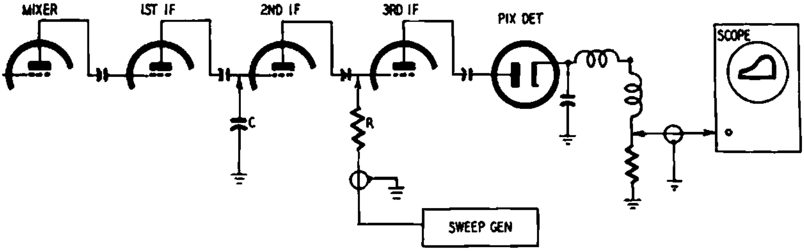


Fig. 1030. Technique for i.f. stage alignment. Capacitor C kills operation of all i.f. and r.f. stages preceding the isolation resistor R connected to cable of the generator. Values of C and R are not critical. C can be .001 μf and R can be 1 megohm.

Visual alignment of TV circuits

The visual alignment of TV i.f., r.f., and video-frequency circuits has been developed to eliminate the tedious and time-consuming procedure of making point-to-point determinations of frequency response in wide-band circuits. Since most of the signal gain and selectivity in a TV receiver is developed in the i.f. circuits, a discussion of visual alignment in TV service starts logically with consideration of this portion of the receiver system.

Although simple in principle, efficiency in i.f. alignment comes only with practice and learning. The majority of TV technicians never become satisfactorily proficient in visual alignment to qualify for a position at an alignment bench because they fail to treat the subject with proper respect; "a little knowledge is a dangerous thing", and the old saying is certainly true in this phase of service work. The reader should understand that if he applies himself energetically, that he can become something of an expert in visual-alignment procedures after approximately two years of study and practice. He should also understand that if he is unwilling or unable to undertake such a long-range program, that his efforts will be largely wasted.

To visually align an i.f. amplifier, the VERTICAL-INPUT terminals of a scope are connected across the picture-detector load resistor, as depicted in Fig. 1030. It is preferable to use a shielded lead, such as a length of coaxial cable for this purpose. The scope is then connected across the load resistor of the picture-detector circuit. The central conductor of the shielded cable connects to the high side of the load resistor and to the VERTICAL-INPUT terminal of the scope. The outer shield braid of the cable is attached to the ground system of the TV chassis and the scope's ground terminal. The requirements for scope response are not particularly demanding, and any standard service scope is satisfactory for the application. Of course, the horizontal sweep of the scope must be synchronized with the sweep-generator frequency deviation so that the response curve is properly displayed on the scope screen; these considerations are the same as for sweeping the horizontal amplifier of the scope in FM work.

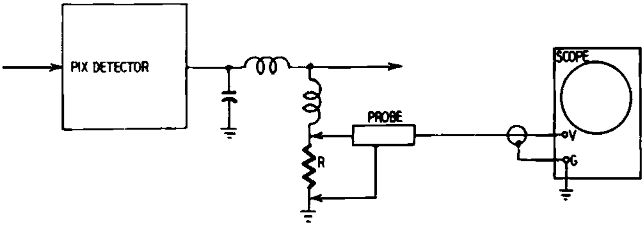


Fig. 1031. A resistive alignment or isolating probe can be used to advantage. The probe, connected across the diode load R, isolates the scope from the receiver, helps avoid circuit disturbance.

Alignment probe

Various test-equipment manufacturers are now merchandising "resistive alignment probes", which may be utilized in the visual-alignment procedure as illustrated in Fig. 1031. Such probes serve the useful function of isolating the scope input circuit from the receiver under test, and are sometimes termed "isolating probes"; they have the useful function also of filtering the marker beat.

The output cable from the sweep generator may be connected between the grid of the mixer tube and the ground system of the TV chassis. At this particular point in the visual alignment procedure, it is preferable not to apply a marker signal until the response curve has been obtained on the scope screen. In this manner, unsuspected marker-signal overloads and curve distortion from this source can be avoided. Any specific instructions in the receiver service manual, such as bias provisions or circuit disabling should be observed at this time. See Fig. 1032.

The bandswitch of the sweep generator is first set to provide a suitable frequency range; TV i.f. amplifiers operate at a higher frequency than FM i.f. amplifiers. Thus, while an FM i.f. amplifier works typically at 10.7 mc, a TV i.f. amplifier operates at 23 mc, 30 mc, or 43 mc. The attenuator of the sweep generator and the scope gain control should both be advanced to maximum at the start, but should be reduced as alignment progresses.

It is always best to have your test instruments turned on for at least ten minutes before starting alignment. This will tend to minimize drift due to changing temperature. To avoid possibility of signal pickup during alignment, either remove the local r.f. oscillator tube or switch the front end to an unused channel. You should, of course, disable the a.g.c. and connect substitute bias. The amount of bias to be used will vary with location, depending upon whether you are in a fringe or strong-signal area.

Technicians are often unnecessarily concerned with the setting of the dial of the sweep generator. Actually, a rough setting is perfectly satisfactory. A good rule to follow is to subtract the low frequency end of the i.f. from the high frequency end, divide the answer by 2 and add the result to the frequency of the low end. This does sound confusing but it is really quite simple. Suppose, for example, that the high frequency end is 25.75 mc and the low frequency of the i.f. is 21.25 mc.

$$25.75 - 21.25 = 4.50 \text{ mc}$$

Now we take this answer and divide it by 2

$$4.50/2 = 2.25 \text{ mc}$$

All that remains to be done is to add this figure to the low frequency end of the i.f.

$$21.25 + 2.25 = 23.50 \text{ mc}$$

You can set your sweep generator to this frequency, or to 24 mc if you prefer. Naturally, for i.f.'s in the 40-mc region you would simply work with higher frequencies. The procedure, however, remains the same.

Set the sweep width dial of the generator to 10 mc and loosely couple the generator to the mixer grid. A small mica capacitor having a value of about 10 μμf and placed in series between the mixer grid and the hot lead of the cable will serve as a decoupling unit. Some technicians simply place the clip of the hot lead close to the control grid. While this technique does work, it does have the disadvantage that the cable lead can be moved accidentally. Another method that is quite effective is to tape the clip of the hot lead to the glass of the mixer tube. The tube shield should be removed first. If you find that this does not give you quite enough coupling, wrap several turns of wire around the tube. One end of the wire connects to the cable clip, the other end remains free. The purpose of these precautions is to prevent overloading of any stage receiving the signal. Ideally, it would be best to feed in a signal having an *average* value equal to that picked up by the receiver in its particular location.

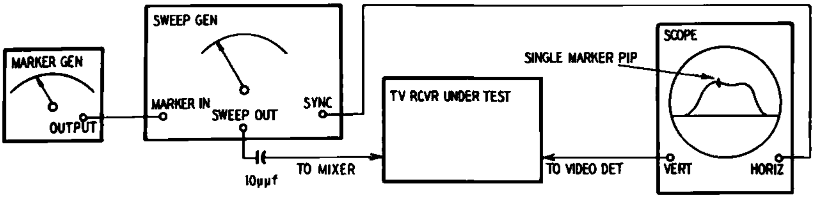


Fig. 1032. Setup for sweep alignment. To get the overall response, connect generator to control grid of mixer or converter. A small mica capacitor (not shown) of about 10 μμf can be connected in series between the sweep cable and the grid. The capacitor acts as a decoupling unit. Do not turn the marker generator on until you get the desired response curve.

The horizontal sweep of the scope should be connected to the sweep terminals of the generator or to a 60-cycle sweep source. Adjust the phasing control of the generator so that the forward and return traces on the scope are superimposed. As the tuning dial of the sweep generator is turned to provide an i.f. signal of the proper frequency, a response curve will be observed on the scope screen. This initial response must be properly phased and centered, exactly as in the FM alignment procedures discussed earlier. Note that considerably more sweep width must be used in TV alignment than in FM alignment; otherwise, the response curve will appear incomplete and clipped at the ends. Adjust the generator output and scope gain as required for on-screen display.

Compare the pattern obtained with the curve specified in the receiver manufacturer's instructions. Fig. 1033 shows a typical example of a "23-mc" i.f. response curve.

Marker insertion

Next, a marker signal should be applied to determine the placement of the picture carrier and the sound carrier upon the response curve, as well as to determine its bandwidth. The marker generator may be built in the same unit as the sweep generator in which automatic mixing of the marker signal with the sweep signal occurs. In case the marker generator is a separate unit, the output from the marker generator must be injected in a suitable manner to mix with the sweep signal. The operating manual for the instruments will supply the necessary information for any particular equipment.

To produce the 22.3-mc marker illustrated in Fig. 1033, the unmodulated output from the marker generator is utilized, and the generator dial is set accurately to this frequency. The attenuator of the marker generator should be advanced only to the point that a convenient size of marker is obtained, as excessively large markers will overload the receiver circuits and distort the response curve. In the type of i.f. system selected for illustration, this 22.3-mc marker should appear just beyond the low-frequency knee of the response. Otherwise, the i.f. circuits must be adjusted to produce the correct marker position on the curve.

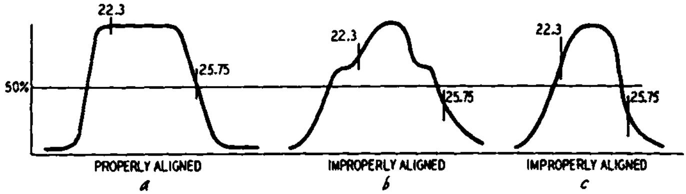


Fig. 1033-a,-b,-c. A properly aligned curve (a) shows that the ideal curve is essentially flat-topped. Undesirable peaking is seen in (b) and inadequate bandwidth is illustrated in (c).

The marker generator dial is then set to 25.75 mc, the frequency of the picture carrier in this particular i.f. system. This marker should fall halfway up the side of the response curve, as indicated in Fig. 1033. If it does not do so, alignment of the tuned circuits is in order. Of course, the frequencies cited apply to only one common i.f. system; correspondingly higher marker frequencies are necessarily utilized in i.f. systems operating at higher frequencies.

The type of i.f. system used in some receivers is termed a "stagger-tuned" arrangement, because each stage is tuned to a different (staggered) frequency. Although widely utilized in present-day TV receivers, other types of i.f. systems are also encountered. Another arrangement is termed the "band-pass i.f. amplifier", and visual alignment of this system is usually specified as a stage-by-stage procedure, starting with the last i.f. stage, and working back to the mixer.

The receiver manufacturer, of course, provides a specified sequence of response curves to be obtained in the alignment procedure, and a set of sample curves appears in Fig. 1034. In the alignment of the bandpass type of i.f. amplifier, the scope is connected across the load resistor of the picture detector, exactly as in the alignment of a stagger-tuned system. For the arrangement illustrated in Fig. 1034, the center frequency of the sweep generator will first be set to 25 mc. The marker generator is set to 27.1 mc, and a marker "bug" appears on the curve at this frequency. The sweep signal is applied to the grid of the last i.f. amplifier.

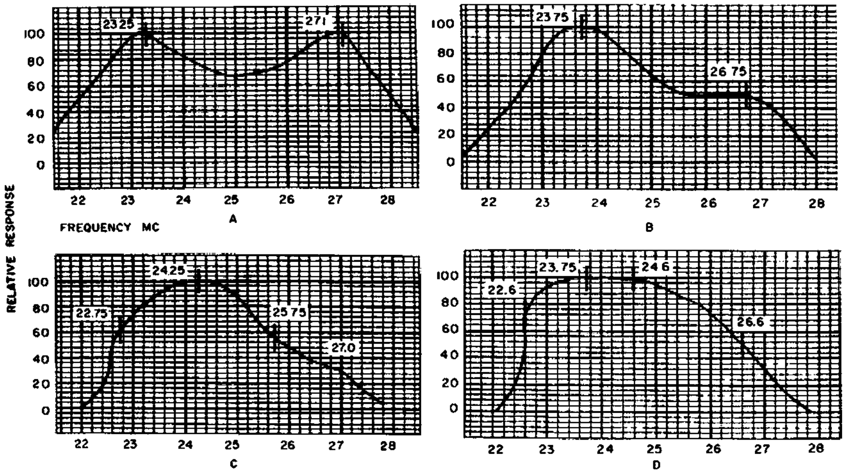


Fig. 1034-*a,-b,-c,-d. Typical i.f. amplifier responses for the bandpass type of i.f. amplifier. Wide bandpass is obtained by overcoupling and staggering the primaries and secondaries of the coupling transformers.*

The primary and secondary of the last i.f. transformer are then adjusted to display a single peak centered on the 27.1-mc marker. Next, the marker frequency is set to 23.25 mc. The coupling adjustment in the transformer (coupling capacitor) is adjusted to develop a peak centered at 23.25 mc, and the response appears as shown at (a) in Fig. 1034.

Next, the sweep signal is applied at the grid of the preceding i.f. stage. Since the gain is increased, the output from the sweep generator is reduced to avoid overloading of the receiver circuits under test. The secondary of the next-to-the-last i.f. transformer is adjusted for a peak at 23.75 mc, and the primary is adjusted for a peak at 26.75 mc. In the particular amplifier taken for illustrative purposes here, there is no coupling capacitor provided for this i.f. stage. Hence, the curve shape must be adjusted solely by means of the primary and secondary trimmers. At this point in the procedure, the response curve appears as illustrated in Fig. 1034-b.

Now, the sweep signal is applied at the grid of the next preceding stage. The trimmers for the primary and secondary of this transformer are adjusted to obtain a response curve as seen in Fig. 1034-c. At this point in the procedure four marker check points are specified for this amplifier: the check points shown in the illustration appear at 22.6, 23.75, 24.6, and 26.6 mc. By counting squares on the scope-screen reticule, the technician determines whether the relative output voltages at these frequencies are correct, or not; if incorrect, the trimmers are adjusted to obtain the relative responses insofar as possible. The overall response curve is shown in Fig. 1034-d.

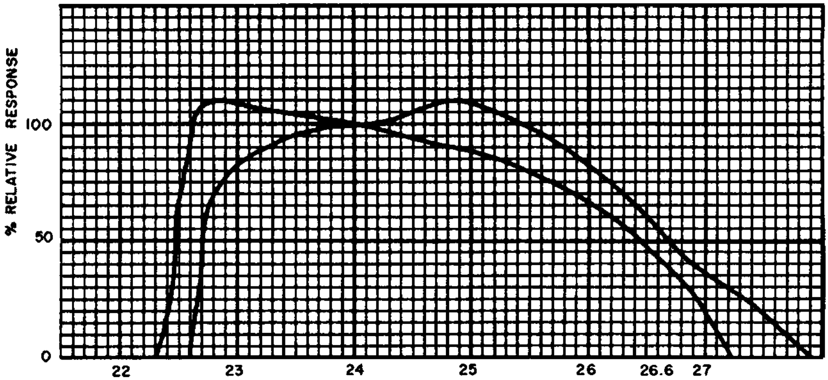


Fig. 1035. Typical tolerable variation in shape of i.f. response curve obtained in step (d) of Fig. 1034. Note that an ideal response curve is usually unobtainable.

In this, as in all i.f. alignment procedures, touch-up adjustments are permissible to improve the shape of the response curve, even if these depart somewhat from the settings specified in the receiver service manual. The reason for the departure is based upon manufacturing tolerances and varying tube amplifications. Fig. 1035 illustrates the acceptable limits of the response-curve shape for this particular receiver, with the 24-mc output voltage as reference.

The discussion has not considered the adjustments for the traps, but these are not usually made upon the basis of a visual-response curve. Instead, most technicians set the traps upon the basis of a signal-generator voltage and a v.t.v.m. indication. Hence, trap adjustments are only noted here.

Sound section

The sound section of a TV set is similar in many respects to the signal system of an FM receiver, except that the center frequency is often considerably higher or lower. For example, in an intercarrier TV receiver, the sound i.f. system has a center frequency of 4.5 mc; in a split-sound TV receiver, the center frequency of the sound channel may be 21.25 mc, or 41 mc, as compared with an i.f. center frequency of 10.7 mc in a standard FM broadcast receiver. The alignment usually starts with the sound detector in a TV receiver, but if the manufacturer recommends some other alignment sequence, his instructions should be followed.

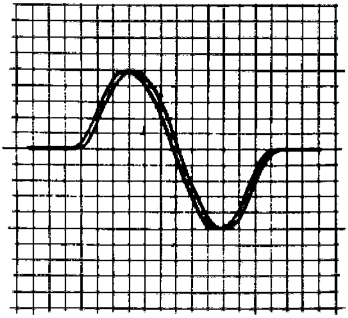


Fig. 1036. Discriminator S curve in TV set is same as in FM receiver, except bandwidth is somewhat less.

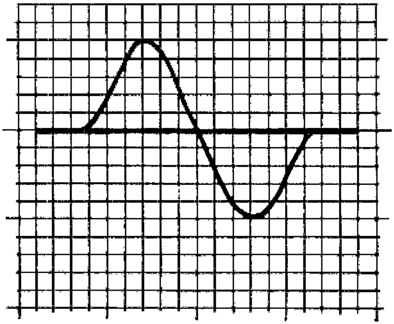


Fig. 1037. When the zero-volt return-eliminator function of the generator is used, the curve changes as shown.

Because the bandwidth of the sound i.f. is much less than that of the picture i.f. amplifier, the sweep-width control must be greatly reduced in setting; between 100 kc to 1 mc of sweep width is usually satisfactory. When the generator and scope controls are suitably set, the resulting display observed is that of the detector response, as illustrated in Fig. 1036. This type of response is termed an "S" curve, due to its general outline. If the return trace is blanked with a zero-volt return-eliminator (provided by many modern sweep generators), the S curve then has the appearance of the curve illustrated in Fig. 1037.

Marking this type of response is often a problem, as has been noted previously in the discussion of FM receiver alignment. One of the expedients often recommended by receiver and test-equipment manufacturers is to apply a *modulated* marker signal, in case the marker "bug" obtained with an unmodulated marker signal is not satisfactory. A pattern similar to that shown in Fig. 1038 results.

The operator should then adjust the secondary to make the 400-cycle pattern minimize or disappear, and then to reappear as the adjustment is made further in the same direction. Be sure to make this adjustment to the null point. The primary is then tuned to obtain a maximum height of symmetrical pattern. Finally, the adjustment of the secondary should be rechecked.

If a check of the bandpass of the sound i.f. system is desired, the operator can connect the output cable from the sweep generator to the grid of the mixer tube, and run the marker "bug" from the 70% (half-power) point on one side of the curve to the corresponding point on the other side of the curve (See Fig. 1039).

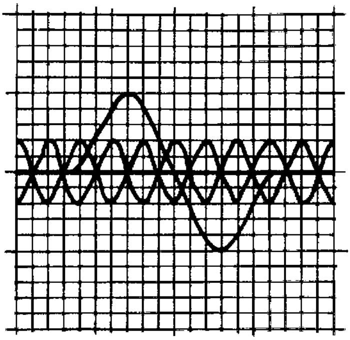


Fig. 1038. Appearance of S curve when a marker, modulated at 400 c.p.s. is used.

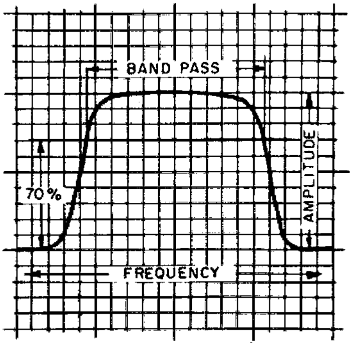
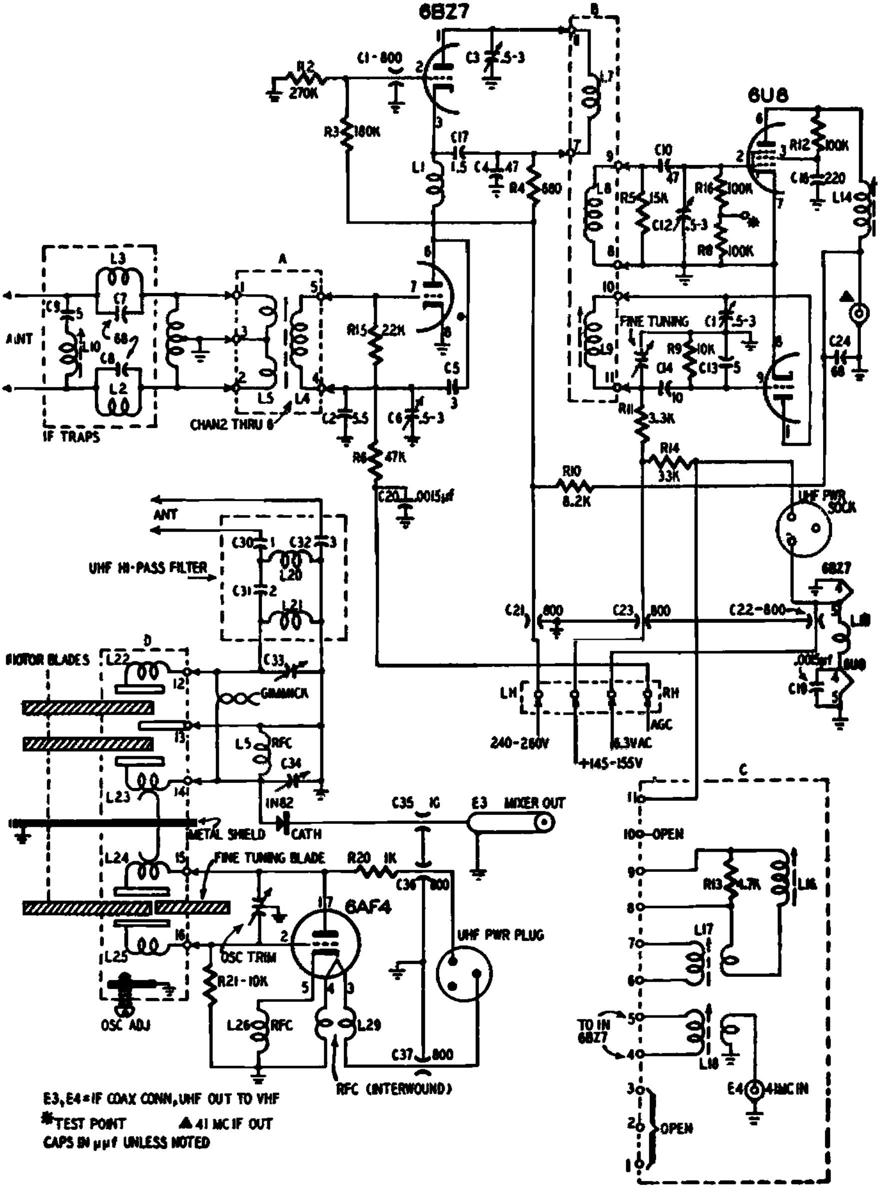


Fig. 1039. The bandwidth of the sound i.f. is measured between the 70% response points.

Front-end alignment

Considerable sweep width (in the order of 15 mc) must be used in this portion of the alignment procedure, as the bandwidth of the front end is greater than that of any signal circuit.

The tuner shown in Fig. 1040 is a high gain, low noise detent type for v.h.f. and u.h.f. reception. The antenna input circuit contains traps (L10, C9; L3, C7; L2, C8) to reject r.f. interference. The signal enters the first half of the cascode r.f. amplifier through coils L5 and L4 mounted on strip A. This particular strip covers the low-frequency channels (2 to 6). The secondary winding, L4, is tunable. Capacitor C6 (in parallel with C2) is a variable unit, compensates for differences in tube input capacitance when re-



E3, E4 = IF COAX CONN, UHF OUT TO VHF
*TEST POINT ▲41 MC IF OUT
CAPS IN μμf UNLESS NOTED

Fig. 1040. Schematic diagram of all-channel turret-type television tuner.

placing the r.f. amplifier tube. C5, a fixed neutralizing capacitor, is connected from the plate (pin 6) to the input. Its action is to maintain a flat signal characteristic. Resistor R15, connected across L4, reduces the Q of that coil, broadens the bandpass. R2 and R3 at the input to the second half of the r.f. amplifier place the control grid (pin 2) at the proper potential with respect to the cathode (pin 3).

The second half of the r.f. amplifier is also neutralized by a fixed capacitor (C17). The output of the cascode r.f. amplifier is then electromagnetically coupled by transformer action (L7 and L8) into the mixer grid. The transformer is overcoupled to give the necessary wide bandpass for the TV signal. A damping resistor, R5, also broadens the frequency response of L8. The junction of R16 and R8, in the control-grid circuit of the mixer tube, provides a test point for the injection of a test signal. Capacitor C12, shunted across these resistors should be adjusted to compensate for differences in input capacitance when making a mixer tube replacement. The i.f. output of the mixer is tuned by the series network consisting of L14 and C24. L14 is adjusted to give the bandpass recommended by the manufacturer.

As in the case of FM receiver alignment, the output cable from the sweep generator should be provided with a suitable impedance-matching pad to accommodate the 300-ohm input impedance of the front end. The scope should be connected to the r.f. test point through a resistive isolating probe. Since the gain of a front end is considerably less than the gain of an i.f. amplifier, correspondingly high output must be applied from the sweep generator.

If the scope is now applied at the output of the picture detector, the over-all r.f./i.f. response curve will be displayed. Note carefully that this response curve will be dominated by the characteristics of the i.f. amplifier, and that the picture-carrier marker "bug" will appear at the 50% point of the response. If the r.f. alignment has been properly performed, the shape of the over-all response curve will be almost exactly the same as the shape of the i.f. response curve by itself.

To adjust the local oscillator frequency in the front end on the basis of the over-all curve display, set the frequency of the marker generator to the picture-carrier frequency of the channel to which the front end is set. Then, with the fine-tuning control at the mid-point of its range, align the local oscillator to place the picture-carrier marker "bug" 50% up the side of the over-all response curve.

generator terminology

A

Absorption marker. An abrupt attenuation of the output from a sweep generator at a chosen frequency point, obtained by coupling a resonant circuit into the sweep-signal circuit of the generator.

AM. The abbreviation for amplitude modulation.

Amplitude modulation. Variation of a signal voltage with respect to time.

Attenuation. Reduction of a given signal level to a lower level.

Attenuator. Device utilized to control a signal level.

B

Balanced output. A three-terminal output system in which one terminal is grounded and two terminals are active. As the signal rises at one active terminal, the signal falls at the other active terminal.

Bandpass filter. An inductance–capacitance arrangement which permits flow of current only within a specified band of frequencies.

Beat frequency. A new frequency obtained by application of two signal frequencies to a nonlinear mixer. The output from the nonlinear mixer contains a difference beat frequency, a sum beat frequency and their harmonics.

Beat fundamental. The fundamental beat frequency obtained from a nonlinear mixer, as contrasted with the harmonic output and with the pure fundamental output from a simple oscillator.

C

Calibration. Correspondence of dial scale to frequency of output from a generator.

Center frequency. The midfrequency point in a band of sweep frequencies (midfrequency of a frequency-modulated signal).

Center-frequency indication. A system of sweep generator operation wherein the tuning dial of the generator always indicates the center frequency of the sweep output.

Continuous coverage. Provision of all frequencies between a given lower limit and a given upper limit by a generator, as contrasted to skip coverage in which some frequency interval is omitted between the lower and upper limits.

Cross-beat. A heterodyne beating of two signal frequencies resulting in a difference frequency and a sum frequency. The difference and sum frequencies are termed cross-beats.

D

Demodulation. The rectification and partial filtering of a modulated wave. Filtering is incomplete in the demodulation process, thereby permitting the envelope of the modulated wave to be recovered.

Deviation. The frequency variation of a frequency-modulated signal, also termed the *sweep width* of the output.

Difference frequency. One of the new frequencies generated in a heterodyne mixer when two signal frequencies are applied to the mixer. The difference between the two signal frequencies appears in the mixer output.

Distortion. Partial loss of the original characteristics of a signal. Distortion may take place in voltage at various levels (amplitude distortion) or at various frequencies (frequency distortion), or may consist in a shift in phase of some of the frequencies in a complex output (phase distortion).

Drift. Instability of a tuned circuit or oscillator arrangement, causing the output frequency to vary with time and the dial indication to become incorrect.

E

Eddy current. Flow of current in a conductor such as a sweep-modulator disc by transformer action on associated magnetic fields.

Edge-frequency indication. A type of sweep generator operation in which the dial indicates the frequency at one edge of the sweep band.

Electronic attenuator. Attenuation obtained by electronic means, such as by varying the plate voltage or the grid bias on a heterodyne mixer tube.

F

Feed-through frequencies. Amplifier action incidental to a heterodyne mixer, whereby the applied signal frequencies appear in the output with their sums and differences.

Filter. An arrangement of inductance and capacitance for passing signals of desired frequencies and stopping the flow of signals of undesired frequencies.

Fine attenuator. An arrangement for continuous variation of an output signal level.

Fixed oscillator. One of the oscillators utilized in a beat-frequency circuit which is operated at the same frequency at all times.

Flatness of output. Uniformity of output voltage over the sweep band (lack of amplitude modulation).

Frequency modulation. The variation of a signal frequency from a lower limit to an upper limit as a function of time and in a cyclic manner. Sweep generators usually develop a signal which is frequency-modulated in accordance with a sine law.

Fundamental frequency. The first harmonic of a generated signal, to which all other harmonics (if present) are integrally related.

G

Grid tank. The resonant circuit utilized in the grid circuit of an oscillator.

H

Harmonics. Integral multiples of a fundamental sine-wave voltage which are generated by amplitude distortion of the fundamental.

Heterodyne mixer. A device for combining two signal frequencies in a nonlinear arrangement for the purpose of generating sum and difference frequencies.

Highpass filter. An arrangement of inductance and capacitance for passing currents of high frequencies and stopping the flow of currents of low frequencies.

I

Impedance. A combination of resistance with inductive reactance or capacitive reactance, or both.

Insertion loss. A fixed attenuation of signal caused by introduction of a device into a circuit, such as the insertion loss of a filter containing resistance as well as inductance and capacitance.

L

Ladder attenuator. An arrangement of series and shunt resistances in combination with a switch to provide step attenuation of signal level and to maintain a virtually constant impedance at input and output terminals.

Linear mixer. An arrangement for combination of two signals without generation of new frequencies, such as the combination of a sweep and marker signal in a linear amplifier arrangement.

Linear sweep. (May refer to vertical or horizontal linearity.) A completely linear sweep signal maintains constant amplitude over the sweep band and thus has vertical linearity. It also progresses through equal increments of frequency in equal intervals of time and thus has horizontal linearity.

Lowpass filter. An arrangement of inductance and capacitance to prevent current flow at high frequencies and to permit current flow at low frequencies.

N

Nonlinear mixer. Circuit element or arrangement in which the output is disproportionate to the input, as exemplified by a detector tube or by a germanium crystal diode.

Nonlinear sweep. A sweep signal lacking in constancy of output voltage over the sweep band or lacking the provision of equal increments of frequency in equal intervals of time, or both.

O

Oscillator crystal. A quartz crystal used as the grid "tank" in an oscillator circuit having a high degree of stability and absence from drift. Used to calibrate a marker generator in frequency.

Oscillator pulling. The interaction of a pair of beating oscillators as their frequencies of operation approach the same value. Pulling causes waveform distortion and frequency error.

Oscillator locking. The seizing of control of one oscillator by another as pulling becomes severe. Locking causes the output from the generator to drop to zero over the locking range of frequencies.

Output cable. A shielded coaxial cable used with a generator for the purpose of transporting the signal from the point of generation to the point of application.

P

Peak-to-peak voltage. The total voltage excursion of a waveform from its positive to its negative peak.

Piston attenuator. An attenuator arrangement which operates as a waveguide below its cutoff frequency.

Potentiometer attenuator. A simple attenuator arrangement consisting of a continuously variable resistance.

Pure fundamental output. A single-frequency generator output voltage.

Push-pull oscillator. A double-ended oscillator arrangement which provides a balanced output voltage.

Q

Q. The figure of merit of an inductor or capacitor or tuned circuit; the ratio of reactance to resistance.

Quartz crystal. An electrically active mineral which has very high Q and operates as a grid tank in an oscillator circuit, providing high-frequency stability.

R

Resonance. In most cases, the frequency at which the capacitive reactance is equal to the inductive reactance. Series resonance develops a very low impedance equal to the circuit resistance, while parallel resonance develops a very high impedance.

R.m.s. voltage. A rating of a.c. voltage equal to 0.707 of the peak value when the waveform is sinusoidal. R.m.s. voltages correspond to d.c. voltages, in that either voltage will develop the same power in a circuit.

Retrace line. A visible trace developed by the return excursion of the sweep voltage from a sweep generator. The retrace line usually is placed at the zero-volt level by the sweep generator circuits.

S

Sensimeter. Trade name for a true marker generator comprising a signal source covering channels 2 through 6, an output meter, and a calibrated bellows-type waveguide attenuator. Used for checking the microvolt sensitivity of TV receivers.

Signal generator. A generator which develops a single frequency. The output frequency can be set to a desired value by the operator and can be varied in level likewise.

Skip band. A missing interval in the band of output frequencies available from a generator. For example, a marker generator may provide output only from channel 2 through channel 6 and from channel 7 through 13. The band of frequencies from channel 6 to channel 7 is referred to as a skip band.

Sum frequency. One of the new frequencies developed by a nonlinear mixer as a result of application of two signal frequencies at the input of the mixer.

Spurious frequencies. Undesired frequencies in the output from a generator.

Spurious markers. Undesired markers appearing on the sweep output voltage from a sweep generator, caused by spurious frequencies from the sweep generator or from the marker generator, or both.

Spurious sweeps. Undesired sweep signals in the output from a sweep generator caused by improper design of the frequency-modulation circuits.

Sweep modulator. The device utilized in a sweep generator to obtain frequency modulation of the output signal.

Sweep width. The deviation of the frequency-modulated output from a sweep generator.

Sweep oscillator. The oscillator which is frequency-modulated by action of the sweep modulator.

Standing waves. Reinforcements and cancellations of a sweep voltage from reflections.

Step attenuator. An attenuator which provides variation of the output signal level in given steps, such as a decimal step attenuator.

Subharmonic. An array of frequencies from which the fundamental is absent; the missing fundamental is termed the subharmonic. A signal of this type can be generated by passing the output from an oscillator which develops an array of harmonics through a highpass filter having a cutoff between the first (fundamental) and second harmonic.

Sweeper. Synonymous with sweep generator. This word is often used by technicians for the sake of brevity.

Sweep-frequency generator. Synonymous with sweep generator; a more precise terminology, avoiding confusion with other devices such as the sweep generator (sawtooth generator) utilized for horizontal deflection of an oscilloscope.

Sync. An abbreviation commonly used for the word synchronous. Two frequencies in sync are said to be in step (having identical frequencies). Sync controls appear on generators, scopes, and TV receivers. The horizontal and vertical frequency controls on a TV set are sync controls.

T

Termination. The shunt resistor utilized at the end of a generator output cable to provide a load equal in value to the characteristic impedance of the cable. Proper termination eliminates reflections and resulting standing waves.

Trimmer. A device utilized for limited variation of inductance or capacitance in an oscillator tank for calibration of the oscillator frequency.

V

Vernier attenuator. A continuous attenuator utilized to provide control of signal level between the steps of a coarse or step attenuator.

Variable-frequency oscillator. An oscillator with a tuning control, permitting the operator to vary the output frequency, as contrasted with a fixed oscillator.

Video frequency. The range of frequencies from d.c. to 4.5 mc, as used in TV circuits.

W

Wobbulator. A term synonymous with sweeper, or sweep generator. The word wobbulator is gradually becoming obsolete.

Z

Zero frequency. The special case of frequency where a.c. becomes d.c. Note that no service generators provide an output down to zero frequency: the beating oscillators pull and lock before zero frequency is attained.

Zero-volt reference line. Conversion of the return trace in a response curve to a horizontal line at the zero-volt level, usually obtained by keying the grid of the sweep oscillator in the sweep generator with a 60-cycle square wave.

index