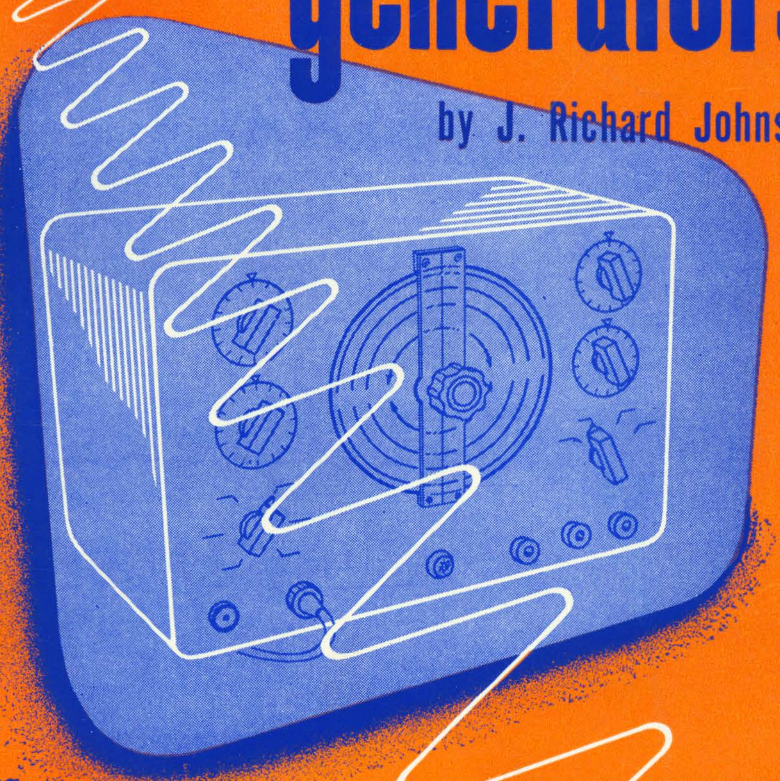
No. 147

HOW TO USE signal & sweep generators

by J. Richard Johnson



Including

- AM SIGNAL GENERATORS
- FM SWEEP GENERATORS
- TEST OSCILLATORS
- MARKER GENERATORS
- CALIBRATORS
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HOW TO USE signal and sweep generators

by J. Richard Johnson

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PREFACE

Signal and sweep generators are of great value and importance to any radio or tv serviceman, experimenter, or student. While much has been written about the theoretical aspects of these instruments, there has been a scarcity of information about their actual manipulation and applications to practical problems. This book aims to provide just such information. The emphasis in on the methods of setting up the instrument, setting the controls, making proper connections, use of accessories, and the general techniques of operating the instrument itself. It felt that many people who are now hesitant about using signal and sweep generators to their full capabilities would, after receiving this information, be able to put them to their full use.

The book includes sufficient information about the foundamentals of generator operation to make the purpose and reason for all practical steps clear. Otherwise, theory discussions are avoided in favor of practical instruction. Besides its appeal to radio service technicians, experimenters, hobbyists, and radio amateurs in the field, the text should be a valuable aid in radio and television laboratory courses of technician schools.

The book is written in such a way that the reader need have only that basic knowledge of electricity, radio, and electronics possessed by most members of the groups of readers mentioned above. It is designed to tell him, specifically:

(1) The types of equipment available.
(2) Their basic principles of operation.
(3) Controls and adjustments, what they are, their purposes, and where to find them.
(4) How to set up and adjust generators for various applications.
(5) How to maintain generators.

The practical flavor and authenticity of the text were greatly enhanced by the cooperation of the John F. Rider Laboratories, whose facilities were made available to the author for gathering important practical data. In addition, the author wishes to thank Milton S. Snitzer, managing editor of John F. Rider Publisher, Inc., for his helpful technical editing, corrections, and additions to the book.

It is my earnest hope that this book will enable many more to derive the great benefits of full and complete use of signal and sweep generators.

September, 1953 *J.R.J.*

CONTENTS

Chapter 1

PURPOSES AND TYPES OF SIGNAL GENERATORS

1-1. Definition of a Signal Generator

A *signal generator* is a device used to generate a signal. The term "signal generator" is self-descriptive. Under this general definition, even a device which generates a signal in the normal operation of a piece of equipment is covered. However, a signal generator, as the term is used here, is normally a *test instrument*, used in measuring, testing, and servicing.

The signal generator generates a signal for test purposes. But what is a "signal?" A signal can be any alternating current or voltage. In its original sense, the word "signal" referred to the modulation or intelligence of any composite electrical wave. However, through loose usage, it is now generally applied to any alternating current or voltage, regardless of whether it is a carrier or its intelligence component, as long as it is used directly in the transmission of intelligence, or participates directly in modification of a transmitted or received wave.

For example, the alternating current in the power transformer or in the heaters of the tubes in a radio receiver is not a signal since it is not directly involved with the received intelligence. However, the electrical wave received from the antenna, that produced by the local oscillator, the intermediate-frequency current, and the a-f current after demodulation are all referred to as signals.

A signal generator is thus an instrument which can provide artificially a signal which is as nearly as possible identical with, or representative of, a signal present in a circuit or device when it is in normal use.

1-2. Purposes of Signal Generators

A signal generator provides a signal in a circuit or device so that device will operate or react in the same way it would with a signal from its normal source. For a radio or tv receiver, the normal signal source is the antenna. A suitable signal generator is used to supply to the antenna circuit a signal which substitutes for the normally-received antenna signal. But the signal generator is so designed that the available signal can be modified in intensity, frequency, and modulation type and percentage, and in other ways in which there is no control over the antenna signal normally received. The receiver can thus be subjected to various signal-input conditions, and its performance checked. Certain signal factors, such an amplitude-modulation percentage or frequency, which are continually varying in broadcast-station reception, can be kept constant at desired values while receiver tests are made.

Signal generators are not limited in their use to radio and tv receivers. They are suitable wherever alternating current or voltages over a desired range of frequencies are required. For example, in radio-frequency bridges which measure r-f impedance, signal generators provide a suitable source of r-f current at the radio frequency at which measurements are desired. They also can be used as a source of signal voltage in measuring the response of a transformer, or the response of a filter. Many of the hundreds of possible uses are discussed later in this book.

1-3. Test Oscillators

The term "test oscillator" has often been used interchangeably with the term "signal generator." There is on record no official or generally accepted definition which distinguishes a test oscillator from a signal generator. "Test oscillator" is the older term; that is, at one time most instruments now referred to as signal generators were called test oscillators. In present usage, there is some tendency to classify the simplest signal-generating instruments which do not include output voltage measuring or indicating devices, or attenuators, as test oscillators, and others as signal generators. However, such usage is certainly very far from standardized, and the reader is warned not to make any arbitrary classification according to these terms.

Because of the lack of any well-recognized definitions of what a test oscillator is as compared to a signal generator, in this book we shall use only the term "signal generator." Test oscillators, of whatever classification, will then fall in as special examples of signal generators, and will be treated as such.

1-4. How a Signal is Generated

There are several ways in which a radio-frequency signal can be generated, but all ordinary signal generators employ electronic oscillators. In practically all cases this is a vacuum-tube oscillator. Regular oscillator circuits are used, with the Hartley and Colpitts among the most common. In most units, several tuning bands are required to cover the desired range of frequencies. These bands are selected through a range switch which connects any of several coils, or taps on a coil. Tuning within each band is usually by means of a variable capacitor controlled by a knob with a calibrated dial on the front panel. In other cases the output frequency generated is fixed for any given switch position, each position corresponding to a specific frequency or band of frequencies, such as a television channel. Sometimes crystal control is used, either directly, or for use in calibrating a variable oscillator.

Most signal generators make provision for modulating the generated frequency. This may be either amplitude modulation, frequency modulation, or both. Frequency modulation is ordinarily provided for use in *sweep analysis,* in which a response curve is traced out on an oscilloscope rather than as an f-m signal for f-m receivers. Methods of modulation are discussed more fully in the next three chapters, for each type of generator.

1-5. Types of Signal Generators

There are a number of ways of classifying the many types of signal generators. There are so many varieties and combinations that no classification method can be complete. However, it is common practice to designate generators by application, frequency range, and type of modulation. For a complete specification of the type of instrument, a combination of all three of these factors must be stated. For example, a-m signal generators for radio receivers ordinarily cover the range from 100 kc to about 30 mc. But there are generators with the same type of signal output and modulation whose frequency range may extend from 5 or 10 mc to thousands of megacycles. The frequency range and purpose of the latter should be stated to distinguish them from simply ordinary "a-m generators."

For the introductory discussion of generators in the next three chapters, we have divided them, according to both application and type of signal output, into three classes:

1. A-M SIGNAL GENERATORS. Here we include all those generators designed to produce a steady r-f carrier signal, with optional amplitude modulation by a tone or other modulation signal. These can be further divided into:

   a. Radio servicing type generators, which normally cover from about 100 kc to about 20 or 30 mc.

b. Laboratory type a-m generators. These have various frequency ranges, many about the same as for radio servicing generators, but many others extending higher and lower in frequency range. Special types for vhf and uhf ranges may not include the lower frequencies at all, but start at 50 to 100 mc or higher. Generally laboratory types have relatively more rugged construction and tolerances as to stability, calibration, and output voltage readings, and are much more exacting than those for servicing instruments.

c. Special units, in which the amplitude modulation is by a specialized waveform or frequency. For example, for testing tv receiver linearity, an r-f carrier signal may be amplitude modulated by a sine wave or pulse wave of various frequencies up to about 400 kc.

2. Marker Generators. These are generators of unmodulated r-f signals of desired spot frequencies. The signal output is the same in *nature* as that of a-m generators with the modulation shut off, but the definite difference in *use* sets these units apart. The r-f unmodulated signal must be exactly of a known definite frequency, and is ordinarily used to mark a spot along a response pattern to indicate the frequency coverage of that pattern, or the relative location of parts of the pattern in the frequency spectrum. Since different response-pattern tests may involve frequencies from a few cycles per second to thousands of megacycles, marker generators are not limited to any particular frequency range. However, the majority of marker generators now in practical use are employed in checking tv receiver response, and have ranges in the region from 1 mc to 220 mc. Many marker generators are installed as part of tv sweep generators, with which they are used in tv alignment or response checking. Since, as was explained above, the marker signal is simply an unmodulated carrier, any a-m signal generator of suitable frequency range can be used to provide it, although the required accuracy of frequency may not be obtained. The principles of marking and marker generators themselves are covered more fully in Chapter 3.

3. Sweep Generators. These units provide a signal which is of variable frequency, the variation taking place in a rapid, periodic manner called *sweep*. In other words, the r-f carrier is frequency modulated. The modulating signal is ordinarily the 60-cycle power-line frequency, so that the radio-frequency carrier changes from its lowest frequency to its highest frequency and back again 60 times each second. The same power-line voltage which is used to sweep the frequency is usually brought out through a terminal to the horizontal-deflection circuit of

the oscilloscope on which a response pattern is to be observed. Sweep generators are available in a variety of potential sweep widths from a few kilocycles to many megacycles. Most common is the type designed for tv response checking and alignment, in which sweep widths up to 15 mc are ordinarily available, with center frequencies in the range 0 to 220 mc and above. Other units are designed only for f-m receivers, and are limited to maximum sweep widths of about 1 mc, and may have center frequencies extending only to 108 mc.

In this book, we shall discuss the three main types listed above. The audio signal generator, producing signals up to 20 kc or more from a low limit in the order of 15 to 20 cycles, is considered in a separate field of work entirely. It is thus not discussed in this book, except where a-f generators are part of a-m generators, where they are used to provide modulation. However, video sweep types, in which the frequency of the signal is swept from near 0 mc up to about 10 mc, are so closely allied to other sweep types that they are discussed in connection with them.

Chapter 2

A-M SIGNAL GENERATORS

2-1. Basic Parts of A-M Generators

The central and most important part of any signal generator is the r-f oscillator. This oscillator must be adjustable to any frequency within the desired specified frequency range, adjustable to any set frequency (as with crystal control) available, or both. In most generators of the a-m type, continuous frequency coverage is provided from somewhere near 100 kc to between 30 and 60 mc. The oscillator is designed to operate with good stability, and its frequency is controlled over each range with a tuning dial calibrated in kilocycles or megacycles.

A large percentage of the uses of a-m signal generators requires that the output signal be modulated by some kind of tone. 400 cps has been chosen as the standard single tone for modulation in testing radio receivers, with 1,000 cps as an alternate. Usually the modulation is applied

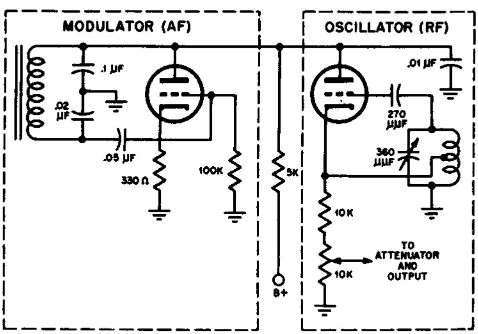


Fig. 2-1. The basic parts of any a-m signal generator are the r-f oscillator and the modulator. Typical circuit arrangements for these two basic parts are shown here.

to the carrier signal from the oscillator by means of a modulator tube and circuit. Simple Heising plate modulation is common. A typical circuit for an r-f oscillator and modulator in a signal generator is illustrated in Fig. 2-1. The r-f oscillator is a triode grounded-plate Hartley type. The modulator is a Colpitts a-f oscillator. The modulation is applied to the r-f oscillator by connecting the plates together as shown, and feeding B-plus to both through a common resistor of 5,000 ohms.

2-2. R-F Output Attenuators

The various applications of signal generators require a variety of signal strengths for testing, measuring, and aligning. Sometimes different signal-voltage outputs are required in rapid succession, as in radio receivers when the signal is to be injected into different stages. In some equipment, excessive signal overloads the circuits, giving false indications. If the signal is not reduced in some practical manner to just the proper value, tests are difficult or impossible. For this reason, some device for controlling the r-f voltage output is usually included. This device is called an *attenuator.*

Attenuators may take the form of a continuously variable control or of a step-switch, which changes the output voltage by a specified ratio (ordinarily 10 to 1) for each successive switch position or step. Sometimes the continuously variable type is included alone, without the step type. The step type, however, is nearly always accompanied by the continuous type, since the latter provides a fine adjustment to provide variations of signal voltage between the step attenuator positions.

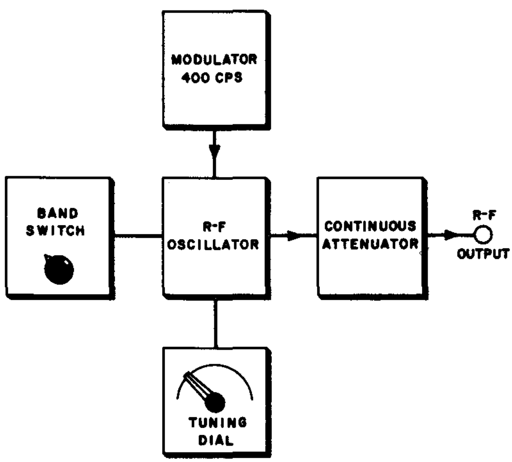


Fig. 2-2. Block diagram of the simplest service-type a-m signal generator.

2-3. Panel Arrangement For Simple A-M Generator

One of the simplest arrangements for an a-m generator is that in which a variable r-f oscillator is modulated approximately 30 percent by a modulator with a fixed tone and the modulation percentage is not variable. The block diagram of such an arrangement is shown in Fig. 2-2. The r-f output voltage is controlled by a simple continuous attenuator. The panel arrangement typical of such generators is illustrated in

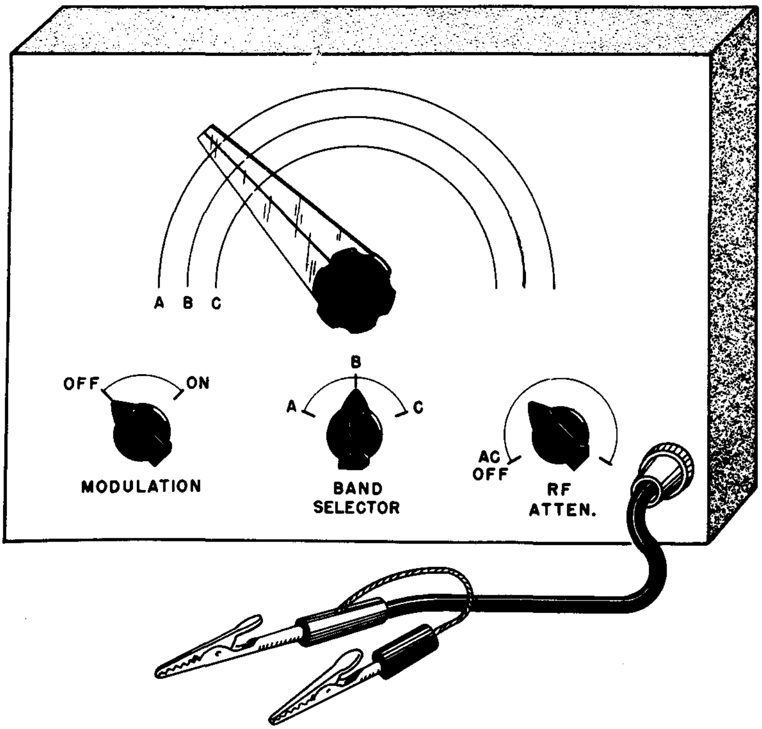


Fig. 2-3. Typical panel layout for simple service-type a-m signal generator.

Fig. 2-3. Frequently there is a switch by which modulation can be turned on or off, without any variation of the modulation percentage. The a-c switch for turning the generator on is mounted on the back of the r-f attenuator and operates at the lower end of the range of that control.

2-4. More Elaborate Arrangement

The block diagram of an a-m generator with several additional features is shown in Fig. 2-4, and a typical panel arrangement is illustrated

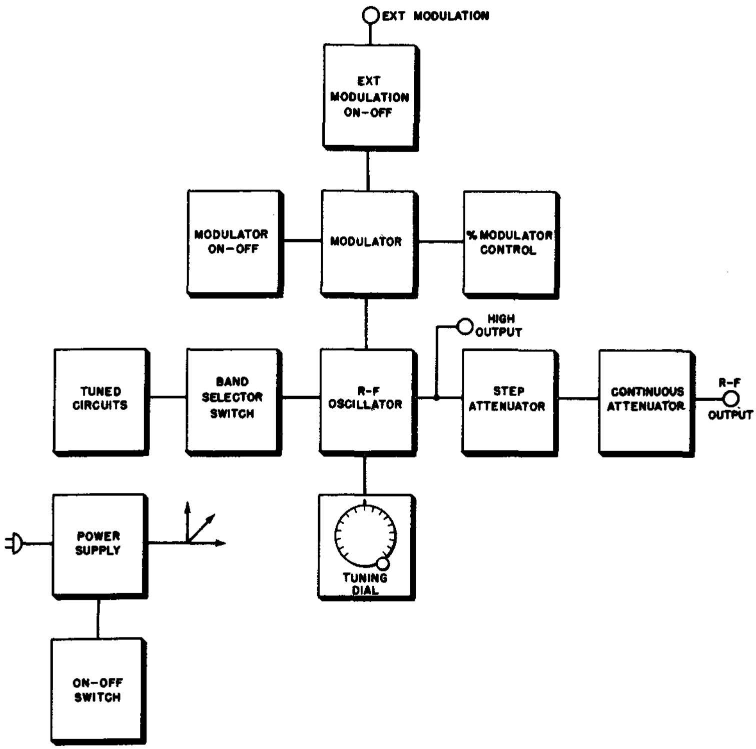


Fig. 2-4. Typical arrangement for a-m signal generator with most ordinarily used features. This arrangement is typical of many service type and laboratory type a-m generators.

in Fig. 2-5. Here the modulation percentage is controlled by an additional knob, which is mounted on a volume control in the modulator circuit. Another feature included here is the jack for external modulation. Often the r-f signal is to be modulated by different audio frequencies for a series of tests, or the modulation frequency must be some other than that supplied in the generator unit itself. The external modulation provision allows the use of an external a-f oscillator, whose frequency or waveform can be varied at will, to modulate the r-f oscillator. An example of such a situation is the test of the overall frequency response of a radio receiver. The r-f signal is applied to the receiver and is modulated. The a-f modulation signal voltage at the loudspeaker is then measured for various modulation frequencies. For each modulation fre-

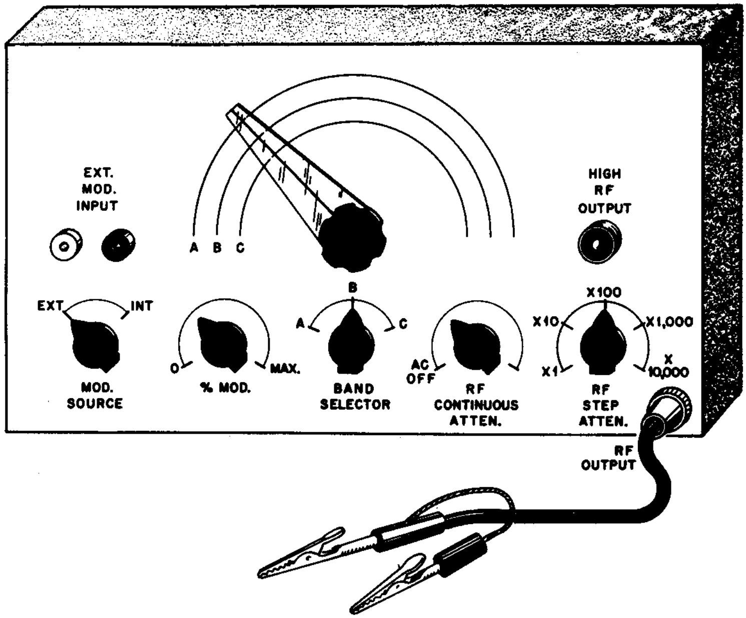


Fig. 2-5. Typical panel layout for signal generator for the type illustrated by the block diagram of Fig. 2-4.

quency, the external a-f oscillator is adjusted to apply the same a-f voltage at the external modulation jack of the signal generator.

When an external modulation connection is provided, there must also be a switch to select external or internal modulation. This switch turns off the internal a-f oscillator when in the external position.

Also included in the controls of the panel of Fig. 2-5 is a step attenuator. As previously explained, this device provides a change of 10 to 1 (or other ratio) in the output signal voltage for each change in position of the switch. For example, suppose there is an output voltage of 100 microvolts with a given setting of the continuous r-f attenuator and the step attenuator on the "X1" position. If the step attenuator is then changed to the "X10" position, the output voltage goes to 1,000 microvolts. In the "X100" position, the output goes to 10,000 microvolts and so on. Attenuators are usually designed to keep the output impedance of the generator the same for all output voltage levels, or as nearly the same as possible. A standard value for output impedance is 75 ohms, or 50 ohms, which matches the characteristic impedance of the output lead. This matching is very important at the higher frequencies (above 20 mc).

As the output lead length becomes an appreciable fraction of a wavelength, standing waves start to interfere in certain applications if impedances are not properly matched. More is said about matching in Chapter 7.

2-5. Output Indicators

In making sensitivity, selectivity, and other tests on radio receivers, it is important that some method of signal generator output voltage indication be available. A few service-type signal generators, and many laboratory types, include a meter by which output voltage for any setting of the attenuators can be observed. The meter may read microvolts directly, or may have a setting knob adjustment to set the meter at a certain mark on the scale, after which the attenuator controls indicate output voltage directly. A typical panel arrangement for an a-m signal generator with an output meter is shown in Fig. 2-6.

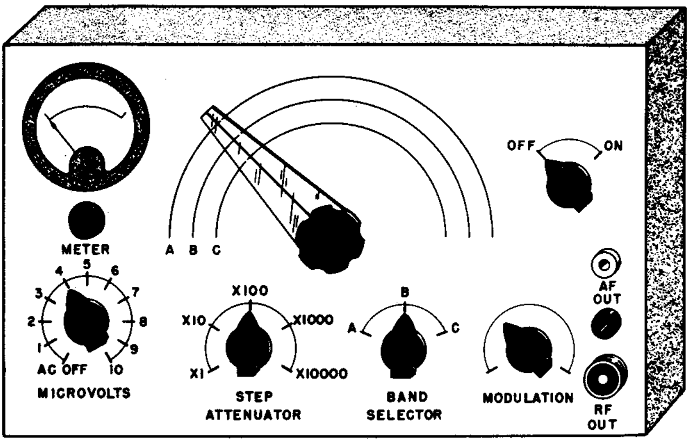


Fig. 2-6. Typical panel layout for signal generator using a meter-type output indicator.

The two methods used to determine the actual output voltage by means of a meter and controls are illustrated in Fig. 2-7. In the arrangement of (A), the meter reads directly in microvolts; the multiplier control selects the desired range. For example, with the meter reading of 2 and multiplier setting of 100 as shown in the figure, the output voltage is indicated as 200 microvolts. At (B) is shown another arrangement. The meter is used to set the output reference level at an indicated point, and the output voltage is then indicated by the settings of the step

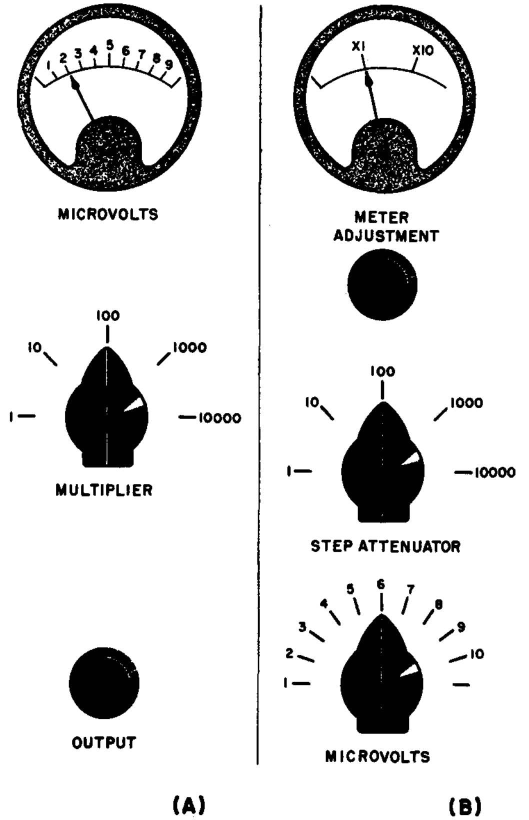


Fig. 2-7. Two methods in which a meter is used to indicate r-f output voltage of a signal generator. At (A) the meter reads microvolts directly, and its indication is multiplied by the multiplier dial indication. At (B) the meter is used to set the reference voltage, after which the output is read from the dials.

attenuator and microvolts knobs. For example, with the settings shown, the output is 600 microvolts. This is obtained by multiplying the microvolts control reading (6) by the step attenuator reading (100) by the multiplier indication of the meter, which in the case shown is 1. In some cases, there is only one reference mark on the meter; in these cases the multiplier is always 1.

The procedure in setting the arrangement at (A) for a desired output voltage is to set the multiplier for the correct range, then increase the signal voltage with the output control until the meter reading, when multiplied by the setting of the multiplier, indicates the required output level.

The procedure in setting the arrangement at (B) for a desired output voltage is to set the microvolts and step-attenuator dials for the desired voltage, then use the meter adjuster to set the meter pointer to X1. If a high voltage is desired, it may be more convenient to set the microvolts and attenuator controls for one-tenth the desired voltage, then set the meter for X10, if such a reference mark is provided.

A variation of the method of (B) is one which uses a *tuning eye* instead of a meter. In other words, when the adjuster knob is set to close the eye, it is the same as though the meter were set to X1 in generators having a meter.

2-6. Audio-frequency Output

It is often desirable to have an a-f signal available from the r-f signal generator for tests of the a-f sections of receivers, a-f amplifiers, and many other applications. Since some kind of a-f oscillator is required for modulation, the same oscillator can be used to provide a-f output, and this is done in many a-m generators. The audio output is obtained either from a separate output jack, or from the r-f output jack with a different setting of one or more of the controls. Except in very special types, the a-f signal is of one frequency, the same as that used to modulate the r-f signal.

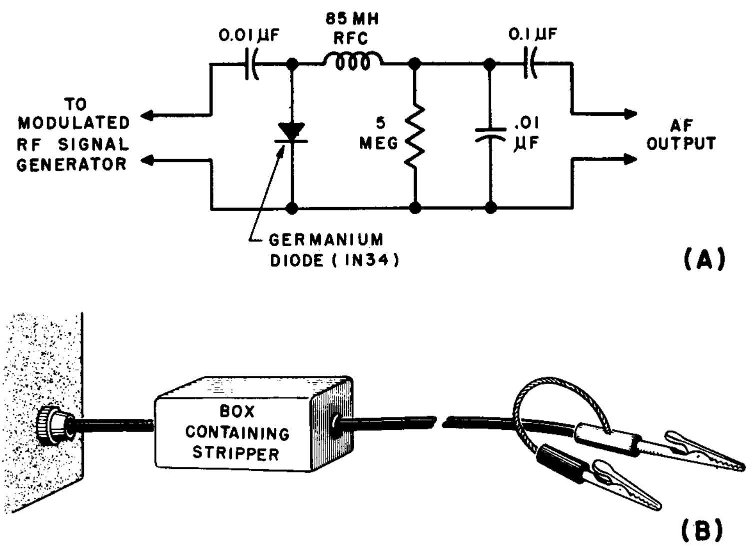


Fig. 2-8. If audio-frequency output is not directly available from the signal generator, it may be obtained from the modulated signal by an "audio stripper". A typical circuit and physical arrangement is shown here.

2-7. A-F Strippers

Quite a few signal generators in which modulation of the r-f signal is obtainable do not have an a-f signal available at an output terminal. In such a case, an audio signal may be obtained by using what is known as an *audio stripper,* which removes the modulation signal after the modulated r-f leaves the generator unit. A typical circuit for a stripper (also sometimes called an *audio extractor*) is shown in Fig. 2-8. For practical use, the stripper circuit can be built into a metal box connected into an extra lead used only for a-f output, as shown in the figure. Alternatively, a fitting may be mounted on the lead side of the box and the regular r-f lead connected at that point when a-f output is desired. The signal-generator side can then be connected by means of a short lead from the box with a fitting to go on the generator output jack.

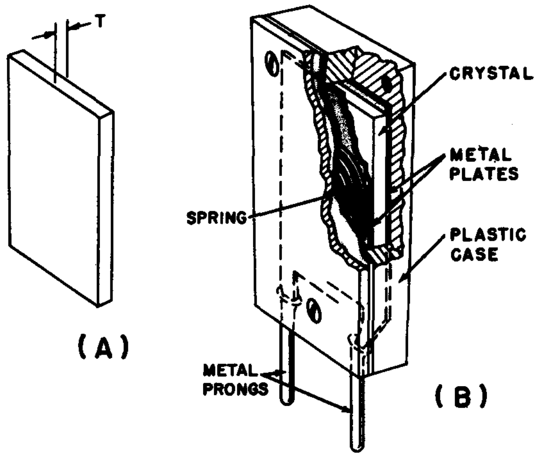
2-8. Crystal Controlled A-M Generators

A high degree of accuracy and stability of carrier frequency are possible with *crystal-controlled oscillators.* These make use of *quartz crystals,* which keep the oscillator frequency very nearly constant at a specified frequency.

A quartz crystal is a flat slab of quartz usually of square or rectangular shape, as illustrated at (A) of Fig. 2-9. Occasionally, circular slabs are used. Quartz has the property of generating a small voltage between surfaces when physical pressure is applied or released from these surfaces. This is known as the *piezo-electric* effect. A properly ground crystal has a mechanical resonant frequency just as a vibrating reed or string of a musical instrument. The piezo-electric effect links a voltage across the surfaces of the crystal to the mechanical vibrations, so that the mechanical vibrations control the frequency of an oscillator into which the crystal is connected. The crystal, when oscillating, actually varies its surface pressure and flexes its mechanical structure at the radio frequency for which it is ground. The piezo-electric effect translates this mechanical action into a radio-frequency voltage across the crystal's surfaces. Since the mechanical resonant frequency depends largely upon the thickness of the crystal (t in Fig. 2-9), the electrical resonant frequency does also. The higher the resonant frequency, the thinner the crystal.

To obtain proper action from the crystal, it is mounted in a *holder,* as shown at (B) in Fig. 2-9. A metal plate is placed against each surface of the crystal, and these metal plates are connected respectively to two metal prongs protruding from the bottom of the holder. In many

Fig. 2-9. (A) Appearance of a quartz oscillating crystal. (B) How the crystal is mounted in a crystal holder. This holder plugs into a socket usually mounted on the front panel of the signal generator.



holders, a spring is added to provide gentle pressure of the metal plates against the crystal surfaces.

A crystal has the effect in an oscillator hook-up of a resonant circuit of extremely high Q, far higher than would be possible with any practical combination of coil and capacitor. A good crystal will oscillate at only one fundamental frequency, and can thus be depended upon, within certain tolerances, to be very close to specified frequency if it operates at all.

In general, crystals for fundamental frequencies up to 10 mc are commonly available, and others up to 20 mc can also be obtained. Special types are manufactured to operate on a "mode" of the crystal, so that operation is at some odd multiple of the fundamental frequency (usually the third or fifth). These are available for frequencies as high as 70 mc.

Crystals are of particular interest in signal generators because they are used for two main purposes: (1) to control the frequency of the main r-f oscillator and thus provide "spot" frequencies, each controlled by its own crystal, which are very accurate and stable, and (2) to provide check frequencies against which self-excited r-f oscillators in generators can be checked and calibrated.

A typical signal generator which is completely crystal controlled is shown in Fig. 2-10. A switch provides selection of any one of seven crystals mounted inside the unit for a crystal plugged into an external socket on the front panel. Supplied with the unit is a crystal on each of the following intermediate frequencies: 175, 262, 370, 455 and 465 kc. For other applications, the other two crystals inside the unit are for 200

Fig. 2-10. A typical crystal-controlled a-m signal generator.

Courtesy: Bliley Electric Co.

kc and 1,000 kc. These are primarily for *harmonic output.* That is, output from the 200-kc crystal can be obtained at the fundamental frequency of 200 kc and also at 400, 600, 800, 1,000, 1,200, 1,400, 1,600 kc, etc., and every 200 kc well up through the short-wave range. In the same way, harmonics of the 1,000-kc oscillator are available. Harmonic operation is discussed further in Sec. 2-9.

More frequently, crystal oscillators are used as auxiliary equipment in signal generators for checking calibration of the variable self-excited oscillators employed for the main r-f carrier output source. The variable oscillator has the advantage that it can be changed a little on either side of the desired alignment or test frequency and is useful when alignment frequencies are to be changed slightly to avoid interference. For this reason the latter type is most popular as the main oscillator; however, because there is no crystal to constrain it, its calibration is subject to variations with aging, temperature, humidity, and human error in operation. Consequently, the crystal calibrating oscillator is an important adjunct for checking variable oscillator frequency.

Because crystal frequency checking and calibrators are most closely related to markers and marker generators, they are discussed in Chapter 3.

2-9. Harmonic Operation of A-M Generators

Except when special design measures are taken, practically all r-f oscillators generate *harmonic* components of appreciable magnitude, as well as the fundamental frequency component. A harmonic component is one having a frequency equal to exactly an integral multiple of the main specified fundamental frequency of the generating oscillator.

For example, suppose we build an oscillator whose tuned circuit resonates at 1,000 kc. The oscillator oscillates at that frequency and produces a signal accordingly. However, also emanating from that same oscillator will be a radio-frequency signal at 2,000 kc, another at 3,000 kc, another at 4,000 kc, and so on, up to relatively high multiples of the basic 1,000-kc main frequency. The 1,000-kc frequency is known as the *fundamental* frequency. The individual harmonics are named after the number by which the fundamental frequency must be multiplied. The 2,000-kc harmonic is called the "second harmonic" because the fundamental frequency of 1,000 kc must be multiplied by 2. In the same way the 3,000-kc harmonic is called the "third harmonic," the 4,000-kc harmonic the "fourth harmonic" and so on.

In some applications, the presence of harmonics is annoying, but in signal generators it can sometimes be helpful. One oscillator frequency can be made to do for two or more. For example, our 1,000-kc oscillator can also be used to align a receiver at 2,000 kc, 3,000 kc, and other harmonic frequencies, as well as at the fundamental of 1,000 kc.

Employing this principle, many a-m signal generators provide extended frequency range without additional coils by specifying the use of harmonics for the highest range. For example, suppose the highest fundamental frequency range were 15 to 30 mc on a given generator. Another range, employing the second harmonic, would provide 30 to 60 mc with the same generator settings as for the 15 to 30-mc range. The generator would remain exactly the same, but the receiver or other device with which the generator is used would be tuned to frequencies in the higher range, and the dial-calibration frequencies would all have to be multiplied by 2. In many of the signal generators in which harmonics are to be employed, the dial is calibrated for both fundamental and harmonic frequencies, wherever the latter are recommended. Then, instead of having to multiply each value by 2 (or other whole number multiples) the operator may refer to the additional scale calibrated in values which are a multiple of the actual fundamental frequencies. Most manufacturers of signal generators will specify what ranges of frequencies are covered by the fundamental and what ranges employ harmonics.

In the same way, harmonics of crystal-controlled oscillators are available. If we have a 1,000-kc crystal oscillator, we also have available harmonic components at 2, 3, 4, 5, etc. mc. As will be explained in Chapter 3, these harmonics provide convenient check points against which the calibration of the variable oscillator can be checked.

One important fact must be kept in mind wherever harmonics are involved. Any imperfection in the fundamental signal is multiplied in the harmonic components. For example, a frequency error of 1 kc in a fundamental frequency of 1,000 kc will be reflected as a frequency error of 10 kc at the tenth harmonic of 10 mc. In other words, the frequency variations maintain the same *percentage* no matter what harmonic component is used. Accordingly, what may be a negligible error on the fundamental frequency may be excessive on a harmonic component being employed on a test. This is discussed further in Chapter 5.

2-10. Cross-hatch Generators

A special type of a-m signal generator is used to test linearity and other factors in tv reception. This is known as the "cross-hatch" generator or linearity-pattern generator. One type, which is designed to produce a series of parallel strips, or bars, on the screen of the tv receiver, is sometimes called a "bar generator." A bar generator may be designed to produce horizontal or vertical bars only. A cross-hatch generator, on the other hand, produces vertical and horizontal bars at the same time. For proper linearity, the parallel bars in each direction should remain equidistant and of the same thickness.

Generators of this type merely produce an r-f signal of the intermediate frequency or the front-end frequency of the tv receiver, amplitude-modulated by a relatively high frequency (200 to 400 kc) for vertical bars, and by an audio frequency (500 to 2,000 cps) for horizontal bars.

How the vertical bars are formed is illustrated in Fig. 2-11. The modulation signal will be assumed to be about 200 kc. This signal is recovered from the carrier by the video second detector in the receiver,

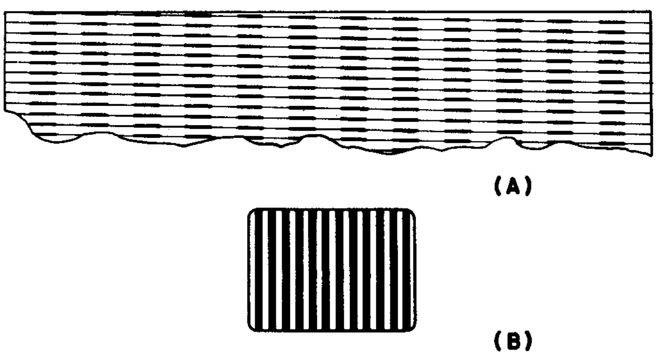


Fig. 2-11. How vertical bars are formed in a tv raster by presence of a modulation signal of a frequency considerably higher than the horizontal-deflection frequency. Several modulation signal cycles take place during one horizontal line period, thus producing a series of black spots along the line. When the frequency ratio is just right, the black spots on the successive lines align themselves, producing the vertical bars.

amplified, and applied to the grid of the picture tube. Whenever the modulation signal goes through a negative peak (once each cycle) the picture tube beam is blanked and a dark spot appears in the trace. If the modulation signal frequency is such as to produce twelve cycles during the time it takes to scan one horizontal line, as in this case, blank spots (dark spots) appear twelve times across each horizontal trace. If the relation between the modulation frequency and the horizontal deflection frequency is correct, the dark spots in successive lines down the screen line up and thus form the black vertical bars as shown in part (B) of Fig. 2-11. Of course the frequency relation must be such as to take account of the retrace time between each pair of lines. Although good bars for checking linearity can be obtained with a sine wave modulation signal, square-wave pulses will produce more distinct bars having sharp edges, which are useful for checking video response.

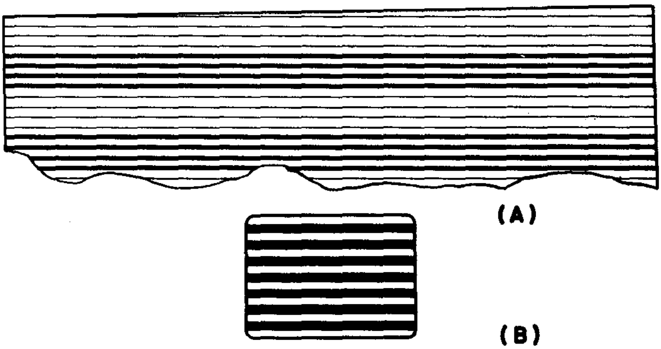


Fig. 2-12. How horizontal bars are formed in a tv raster by the presence of a modulation signal of frequency lower than the horizontal-deflection frequency. The negative portion of each modulation cycle blanks the beam for several horizontal lines.

Suppose now that the modulation frequency of our generator is variable, and that we gradually reduce the modulation frequency. As it is lowered to a frequency which is such as to produce 11 cycles during one scanning line, we see 11 vertical bars, 10 cycles produces 10 vertical bars, and so on, until we reach the horizontal deflection frequency of 15.75 kc, when there will be only one vertical bar. Now if we lower the modulation frequency still further, *the bars change from vertical to horizontal.* The reason for this is shown by Fig. 2-12. A modulation signal of a frequency that is several times lower than the horizontal deflection frequency has individual cycles which extend over a number of horizontal scanning lines. Consequently, at least several lines are blanked out at a time, thus giving the effect of horizontal bars. The number of bars may be changed by varying the frequency of the modulating signal.

Fig. 2-13. Photographs of typical, modern a-m signal generators.

***Note:** The above photos are reproduced through the courtesy of the manufacturers indicated.*

Now if the signal generator carrier is modulated by both the high and low frequency signals at the same time, both horizontal and vertical bars appear, and the instrument becomes a cross-hatch generator.

The same effects can be obtained if the modulation signal alone is fed into the video amplifier of the tv receiver, simulating the condition when the modulated r-f signal is demodulated in the previously described process.

Chapter 3

MARKER GENERATORS AND CALIBRATORS

3-1. Purpose of Marker Generators

The name "marker generator" is quite descriptive. Marker generators are designed to operate on fixed frequencies, so as to mark these frequencies on a response characteristic. When a response curve of a component or piece of equipment is being swept out by a sweep generator and oscilloscope, the *exact* limits of the sweep range, or the scale of frequency along the horizontal axis, are not usually known. Even if the approximate limits are known, it is generally difficult and inconvenient to measure off the frequencies of various significant points along the response characteristic. This is particularly true if the frequency change is not linear. An extra signal, which produces a small mark to identify its frequency on the response curve, is of great help in evaluating the curve and making any necessary adjustments.

For example, if a tv receiver is being aligned visually with a sweep generator and oscilloscope, a typical response characteristic may be that shown in Fig. 3-1 (A). Of particular interest in the shape and width of the curve are points *a*, video i-f frequency; and *b*, sound i-f frequency. (The response curve shown is that of the video i-f section of a receiver.) Also important in the observation and adjustment of such a response curve are such points as the peaks, such as marked at *c*, and the minimum point in the "valley" of the curve shown at *d*.

Figure 3-1 (B) shows a typical response curve for the video-amplifier section of a tv receiver, with a marker at each megacycle. The usefulness of such markers in providing an accurate frequency scale is obvious.

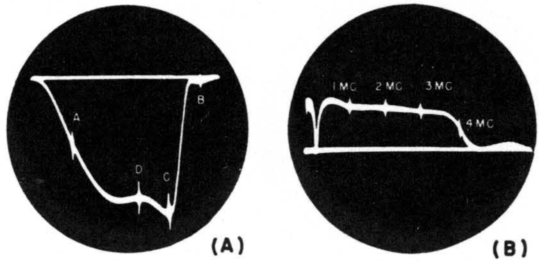


Fig. 3-1. (A) Use of marker pips to indicate frequencies of important points on a tv i-f response curve: a—video i.f., b—sound i.f., c—check point often specified by manufacturers. (B) Typical tv receiver video-response curve, showing marker pips every megacycle.

3-2. How a Marker Pip Is Produced

When a steady, unmodulated signal, at a frequency within the pass band of a circuit whose response to be observed, is fed into a tv receiver, this constant-frequency signal will be rectified by the video detector and appear at its output as a d-c voltage. Since direct coupling is frequently used between the video detector and the first video amplifier, the steady r-f signal will merely change the bias on that stage.

Now if a sweep signal for alignment or response observation is applied to the receiver and a response curve traced on an oscilloscope screen, the marker signal will become visible if it is of a frequency within the range through which the sweep generator is sweeping and if it is of the proper relative amplitude.

Let us consider why the sweep signal must be present before the marker is visible. As explained above, a single unmodulated r-f signal, even if within the pass band, becomes merely a steady d-c voltage in the video section, and is not even that after an r-c coupled stage or instrument is passed (such as, for instance, the vertical amplifier of most oscilloscopes). Now suppose the sweep signal is also applied. As the sweep signal passes the frequency of the fixed marker signal, it heterodynes with it. As the sweep signal frequency approaches that of the marker, the beat signal between them has a relatively high frequency; the beat frequency decreases to zero, and then rises until it disappears again, just as occurs in a radio receiver as we tune through a steady carrier with the beat-frequency oscillator on. However, since the sweep generator signal frequency sweeps rapidly across its range, the heterodyne is produced only momentarily on each sweep and retrace motion. These momentary heterodynes are repeated so rapidly that they blend into one steady indication on the oscilloscope. On an oscilloscope of limited bandwidth, or on a wide-band scope whose response is temporarily reduced by means of a shunt capacitor, an indication of the heterodyne appears for only a few hundred kilocycles on either side of zero beat. Since this represents only a very narrow spread compared to the entire

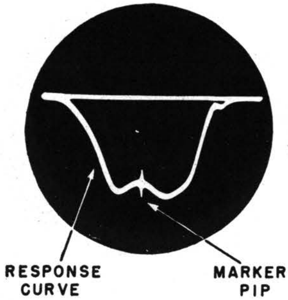


Fig. 3-2. The appearance of a typical marker pip on a response curve.

response of the circuit, a fairly sharp, well-defined indication appears on the response curve at the frequency of the marker generator.[1]

The indication given by a marker on a response curve is called a "pip." The appearance of a pip is shown in Fig. 3-2. The height and broadness of the pip depend upon the amplitude of the marker signal, the response of the oscilloscope, and the *relative response of the receiver at the marker frequency.* Since the pip is a heterodyne between the marker and sweep signals at the second detector, its size depends upon the amplitudes of both signals in the detector circuit. For example, consider the response curves in the double exposure of Fig. 3-3. When the marker frequency corresponds to a high-response portion of the curve (as at *a* on the inner curve), not much marker amplitude is required for a substantial indication. However, at the sides and at the edges of the response, as at point *b* on the outer curve, there is not much receiver response. Therefore, the marker amplitude must be increased to provide indication.

If equipment for sweep analysis is not available, a variable-frequency marker can be used to determine roughly the receiver response. For this it is desirable to have amplitude modulation of the marker carrier. The

Fig. 3-3. The marker signal must heterodyne with the sweep signal in order to produce a pip. Where the receiver response is low both signals are weak at the second detector, thus their beat signal and the pip are weak. That is why much more marker amplitude is required to produce a pip at b than at a.

[1] Further details about the conditions for producing this indication are given in Chapter 9.

modulation is turned on, the marker generator is coupled to the receiver, and the resulting audio output from the video section is indicated on an output meter. The frequency of the marker generator is then varied through the response range and the resulting variation of output is noted. A graph of the output against frequency can be developed by taking readings at regular steps in frequency, as for instance, every tenth or quarter of a megacycle. Of course the input r-f signal must be kept to a low enough level to prevent overloading or agc action, or a bias battery added to keep the output-versus-input relation as linear as possible.

3-3. Requirements of a Marker Generator

From the discussion in the previous section, it becomes evident that a good marker generator must have the following qualifications:

1. It must produce a steady unmodulated r-f signal at desirable frequencies in the pass band to be investigated.

2. It must cover the desired frequency range, preferably by continuous variation, or, if crystal controlled, at a sufficient number of frequencies to provide all the information desired.

3. Some method of checking the exact frequency within close limits should be provided, to ensure that the marker indications have proper meaning.

4. The marker frequency should be stable, so that between frequency checks and during tests the frequency will not change to give wrong indications.

5. The amplitude of the marker output voltage should be variable by means of a smooth-variation control and preferably also by a step attenuator.

6. It is desirable in some cases that amplitude modulation by an a-f tone be available, for identification and other purposes.

3-4. Use of A-M Signal Generator for Marker

A study of the requirements listed in the previous section makes it apparent that an ordinary a-m signal generator whose frequency range includes frequencies desired for marking, can be used as a marker generator. The calibrated dial, the output attenuator, and the modulation are all useful for marking purposes as well as in other a-m generator applications. However, the calibration by itself should not be depended upon as final in setting the marker frequencies. Some sort of frequency check should be made to make sure the frequency of each marker is correct.

3-5. Marker Generators

Most commercial generators labeled "marker generators" are of the type designed for tv visual response checking. They have variable oscillators which cover the i-f range from 20 to 30 mc, or from 20 to 50 mc, and the r-f channel range from 54 to 216 mc and above. However, a few special laboratory instruments are available for providing markers at various other frequencies.

The controls on marker generators are very similar to those on regular a-m generators, including continuous and step attenuators, modulation on and off switch, frequency range switch, and calibrated dial.

3-6. Calibrators

The requirement that the frequency of the marker be checked and known to be accurate is an important one. For this reason, marker generators are usually accompanied by devices called *calibrators.* Calibrators are simply crystal oscillators with some additional circuit in which the marker-generator signal can be mixed with the calibrator-oscillator signal or one of its harmonics for comparison. The block diagram of a crystal calibrator is given in Fig. 3-4.

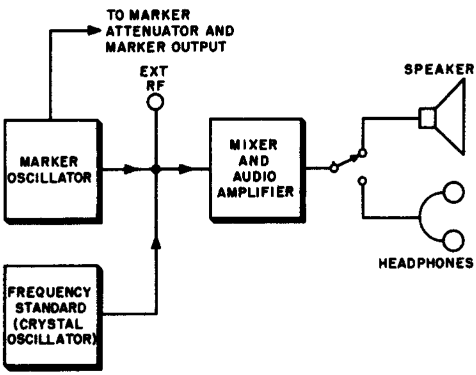


Fig. 3-4. Block diagram expressing the action of a crystal calibrator. The marker signal beats against harmonics of the crystal-oscillator output. The beat signal is detected by the mixer, amplified, and reproduced by speaker or headphones. The marker oscillator is adjusted so that the beat signal is at zero beat. Provision is made on some models for an external marker signal to be checked, as indicated by the terminal "Ext RF."

The frequency of the crystal oscillator is usually chosen at some even number, such as 100, 250, 500 or 1,000 kc or 2.5, 5, or 10 mc. Then the harmonics fall at convenient divisions along the calibration scale. For example, as in Fig. 3-5, the crystal oscillator may be at 2.5 mc when the marker oscillator is to be checked at 25 mc. When the marker is tuned close to 25 mc, its signal will start to beat against the tenth harmonic of the crystal oscillator, which is also at 25 mc. As additional

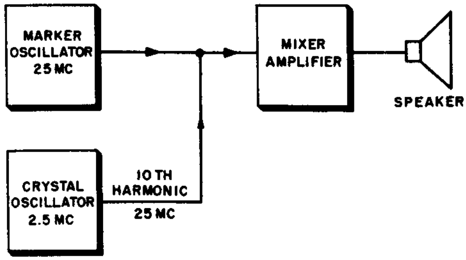


Fig. 3-5. Block diagram giving example of frequency values possible in a typical case of checking a marker at 25 mc against the tenth harmonic of a 2.5-mc crystal oscillator.

checks, there will also be another harmonic of the crystal oscillator at 22.5 mc (ninth harmonic) and another at 27.5 mc (eleventh harmonic). If the marker frequency dial is even reasonably well calibrated, it can be used to determine quite closely frequencies between two successive 2.5-mc harmonics, once the harmonic points have been checked. If the calibrated dial readings do not check with the crystal-oscillator harmonics, the difference in each case should be noted, and the readings between harmonics corrected accordingly. Frequently, the marker frequencies to be used fall exactly on a harmonic of the crystal calibrator oscillator. Then the marker can be set directly on the desired frequency by zero-beating it with the crystal-oscillator harmonic, and no reference to dial calibration is necessary, except to make sure that the proper harmonic is being used.

It is desirable to have more than one crystal calibrator frequency, with one frequency much higher than the other. The higher frequency harmonics can be used to place the marker frequency dial fairly close to the proper setting. The lower frequency oscillator harmonics can then be used for the final close check. In fact, usually without the higher frequency check point, it is difficult to identify the proper harmonic.

As a case in point, consider Fig. 3-6. This shows a typical dial calibration, in megacycles, of a marker generator. Suppose a 250-kc oscillator is used to provide calibration check points. Its harmonics will provide signals at each multiple of .25 mc. However, suppose the dial calibration is in error by the difference between the solid and dotted arrows in the figure. We cannot then tell whether we are beating against the 21.0, the 21.25, or the 21.5-mc harmonic if we have the dial set at the point indi-

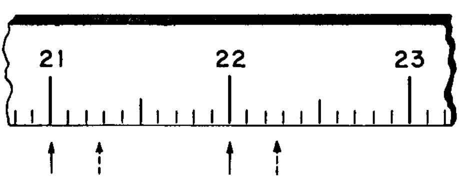


Fig. 3-6. Calibration such as might be used for the tuning dial of a marker oscillator. This diagram is used in the text to show why two crystal oscillators are desirable in making a good check of frequency calibration.

cated by the first (left) dotted arrow. But now suppose we have also a crystal oscillator at 1 mc (1,000 kc). If we switch on this 1-mc oscillator, and turn off the .25-mc oscillator, we shall then have check points every megacycle. It is unlikely that the dial calibration in this case is off more than a relatively small part of a megacycle; thus the nearest 1-mc point can always be identified. Once the 1-mc point is identified, the 1-mc oscillator can be shut off and the .25-mc oscillator turned on. Then starting from the 1-mc point, we can count .25-mc points until we come to the one we want. For instance, suppose we want a marker at 21.5 mc. We turn on the 1-mc oscillator and turn off the .25-mc oscillator. We can then identify the 21-mc point as the nearest harmonic to the 21-mc dial calibration point. We set the dial to this point, switch back to the .25-mc oscillator, and then tune the generator dial higher until we hear the next harmonic beat, which will be 21.25 mc; we then continue to tune higher until we beat against the next harmonic, which is the desired 21.5-mc point.

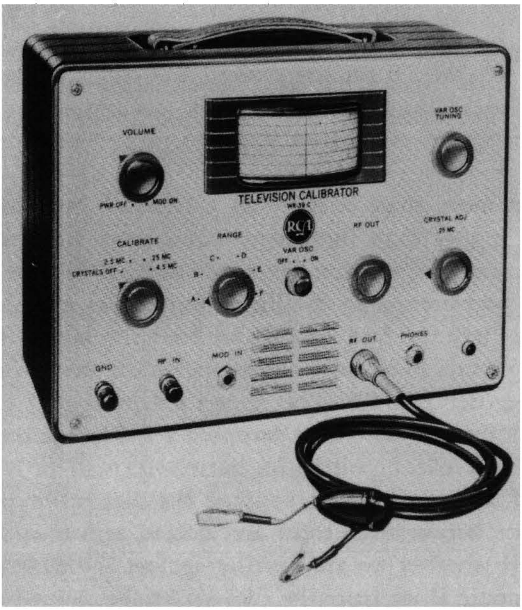


Fig. 3-7. Typical combination marker oscillator and crystal calibrator.

Courtesy: RCA

A typical marker oscillator and crystal calibrator is illustrated in Fig. 3-7. It covers the i-f range from 19 mc, and all the vhf tv channels. The crystal calibrator is completely self-contained, and has .25-mc, 2.5-mc, and 4.5-mc oscillators. A loudspeaker mounted on the front panel reproduces the beat signal between the calibrator harmonics and the marker signal. An external marker or crystal-oscillator signal can be injected into the calibrator through a terminal on the panel; thus other marker signals can also be checked with the same calibrator. There is a suitable attenuator to provide variation of the amplitude of the marker signal.

3-7. Absorption Markers

There is another way to provide marking on a response curve, without the use of a marker generator. This is known as the *absorption* method. While the absorption marker is not derived from a generator, its facilities are often provided in a sweep-generator unit.

The principle is simple. A series tuned resonant circuit is connected across the leads from the sweep generator to the receiver. Whenever the sweep-generator frequency sweeps through the marker frequency to which the resonant circuit is tuned, the resonant circuit acts as a very low impedance and causes a momentary reduction of r-f output until the sweep signal has passed the marker frequency. This produces a noticeable dip in the response curve at the frequency to which the resonant circuit

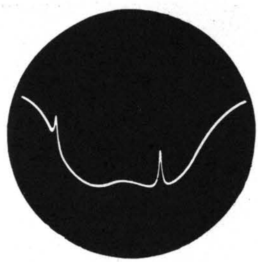


Fig. 3-8. Appearance of absorption marker indications on a response curve.

is tuned. Marker frequencies are adjusted by simply tuning the variable element of the tuned circuit, which is usually equipped with a calibrated dial. The appearance of such absorption markers in a response curve is shown in Fig. 3-8.

It is also possible to produce a marker on a response curve by means of a parellel tuned resonant circuit. This circuit is connected in series with the hot lead from the sweep generator to the receiver. Whenever the sweep-generator frequency sweeps through the marker frequency, the parallel-tuned circuit acts as a very high impedance and causes a reduction in r-f output. Under some conditions, a peak rather than a dip may occur at the resonant frequency of the parallel circuit with this hook-up. This may be due to a sudden reduction in sweep-generator loading at

Fig. 3-9. Photographs of typical, modern marker generators and calibrators.

Note: The above photos are reproduced through the courtesy of the manufacturers indicated.

resonance, which causes a pronounced increase in generator output at th marked frequency. In any case, whether a peak or a dip occurs, the indi cation that should be looked for is a sudden irregularity in the appea ance of the response curve at the resonant frequency.

Chapter 4

SWEEP GENERATORS

4-1. Types of Sweep Generators

Sweep signal generators are those which provide frequency modulation of the r-f carrier signal, so that they may be used for sweep analysis of a response curve of a radio or tv receiver or other device. The methods by which such sweep analysis is accomplished are explained in Chapter 8. In this chapter we are primarily concerned with the basic types of sweep generators and their principles of operation.

Sweep signal generators can be roughly divided into three classes: (1) those with a rather limited sweep range (up to about 1 mc) designed primarily for f-m receiver alignment, (2) those designed for tv receiver alignment (sweep up to 15 mc or so), and (3) special laboratory devices with greater sweep ranges.

Although some sweep generators of type (1) have been available, they are now in the minority in practical use. This is because those of type (2) nearly always have sweep-width controls which will allow adjustment of the sweep width to a low enough value to provide for f-m receiver alignment, as well as provide for the greater sweep width necessary for tv alignment. Type (3) generators are special laboratory equipment and not of as great an interest in the field as those of type (2). Accordingly, it is type (2) which we will be concerned with mainly.

4-2. Use of Reactance Tube for Frequency Sweep

The reactance tube is one of the main methods used for providing frequency modulation in sweep generators. Let us review briefly how a reactance tube works. The reactance tube produces artificially, by electronic means, the effect of capacitance or inductance. More important, it provides the means of varying the value of that capacitance or inductance by variation of a d-c control voltage applied. If the effective capacitance or inductance produced by the reactance tube is made to form an appreciable part of the capacitance or inductance of the tuned circuit of an oscillator, the frequency of that oscillator's signal can be made to vary by the variation of a d-c control voltage applied to the reactance tube. If the d-c control voltage is made to alternate (that is, become low-frequency alternating current) the oscillator frequency also alternates and thus becomes a "sweep" frequency. This is the method used in some sweep generators to provide the desired frequency sweep.

A typical reactance tube circuit is shown in Fig. 4-1. The operation is as follows:

1. R-f is coupled to the plate and cathode of the reactance tube from the oscillator tank through *C2* and *C3*.

2. This causes the reactance tube plate-cathode circuit to act as a load across the oscillator tank. The current drawn through this load depends upon the value of the grid bias, which in this case is the control voltage across *R1*.

3. Also across the oscillator tank circuit is the series combination *C1-R1*. This series circuit is designed so that the reactance of *C1* is much greater than the resistance of *R1*. The current through this circuit is therefore leading the oscillator voltage applied by nearly 90 degrees. This current through *R1* produces a voltage drop which is also nearly 90 degrees ahead of the oscillator voltage. This *R1* voltage is applied to the grid of the tube and there acts to control the current in the plate circuit. The plate current variations are in phase with the grid voltage variations. Since the latter are almost 90 degrees *leading* with respect to the r-f voltage applied from the oscillator, the plate current is also almost 90 degrees leading with respect to the oscillator r-f voltage.

The result of all this is that, looking from the oscillator toward the reactance tube, the oscillator sees a load which draws current that leads the applied voltage by nearly 90 degrees. Since this is exactly what would happen if a capacitor were connected in place of the reactance tube, the oscillator does not distinguish it from a capacitor, and its frequency is controlled accordingly.

The larger the capacitance, the greater r-f current it will draw from the oscillator; in the same way, the more positive (or less negative) is the control voltage on the reactance tube, the more current the tube draws. Thus the more positive the control voltage, the larger will be the capacitance exhibited by the reactance tube; the more negative the control voltage, the less the capacitance.

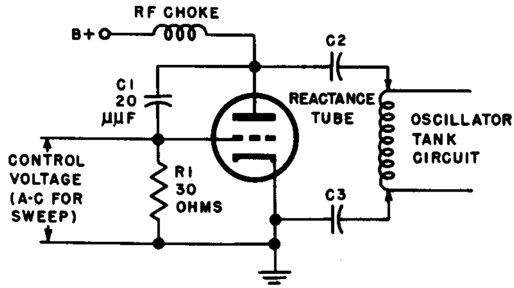


Fig. 4-1. Reactance-tube circuit, such as is used to frequency modulate the r-f oscillator in a sweep generator.

Now if the control voltage is made to vary rapidly back and forth, we produce the same effect as though we were rapidly rotating a variable capacitor across the oscillator tank circuit. This effect causes the oscillator to change frequency rapidly in accordance with the control voltage changes. In other words, the oscillator frequency "sweeps" back and forth.

In sweep generators of the reactance-tube type, a small voltage derived from the power line is applied as control voltage. This voltage is ordinarily a 60 cps a-c sine wave, and thus causes the oscillator frequency to vary sinusoidally.

In sweep generators, the sweep width is controlled by variation of the a-c control voltage applied to the reactance tube. The oscillator whose frequency is being swept is usually operated at a rather high frequency (the values in Fig. 4-1 are for an oscillator at 40 mc) so that a given percentage of frequency deviation can produce as high as possible a sweep in megacycles. For constant sweep width with varying output center frequency, and for reasons of stability, the oscillator which is thus frequency modulated is usually kept at a fixed center frequency, while variable output center frequencies are obtained by *heterodyning* with another, unmodulated, variable frequency oscillator. This is explained more fully later in this chapter.

4-3. Use of Vibrating Capacitor for Frequency Sweep

The second method for obtaining frequency sweep is a mechanical method, usually employing a vibrating capacitor. This is a development from an older method, in which the shaft of a variable capacitor was made to rotate rapidly, causing the capacitance to change rapidly from minimum to maximum and back again in a regular periodic manner. This capacitor, connected in an oscillator tank circuit, caused the frequency of the oscillator to sweep back and forth in the desired manner.

The more modern method frequently utilizes a capacitor whose plates can move closer or further apart. The spacing between them is varied by means of an electromagnet connected to an a-c power-line voltage. The idea is shown in Fig. 4-2. In most cases the capacitor plates are cylindrical, as shown, with one moving inside the other. One plate is fixed in position, while the other is kept in motion by a coil-and-magnet arrangement (similar to the voice coil and magnet assembly of a loudspeaker), actuated from an a-c voltage source. A springy suspension of some kind keeps the armature in its static position. As the moveable plate moves out of the stator, the capacitance becomes less; as it moves into it, the capacitance becomes greater. Since the voltage applied to the moving coil is alternating rapidly, the capacitor rotor plate is moved rapidly back and forth, thus rapidly varying the capacitance. As shown, the capacitor plates are connected across the oscillator tank coil. The rapid variations in capacitance cause rapid variations in oscillator frequency, and the desired sweeping action is accomplished. Frequently the stator is made in two sections so that a split-stator capacitor is formed.

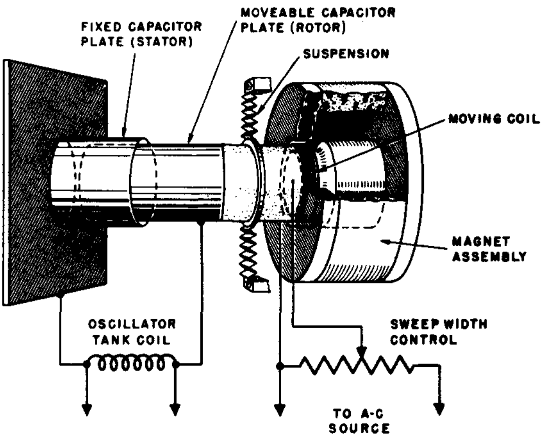


Fig. 4-2. Diagram showing the operation of a vibrating capacitor for sweeping the r-f oscillator in a sweep generator.

The distance the moving assembly travels back and forth depends upon how much voltage is applied to the moving coil. The amount of capacitance variation, and thus the sweep width, depends upon the distance through which the assembly moves. Consequently, the sweep width depends upon the voltage applied to the moving coil. This is the principle used in controlling sweep width in generators using modulation of this type. As shown in the figure, the sweep-width control is one which varies the voltage applied to the actuating coil.

A typical vibrating capacitor is illustrated in Fig. 4-3. Note that, to increase the capacitance and its variation, several coaxial plates are used in the capacitor. In this case, the rotor plates are grounded through

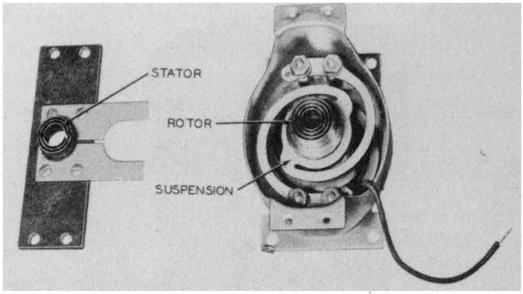


Fig. 4-3. Typical vibrating capacitor.

Courtesy: RCA

the centering spider, and the split stator plates are insulated above ground by the insulating material at the top.

(NOTE: The type of electromechanical driving mechanism described above is also sometimes used to move a copper or aluminum disc toward and away from a coil which forms the inductance of the swept oscillator. As the disc is moved closer to the coil, the inductance is reduced and the oscillator frequency is raised. As the disc is moved away from the coil, the inductance is increased and the oscillator frequency is lowered. When a.c. is applied to the coil in the driving mechanism, the disc moves alternately back and forth and thereby causes the oscillator frequency to vary in step.)

4-4. Use of Controllable Inductors for Frequency Sweep

Still another method of producing frequency sweep is by the use of a controllable inductor such as the Increductor.[1] This is a special type of saturable inductor which operates at radio frequencies. In a saturable inductor, the effective inductance of a winding on an iron core is caused to decrease if the core is partially saturated with flux produced by current flowing in another winding.

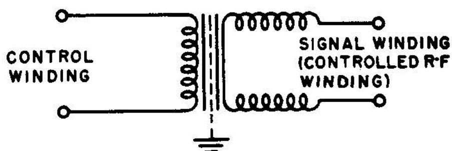


Fig. 4-4. Schematic diagram of a controllable inductor.

The schematic diagram of a controllable inductor is shown in Fig. 4-4. Note the use of the two windings: the *control winding*, to which the changing current is applied which produces the flux that partially saturates the core, and the *signal winding*, whose inductance is caused to change because of the changing flux in the core. This flux, as it approaches core saturation, reduces the permeability of the core and thus results in a reduction of effective inductance. The two windings

[1] Trademark of C.G.S. Laboratories Inc.

Fig. 4-5. A photograph of a typical controllable inductor.

Courtesy: C.G.S. Laboratories

are separated by an electrostatic shield, and are so arranged that practically no electromagnetic coupling exists between them. The entire unit is usually supplied in a hermetically sealed can, which may be mounted in any position. The appearance of one such typical unit is shown in Fig. 4-5.

In normal operation in a sweep generator, an alternating current at the line frequency is applied to the control winding. This causes the inductance of the signal winding to vary over a considerable range. By using the signal winding as all or part of the inductance of an L-C tuned circuit of an oscillator, the oscillator frequency is made to vary back and forth at the line-frequency rate about a center r-f frequency. In this manner, a frequency sweep is produced.

4-5. Phasing

When a sweep generator is being used to produce a response curve on an oscilloscope screen, the sweeping action of the generator frequency and the horizontal sweeping action of the oscilloscope beam should be synchronized not only in frequency but also in phase. If the phase relation is not properly adjusted, then one end of the oscilloscope horizontal trace does not correspond to the lowest frequency swept through by the generator, and the other end does not correspond to the highest frequency, as should be the case. This is illustrated in Fig. 4-6. In this figure, it is assumed that a sweep generator is sweeping between 20 and 30 mc, and that it is being used to depict a response curve on an oscilloscope screen. To make the explanation clearer, the forward and return traces are shown separately (return trace below the forward trace) although in practice they usually coincide.

At (A) the phasing is properly adjusted, so the response curves swept during the forward and return traces coincide. The forward trace sweeps through the frequency range from 20 to 30 mc, while the return trace sweeps in reverse order, from 30 to 20 mc. Thus, when phasing is proper, each point along the horizontal axis represents the same frequency for both the forward and return traces.

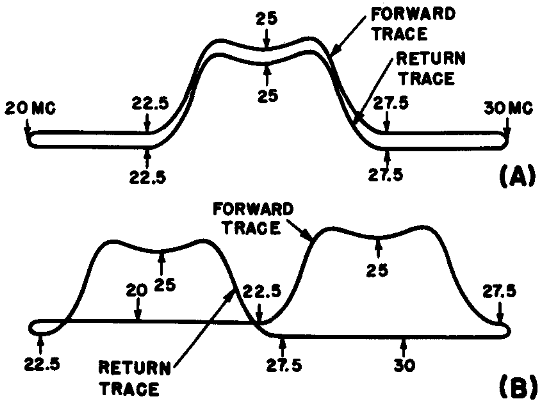


Fig. 4-6. The effect of (A) proper phase adjustment and (B) improper phase adjustment in sweep-response analysis. The forward and return base-line traces are shown separated for clarity, but in practice these would coincide.

At (B) is shown what happens if the phasing is not correct. The sweep generator is starting from its low-frequency extreme (20 mc) *after* the oscilloscope beam has started its forward sweep; by the time the sweep generator reaches 30 mc, the oscilloscope beam has completed its forward sweep and started its return sweep. The result is that the forward and return response curves do not occur at the same point along the horizontal axis and are staggered as shown at (B).

The phase relation between the sweep-generator signal and the oscilloscope sweep is adjusted by a circuit between the generator and the oscilloscope deflection plates. This phase-adjusting circuit may be in the generator or in the oscilloscope, or sometimes there is one in each unit. A common method of obtaining sweep voltage for the oscilloscope and adjusting its phase in the sweep generator is shown in Fig. 4-7. The a-c voltage for both the vibrating capacitor in the sweep generator and the deflection circuit of the oscilloscope are obtained from a low-

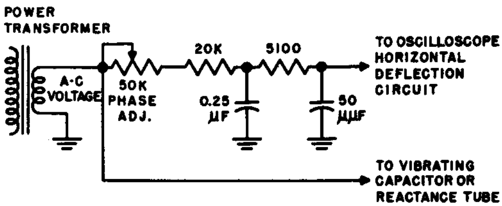


Fig. 4-7. A typical phase-adjusting circuit used in a sweep generator.

voltage secondary winding of the power transformer in the sweep generator. The voltage is applied directly to the vibrating capacitor, but through the network shown to the oscilloscope horizontal input circuit. The relative phase between the two outputs depends upon the adjustment of the 50k-ohm phase adjuster, which varies the amount of resistance in the circuit with the .25-μf capacitor.

4-6. Blanking

As shown in Fig. 4-6, there are actually two traces visible in ordinary sweep alignment or response-curve observation. One is the forward trace, as the oscilloscope beam sweeps from left to right, and the other is the return trace, when the beam returns from the right to the left. If the phasing is properly adjusted, as shown at (A) of Fig. 4-6, the response-curve traces coincide (the traces are shown separately vertically in the figure for clarity, but coincide in practice) and the region *under* the traces is blank. Sometimes it is desirable to remove the return trace of the response curve by eliminating the generator r-f signal during the return-trace period. The oscilloscope beam then returns without vertical deflection, and forms a *base line* for the response curve in the

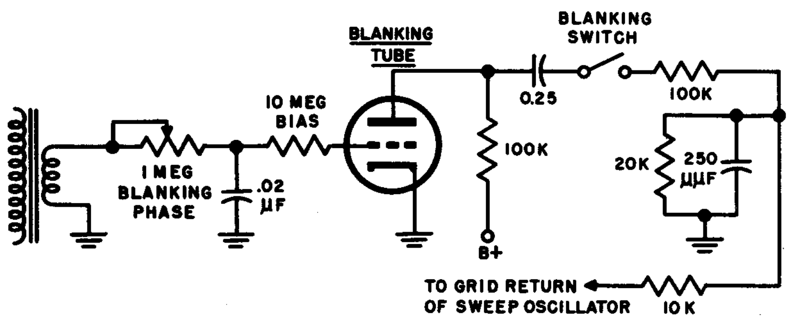


Fig. 4-8. A typical blanking circuit used in a sweep generator.

forward direction. This process is known as *blanking* and a circuit to effect this is provided on many sweep generators.

A typical blanking circuit is shown in Fig. 4-8. Here the blanking tube is normally held cut-off by the bias developed across the large (10 meg) bias resistor. Under these conditions the sweep oscillator operates normally. During the positive alternations of the input a.c., the blanking tube conducts. It therefore operates to place a high negative bias voltage on the oscillator tube so the oscillator stops oscillating and the sweep-generator signal is absent. The blanking-phase control forms a phasing circuit with the .02-μf capacitor so that the phase of the blanking voltage may be adjusted to stop the operation of the sweep oscillator during exactly the proper time (while the sweep generator produces the reverse sweep and the scope retrace occurs). Examples of response curves with base lines produced by the blanking facility of the sweep generator have already been shown in Fig. 3-1.

4-7. Sweep-generator Combinations

Sweep generators are manufactured in a number of combinations with other auxiliary features. Many of them contain marker oscillators independent of the main sweep oscillator. Sometimes there are also calibrator arrangements for frequency checking of the markers.

Several combinations are available for providing practically all the units necessary for sweep-response analysis in one unit. For example, the Philco Visual Alignment Generator, Model 7008, and the Simpson Genescope, include sweep generator, marker generator, and oscilloscope all in one interconnected unit, controlled by switches from the front panel. In these units, the individual parts operate on the same principle and generally contain the same features as these units do when employed separately.

4-8. The Heterodyne Principle Employed in Sweep Generators

The methods used to sweep the frequency of the r-f oscillator, explained earlier in this chapter, are limited in the practical percentage of frequency change they can produce and still maintain symmetry, linearity, and stability. For this reason it is usually more feasible to modulate the frequency of an oscillator at a high, or moderately high frequency; then, with the same *percentage* of frequency variation, a wide sweep width can be obtained.

Accordingly, a large number of sweep generators employ the heterodyne system of adjusting center frequency while keeping the sweep at a constant width. Different manufacturers use different combinations of frequencies, but the block diagram of Fig. 4-9 will illustrate the idea. The frequencies are not those of any particular model but are chosen to demonstrate how this system works. An oscillator is operated at a fixed center frequency of 100 mc, and is connected to either a vibrating capacitor or a reactance tube, so its frequency is swept over the desired range. A second oscillator is designed so that its frequency can be varied by adjustment of the main tuning knob, but its frequency is not modulated, or swept. This oscillator can be tuned either from 100 to 200 mc or from 200 to 300 mc.

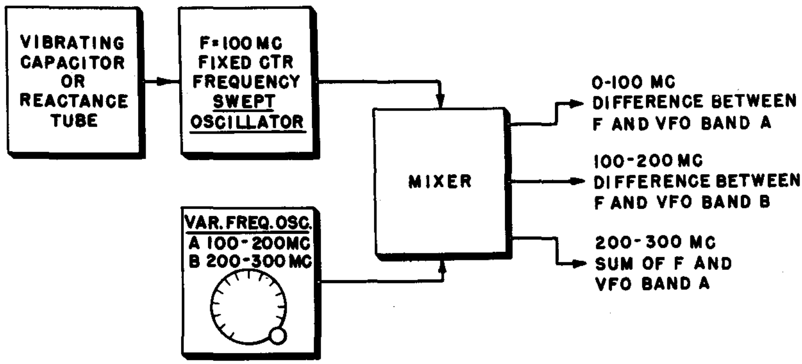


Fig. 4-9. How a variable-oscillator signal and a signal from a swept oscillator with a fixed center frequency are combined to provide a wide range of output frequencies with a constant sweep width.

The output signals from both these oscillators are fed to a mixer circuit where they heterodyne with each other to produce sum and difference frequency components. As shown in the figure, by proper use of the beat signals, a range from zero to 300 mc is available. But the important factor in this case is not the range, which would be more easily available with a single oscillator. What is more important is that all the output beat signals have the frequency sweep of the same width as the swept oscillator. Since the output has either the sum or difference frequency, this output frequency must follow the frequency variations of the swept oscillator. Because no frequency multiplication has taken place, the width of the sweep is the same at all output frequencies. If harmonics of the swept oscillator were used, the sweep width, in megacycles, would be multiplied by the same factor as the center frequency. For example, in Fig. 4-9, if the second harmonic of the swept oscillator, instead of a heterodyne, were used for 200-mc output, the sweep width at the harmonic frequency would be twice that obtained at the fundamental 100-mc frequency.

In most generators to be used for sweep output only, the main dial is the frequency control for the variable oscillator. This dial is calibrated in terms of the heterodyne frquency which is actually to be used at the output, rather than in terms of the frequency of the variable-frequency oscillator which it controls. The latter is of no particular importance to the user of the generator.

4-9. Generators in Which the Swept Oscillator Itself is Tunable

It is ordinarily not desirable to tune the center frequency of a swept oscillator through a range on continuously tuned sweep generators. This is because most tuning is accomplished by means of a variable capacitor. If a vibrating capacitor is used for sweep, its varying capacitance is added in the circuit to that of the variable capacitor used for tuning. When the variable capacitor is adjusted for maximum capacitance, the vibrating capacitor is then only a relatively small part of the total circuit capacitance, and the sweep width is small. When the variable capacitor is adjusted for minimum capacitance, the vibrating capacitor is a large part of the circuit capacitance, and the sweep width is relatively large. This would be highly inconvenient in the use of the generator, since each time the center frequency is changed the sweep width must be checked or adjusted.

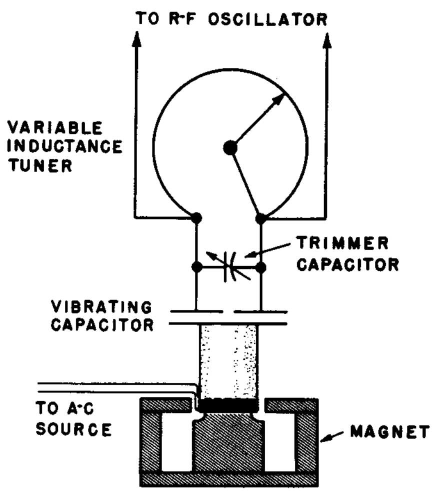


Fig. 4-10. Tuning and sweeping circuit of the Philco Model 7008 sweep generator, in which the swept oscillator itself is also tunable through a range. The use of inductance tuning allows tuning the center frequency through a range without much change in sweep width.

Fig. 4-11. Photographs of typical, modern sweep generators.

***Note:** The above photos are reproduced through the courtesy of the manufacturers indicated.*

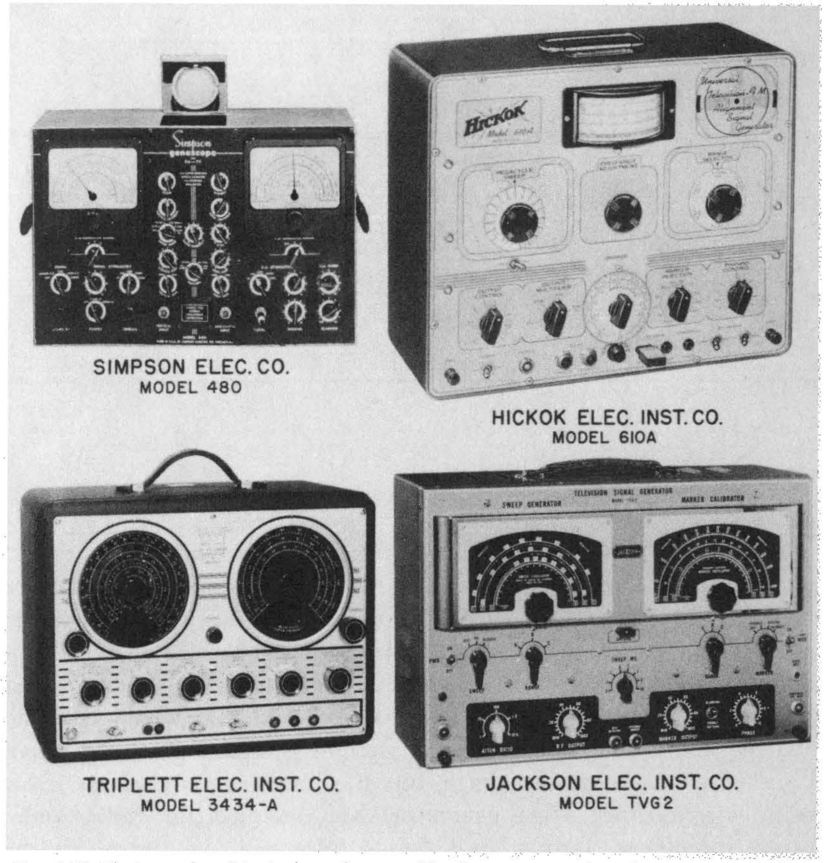


Fig. 4-12. Photographs of typical, modern combination sweep and marker generator units.

Note: The above photos are reproduced through the courtesy of the manufacturers indicated.

However, when the oscillator is designed to be tuned by variation of *inductance* instead of capacitance, the swept oscillator can be tuned through a range of frequencies without too much variation of sweep width. This is because the variation of capacitance of the vibrating capacitor remains the same percentage of the total circuit capacitance as the frequency is changed by variation of the inductance. A typical oscillator circuit tuned by inductance and swept by a vibrating capacitor is shown in Fig. 4-10. The swept oscillator can thus be varied over its own center-frequency range, and this oscillator can be used directly for output over that range. For other ranges it is simply heterodyned with a fixed-frequency unmodulated oscillator to provide sum and difference frequency outputs.

Chapter 5

FREQUENCY CHARACTERISTICS

5-1. Range

In Chapter 1, we discussed the frequency ranges of various types of instruments. It is naturally desirable that as much of a frequency range as possible be included in each instrument. However, if a generator is to be reasonably priced, there is a limit to the range which can be provided. Tuning systems for the oscillator frequency have a limited coverage, and the number of ranges must not exceed that which is feasible in wiring and switching. Therefore, attempt is seldom made to provide a "universal" frequency coverage, but the range is planned for certain specific applications. Most generators are designed for radio and tv receiver alignment, testing, and design. However, incidental to their primary design purposes, they find many other varied applications, some of which are reviewed in Chapter 10.

5-2. Calibration

Most dial calibrations are simple, straightforward, and more or less self-explanatory. In most models, all ranges are calibrated on the same dial, with a selector switch to choose the desired range. In most general-coverage a-m generators, as many as seven or eight ranges may be necessary to cover all frequencies included. If the dial is circular, these ranges are ordinarily calibrated in concentric circles.

If the full range of the tuning capacitor is covered in 180 degrees of rotation or less, two sets of scales are sometimes placed on one circular dial. This arrangement is illustrated in Fig. 5-1. Half of the ranges are placed on the top part of the dial and the other half on the lower portion. There is a separate indicator pointer mark for each set of cali-

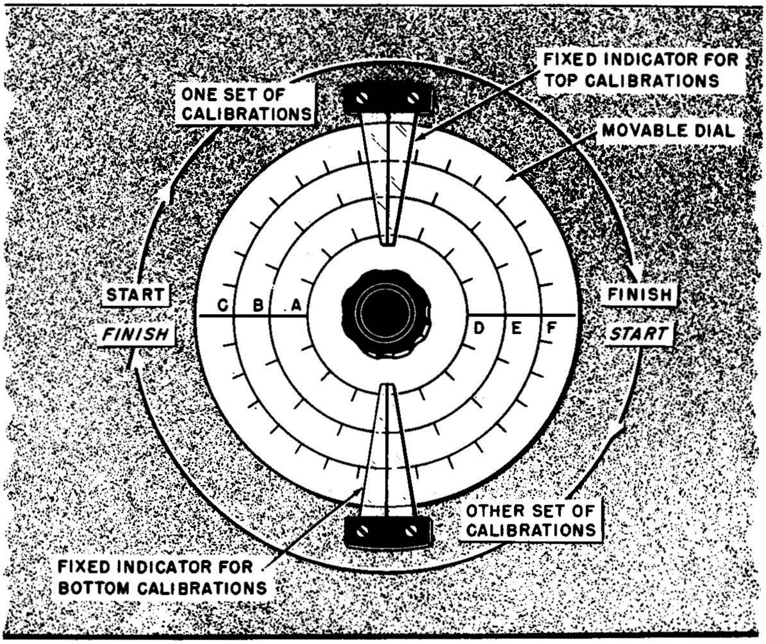


Fig. 5-1. When a circular dial is used, and the total range is covered in 180 degrees or less of rotation, two sets of scales can be available, one set in the upper portion and the other set in the lower portion. This is illustrated by the dial shown here.

brations. Some generators have the calibrations fixed on the panel and the index, or indicator mark, rotates over it, as shown in Fig. 5-2.

Not all dials and scales are of the circular type. Some are of the "slide-rule" type popular in many radio receivers. In others, the scale face is a revolving cylinder whose axis is vertical. This cylinder, with the calibrations marked on it, revolves past the vertical index marker on the generator panel. An example of such an arrangement is shown in Fig. 3-7.

5-3. Verniers

A vernier is a device for either indicating, or allowing setting to, given values of dial settings with greater accuracy than is possible with an ordinary dial. If the electronic system is stable, very good accuracy of frequency indications is obtained.

The vernier was originated by the French mathematician Pierre Vernier in the 17th century. A typical vernier scale drawn on a horizontal base is shown in Fig. 5-3. The fixed index indicator, instead of

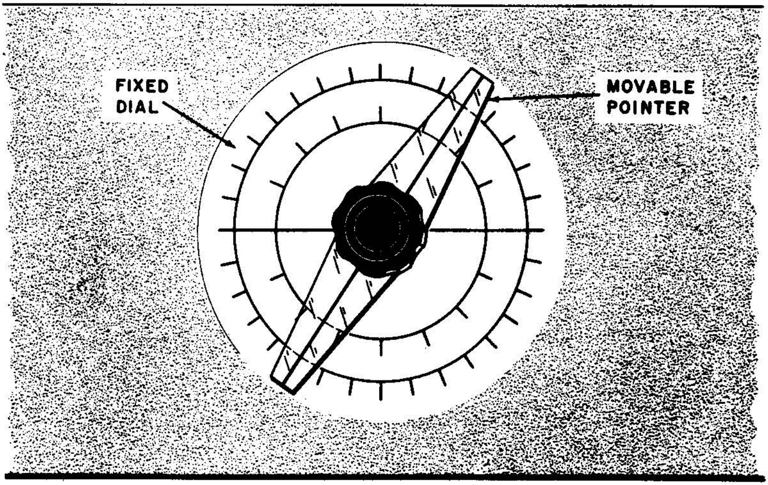


Fig. 5-2. With some generators, the calibration scale is stationery, while the index mark revolves over it, as shown here. The revolving pointer is made of clear plastic.

being just a single vertical line, is a series of 11 vertical lines, calibrated from 0 to 10 inclusive. In its use, we first set the dial to approximately the frequency desired (or read it as already set) by use of the 0 (zero) mark used as an ordinary index, as on ordinary dial arrangements. Then, the one fixed index line that aligns itself exactly with a main dial calibration line shows how many tenths of a main dial calibration we are set above the previous calibration line. For example, in Fig. 5-3, the zero index line is showing that we are set for something between 15.7 and 15.8, but the second decimal place is not clear. We then note that on the fixed index scale the line marked "3" aligns itself exactly with a line on the main scale below. This shows that the exact, correct reading

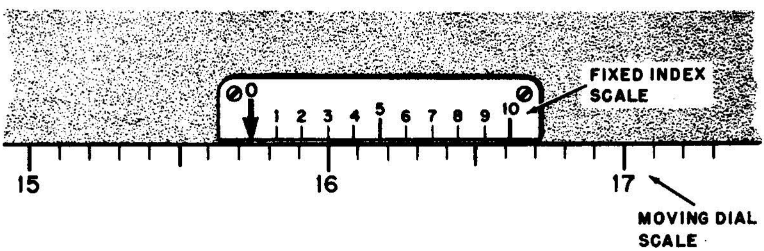


Fig. 5-3. Diagram showing how a vernier is used to indicate small changes in dial reading.

is 15.73. If the main scale is moved a little bit to the left (say 1/10 of a small division), line 3 will no longer be aligned and line 4 will become aligned with the main scale division line nearest it. Under these conditions, the reading is 15.74. Which of the main scale divisions aligns itself with the index line involved in each case is of no consequence.

Of course, verniers do not have to be straight and horizontal. The one shown in Fig. 5-3 is drawn this way only for the sake of simplicity and clarity. Actually, in practice, most verniers are curved and used in conjunction with a circular scale, but the principle is exactly the same.

Although the system just described is the true vernier system, other devices are often loosely referred to as "verniers." This name has in fact been used for almost any arrangement in which a knob is mechanically coupled to the main shaft so as to turn the latter more slowly than if it were turned directly. It is then easier to set the dial for a given frequency or to turn it slowly for certain tests where this is an advantage.

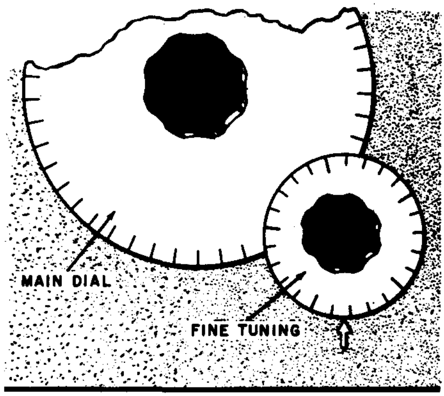


Fig. 5-4. How a fine tuning control is added to the dial in some generators, to provide a means of indicating small increments of r-f oscillator frequency. This is particularly useful in making selectivity measurements.

A few a-m generators have a calibrated fine tuning knob, such as is illustrated in Fig. 5-4. This may be calibrated in percent frequency change, as in such laboratory generators as the General Radio 605B. One of the most important uses of such an arrangement is in checking selectivity. The main dial of a generator cannot be designed to indicate a few kilocycles variation, especially at short-wave frequencies. In the use of the calibrated fine tuning knob of Fig. 5-4, we set the generator for center frequency as checked by the receiver dial. Then we set the generator attenuator for a good reference level output from the receiver, making sure that avc action is not present or is negligible. Next the step attenuator is advanced to give 10 times the voltage output; the generator frequency is then changed *by means of the fine tuning dial* until the receiver output is reduced to the original value. The frequency change indicated by the fine tuning dial indicates the "10-times-down" deviation on the selectivity curve, or half the 10-times-down bandwidth. Fine tuning calibrated dials are also useful for such things as frequency drift checking.

5-4. Frequency Drift and Warm-up

No oscillator is absolutely stable, and signal generator r-f oscillators are no exception. Even crystal-controlled oscillators have a definite drift characteristic, although their drift is negligible compared to all but the most carefully designed self-excited oscillators. Drift is mainly due to temperature effects. It is therefore most apparent when the generator is cold and has just been turned on. The heat dissipated in the tubes, transformers, and resistors is gradually transferred through the unit,

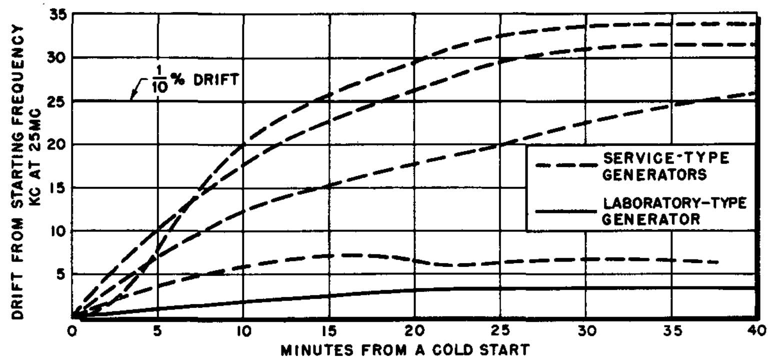


Fig. 5-5. Graph showing the extent of generator drift during warm-up period.

warming up the oscillator components. For this reason it can be expected that, even in the best of generators, some frequency drift will inevitably occur in the first few minutes after the unit is turned on if it has not been used for a while. That is why one of the cardinal rules of signal generator use is: *Always allow the generator to warm up for from 20 minutes to a half hour before using it for any applications in which frequency is important.*

To illustrate the effect of warm-up, Fig. 5-5 shows the warm-up frequency characteristics of several service-type generators and one laboratory type. These characteristics are merely spot checks, but they do give a rough idea of the order of magnitude of frequency change usually involved.

Manufacturers of signal generators try to minimize drift as much as possible. Of course the extent of the measures they can afford to take varies with the ultimate cost of the unit; thus the higher priced laboratory precision types can be expected to be much more stable than the moderately priced service types, as is indicated by Fig. 5-5.

The method of design of oscillators for stability usually involves designing the oscillator circuit and components for best inherent stability consistent with cost, then adding *compensation* in the form of negative temperature coefficient capacitors and similar devices. However, such compensation is difficult to maintain over a large frequency range, so generators with a great frequency coverage may be expected to have slightly worse drift in some portions of the range than comparable generators with a smaller range.

It can be seen from the characteristics shown in Fig. 5-5 that about a half hour warm-up is sufficient to reach the "leveling-off" condition for most types of generators. After this, the unit has usually about reached thermal equilibrium, and further changes in frequency due to temperature change are relatively small.

5-5. Effect of Voltage on Frequency

Another factor which may cause instability of the r-f oscillator is the applied voltage. In most oscillators, there is a definite effect of line voltage changes on oscillator frequency. For this reason, if line voltage is likely to fluctuate, it is important to take this into account, or to provide some means of voltage regulation. In a few of the higher priced generators, a voltage regulator is provided for the plate and screen voltages of the oscillator. This practically eliminates line voltage fluctuation effects within a voltage range of about ± 10 percent. However, a large number of generators do not include this feature, and the reader is urged to investigate the performance of his generator with line voltage changes and take them into account. Without voltage regulation, frequency changes with a 10 percent line voltage variation may be as high or higher than 0.1 percent, or 25 kc at 25 mc.

5-6. Effect of Controls on Frequency

Because of the critical nature of stray capacitance and inductance effects, especially at high frequencies, it is natural that we often encounter variations of carrier frequency with control adjustments. This is particularly true of the continuously variable attenuator. Adjustment of this control in various signal generator models has resulted in a frequency shift of as high as 50 kc at 25 mc in extreme cases, although the average is about 10 kc. At higher frequencies, a somewhat greater percentage of change can be expected, and at lower frequencies, a somewhat lower percentage. Other controls, such as meter setters, width controls, etc., may also affect frequency considerably.

If the variation of frequency involved is important in the tests being made, such control effects must be checked each time an adjustment is made. It is a good idea for the owner of any signal generator to make tests as to just what the effects of the controls are on the output frequency at various carrier frequencies. He will then know what to expect in any given test, and know whether he must correct for such variations or not.

5-7. Center Frequencies in Sweep Generators

In most sweep generators, the variations of frequency due to the factors previously discussed (temperature, voltage, and controls) is negligible compared to the sweep width. For example, sweep generators designed for tv receiver analysis have a sweep width of at least 10 mc. Even an extreme variation of 100 kc would hardly be noticeable. The sweep width is purposely adjusted to extend a megacycle or more beyond the actual response curve width; the frequency drift or variation of 100 kc would merely shift the response curve very slightly along the horizontal axis. In sweep generators designed for f-m receiver analysis, the sweep width is in the order of 500 kc to 1 mc. Consequently, frequency fluctuation may be more noticeable if very severe, but can hardly be considered a serious problem, since in these generators sweep center frequency is nearly always readily adjustable.

In any kind of sweep analysis, markers are required. The marker indications show immediately when the sweep generator's center frequency has drifted. This, of course, emphasizes the importance of extra good stability for the marker frequencies, and it is in marker generators that drift must be carefully controlled.

Chapter 6

OUTPUT VOLTAGE CHARACTERISTICS

6-1. Range of Output Voltage

The output voltage capabilities of various types of signal generators fall into one generator range, namely, from roughly zero to either 10,000 or 100,000 microvolts. This voltage is what is obtainable from the regular output lead, with normal attenuator control. In many generators, an additional output jack is provided from which a voltage in the order of 1 volt or more is obtainable. The latter is usually from a connection on the oscillator side of the step attenuator, so it represents voltage more or less directly from the oscillator. The high output jack is intended primarily for cases in which a radio receiver may be far out of alignment, and can be used until the alignment adjustments are near enough so that the normal output jack can be used. Generally, better stability and control can be expected when the lower voltage from the normal jack is used.

6-2. Attenuators

The purpose and function of attenuators have already been considered (Sections 2-2 and 2-4). There are two types used in generators: the continuous type and the step type. The continuous type is ordinarily just a potentiometer connected across the r-f oscillator output, with the variable tap connected to the output jack, or to the step attenuator, if there is one. Its function is just like that of the volume control of an ordinary superheterodyne receiver, except that here the intensity of r-f voltage instead of a-f voltage is being controlled. If a step attenuator follows, the continuous attenuator controls the input voltage to the step attenuator; the latter controls the maximum voltage at any position, usually in steps of 10.

In step attenuators, the design is such as to attempt to maintain a constant output impedance while the output voltage is varied in the "times-10" steps. A typical example of a circuit that will do this is shown in Fig. 6-1. This diagram shows both the continuous and step-type attenuators used together. Note that the continuous attenuator varies the voltage applied to the input of the step attenuator. At each step of the step attenuator, an output impedance of about 33 ohms is maintained. The step attenuator network used here is often referred to as a "ladder" network, because of the way in which the resistors are arranged.

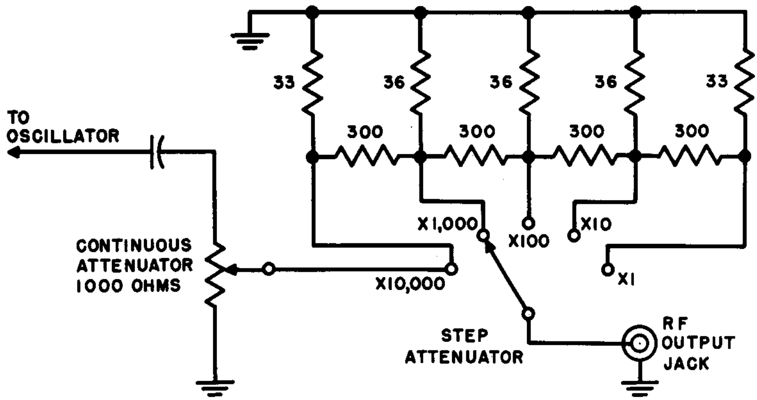


Fig. 6-1. Typical combination continuous and step attenuator circuit for a signal generator.

As the step attenuator switch is moved from the "×1" toward the "×10,000" position, the output signal voltage increases in steps of 10. Occasionally, the markings on the step attenuator are just the opposite to that shown in the figure; that is, the signal output is *reduced* as the setting is changed from "×1" to a "×10,000" position. In this case, the markings indicate the amount of signal attenuation or reduction of signal strength rather than the amount of output signal.

One of the problems of attenuators is leakage. For instance, consider again the circuit of Fig. 6-1. If all these resistors are simply connected inside the generator cabinet without any shielding, the r-f voltage from the oscillator and from the lead at the high-voltage end of the continuous attenuator would be coupled through stray capacitance to the low voltage (×1) end of the step attenuator. The r-f voltage picked up on the two lowest positions (×1 and ×10) may then easily be many times the r-f voltage which is supposed to be there after the action of the attenuator. The result would be that the output voltage would not be affected, or at least not controlled below a minimum value for the attenuator's lowest positions. In the same way, the action of the continuous attenuator when adjusted for very low output voltage may be impaired. R-f voltage can feed by capacitance coupling from the high end of the continuous control to the r-f output jack of the generator.

To avoid such direct leakage and impairment of attenuator action, attenuators are usually shielded, especially the step attenuator. A shield completely surrounds the entire step attenuator, while a separate shielded compartment is provided for the resistors in each step.

As has been previously explained (Chapter 2), the step attenuator is used to provide "jumps" of 10 to 1 in output voltage, and the continuous attenuator can be used to adjust voltages between attenuator steps. Often the continuous attenuator is referred to as the "microvolts" control, and it is then calibrated from 1 to 10 to represent microvolts. For example, on a signal generator with a calibrated output, if the microvolts control reads 7, and the step attenuator is on the $\times 10$ position, the output voltage is 7 x 10, or 70 microvolts. In many cases, the output attenuator is not accurately calibrated so that this control simply serves as a coarse adjustment of the level of the output signal.

6-3. Leakage

Theoretically, all the r-f voltage from the oscillator is applied to the attenuators, is properly adjusted by them, and appears at the end of the output lead for use. In practice, this is not strictly true. In fact one of the greatest problems of manufacturers and designers of signal generators is to keep r-f voltage from radiating, coupling, or conducting to places where it is not wanted, thus affecting the accuracy of adjustments and limiting use of the instrument.

Many a-m receivers have a sensitivity in the order of 1 microvolt. That is, satisfactory reception can be obtained with an r-f voltage applied at the antenna terminals of only 1 microvolt. A very small, low-power oscillator, unshielded, will radiate enough r-f energy from a distance of hundreds of feet to be picked up by such a receiver. To prevent direct radiation from the oscillator in a signal generator to a sensitive receiver, extreme care in shielding of the generator is necessary. For this reason, most signal generators are enclosed in a tight fitting metal cabinet, and most of the individual components inside it are shielded separately. Besides this, as has been explained in Section 6-2, the attenuators are also shielded carefully.

In the higher priced laboratory-type signal generators, the complete generator assembly is enclosed in heavy sheet copper, with individual components also shielded. The more conductive the shielding material, the more effective it is as an r-f shield. However, the service-type generator is ordinarily somewhat less critical, and steel, aluminum, or other types of metal cabinets and shielding are used.

From all except elaborate laboratory types, there should be expected some appreciable amount of leakage. For this reason, when testing with low signal voltages (from 1 to 100 microvolts), one should take all possible measures to overcome the leakage problem. One way to minimize it is to place the signal generator as far away from the receiver or other device to be tested as the generator output lead will allow. However, never try to tamper with, or add to, the output leads supplied by the manufacturer of the generator; the reason will be explained in Chapter 7. Another way to keep the effects of radiation and other leakage down, is through complete and proper grounding. This is also discussed further in Chapter 7.

The relative amount of leakage of a signal generator can be roughly determined if a sensitive receiver is available. Couple the signal generator leads to the receiver and connect an output meter to the receiver output circuit (or use the S-meter if the receiver has one). Now adjust the generator and receiver frequencies so that a signal is picked up by the receiver from the generator. If the receiver is of the high-frequency or short-wave type, the radiation effect is worse at the higher frequencies and should be tested there. Now gradually reduce the output of the signal generator, and with the receiver adjusted for maximum sensitivity try to make the signal disappear. Be sure to allow for frequency changes due to control adjustment and keep the signal always tuned in on the receiver. If there is appreciable leakage, a point will be reached at which the signal in the receiver is no longer reduced by lowering the attenuator control adjustment on the signal generator. This means that the receiver is picking up the signal by radiation, which remains constant, and is therefore not affected by voltage at the signal generator output jack. Of course the effectiveness of this experiment is also affected by the degree of shielding used in the receiver. Some communications receivers are so well shielded that direct radiation from the generator does not enter the receiver circuits. However, leakage in the generator to the output lead connection will still show up in even a well shielded receiver.

The above type of test will show quite a variety of degrees of radiation in different signal generators. In some cases, attempts to reduce input to the receiver of less than 100 microvolts fail. In the best laboratory signal generators, output from the leads can be reduced to a fraction of a microvolt before radiation effects are noticeable.

One important method by which leakage takes place in some signal generators is through the power line. The r-f current from the oscillator is coupled back through the power supply and into the power line. The r-f current in the a-c lead to the generator then acts as an antenna, and radiates the r-f signal to the receiver or the connecting leads from the generator to the receiver. For this reason, many of the more elaborate signal generators use line filters and some even employ shielded power leads.

6-4. Reducing Output Voltage by External Means

In some cases, when a sensitive receiver or similar device is to be tested or aligned, we may have difficulty with *too much output voltage*, due to the effects of radiation. As was explained above, this is most likely to occur when a lower priced type of generator and a sensitive, not-to-well shielded receiver are used. If we are not particularly interested in the value of the voltage applied to the device, but merely want the voltage for such an operation as alignment, the voltage can be reduced by external means.

One of the simplest ways to reduce signal which is excessive is to disconnect the signal generator from the receiver completely. If this does not provide enough reduction, simply start moving the signal generator away from the receiver until the desired intensity of received signal is reached. When only a signal of a given frequency and modulation type is required, and signal voltage need not be measured, there is no necessity at all for connecting the generator unless this is needed to obtain enough signal amplitude, or unless coupling must be accomplished to one specific point. It is not unusual to see someone completely align a sensitive a-m receiver with the generator on a bench ten feet away. However, the moment we are concerned with either absolute or relative signal voltages at the receiver antenna terminals, we must have a direct, proper connection to the receiver. It is then that terminating and shielding become so important, as discussed further in Chapter 7.

Another way of providing reduced output in cases where output voltage is not to be an important factor, is by simply laying the leads against a tube or input circuit without a direct connection. Another way is to wrap the hot lead around the tube of the section in which the signal is to be injected. If a wire from the device to be tested and a wire from the hot lead of the generator are twisted together for a few inches (with one or both wires insulated), the coupling can be varied by twisting and untwisting these wires. All these methods apply primarily to cases in which the direct connection of the generator gives too much voltage, while completely disconnecting it gives too little voltage. Of course, a variable capacitor connected between the generator lead and the receiver input circuit can be used. How large the capacitor is depends upon the frequency and impedance into which the signal is fed. For radio receivers in general, at low frequencies, the capacitor should be several hundred micromicrofarads maximum. At frequencies from 20 mc and up, a small 50- or 100-$\mu\mu$f capacitor should be sufficient.

6-5. Output Meters

It was explained in Chapter 2 that signal generators which are designed to indicate accurately their output voltage must have some kind of meter or other indicator so that variations in output due to temperature, humidity, and aging can be compensated for. The meter may indicate microvolts directly, or may indicate a reference mark or marks at which reading the attenuator and microvolts controls indicate output voltage. In either case, the meter is accompanied by a meter adjuster knob. This knob is adjusted to place the meter to the proper reference point or, with the microvolts type, to the desired voltage.

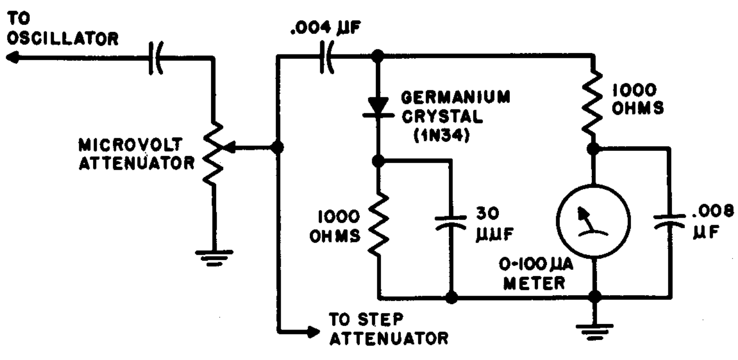


Fig. 6-2. Typical signal generator output voltage meter circuit.

Such a meter is either a vacuum-tube voltmeter or a sensitive d-c meter connected in a rectifier circuit with a crystal rectifier. The r-f output is rectified and actuates the meter, thus indicating the relative output voltage. A typical meter indicator circuit for a signal generator is shown in Fig. 6-2. The voltage which actuates the meter is obtained from the output of the continuous attenuator, which becomes the microvolts control. The step attenuator then follows both, and determines the multiplier, or ratio, between this voltage and the actual output value. In some generators, rectification of the r-f output signal is followed by a d-c amplifier circuit which then actuates the meter.

6-6. Effect of Harmonic Content on Output Voltage

Normally the meter indicator circuit of a signal generator is not selective as far as frequency is concerned. That is, the voltage which actuates the meter is the *total* voltage output of the generator oscillator and continuous attenuator. If the oscillator output voltage contains an appreciable amount of harmonics, the meter measures the sum of all the harmonic components and the fundamental. In cases in which the fundamental signal from the generator is being used, the harmonics are not usually great enough in amplitude to affect the accuracy of voltage readings seriously. However, if we use a harmonic of the frequency at which the oscillator is working, voltage readings will not be at all indicative of the actual output at the frequency in use.

For example, suppose the signal generator covers only up to 20 mc and we wish to use it for tests on a receiver at 30 mc. We may do so by adjusting the generator to 15 mc and using the second harmonic of the generator output. However any voltage indication on the generator will be in error. Say, for example, that the fundamental output voltage is about 1,000 microvolts. The second harmonic may be only about 10 percent of this, or about 100 microvolts, or even considerably less. What is more, the second, or other, harmonic component may vary considerably in relative strength as the fundamental frequency is varied and as attenuators are changed. This fact should be kept in mind; voltage indications should not be used for harmonic operation.

Chapter 7

TERMINATING, MATCHING, AND GROUNDING

7-1. Why Generators are Designed for Low-Impedance Output

In the use of a signal generator, especially where output voltages are to be measured, it is desirable to have the source (generator) impedance as low as possible. This is so that the voltage regulation of the generator output will be as good as possible. The ideal situation is that in which a low-impedance generator is connected to a very high impedance load; appreciable change in load resistance will then not affect generator output voltage.

Accordingly, most signal generators have output impedances of from 30 to 300 ohms. For high frequency a-m generators (above 20 mc) and vhf sweep generators, the output impedance is often chosen to match the characteristic impedance of the line used in the connecting lead. As we shall see, it is important to do this, especially where wide ranges of frequencies are involved.

Another important reason for the use of low impedance for the output circuit is the effect of stray capacitance at radio frequencies. If a high impedance were used, stray capacitances between leads and between leads and ground would all become serious problems.

For example, a stray capacitance of only 1 $\mu\mu$f has a reactance value at 100 mc of only about 1,600 ohms. If the output impedance were, say 2,000 or 5,000 ohms, it can be seen that almost any tiny stray capacitance would have a considerable loading effect and would tend to throw output voltage readings off and produce considerable instability.

7-2. Output Termination

To maintain proper output voltage indication and preserve stability, it is important that the lead from the signal generator be terminated properly. This termination is important not only from the standpoint of the generator operation, but also from the standpoint of the device being tested. In many cases the device to which the generator is connected must "see", in the generator lead, the impedance for which it is designed in normal operation. If the device is a radio receiver, and the generator is to be coupled to the antenna circuit, the generator lead, or an auxiliary circuit used with it, must exhibit to the receiver input circuit the same impedance as the antenna for which the receiver was designed. In most f-m and tv receivers this impedance is 300 ohms. In some tv receivers it is 72 ohms. For broadcast and all-wave type a-m receivers, a standard "dummy antenna" may have to be used.

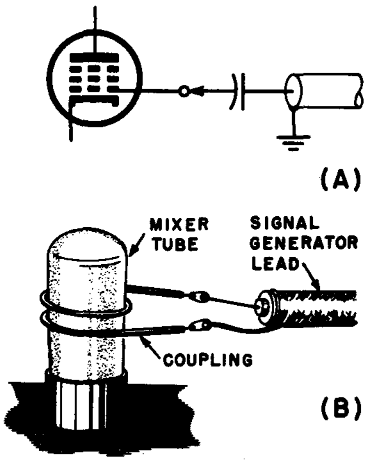


Fig. 7-1. Two ways of applying the low impedance of the signal generator output to a high-impedance circuit, when it is not necessary to know from signal generator indications how much is the input voltage to the circuit.

When feeding into the grid of a vacuum tube or other very high impedance device, some arrangement must be made to prevent the low impedance of the generator from shunting the input circuit of the tube. Two ways in which this can be accomplished if the measurement of the generator output voltage is not important are shown in Fig. 7-1. At (A), a small value capacitor is connected in series with the generator lead to the receiver grid. The value of capacitance used must be small so that it will have a relatively large impedance at the frequency at which the tests are being made. In many cases a capacitance as low as 1 or 2 $\mu\mu f$ is sufficient; for low-frequency receivers, such as the a-m broadcast type, 50 $\mu\mu f$ or more may be necessary. Frequently, it is only necessary to clip the hot lead of the signal generator to an insulated lead or other insulated component that is connected to the grid of the tube to which coupling is to occur.

At (B) is shown another popular method of loosely coupling the generator to a circuit of a radio or tv receiver. A loop of wire is formed, with about two or three turns, by wrapping a wire around the tube into whose circuit the signal is to be injected. The wire should preferably be insulated. The ends of the wire loop are connected to the two leads from the signal generator. The loop is then slipped over the tube and the signal is injected into the tube by capacitive and inductive coupling. It may also be possible to simply wrap the end of the hot lead of the signal generator around the tube envelope to produce this same effect.

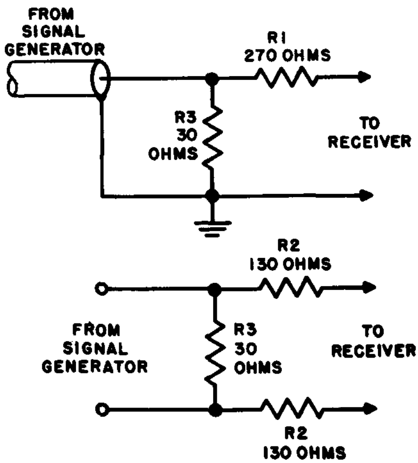


Fig. 7-2. Two ways of terminating signal generator leads to offer the desired impedance to the device tested while maintaining proper impedance load to the generator itself.

If absolute voltage measurements are to be made from indications on the generator meter and attenuators, the above methods will not do.

Two methods of terminating with resistors to provide proper load for both signal generator and tested device are shown in Fig. 7-2. Each provides for a signal generator load of 30 ohms and a load on the receiver or other device of about 300 ohms. For feeding into larger resistances, resistors *R1* and *R2* are made high enough in resistance so the output adds up to the desired resistance, while the 30-ohm resistor remains the same to keep the signal generator load constant. If the signal generator is designed for a higher output impedance, such as 72 ohms or 100 ohms, *R3* is chosen accordingly, to match it.

7-3. Balanced and Unbalanced Circuits

The output circuit of practically all signal generators is an unbalanced or single-ended circuit. This simply means that one lead of the

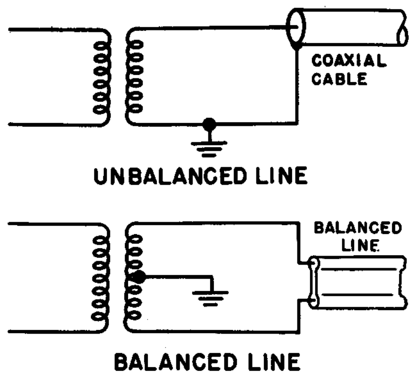


Fig. 7-3. Difference between balanced and unbalanced lines.

output is grounded. The grounded lead is often referred to as the "ground lead" and the other lead as the "hot lead." The advantage of such a circuit is that it can be connected to a coaxial transmission line consisting of an inner conductor surrounded by a shield of metal braid with low-loss insulation between. The advantage of transmitting r-f current this way is that the shield can act as the ground lead, shielding the inner conductor, which is above ground. This prevents radiation from the lead, since electromagnetic radiation is stopped by a grounded shield in its path.

Sometimes another type of circuit is used for r-f energy – the balanced circuit. In this circuit both leads are above ground by the same potential and the currents in these leads are 180 degrees out of phase with each other. The balanced circuit is sometimes referred to as a "push-pull" circuit. The difference between an unbalanced and a balanced circuit is shown in Fig. 7-3. Balanced circuits may also be shielded to prevent radiation.

7-4. Standing Waves

At high frequencies, especially in the vhf and uhf ranges, standing waves may become a problem in signal generator leads. In order to understand this phenomenon, we must review very briefly how it comes about.

Standing-wave problems become important when the length of a transmission line is an appreciable fraction of a wavelength at the frequency of the signal it is to transmit.

For example, consider the wavelength of signals at two different frequencies, one in the a-m broadcast band, and the other in the vhf range (in the f-m broadcast band):

1,000 kc   wavelength – 300 meters, or about 1,000 feet
100 mc   wavelength – 3 meters, or about 10 feet

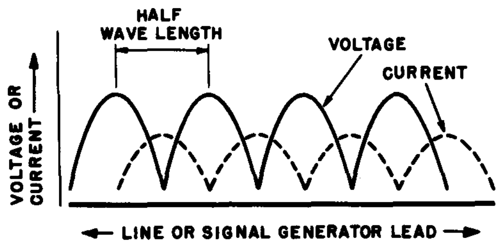


Fig. 7-4. How the voltage and current is distributed along a transmission line when there are standing waves.

Note that at 1,000 kc a 3-foot signal generator lead is a very small fraction of the 1,000-foot wavelength. At 100 mc, however, the 3-foot lead is about one-third of the wavelength. In the latter case the problem of standing waves may become severe.

Standing waves result on a transmission line when part of the energy of the signal that is sent along the line is *reflected* from the receiving end of the line back toward the sending end. The transmitted signal and the reflected signal combine; at some points they are in phase and the current is large; at other points they are in phase opposition and the current is low. The same thing happens with voltage, except that the voltage maxima and minima are at points one-quarter wavelength away from the current maxima and minima. Figure 7-4 shows a graphical indication of the voltage and current along a line with standing waves.

One of the most mystifying factors about standing waves to the beginner is the fact that the current along a line which is not connected to anything else can change, since in d-c circuits this can never happen. Actually, as illustrated in Fig. 7-5, there is something "connected" to the line in a sense. A signal generator lead has appreciable capacitance between conductors and appreciable inductance along its length. They are called the "distributed constants" of the line. The capacitance shunts the line and draws current across it; the inductance keeps shifting the

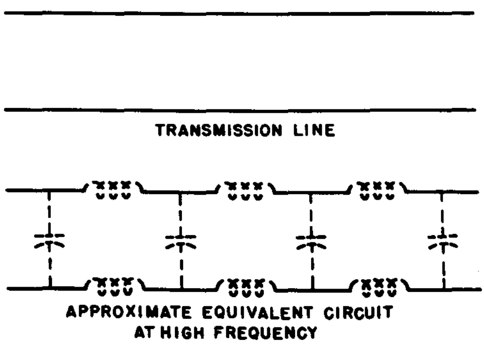


Fig. 7-5. At high frequencies, a transmission line is equivalent to a series of inductances and capacitances blended together into "distributed constants."

phase of this current as we go along the line. If the end of the lead is not properly loaded, both the current and the voltage of the line change and there are standing waves.

There is one basic way in which standing waves can be eliminated from a line; that is by "matching" the line. Each transmission line has a constant, called its characteristic impedance or sometimes its surge impedance. Its value depends upon the physical characteristics of the line. For coaxial cable, the characteristic impedance of some is 50 ohms, for most types it is 72 ohms. Ribbon or twin lead open-wire lines are available in various values of impedance, from 72 ohms up to 300 ohms. Other types of open-wire lines may run as high as 800 or 1,000 ohms.

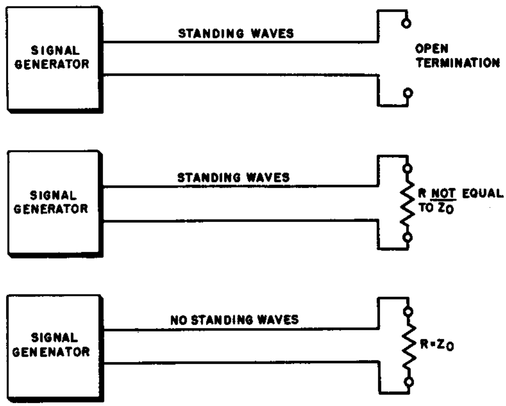


Fig. 7-6. Standing waves can be eliminated by terminating a line in its own characteristic impedance.

Standing waves can be eliminated from a transmission line if the line is terminated in its own characteristic impedance, as illustrated in Fig. 7-6. In other words, a line is said to be perfectly "matched" and its standing waves are eliminated when the impedance of the source at the sending end and the load at the receiving end are both equal to the characteristic impedance. The characteristic impedance is a pure resistance, without reactance.

In studying the construction of signal generators themselves, we are primarily interested in the *shielded* types of line which would be used for connecting leads. There are two main types. The more common type is the simple coaxial cable, in which a single conductor surrounded by low-loss insulation is centered inside a copper-braid shield. This cable thus forms an unbalanced circuit. In another type of shielded lead, two inner conductors are used, both insulated from, and enclosed by the shield braid. This forms a balanced circuit against the shield ground. Nearly all signal generators use the simple unbalanced line; when balanced output is required, they have a special lead to convert the unbalanced output to balanced at the end of the lead, as will presently be explained.

7-5. Effect of Standing Waves on Signal Generator Performance

It has been explained that standing waves consist of a series of high voltage and low voltage, and high current and low current points along a transmission line such as the lead from a high frequency signal generator. The distribution of standing waves along a line is shown in Fig. 7-4. Places where voltage is a maximum are called *voltage loops,* and where voltage is a minimum, *voltage nodes.* In the same way, current maxima and minima are respectively called *current loops* and *current nodes.* Successive voltage loops are spaced one-half wavelength apart along the line; successive voltage nodes are also one-half wavelength apart but are located midway between the voltage loops. Therefore, adjacent pairs of voltage loops and nodes are spaced one-quarter wave apart. Wherever there is a voltage loop, there is a current node; where there is a voltage node there is a current loop.

Because standing waves are spaced in terms of wavelength, their position changes along the line as frequency is changed, so their particular location is not predictable except for one particular frequency, or with complicated calculations. At a voltage loop, the voltage may be many times that which would normally be present if there were no standing waves. Thus the generator output voltage may vary through wide ranges as frequency is changed if there are standing waves present.

Standing waves are particularly troublesome with sweep generators operating in the vhf region, because as the frequency sweeps through its range, the output voltage changes radically. The result is that the sweep amplitude is variable, and the voltage applied to the device whose response is to be observed is not constant through the sweep range. This naturally affects the apparent shape of the response curve greatly, producing spurious peaks and valleys and giving other misleading results. The reflections in the lead also give trouble, causing double trace lines and difficulty in obtaining a sharp stable image. In addition, when standing waves exist, the output lead is very "touchy" and is very sensitive to changes in position and connection. Standing waves may even exist on the outside of shielded cable so that the output of the generator varies as the cable is touched and as the hand is moved along the length of the lead. As we have mentioned before, the way to eliminate standing waves is to terminate the lead in its own characteristic impedance. There are a number of ways of doing this. We shall consider several in the next section.

7-6. Types of Leads Used for Signal Generator Output

We have now established that the output lead and its termination must:

1. Provide a proper load for the generator, so its output voltage is stabilized and properly indicated.
2. Provide a proper load equivalent to the characteristic impedance of the lead line, especially at high frequencies, to minimize standing waves.
3. Exhibit to the device an impedance which will reasonably approximate its normal operation, so that tests made on it will have a practical meaning.

At frequencies below about 20 or 30 mc, standing waves are not likely to be a factor. Line losses are not appreciable, so ordinary shielded wire is commonly used for the leads. At higher frequencies (or for generators whose range extends into the vhf and uhf regions) coaxial cable is most frequently used.

Sometimes a terminating network is connected right into the end of the lead, and sometimes the lead has no self-contained termination.

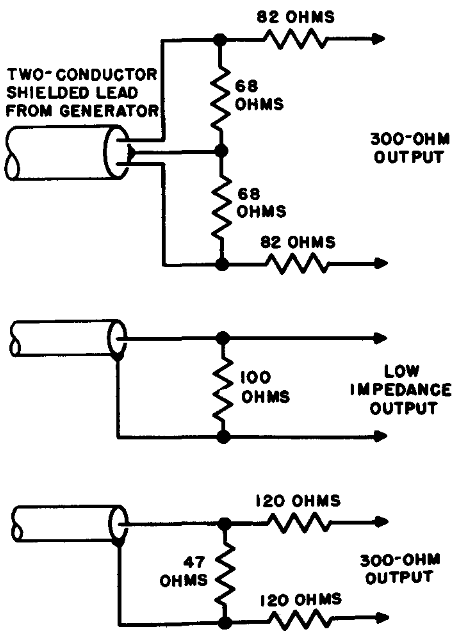


Fig. 7-7. A few typical methods for terminating signal-generator leads. Some are these included in the generator leads; others are recommended by manufacturers as external additions.

In the latter case it is expected that the operator will add whatever termination is necessary externally. Two typical terminating arrangements are illustrated in Fig. 7-2.

It should be pointed out here that each signal generator model may be somewhat different from other models. The type of termination best for each purpose in each case is likely to be a little different. The ultimate authority on this subject is, of course, the manufacturer of the generator. The reader is, therefore, urged to consult the manufacturer's instruction manual for a signal generator before he attempts termination himself. These instruction manuals usually provide much data on the ways in which the output leads can be adapted to different purposes and will frequently show the details of the lead construction for their models. The following information is given to provide examples and as a guide when no other data are available, but should not be substituted for specific information in the manufacturer's instruction book.

A number of typical terminating networks are illustrated in Fig. 7-7. These are arrangements which are given in signal generator manufacturers' instruction books and include both circuits included in the generator lead and others recommended to the user of the generator as an addition. Note the idea is always about the same as that previously set forth in Fig. 7-2, that is, to present to the generator and the device being tested their proper load impedances.

The termination end of the signal generator lead used is most commonly equipped with clips to facilitate connection to the receiver or other device being checked. Another variation is a pair of binding posts mounted at the end of the load. Two typical arrangements are shown

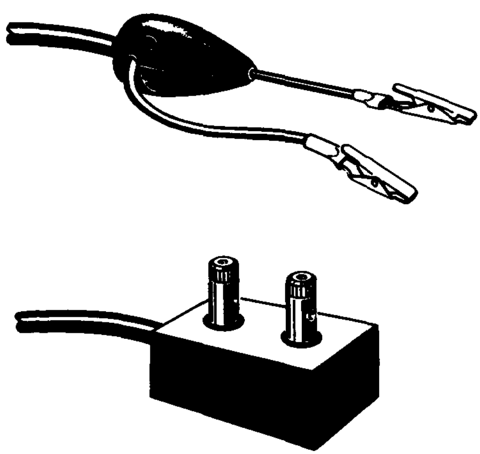


Fig. 7-8. Two ways of making connection from the end of the signal-generator lead to the device to be tested.

in Fig. 7-8. Sometimes it is desirable to connect a balanced output lead which the test equipment manufacturer has provided for a 300-ohm load to an unbalanced circuit. A typical arrangement for doing this is illustrated in Fig. 7-9. The output between one conductor and ground is used, while the other "side" of the circuit between the other hot lead and ground must be terminated in its impedance, in this case, 150 ohms. Note that when the 75-ohm load is connected, the other "side" of the circuit is also terminated in 150 ohms.

At the generator end, the lead is usually terminated in either a standard microphone connector or a phone plug, whichever is necessary to match the connector on the generator itself. If the lead is for balanced output, a two-conductor shielded type connector is necessary.

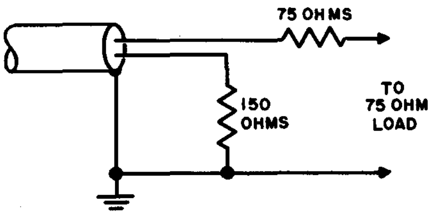


Fig. 7-9. Arrangement for adapting balanced 300-ohm output to match 75-ohm circuit.

7-7. Dummy Antennas

A *dummy antenna* is a device used to connect a load or generator to a receiver or transmitter to provide rated load resistance or impedance during tests or measurements. For signal generators a dummy antenna is a device used to couple the generator to the antenna circuit of a receiver in such a way that the impedance offered to that circuit is the same as that offered by an actual antenna, or the antenna for which it was designed. Actually all the terminating devices so far discussed qualify to be called dummy antennas if used with receivers.

For use with a-m receivers operating from 550 kc through 30 mc or so, a standard dummy antenna has been adopted and recommended by the Institute of Radio Engineers. The circuit of this dummy antenna is given in Fig. 7-10. It offers an impedance to the receiver which is a good average approximating that of a-m receiving antennas in general. At the short-wave frequencies it is equivalent to the receiver end of a matched 400-ohm transmission line. Consequently, the dummy antenna provides an impedance to the input of the receiver which is the same as that which might be expected in practice, so that tests and alignment adjustments will be proper. Otherwise, adjustments in the input

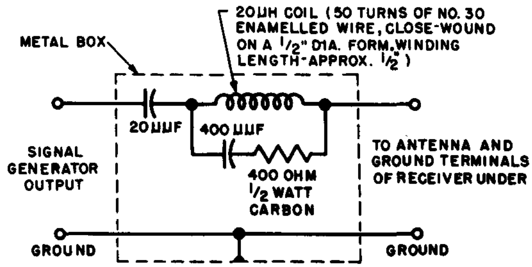


Fig. 7-10. Standard dummy antenna circuit for coupling the signal generator to an a-m receiver to match the receiver input over a wide range of frequencies.

circuit, without proper antenna impedance connected, might be wrong under actual conditions.

An alternative dummy antenna suitable for tests only in the a-m broadcast band is shown in Fig. 7-11. This offers the same impedance as the circuit of Fig. 7-10 in the a-m broadcast range. The IRE has the following to say about the construction of the dummy antenna:

> The stray capacitance between any two points must be so small as to be negligible at operating frequencies, and the dummy antenna must be so devised as to avoid coupling to other equipment. . . . The leads used in connecting the signal generator through the dummy antenna to the receiver should be short so as to introduce negligible voltage drop. They should be shielded to reduce external fields.[1]

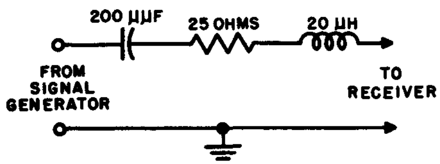


Fig. 7-11. Alternative dummy antenna circuit for a-m broadcast receivers only.

7-8. Importance of Shielding in General

From time to time in our previous discussions, we have mentioned the importance of shielding. Probably no other electronic device requires the degree of shielding needed by the highest quality types of signal generators. The reason the generator itself must be shielded is to avoid leakage and radiation, which prevent attenuation of the external signal to low values of output. Another reason for shielding of the unit is that both output voltage and frequency can be affected by external objects if shielding is not present. The operator's body can introduce

[1] IRE Standards — Methods of Testing Amplitude Modulation Broadcast Receivers, 1948, 3.02.02

stray capacitance and loading effects which will cause both amplitude and frequency to vary as he moves around near the generator. In addition, lack of shielding can cause pick-up of energy from external fields, particularly power-line hum. This hum can modulate the signal and cause other troubles, if there is not sufficient shielding. Radiation of the signal directly from the generator can cause it to be picked up on power cords, connecting leads, telephone leads, and other wiring.

As was previously explained, the degree of perfection of the shielding of the signal generator used depends upon the type of instrument and its requirements in practice. A very low-cost generator designed only for a-m broadcast receiver testing would not be expected to have very elaborate shielding. On the other hand, precision laboratory types for vhf and uhf ranges will be shielded with great care. Thick copper shielding material is ordinarily used in the latter, with both the individual sections inside and the whole unit completely enclosed. Leads are passed through shield partitions only in shielded connectors, and there is plenty of bypassing at all strategic points. An elaborate line filter is also usually installed. When such measures are employed, it is often possible to set the generator for a small fraction of a microvolt output without experiencing any serious radiation.

In other generators for purposes with less rigid requirements (such as ordinary radio and tv receiver servicing) the shielding may not be so elaborate, since it is seldom necessary to drop below 25 to 100 microvolts.

In the use of sweep generators for tv receiver response analysis, it is difficult to obtain a good response picture if the shielding of the generator is not quite good, and if this shielding is not properly grounded.

Besides the signal generator unit itself, all leads to and from it must be shielded (or filtered) or the shielding of the unit itself will be to no avail. That is why shielded leads of the type described in Section 7-6 are used. In many of the more elaborate laboratory types the power-line lead to the generator is also shielded, with a line filter inside the unit. The shield braid is connected to the chassis-cabinet of the unit and may be connected into a polarized plug at the other end, if such a plug is used. Otherwise, there may be a short clip lead protruding from the plug end of the power cord, to be clipped to the nearest ground connection.

Most of the problems concerning shielding arise when low signal voltages are to be used. This is quite often so with sensitive receivers, since it is desirable to keep the signal intensity to as low a value as possible and still obtain a useful signal. When receivers are tested at very low signal levels, or in areas where external signals are strong, interference from such external signals from other signal generators and from local broadcast stations may become severe. For this reason a *shielded room* is often used. Ordinarily this consists of a room completely surrounded by wire netting or screening of some kind. Sometimes one or more of the walls is lined with metal plate. The door to the room is also completely covered with the shielding material, and provisions are made so that when it is closed, the shielding on the door and that on the remainder of the room become electrically continuous. The signal generator, the receiver to be tested, and any other equipment necessary is set up on a bench inside the shielded room. Power-line leads into the room must be filtered and shielded. The operator and his equipment are thus completely enclosed in a large metal box, which prevents external signals from interfering with tests in progress. Shielded rooms are used primarily in cases where very exacting testing, design, and development work are necessary. Most receiver manufacturers and electronic testing laboratories are so equipped.

7-9. Grounding

Shielding and grounding usually go together. In fact, all the measures explained for shielding in Section 7-8 would be useless if all the shielding were not grounded.

Because there is a large metal cabinet around a unit, this does not necessarily mean that the cabinet is at ground potential. We must make sure it is securely grounded. Otherwise points which are supposed to be at ground potential will actually develop an r-f voltage above ground and interfere with the effectiveness and accuracy of any tests being made.

Most grounding trouble arises because of the fact that an ordinary straight wire has some inductance and some resistance. Even though these values are small, their effects may become very great at radio frequencies, especially the higher radio frequencies. The resistance of a piece of wire rises as frequency increases. This is due to a phenomenon called *skin effect*. The higher the frequency, the more the current tends to flow only in the outer surface of the wire, thus increasing its effective resistance because only a small part of the conducting material is used.

For example, a wire about 40 mils in diameter has, at 100 mc, 35 times its resistance to direct current.

Both the inductance and the r-f resistance of a wire decrease as the diameter of the wire is increased. The decrease in r-f resistance is not as great as its decrease in d-c resistance, but it is a definite decrease. For this reason, it is important that the ground connections used be made with large diameter wire to be sure that an r-f potential does not build up between the supposedly grounded point and true ground.

The reference point for true ground is usually considered to be the earth itself. Since often the testing area in which the generator is used is considerably above the earth, obtaining a direct ground may be a problem. However, usually a water pipe is satisfactory for most moderate and low frequencies, since it travels underground and thus makes good contact with the earth. Copper piping is naturally better than iron piping, because of the much better conductivity.

It is desirable that in the location in which a generator is to be used for some time, and when rather exacting tests are to be made, a good low-impedance ground connection be arranged for. If a water pipe runs nearby, a heavy wire lead of about #8 or larger should be run from a heavy clamp attached to the pipe, to a convenient connecting point on the test bench. Even better than heavy wire is shield braid about one inch wide; this has low inductance and resistance at high frequencies and is often used in exacting grounding requirements.

Where the distance between true earth ground and the testing point is rather great, no ground can be really good for vhf and uhf testing. There is then no point in doing more than the normal things required for a good ground at lower frequencies.

The importance at these frequencies then shifts to ensuring that everything is connected to a *common grounding point.* Then even if the grounding point is somewhat above ground to r-f, the fact that each unit in the system is shielded and grounded at a common potential will be satisfactory. To do this it is suggested that the units all be connected to a solid copper strip, bar, pipe, or rod, which runs along the bench and is grounded to the best available ground.

Another very useful way of maintaining a good common ground, especially for testing radio and tv receivers, is the use of a *ground plate.* This is simply a sheet of metal, preferably copper, which covers the whole working area of the top of the test bench. The signal generator, the receiver, and any other equipment are then placed on this metal sheet. If the chassis is clean and rests directly upon the metal for each unit, everything will be automatically grounded; otherwise means must be used for providing a direct ground from each chassis to the metal plate. The ground plate not only establishes a common ground potential, but tends to provide shielding against interference effects.

The ground plate should not be considered a substitute for a good ground; it is merely an extension of a good ground and must be itself a good ground to be effective.

Another important factor about grounds is that each unit to be grounded through wires should be grounded separately. That is, if three units are to be grounded, run a good ground wire from each unit to a common connecting point, rather than from one unit to another, then to the next, then to ground. This minimizes the build-up of r-f voltages between units.

Chapter 8

PRINCIPLES OF SWEEP GENERATOR RESPONSE ANALYSIS

8-1. Advantages of the Sweep Method

One of the most frequent uses of signal generators is the determining or checking of frequency response. For radio receivers, the overall frequency response is important because it influences the width of the a-f modulation range available and because the response must meet certain requirements in order to minimize interference. In f-m radio receivers, the shape as well as the extent (width) of the response is important for proper reception. For tv receivers, a wide response, meeting several shaping requirements is necessary for proper reception of both picture and sound. In addition to radio and tv receivers, response analysis is often desired for such components as transformers, filters, and antennas. It is therefore evident how important response analysis is as an application of the signal generator.

There are two ways of obtaining a response characteristic. The first, shown at (A) in Fig. 8-1, is the "step-by-step" method. The signal generator is applied to the device to be tested. Its frequency is set within the expected pass band. An output meter is connected at the output circuit and the signal generator is adjusted until a convenient output indication is obtained. The signal generator is then adjusted for the lowest frequency at which there is any response and the output recorded. Then the frequency is advanced in equal "jumps" or steps through the response range, and the output for each frequency is recorded. After this data is accumulated, it is plotted on graph paper; the frequency is plotted horizontally, the output vertically. The resulting graph is the response curve.

Obviously the above operation consumes considerable time. As many as a dozen readings may be necessary. Then, if the response is not satis-

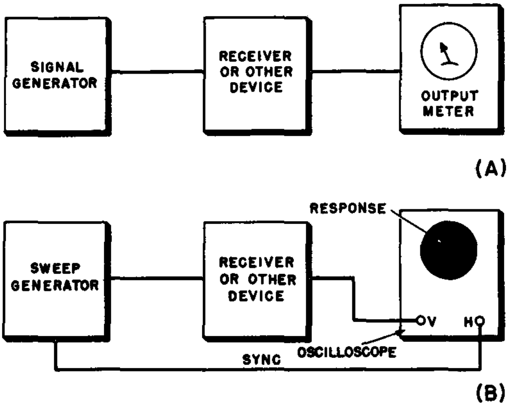


Fig. 8-1. Two ways to obtain a frequency-response characteristic of a device. (A) Step-by-step method, using individual readings at various frequencies in the pass band. (B) Sweep method, in which complete response characteristic is continuously observed on an oscilloscope screen.

factory and alignment is necessary, the curve must be replotted each time an adjustment is made. For this reason, the second response-checking method, sweep-generator analysis, has become popular for this purpose. The response curve is then continuously exhibited, and the effect of adjustments observed as they are made.

8-2. Step 1 — The Horizontal Sweep Motion

The process of sweep-response analysis is best understood by considering separately the two main steps in forming the response image. The first step is the horizontal sweep action of the oscilloscope beam and its relation to the frequency sweep of the generator.

We have already considered the principles of action of the basic sweep generator (Chapter 4). We have seen how the generator sweeps the frequency of the r-f carrier signal through a range of frequency over and over in a definite rapid pattern, from the lowest frequency of the sweep width to the highest and then back again. The action is produced through a power line frequency voltage (60 cps in most cases) and thus occurs at the same rate as the alternations of that voltage. The same voltage which causes the frequency sweep is brought out through a binding post on the panel in most generators. This voltage is applied to the horizontal deflection circuit of the oscilloscope used for response indication. This is the first step, as illustrated in Fig. 8-2. The sweeping voltage from the generator, sometimes called the "sync" voltage, operates the horizontal deflection system of the oscilloscope, moving the beam back and forth across the oscilloscope screen. The motion of the beam is in synchronism with the variation of frequency in the sweep generator. In other words, when the frequency is just starting to sweep from the low-frequency edge of the sweep width, the oscilloscope beam is at the left side of the screen, ready to sweep toward the right. Therefore, distance along the horizontal sweep path of the oscilloscope beam is proportional to frequency change of the sweep generator carrier. When the deflecting voltage has completed its change from maximum of one polarity to maximum of the opposite polarity, it reverses its direction of change and starts back, causing the oscilloscope beam to start from the right-hand end of the horizontal trace and move toward the left-hand end again. Also, at the same time, the signal generator r-f carrier has reached its highest value and started downward again. As the generator frequency sweeps back again toward the low-frequency end of the sweep width, the oscilloscope beam also sweeps back leftward. Thus, if the two are synchronized properly, each point along the horizontal path traced by the electron beam on the oscilloscope screen represents the same sweep generator instantaneous frequency on the return sweep (right to left) as it did on the forward sweep (left to right).

It is also possible for the direction of beam travel to be exactly the reverse of that just described, that is, the beam may be at the left-hand end of the trace at the highest instantaneous frequency and at the right-hand end of the trace at the lowest instantaneous frequency. In this case the frequency indicated decreases rather than increases as we move from left to right along the forward trace. This may be caused by a reversal of polarity of the sync voltage coming from the sweep generator or passing through the horizontal amplifiers of the scope. In this case, the response curve is merely "flopped over," but its shape is unchanged. In either case. the direction of frequency increase should first be determined by the use of known marker signals so that the response curve may be interpreted correctly.

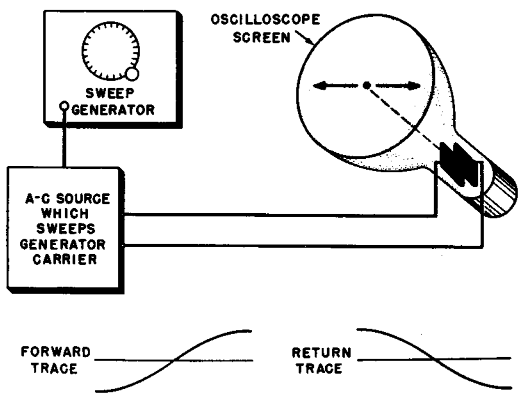


Fig. 8-2. The first step in the development of a response curve on the oscilloscope screen. The oscilloscope beam is deflected horizontally by the same voltage that produces sweep in the generator.

The first step in establishing a response curve indication produces a horizontal trace and retrace (which should coincide in the same horizontal line) on the oscilloscope screen. This is shown in Fig. 8-2. Although the r-f output of the sweep generator has not yet been used, we do know that each point along the horizontal trace corresponds to a definite sweep generator carrier frequency, and each time the carrier passes through that frequency the oscilloscope beam will be at that point horizontally. This situation should be pictured clearly in the reader's mind before he proceeds to the next step, which is built upon this one.

8-3. Step 2 — The Vertical Deflection

Next consider the action produced by the connection of the sweep generator r-f output to the vertical deflection system of the oscilloscope. This is shown in Fig. 8-3. The output of the receiver, receiver section, or other device, is connected to the vertical deflection system of the oscilloscope. The greater the output voltage, the greater the oscilloscope beam deflection in the vertical direction. Therefore, at any given instant, the height of the beam spot above a center reference line is proportional to the output voltage from the receiver at that instant.

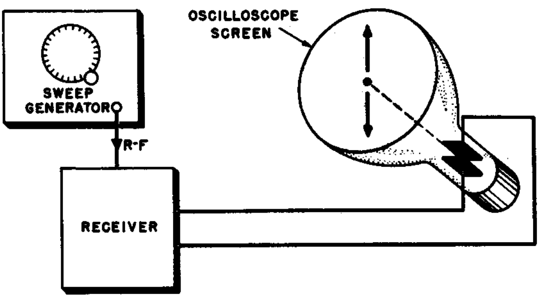


Fig. 8-3. Second step in the formation of a response curve on the oscilloscope screen; the vertical deflection of the beam spot is by the output voltage of the analyzed device, such as a receiver.

The output voltage at any given instant is a voltage resulting from the rectification of the i-f voltage at the detector, and is thus proportional to the response of the receiver. This is an overall response through the r-f and i-f sections if the sweep generator is connected to the antenna circuit, or it is an i-f response through the i-f section if the generator is connected to the mixer or first i-f stage.

8-4. Combining the Vertical and Horizontal Actions

Now consider what happens when the actions of step 1 (Section 8-2) and step 2 (Section 8-3) both occur at the same time. The beam spot on the oscilloscope sweeps across the screen in synchronism with the frequency sweep of the signal generator. At the same time, the beam spot

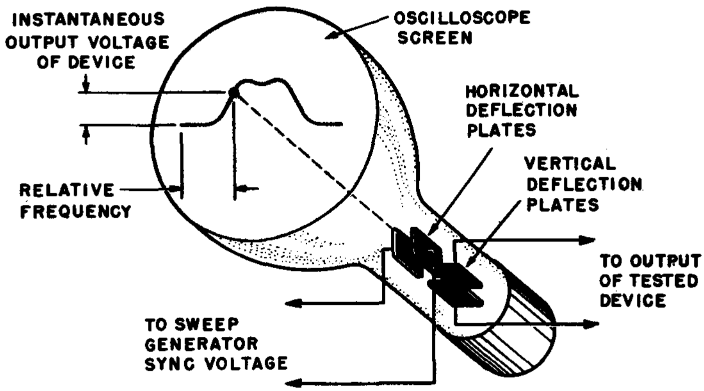


Fig. 8-4. When the two steps of Figs. 8-2 and 8-3 are combined properly, a response curve is traced on the oscilloscope screen, as shown here.

is urged upward or downward in proportion to the instantaneous output voltage of the receiver. The result is that the beam spot moves both across the screen and up and down it, sweeping out the response characteristic of the receiver, receiver section, or other device being tested (see Fig. 8-4).

Whether the response curve is traced upward (as shown) or downward depends on the output polarity of the detector employed as well as the direction of vertical deflection of a given polarity signal on the scope used for the test. The same response curve shape will occur in either case except that an inverted response curve may sometimes appear on the screen of the oscilloscope.

8-5. Sweep Waveform

In most sweep generators, the sweep action of the r-f carrier frequency is produced through some a-c voltage obtained from the power line. This voltage has a sine waveform; thus the frequency of the sweep generator carrier varies at a sine-wave rate. This means that the frequency change is most rapid in the middle portion of the trace, and slower near the beginning and end of the trace, as illustrated in Fig. 8-5. However, since the same voltage that produces frequency sweep in the generator is also used to sweep the oscilloscope beam, the sweep and beam actions both change in the same way at the same time. Therefore, in spite of the non-uniform frequency and sweep variation during each cycle, the fact that both are synchronized results in a linear relation between them. The frequency scale along the horizontal axis is thus linear, and equal intervals represent equal frequency changes. The non-

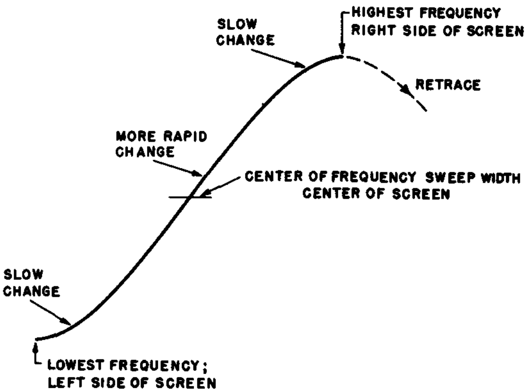


Fig. 8-5. Half cycle of an a-c voltage used to sweep the generator frequency and deflect the oscilloscope beam, showing actions taking place and how the rate of change varies during the deflection period.

uniform sine-wave variation simply causes the beam to move more rapidly in some parts of the trace than in others, an effect which is negligible in practice, and not noticeable since the sweep rate is fast enough so the trace appears as a fixed image anyway.

8-6. Retrace

After the forward trace of both sweep frequency (from lowest to highest frequency) and oscilloscope beam (from left to right), the sweep and beam reverse and return to the starting point, repeating the action but *in reverse order*. In other words the return is a continuation of the sine waveform. The values passed through in the last part of the forward trace are repeated, the last value first, the next-to-last second, etc. Hence, as the oscilloscope beam spot starts back from the right-hand side of the screen toward the left, it passes through the same points it has just passed in the other direction in the forward sweep, and the sweep generator frequency passes through the same frequencies for those points.

Accordingly, any response characteristic which was swept out in the forward trace should be repeated in exactly the same place on the return trace. There are thus ordinarily *two* traces of the same response curve; but, since they coincide, one is directly on top of the other, and the two appear as one curve.

8-7. Phasing

In Chapter 4 we discussed the need for a phasing control on a sweep generator (or in an oscilloscope). If the trace and retrace curves do not coincide, this means that the phasing between the voltage which produces frequency sweep in the generator and the voltage which sweeps the oscilloscope beam spot horizontally is not proper. In other words, these actions are not exactly in phase with each other. If there is a phase difference, the points which represent the highest and lowest generator frequencies are not at the ends of the oscilloscope sweep trace, and the trace and retrace curves are in different horizontal positions. How this happens is explained and illustrated in Chapter 4.

To overcome such a phase difference, a phase adjusting circuit in the sweep generator or oscilloscope is used. This adds reactance to the circuit, usually in the form of a capacitor, so that the phase of one voltage is changed with respect to another. The degree of phase adjustment is determined by a variable resistor, which changes the relative resistance compared to the reactance.

8-8. Blanking

When a response curve is observed by the visual sweep method, the coincidence of the forward and return traces causes one curve (if the phase is correct) to appear, with nothing under it. In other words there is no *base line* under the response characteristic part of the trace. Sometimes it is desirable to have a base line under the curve. It can be obtained by *blanking*. In producing blanking, the signal generator output is cut off during the return trace, and left on during the forward trace. This means that on the forward trace, the beam spot sweeps out the response curve; on the return trace, since there is no generator output, the beam spot is not deflected at all vertically. Since there is no vertical deflection on the return trace, the beam spot traces a straight line which represents zero output, which is thus a true base line. Illustration of blanking and how it is produced in a sweep generator is given in Chapter 4.

Chapter 9

HOW TO SET UP FOR TV SWEEP ALIGNMENT

9-1. Relative Importance of TV Application

Although sweep generators have many applications, the largest number of them now in use are designed for, and used for, tv receiver response analysis. It is therefore well that we review here some of the factors involved in preparing for sweep analysis of the response curve of a tv receiver. Actual details of receiver adjustment are beyond the scope of this book, but the different measures leading up to it are of importance in connection with any study of the sweep generator itself. The nature of the process is such that, if proper preparation is not made, and proper equipment is not available, it is very difficult to obtain the desired results.

9-2. The Sweep Generator

The requirements and characteristics of the sweep generator have been discussed to some extent earlier in this book. The center frequency of the sweep output should be adjustable to the receiver's i-f range, and to the frequency range of any desired channel. This adjustment may be either by continuous dial variation or by selection of the desired ranges by means of a switch, with the center frequency of each range fixed.

The sweep generator output voltage should be adequate, at least 10,000 microvolts, with 100,000 microvolts desirable. It is also desirable that a high output jack be provided, from which 1 volt or more of signal is available, although this is not necessary. There should be a continuous attenuator so that the amplitude of the signal can be adjusted to avoid overloading and to provide a response image of useful size. The generator should also preferably have a phase adjustment, although this is not necessary if phase adjustment is provided on the oscilloscope.

Blanking of the generator signal is another provision which is not absolutely necessary but is desirable and helpful.

The sweep width should be adjustable through a reasonable range. The maximum width required for tv response characteristics is from 10 to 15 mc. This should be controllable down to several hundred kilocycles; the minimum width is useful in observing sound section response, and aligning the sound i-f stages and discriminator.

9-3. Sweep Generator Controls and Connections

Although the characteristics and features of sweep generators have been previously discussed, it is well before proceeding with alignment or response checking to become completely familiar with all the controls and connections involved, if this has not been done before. Let us therefore review briefly these controls and connections.

CENTER FREQUENCY CONTROL: This is a dial or switch, or combination of both, which adjusts the center radio frequency about which the carrier frequency is swept. Frequently it is a dial, similar to those used in a-m signal generators or receivers. Because the center frequency must be adjustable over a wide range for coverage of intermediate frequencies and all r-f channels, more than one tuning range is usually provided. There is then a band selector switch, which determines which of the several dial scales is used. In some cases, a selector switch is used to select the desired coverage, in which case the center frequency is preset at the proper value. In most generators, the dial reading gives true output frequency (within the tolerance of the calibration). However, sometimes the fixed frequency of the swept oscillator must be added to or subtracted from the indicated dial frequency. The latter is rare, but must be considered.

SWEEP WIDTH: This is ordinarily simply a knob, with a pointer or spot to indicate relative position. Sometimes there is a scale of from 1 to 10 or some other range. This scale is usually an arbitrary one, and *does not indicate sweep width in frequency units.* Sweep width must be checked numerically by use of markers on the pattern when the latter is obtained. The sweep width control is used to adjust the width so that the complete response curve is taken in, and not for any exact numerical sweep width.

ATTENUATOR: In sweep generators, there is usually only one attenuator, and that is the continuously variable type. This is used to keep the output amplitude down to prevent overloading, and to provide a reasonable image size, in line with the gain of the oscilloscope.

BLANKING: This controls whether or not the sweep generator oscillator is cut off during the return trace of the oscilloscope. It is ordinarily just an on-off switch which either provides blanking or not. As has been previously explained, blanking provides a horizontal base line under the response curve, because there is zero vertical deflection during the return trace.

PHASE: This is a continuously variable knob control which changes the phase of the a-c voltage fed to the oscilloscope horizontal circuit compared to that of the voltage used to sweep the generator frequency. With this control, the response curves traced on the forward and reverse traces are adjusted to coincide, instead of being separated horizontally on the oscilloscope screen. Of course, if the blanking is on, the phasing adjustment merely moves the single response curve along the horizontal base line.

OUTPUT JACKS: Some sweep generators have one output jack; others have two. When two are used, one is usually for i-f output, while the other is used for r-f output for front-end injection. If the sweep generator is equipped with internal marker oscillators, extra jacks will be provided for marker output. In a few cases, a-f output and occasionally linearity pattern generator output is provided in the same unit. There will then be either a separate output jack for each of these output signals, or else a single output jack for several, with provisions on a selector switch to choose which one is used.

The jacks used are most frequently of the microphone connector type illustrated in Fig. 9-1 (A), and the leads used must have the mating connector at the generator end. Sometimes phone jacks are used, (Fig. 9-1 (B) and (C)), with phone plugs or tips on the leads. In any case, careful shielding must be maintained, and the proper leads must always be used.

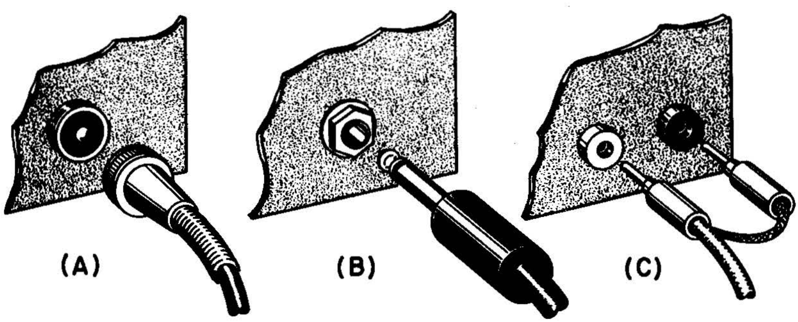


Fig. 9-1. Types of connectors commonly used for signal generator output. (A) Microphone-connector type, (B) phone-plug type, and (C) phone-tip type.

OSCILLOSCOPE CONNECTION: This is most frequently a binding post. From it a wire must be run to the horizontal amplifier input of the oscilloscope, so the horizontal deflection of the scope beam is synchronized with the sweep frequency variation.

GROUND CONNECTION: This is also ordinarily a binding post or screw connection. The importance of good grounding has been discussed in Chapter 7. From the grounding connection, a large short lead should be connected as directly as possible to ground. Some generators have metal grounding feet. If a ground plate is used (as is very desirable) these bare metal feet contact the ground plate and automatically provide a direct ground connection.

9-4. Signal Generator Leads

There may be several different leads provided with the sweep generator; the purpose of each should be reviewed. Normally, there may be two leads: one for single-ended output, for front ends of receivers using coaxial line input and for i-f sections; and one for balanced output, for connecting to balanced front end input circuits. The methods used for terminating these leads and coupling to the impedances involved are discussed in Chapter 7.

9-5. Marker Generator

At least one marker generator or marking device is necessary for proper alignment or response checking. As previously explained, the marker indicates response width, and the locations of different parts of the response curve in the frequency spectrum.

One way of providing marking is by means of a separate oscillator which has its frequency adjusted to the frequency at which marking is desired. This signal is injected along with the sweep signal, and beats against the latter at the marker frequencies to produce pips. The other marking method is by means of absorption markers, which are tuned circuits resonant at the marker frequencies which produce discontinuities at the desired points. These methods have been discussed earlier in this book. Many sweep generators have absorption-type markers or marker generators, or both, self-contained. If a marker generator is provided, there is also usually a marker frequency dial adjustment and an attenuator. There may be an extra switch for selecting the marker frequency tuning ranges. Sometimes provision is made for use of a crystal oscillator as a marker generator, and an external crystal socket may be provided so any crystal of desired frequency may be used.

9-6. Oscilloscope

The oscilloscope used for visual alignment and response analysis must meet certain minimum requirements. The screen size should be great enough to permit comfortable viewing; a 3 inch diameter is usually considered a minimum, and at least 5 inches is desirable, to allow easy identification of parts of the response curve and markers. The vertical deflection amplifier should have good response at 60 cps, so as to respond readily to the sweep cycles, and a reasonably good sensitivity to provide usable deflection when low-output stages of a receiver are being tested. The oscilloscope must have an external connection to the horizontal deflection amplifier, so the sync voltage from the sweep generator can be applied. The vertical and horizontal gain should be adjustable, as is true in practically all oscilloscopes.

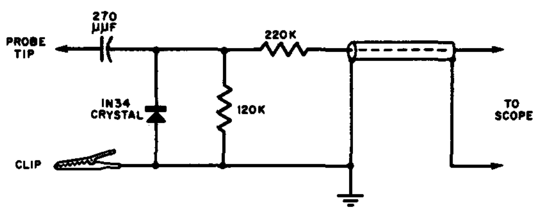


Fig. 9-2. Typical circuit for crystal probe used to rectify r.f. from receiver stages before application to oscilloscope.

It is desirable also that the oscilloscope be provided with a detector probe, which connects to the vertical input circuit. This probe circuit rectifies any r-f signal applied to it from the receiver, passing on to the vertical amplifier a d-c voltage proportional to the strength of the r-f signal. This detector probe is not necessary when the receiver output is taken from the mixer or second detector for i-f amplifier and tuner response checking. However, when the output of one or two i-f stages is to be observed, some method of detection is usually necessary, and the probe is used. A detector is also necessary when the response of the video amplifier section is to be observed by sweep methods. Video-frequency voltages (0-4 mc) are rectified at the output circuit (usually the grid of the picture tube) and applied to the vertical deflection circuit of the oscilloscope. A typical detector probe circuit is shown in Fig. 9-2.

9-7. Bench and Ground Plate

Sweep analysis of a tv receiver is not a simple operation; however, it can be made unnecessarily complicated if not enough room is allowed for the operation. The bench on which the equipment is set up should be of sufficient size to hold all units with extra room to spare.

The bench should preferably be equipped with a good ground plate, upon which all equipment can be placed, as explained in Chapter 7. This will go a long way toward avoiding grounding troubles. Of course, there should be provision for a good ground connection to the bench, and convenient ground connection points should be available so that all units may be grounded. If strong interfering signals are present, it may be necessary to do additional shielding, even to use a shielded room.

One caution should be exercised when *transformerless* power supplies (such as are found in many tv receivers, and in some signal generators and other equipment) are employed and a ground plate is being used. In these supplies, one terminal of the power source is usually connected to the chassis. This means that if the power plug is placed in the receptacle in such a way that the "hot" (ungrounded) side of the power line is the one connected to the chassis, this chassis can become charged with the full power-line voltage with respect to true ground (such as a water pipe). This could easily be a hazard to the operator, and may in some cases burn out signal generator attenuators, receiver antenna coils, or line fuses.

It is strongly recommended that the equipment used include an isolation transformer for the power line. This transformer is a 1 to 1 ratio power transformer, whose function is to provide a power source for the receiver and generator and any other power-operated equipment. The advantage is that the power source thus provided has neither terminal grounded.

Isolating transformers are available in various ratings from 100 to 2,000 watts. About 1,000 watts ought to be sufficient for most tv alignment set-ups. Some isolating transformers have several taps on the primary winding, allowing some compensation for variation in line voltage.

9-8. Coupler for Mixer Tube

When the i-f amplifier of the tv receiver is being aligned or checked as a unit, the output of the sweep generator is usually applied to the mixer tube. In order that the receiver circuits be disturbed as little as possible, the coupling should be very loose. One method for accomplishing this coupling is by wrapping an insulated wire around the mixer tube envelope, as was shown in Fig. 7-1 (B). The "hot" lead from the signal generator is then connected to one end of this wire and the capacitance between this loop of wire and the tube elements provides the desired coupling into the i-f amplifier section.

Another method of coupling to the mixer tube, recommended by many receiver manufacturers, is that shown in Fig. 9-3. The mixer tube

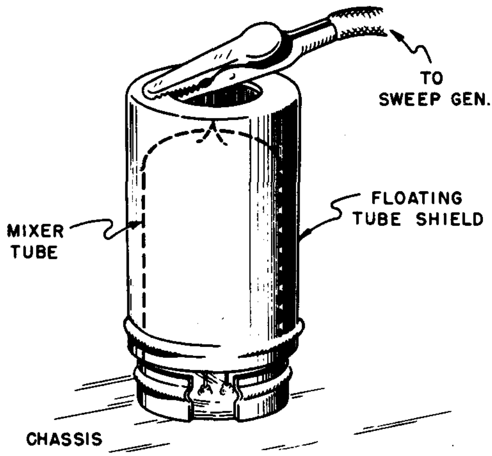


Fig. 9-3. Using a tube shield for coupling to the mixer tube.

shield is simply raised slightly so that it no longer contacts the chassis. The generator hot lead can then be connected to the ungrounded shield. The capacitance between the shield and the tube elements in this case provides the coupling. Some technicians prepare a special mixer tube shield by putting tape on the bottom edge of the shield where it would normally contact the chassis. This permits the shield to be pushed well down on the tube but still not be grounded.

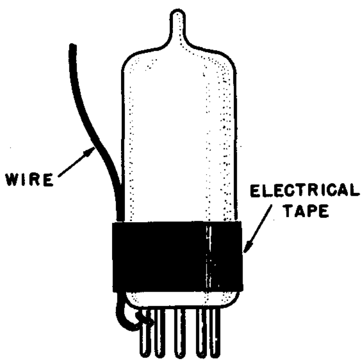


Fig. 9-4. Another method of connecting a sweep generator to the mixer tube.

Still another method recommended by some manufacturers is shown in Fig. 9-4. Here a short lead is connected to the mixer grid pin. The lead is then taped to the tube envelope. In cases where the manufacturer recommends the disabling of the local oscillator, a special mixer-oscillator tube is prepared by cutting off the plate pin of the oscillator section.

9-9. Alignment Tools

The technician will find that he must keep on hand a variety of alignment tools to be properly equipped for the adjustments in various receivers. In addition to ordinary average-sized screwdriver types, he will require very narrow, long types suitable for insertion into the front of tuner units. The tools are preferably of the insulated type with metal only on the tip, or blade, of the instrument. Metal tools may introduce too much capacitance and cause the adjustments to be different when the tool is on the adjusting screw, even though the latter is not directly connected into the circuit. It is well to have tools available for adjustment of iron-dust cores in which the blade of the tool is directly inserted into the core itself, which is slotted. The tool for this purpose preferably has a nonmetallic blade and should be a good fit in the slot, or else breakage of the cores may result at the slot, making further adjustment difficult or impossible.

9-10. Bias Battery

It is difficult, if not impossible, to obtain a proper response curve for many receivers if the agc circuit voltages are not what they would normally be under ordinary conditions of reception. When a sweep generator is feeding its output into the receiver during alignment, normal agc voltages are not developed, therefore the operation of the receiver is not the same as it would be with an ordinary input signal. For this reason, most receiver manufacturers recommend the use of a bias battery, which is connected into the circuit to provide a steady bias during alignment or checking procedures. This bias should be of similar value to the normally developed agc voltage.

The voltages required vary from around 1½ to about 8 volts, depending both upon the receiver to be aligned and the location in which the adjustments are being made. Very appropriate for such requirements is the ordinary type of C-battery. This battery is tapped at every 1½ volts up to a total of 7½ volts. By using clip leads to the battery, the technician can easily select the desired bias for any given operation. This battery should be in reasonably good condition, and the checks ordinarily used in checking radio receiver batteries are appropriate. Some manufacturers recommend the use of a potentiometer (1,000 to 2,000 ohms) across the C-battery in order that an exact adjustment of the value of the agc voltage may be made.

9-11. Importance of Manufacturer's Data

We have now outlined the equipment which must be assembled before we are ready to proceed with alignment or response checking of a tv receiver. We have discussed this equipment from a general standpoint, so the technician can become familiar with what he is likely to need in *all* cases.

But before sweep alignment is undertaken, it is important that he have available all the manufacturer's data possible on just how the alignment *of that particular model* should be accomplished. Since the manufacturer has developed and manufactured the receiver, he is the best authority as to the proper procedure in aligning it. The technician should, therefore, obtain from the manufacturer, or from a publisher of alignment and servicing information, the most complete data available.

When such data has been obtained, it should be studied before the operation starts. It is certainly very much easier to determine first, on paper, the locations of the various adjustments of the receiver chassis, and also the locations of connections provided for equipment, than to have to hunt for these later after alignment procedure has supposedly started. Most modern tv receivers have been designed to include connection points by which the signal generator can be connected and the oscilloscope vertical lead applied, at the top of the chassis, for the convenience of the technician. Location of all such points is greatly to the technician's advantage in minimizing time and trouble. It is certainly desirable that the step-by-step recommended procedure be read through before alignment starts.

The manufacturer's data will also often provide such information as how much bias to use for each test, whether stage-by-stage checking is necessary (as in stagger-tuned systems), about how much generator voltage to use, as well as much additional useful information concerning the actual alignment technique. The manufacturer is, of course, also the final authority on the details of the response curve to be aimed at, specifying the exact frequencies to be marked, and how much tolerance is allowable.

9-12. Laying Out the Equipment

The exact placement and arrangement of the equipment is in each case necessarily a matter for which the technician must use his judgment. The factors influencing the placement are:

1. The availability of good ground connections and the size and location of the ground plate.

2. The availability of power-source connections, to supply the sweep generator, marker generator, oscilloscope, and receiver. Naturally, if these are not consistent with good grounding and conveniences in the functional operations of alignment, *they should be made so.*

3. Adequate spacing between sweep generator and receiver. This spacing is preferably as great as the lead from the generator will allow

to reduce leakage and spurious output effects from the generator to a minimum. However, *never attempt to extend the length of the generator leads.* These are designed to operate as they are with the generator, and if made longer may interfere with operation, as explained in Chapter 7. If both the receiver and the generator are well grounded, and the spacing between them is as great as the leads will comfortably allow, there will seldom be any trouble with leakage or spurious effects with most pieces of test equipment.

4. Completeness of grounding and shielding. Make certain that the shields of all leads, the cabinets of all units, and all other shielding is grounded as directly as possible to a common point. As was pointed out in Chapter 7, connection of all units separately to a common ground point is the best, in preference to grounding of any unit through another unit chassis.

5. Order of signal progress through the equipment. Most technicians find it simpler to arrange the units in order of the signal travel through them, as it is orderly and less confusing in following what is happening. Thus, the sweep and marker generators would be placed at the left, the receiver in the middle, and the oscilloscope to the right. Of course, this is a relatively minor consideration, and should not interfere with such things as good grounding and proper inter-unit connections.

A typical complete set-up for sweep alignment of a tv receiver is shown in Fig. 9-5.

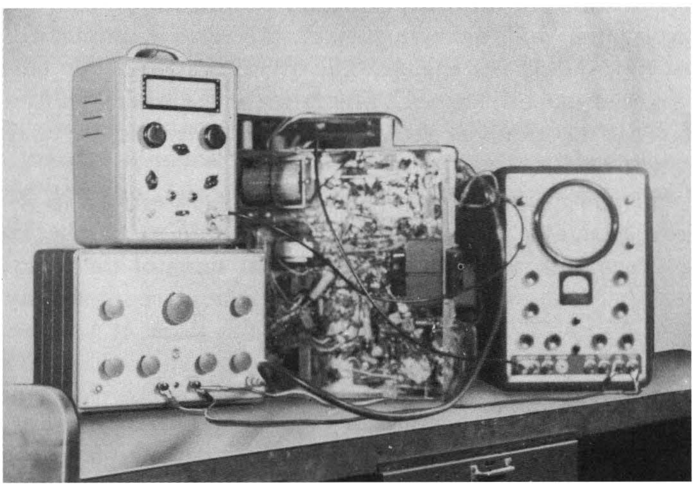


Fig. 9-5. A typical bench set-up ready for sweep alignment or analysis of a tv receiver.

9-13. Warm-up

The importance of signal generator warm-up before use was explained and discussed in Chapter 5. Before such an operation as sweep alignment it is well to allow a full half hour of warm-up before starting actual alignment operations. Warm-up is important not only for the sweep and marker generators, but also for the receiver and the oscilloscope. In short, it is best that all equipment which uses appreciable power from the power lines be turned on ahead of time, so that all heating effects will be stabilized as much as possible by the time alignment operations start.

9-14. Marker Injection[1]

The marker signal may be injected in a number of different ways. General recommendations are made in service literature, but all of them do not prove equally satisfactory with all kinds of marker generators.

Experience has taught most service technicians that injection of the marker signal without affecting the response of the system being checked is sometimes difficult to achieve. Yet the marker signal must be applied.

The primary requirement for marker signal injection is that the marker must be easily seen on a scope; yet the signal level should not be so high as to overload the receiver and affect the response curve. With present-day methods of injection, this is not always possible, although the degree of change in response curve need not be excessive. Some change will be encountered in virtually every receiver i-f system. If the change does not influence the *shape* of the response curve, it is not harmful. Whatever normal peaks and dips are visible in the response curve prior to the application of the marker signal should be present after the marker is applied, and, more important, the relative amplitude of the peaks and dips should not change. The overall height of the curve may change, but the shape must not. The latter is the most important condition, for it is the means of determining the relative degree of response of the system to different frequencies.

One common method of marker injection is shown in Fig. 9-6. Here the marker generator output lead is being coupled to the hot lead from the sweep generator by winding several turns of the marker generator output cable around the hot lead of the sweep generator cable near the feed point or by winding one or two turns of insulated wire around the sweep generator hot lead and connecting the hot lead of the marker generator to one end of this wire. Another way of accomplishing such coupling is by clipping the hot lead from the marker generator to the insulation around the hot lead from the sweep generator-

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[1] This material was excerpted from TELL-A-FAULT, published by John F. Rider Pubisher, Inc.

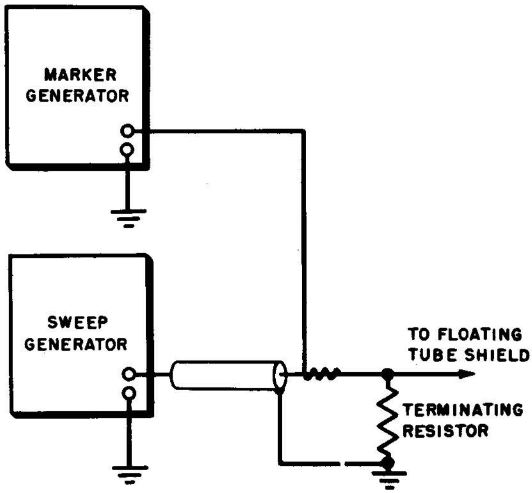

Fig. 9-6. A common method of injecting a marker signal.

ator. Do not force the clip through the insulation of the sweep generator output lead.

A second method of feeding the marker signal consists of connecting the marker generator output leads directly in parallel with the sweep generator output leads. The method is not too satisfactory. More frequently than not, it loads down the receiver because the level of the marker signal fed into the receiver is too high even when the marker-output attenuator is reduced to zero. In addition, there is no isolation of the two pieces of test equipment. The appearance of a response curve that is "knocked down" because of excessive signal from the marker source is shown in Fig. 9-7 (A). Compare this with the curve shown at (B) where the proper marker display exists. With this method it is a common practice to insert a small capacitor between the marker generator lead and the sweep generator lead. The size of this capacitor is

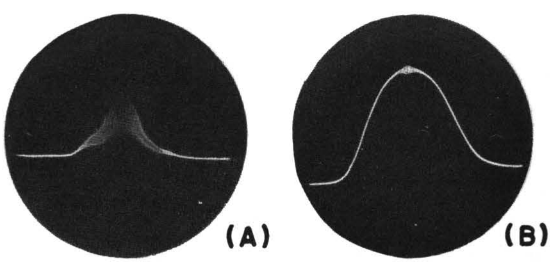

Fig. 9-7. A response curve with excessive marker signal is shown at (A). The proper display appears at (B).

not critical, however it must be as small as possible in order to provide adequate isolation while, at the same time, allowing passage of the marker signal. When this is done, such a method of marker injection may prove to be satisfactory.

A third method may appear to be a strange way of feeding a marker signal into a receiver, but it usually functions satisfactorily in every respect. Both ground and hot leads of the marker generator output cable are connected to the chassis (see Fig. 9-8). The ground lead from the sweep generator is joined to the ground lead from the marker generator. The separation between the ground and hot leads from the marker generator is between 3 and 4 inches. Control of the marker signal level is by means of the marker output attenuator, as is usual, and normal action is obtained with utmost ease. With this arrangement the marker signal is actually produced by means of a ground loop, formed by the portion of the chassis shown, and the leads.

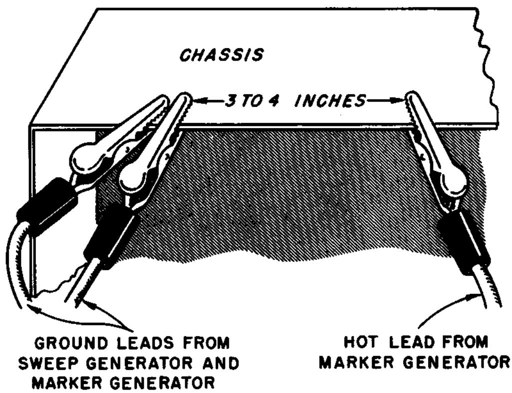

Fig. 9-8. Marker injection by means of a ground loop.

In addition to the foregoing methods, marker injection may also be accomplished by connecting the hot lead of the marker generator through a small capacitor (say 2 to 10 $\mu\mu$f) to various points in the tv i-f circuitry. Some such connection points which have proven satisfactory for marker injection are as follows: screen-grid circuits of the i-f amplifiers, various points along the agc bus, and the B-plus end of the plate windings of i-f stages.

9-15. Checking Generator Characteristics

It is assumed that the technician will have investigated, and become quite familiar with, his sweep and marker generators before he starts his alignment of the receiver. Most checks of the performance of generators themselves can be most correctly classed as *maintenance*, and are therefore discussed in Chapter 11. If such maintenance is attended to regularly, the technician will know the response of his generator output, sweep width as compared to that specified, linearity of sweep, and other characteristics. Other items of equipment should also have been carefully checked. For example, crystal detector probes should be checked for response, and it should be known that the detector response is good over the desired sweep ranges to be used, so, that where it is not good, it can be properly corrected for.

However, even though these operations are really maintenance, there are a few routine tests which can be performed each time alignment is to be done. If the maintenance measures discussed in Chapter 11 are taken, certain parts of the checks described there will be gleaned as checks which can be used in each alignment operation as a double-check and insurance against poor results due to some defect which may have crept into the equipment.

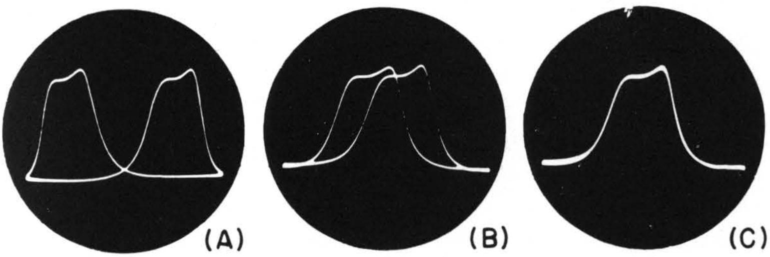

Fig. 9-9. When the phasing is misadjusted, with blanking off, two response curves appear. Adjustment of the phasing brings the curves together to coincide.

Several routine checks can be made after the units are all operating and a response curve has been obtained. Leave the blanking control off at first and adjust the response curve for proper phasing with either the sweep generator or the oscilloscope phasing control. With blanking off, improper phasing will be indicated by the presence of two response curves, horizontally displaced from each other, as explained in Chapter 4. A typical case of improper phasing is shown in Fig. 9-9. When the phasing has been adjusted, the two curves, one from the forward trace and the other from the return trace, coincide, as shown in Fig. 9-9 (C).

Next, the sweep width can be adjusted for proper inclusion of the complete response curve and the sweep width checked as explained in Chapter 11.

It is also desirable to check the frequency calibration of the marker generator or generators. This should be done periodically during the alignment process, but of course is especially important just before it starts. The frequency checks can be made by use of a calibrator or a heterodyne frequency meter, which is about the same in operation as a crystal calibrator. The heterodyne frequency meter may not have a crystal reference oscillator, but is designed to be sufficiently stable in itself to maintain a very accurate calibration.

If a crystal calibrator is not available, a separate crystal oscillator or other accurate known source of r-f signal can be fed into the receiver to be aligned along with both the sweep generator signal and the marker whose calibration is to be checked. With the response curve of the receiver present on the oscilloscope screen, marker pips can be obtained from both the marker generator and the reference signal of accurate frequency (providing, of course, they are within the pass band of the receiver). A typical response curve with two marker pips such as might result in this case is shown in Fig. 9-10 (A). The marker oscillator is then tuned until the marker pip moves along the receiver response curve and finally coincides with the reference-frequency pip. As the two frequencies come together, they produce a beat signal (see part (B) of Fig. 9-10), gradually decreasing in frequency (see part (C) of the figure). The adjustment of the marker frequency at which the frequencies are zero beat (exactly coincide) can easily be recognized. The calibration of the marker oscillator can then be checked against the known frequency of the reference signal. The special advantage of such a check is that it can be done with all units connected and ready for alignment or response checking, and disconnecting and reconnecting of units is not necessary. If the reference frequency is one useful also in the alignment procedure, it can be used as an additional marker. The reference signal can be obtained from a

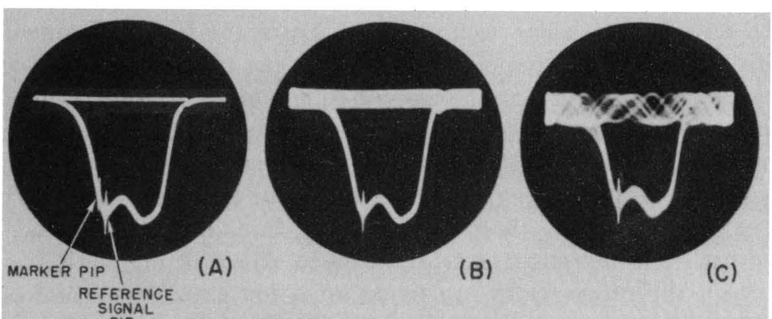

Fig. 9-10. The frequency calibration of the marker generator can be checked against a reference signal whose exact frequency is known. The checking can be done by visual means as shown here. Each signal is indicated by a pip on the receiver response curve; the marker pip is then tuned by adjustment of the marker oscillator until the pips coincide and the marker dial checked against the reference frequency.

crystal oscillator fundamental or harmonic, or from an external frequency standard.

9-16. Common Setting-Up Troubles and Their Solution

Until the beginner at sweep alignment has become thoroughly familiar with the operation and his particular set-up, he may run into difficulties in obtaining a good response curve to work with in subsequent adjustments. Although a discussion of the manner in which receiver response is adjusted in alignment is beyond the scope of this book[2], we are concerned here with the preliminary setting up and adjusting of the sweep generator and associated equipment in preparation for alignment. No book could possibly cover all the types of troubles which may arise in the development of a response curve. However, the following list is a practical set of examples as to what might happen most frequently, and what to watch out for in first obtaining the response characteristic on the oscilloscope screen.

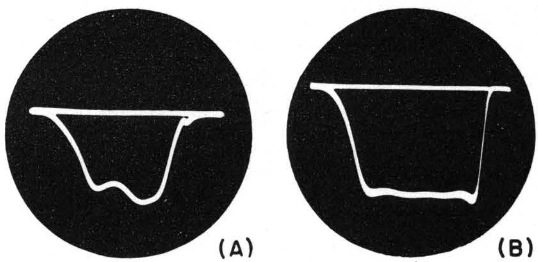

Fig. 9-11. Typical good receiver response curves.

First, the technician should be familiar with the kind of response characteristic he should have. Since the curve shape varies from one receiver to another, as well as according to how much out of alignment the receiver has become, there can be no set indication of curve shape in general. The technician will develop a "feel" for recognizing whether the curve he obtains is truly representative of the actual response of the receiver. This will be developed when the technician knows and has confidence in what he is doing. When the curve is correct, it should be stable and unaffected by motion of the body around the receiver, and should not change shape as the attenuator is adjusted up to the receiver overload point. Typical good receiver response curves are shown in Fig. 9-11.

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[2] For a complete discussion of curve shaping in tv alignment see "TV Sweep Alignment Techniques" by Art Liebscher, published by John F. Rider Publisher, Inc., New York, N. Y.

Fig. 9-12. No response indication.

No response indication at all (see Fig. 9-12). In this case, there must be a discontinuity between the sweep generator output circuit and the oscilloscope vertical deflection plates. A circuit defect anywhere along the line can cause this. First, make sure the sweep generator is putting out r-f voltage. This can be done by listening in on the sound section of the receiver to see if there is evidence of the sweep signal coming through, or by applying the sweep signal to any a-m receiver which tunes within the range. In the latter case, the presence of the signal may be more easily detected if the sweep width is reduced to a minimum. On a selective a-m receiver, the signal will be noted as a buzzing raspy sound, similar to a hum, rather than a fixed carrier, unless the sweep width can be reduced to zero. A VTVM with an r-f probe may also be used to determine whether or not there is output. If the generator is putting out voltage, it may be that the receiver has a defect which does not allow the signal to get through it. This should be traced by ordinary troubleshooting methods. Of course, the connections between the generator and the receiver should also be checked. If the receiver and generator are both alright, then check the oscilloscope. For most ordinary settings of vertical gain, the oscilloscope should show vertical deflection when the vertical circuit lead is removed from the receiver and grasped with the hand. When any discontinuities in the path of the signal from

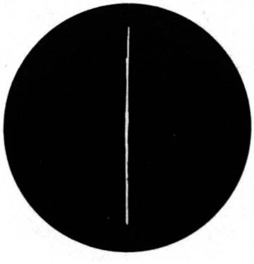
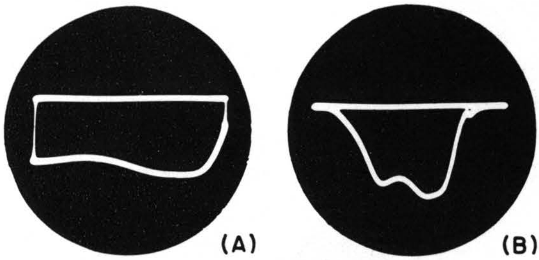


Fig. 9-13. No sweep indication.

the generator to the oscilloscope vertical plates have been removed, some kind of vertical deflection and curve should be obtained.

No horizontal deflection (see Fig. 9-13). In this case, set the oscilloscope for internal horizontal deflection instead of external. If there is no change, there must be trouble in the oscilloscope horizontal deflection circuit. If the horizontal deflection is obtained by this adjustment, then the sync voltage from the sweep generator is not getting through. Check the sync output of the generator with an a-c voltmeter and check the lead which connects it to the oscilloscope.

Fig. 9-14. Insufficient sweep width indication.



Two separated horizontal lines whose spacing can be adjusted by varying generator attenuator (see Fig. 9-14 (A)). This is caused by insufficient sweep width to show the whole response curve. Two horizontal lines will be present this way only when there is blanking in the sweep generator; one line represents the base line, the other the top of the response curve. When the sweep width of the generator is increased, the two lines will approach each other and touch at the edges, restoring the correct pattern as shown in part (B) of the figure.

Rough base line and erratic response (see Fig. 9-15). This can be caused by some extra interfering signal, particularly an overly strong marker signal. Removal of the interference, possibly by better shielding and grounding, or proper adjustment of the marker attenuator, or reduc-

Fig. 9-15. Erratic response indication.

Fig. 9-16. Response curve with 120-cps pick-up distortion on base line.

tion of the marker generator coupling to the receiver should eliminate this effect.

Non-linear base line, 120-cps ripple (see Fig. 9-16). This is usually due to improper or imperfect grounding connections, or a-c pickup on the leads. Sometimes if the signal generator lead connection to the chassis of the receiver is made at some distance from the tuner input circuit, such pick-up results.

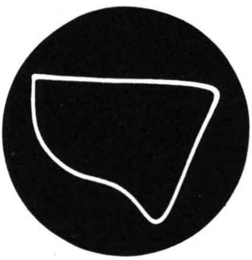
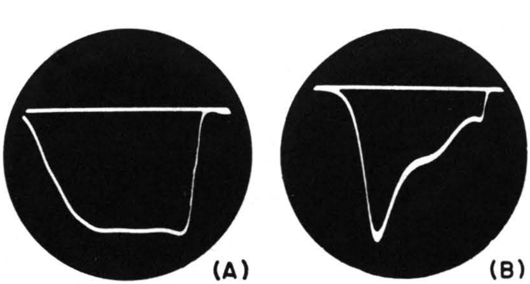


Fig. 9-17. Distortion due to oscillator tube removal.

Distortion of the r-f response curve due to oscillator removal (see Fig. 9-17). This is what may result when the oscillator tube is removed during or for r-f response checking. The oscillator tube should be kept in its socket for front-end alignment, or else the mixer tube receives improper bias and circuit capacitances are not correct. Of course, other troubles in the tuner section can also cause such distortion.



(A) (B)

Fig. 9-18. Distortion due to overloading.

Distortion from overloading (see Fig. 9-18). This may not appear as distortion at all at first. The curve at (A) is obtained with overloading, which causes the apparent flatness of response. However, when the sweep generator attenuator is adjusted to reduce the sweep signal input to the receiver, the response may actually turn out to be as shown at (B), as in the actual case illustrated here. This emphasizes that the sweep generator output attenuator should always be varied and adjusted until it is clear that overloading is not affecting the response curve shape. Adjustment of the attenuator from zero output up to the overload point should vary the height of the response curve but should not affect its shape.

Fig. 9-19. Distortion due to presence of strong local signal.

Curve distortion plus fuzziness (see Fig. 9-19). Try changing the setting of the channel selector; if the response changes, the distortion is probably due to the presence of the signal of a strong local station on the channel to which the receiver is set. The setting of the channel switch can have a marked effect on the response curve distortion. Manufacturers of receivers usually recommend just how the selector switch should be set during i-f alignment; this recommended setting is usually for one of the highest frequency channels (11, 12, or 13) on which there is no local station.

Base line tilt and distortion (see Fig. 9-20). This can result from reflections from the i-f amplifier circuits when the tuner section is being aligned. If this is the cause, it can be eliminated by removal of the first i-f tube from its socket.

Fig. 9-20. Distortion due to i-f amplifier reflections.

Chapter 10

OTHER SIGNAL GENERATOR APPLICATIONS

Signal generators have literally thousands of applications, and no book could attempt a complete discussion of all of them. However, in this chapter we include a few examples of what can be done with signal generators. With such examples in mind, the reader should have no difficulty in picturing many others, and of finding more and better ways of adapting these instruments to his own particular problems.

I. A-M RECEIVER ALIGNMENT

10-1. Review of A-M Receiver Alignment Procedure

The details of a-m receiver alignment procedures have been discussed and explained for many years in much of the available technical literature. It is suggested that for an exhaustive coverage of this subject the reader consult any good book on radio servicing. However, since a-m receiver alignment is one of the most commonly used applications of the a-m signal generator, let us review briefly the fundamental steps involved for the sake of completeness and for refreshing our memory.

A-m receiver alignment for standard broadcast receivers is reviewed in the table on page 101, which outlines the steps normally followed.

The table indicates in step 1 that the signal generator is connected to the grid of the mixer. This does not have to be a *direct* connection in most cases, but the generator can be as loosely coupled as is possible, consistent with a strong enough signal for alignment purposes. In the majority of set-ups, the connection can be through a small capacitor (50 $\mu\mu$f or less), or through a loop of wire placed over the mixer tube, as is done with many tv receivers. In fact, there is often no need for any connection at all, since radiation from the leads (and all too often

ALIGNMENT PROCEDURE

(For standard-band superheterodyne receivers)

Note: Check adjusments at the high-frequency end of the band after aligning the low-frequency end.

Connect Signal Generator to:	Set Signal Generator Frequency at:	Adjust Trimmers in Order Shown:
1. Mixer grid (loose coupling)	Specified i.f.	Output i-f transformer secondary, output i-f transformer primary, input i-f transformer secondary, input i-f transformer primary
2. Antenna terminals through dummy antenna *	Specified oscillator high-frequency adjustment (usually 1400 kc)	Oscillator shunt
3. Antenna terminals through dummy antenna *	Specified antenna high-frequency adjustment	Mixer shunt, antenna shunt
4. Antenna terminals through dummy antenna *	Specified oscillator low-frequency adjustment (usually 600 kc)	Oscillator series or ganged capacitor plate

* See text

directly from the generator when low-cost types are used) may provide sufficient signal in the i-f amplifier itself to satisfy all alignment requirements.

The same is true of the injection of the signal into the antenna circuit, as called for in steps 2, 3, and 4. As explained in Chapter 7, a standard dummy antenna can be used to ensure that the load on the antenna circuit is proper for r-f circuit alignment. However, with so many a-m broadcast receivers using loop antennas, it is generally more convenient to connect the signal generator to a small coil of wire or another loop antenna and bring this coil or loop near the loop antenna of the receiver. This couples the signal without appreciable change in the actual load normally used on the antenna circuit.

It is assumed that the alignment steps in the table are performed by use of a modulated signal with an output meter as an indicator in the a-f output circuit, or with an unmodulated signal and a VTVM reading d-c voltage at the avc lead. All these adjustments are then for maximum reading. When the output meter is used, care must be used to avoid effects of overloading by the application of too much signal to the receiver.

II. A-M RECEIVER PERFORMANCE TESTS

10-2. Selectivity

It has been previously pointed out that for accurate selectivity tests of a-m receivers, the signal generator must have an accurate step attenuator and some means of varying frequency accurately over a small range on either side of the center of the selectivity response checked. The latter facility can be provided by a vernier or fine tuning dial (see Chapter 5), or by a separate frequency meter or accurately calibrated receiver.

Selectivities are most commonly expressed in terms of "times down" of the output at a given bandwidth. In other words, a selectivity might be given as "bandwidth at 10 times down is 9 kc." The expression "times down" means that the voltage output of the receiver or receiver section being tested is that many times as small at the edges of the bandwidth stated as it is directly at resonance with a given received signal. Or, expressed differently, the expression is the ratio between the input off resonance to the input at resonance for a standard output. Typical selectivity curves are shown in Fig. 10-1, one for each end portion of the broadcast band. The selectivity is frequently greater (pass band smaller) at the low-frequency end (550 kc) because the r-f selectivity is greater

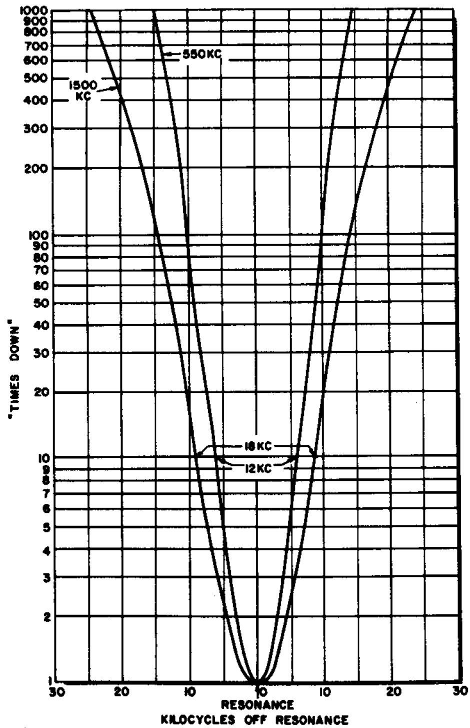


Fig. 10-1. Typical a-m broadcast receiver selectivity curves.

there due to higher circuit Q's and adds to the i-f selectivity. As an example of the expression in words of the selectivity expressed by these curves, note that at 10 times down, the low-frequency bandwidth is about 12 kc and the high-frequency bandwidth is about 18 kc.

Both the arrangement of equipment and the procedure in taking selectivity measurements are shown in Fig. 10-2. First, in step (A), the generator is coupled to the receiver through a dummy antenna. Coupling may also be through a loop of wire coupled to the receiver's loop antenna, but in this case means must be taken to ensure that the coupling stays absolutely constant, since the amplitudes of the signals are important in this test. Another alternative in coupling is to insert the low impedance signal generator lead so the generator is in series with the low side of the loop antenna of the receiver. Then the step attenuator of the generator is set to the lowest setting possible for reasonable output from the output meter, with a modulated generator signal. In the figure it is assumed that the generator is started at the $\times 1$ position of the attenuator switch. The signal used should be as weak as is consistent with a reasonable output, to avoid overloading of the receiver. In some cases, it may be desirable to disable the avc. The adjustment of step (A) is made

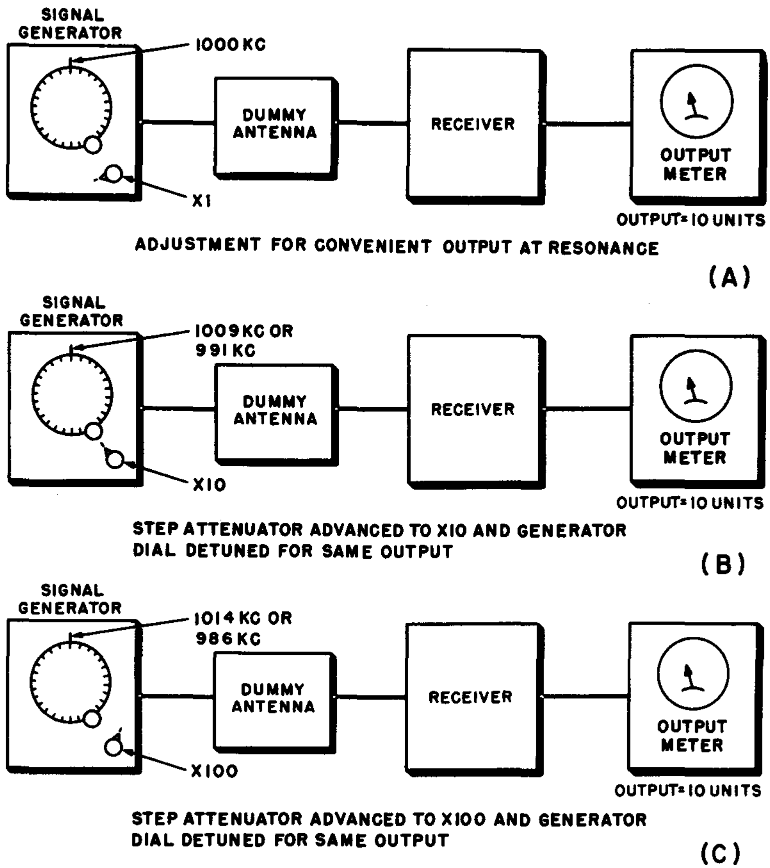


Fig. 10-2. Three steps in determining the selectivity of an a-m receiver.

with the receiver carefully tuned to the generator signal so that the receiver is at exact resonance.

Proceeding to step (B), we turn the step attenuator to its ×10 position (or the next higher position). The output naturally increases so the output meter reads much higher than before. Now, without touching any other controls, we detune the signal generator frequency from resonance until the output reduces to the same value as in step (A). When this has been done, we determine the actual new frequency of the generator. This is done either from a vernier or fine tuning dial on the generator, or by a separate frequency meter or calibrated receiver.

In step (C), we follow the same procedure, this time turning the step attenuator to ×100 without touching any other controls. The generator frequency is now further detuned until the output meter again reads the same as in step (A). Now the generator frequency is again determined.

The difference between the resonant frequency and that of step (B) multiplied by 2 is the bandwidth at "10 times down." The difference between the resonant frequency and that of step (C) multiplied by 2 is the bandwidth at "100 times down." For example, with the figures given in Fig. 10-2, the bandwidth at 10 times down is 18 kc and the bandwidth at 100 times down is 28 kc. Of course, the same procedure can be used for "1,000 times down", "10,000 times down", and to as high a ratio as desired.

If the response of the receiver is known to be quite symmetrical, readings on only one side of resonance are necessary, but otherwise it is safer to detune to each side of resonance in each case. When this is done, it is not necessary to multiply by 2 as mentioned above. As has been previously stated, the output can be observed just as well with an unmodulated signal input if the readings are taken with a vacuum-tube voltmeter at the avc lead.

10-3. Sensitivity

For measurement of the sensitivity of a receiver, the signal generator must have an accurate indicator of generator output voltage. Sensitivity is expressed in terms of the signal voltage that must be applied to the input terminals (antenna terminals) of the receiver to produce a specified output power at the loudspeaker circuit. The receiver output power is measured either with the loudspeaker or a dummy load connected to the voice coil secondary winding of the output transformer.

The arrangement of equipment for sensitivity tests is shown in block diagram form in Fig. 10-3 (A). At (B) is shown the connection of the dummy load in the output circuit and the connection of an a-c meter to read the audio voltage across it. As in the selectivity test, the signal generator may be coupled either through a dummy antenna, as shown here, or through another type of coupling device. However, in this test, if the generator is not connected directly through a dummy antenna or in series with the low side of the loop antenna, the voltage-transfer characteristics of the coupling device must be known, so the sensitivity in microvolts will be correct.

The procedure in determining sensitivity is as follows: First, a weak signal from the signal generator is tuned in on the receiver, with the carrier frequency at the value at which the sensitivity reading is desired. The output power is then observed, by reading the voltmeter or output

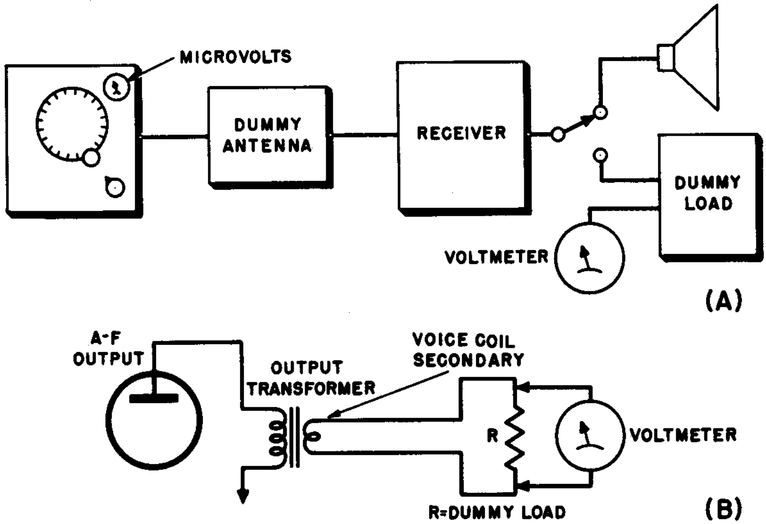


Fig. 10-3. (A) Equipment set-up for sensitivity tests. (B) Method of output voltage indication.

power meter at the loudspeaker circuit. The signal generator output voltage is then changed until the output power is the specified value.

Standard output meters which read directly in power output, and are adjustable for various load resistance values, are available for this purpose. Otherwise, a non-inductive load resistor *R*, of the same resistance as the impedance of the loudspeaker voice coil, may be used, and the output power calculated from the voltage across it. In the latter case, the specified standard power output at which the sensitivity is to be measured is used in the formula $E=\sqrt{PR}$ to determine the desired voltmeter reading. Adjustments are then made at the signal generator until the specified power output is indicated. The receiver tuning should be checked periodically to make sure the receiver remains at resonance with the generator signal.

When the receiver has been kept in exact resonance with the generator signal, and the generator output voltage has been adjusted for the minimum value at which full specified output power can be obtained, the output voltage of the generator is the sensitivity. Ordinarily, sensitivity is measured with the receiver's volume control advanced to maximum.

Standard output is normally 500 milliwatts for high-output receivers (1 watt or more), and 50 milliwatts for low-output receivers. In either case, the output power and condition of controls of the receiver should be specified. Standards also call for a signal generator modulation frequency of 400 cps and a modulation percentage of 30 percent for this test.

The sensitivity may be expressed in microvolts, or in db below 1 volt. For example, if the sensitivity is 100 microvolts, this is one ten-thousandth of 1 volt. A voltage ratio of 10,000 is equivalent to 80 db; thus the sensitivity of 100 microvolts can also be expressed as 80 db below 1 volt.

10-4. Signal-to-Noise Sensitivity

The sensitivity as determined in Section 10-3 is quite adequate for ordinary a-m broadcast receivers and other receivers in which the random noise is negligible. However, in short-wave and all-wave receivers, and very sensitive a-m broadcast receivers, random noise may become appreciable when weak signals are being received. It is therefore of special interest to know at how weak an input signal both the specified output power and the specified *signal-to-noise* ratio can be maintained.

The set-up for doing this is the same as in Fig. 10-3. Now, however, there is an extra step. The modulation of the generator signal is shut off but the carrier is left on; just the random noise in the presence of the carrier will then register on the output meter, and this indication is noted. Then the modulation is turned on and the output power checked. The attenuators of the signal generator and the receiver controls must then be juggled back and forth until the output with modulation is the specified standard value (50 to 500 mw) and at the same time is greater than the noise level without modulation by the proper specified amount. A typical signal-to-noise specification is 20 db, that is, modulation output voltage is 10 times the noise output voltage.

10-5. Overall Frequency Response

Overall frequency response is a check of how the output a-f modulation voltage at the loudspeaker terminals varies with variation of the frequency of the modulation, with modulation percentage and carrier strength constant. It is a check on the combined effects of r-f selectivity, i-f selectivity, and a-f amplifier response. It is sometimes referred to as a "fidelity" test, but this term is not too accurate since the test is of frequency response only, and there are many other factors involved in true fidelity.

The arrangement of equipment is shown in Fig. 10-4. The signal generator must have a connection for applying modulation from an

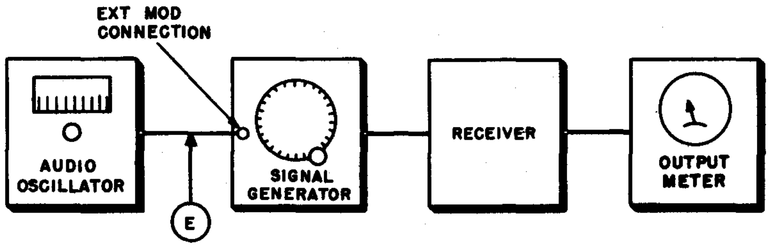


Fig. 10-4. Block diagram of set-up for checking overall receiver frequency response.

external source. A suitable external source in this case is an audio oscillator, which is fed into the signal generator to modulate the carrier. The modulation of the signal generator carrier can then be varied as desired. As a check on the modulation percentage, which mut be kept constant during the test, the a-f voltage from the audio oscillator should be measured at E.

When the set-up is ready, the audio oscillator is set for 400 cps. The signal generator and receiver controls are then adjusted for a moderate output voltage indication. Then the audio oscillator is set successively for various values of audio frequency, and the output voltage for each noted. The voltage E is kept constant by adjusting the attenuator on the audio oscillator whenever E varies from its original value. E must of course be an a-c meter, to read the audio voltage. Except for an occasional check of receiver tuning to keep it at resonance, the other controls should not be touched during a frequency run.

Typical overall response curves are shown in Fig. 10-5. If the receiver has a tone control, it is of interest to note its effect by plotting one curve with each tone control position, as has been done here.

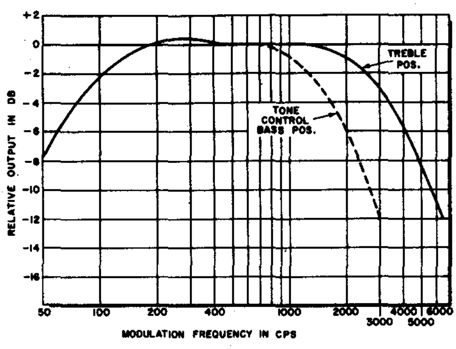


Fig. 10-5. Typical overall frequency response curves for a-m broadcast receiver. The tone control in this case is the simple type most frequently used in moderately priced receivers. As can be seen, it provides "bass" by reducing the high-frequency components of the modulation signal in relation to the lows.

10-6. Gain Measurements

The gain of a receiver stage or section is the ratio of output voltage to input voltage. There are several ways this gain can be measured using a signal generator. The main problem involved is that, in r-f and i-f sections, the measuring instrument and signal generator tend to load or detune the circuits.

The simplest and most direct method is to introduce a signal into the receiver, then measure the input and output voltages of the stage with a high-frequency probe connected to a vacuum-tube voltmeter. The accuracy depends upon how small the loading and detuning effects of the probe are, and these of course increase with frequency. Quite accurate results can be obtained in an i-f amplifier operating at 455 kc, whereas at tv intermediate frequencies and those of f-m broadcast receivers, results at best are only approximate.

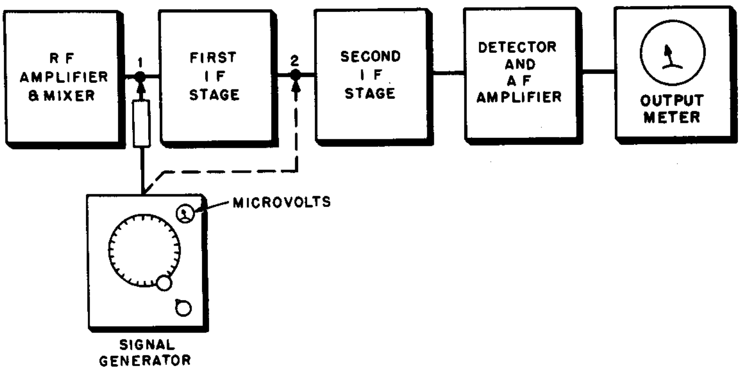


Fig. 10-6. Typical arrangement for measuring stage gain.

Another even greater difficulty arises with this direct method. That is the fact that there are not many meters with scale ranges low enough to measure the input and output voltages of any but the output i-f amplifier stages. For this reason, it is considered preferable to move the signal generator connection point instead of the measuring device. The set-up for this is shown in Fig. 10-6. The generator is first connected through a suitable matching and isolating circuit to point 1. The generator output voltage is adjusted for a convenient output voltage on the output meter, making sure the signal is low enough to avoid overloading effects. To operate the output meter, the generator signal must be modulated at a constant percentage. The signal generator output voltage indication is noted. Then the signal generator lead is moved to point 2. The signal generator attenuator is now readjusted until the signal generator voltage rises enough to provide the same output voltage as before. The ratio of the two signal generator output voltages is the gain of the stage. For example, if it takes 100 microvolts at point 1, and 10,000 microvolts at point 2 to provide the same output reading in the loudspeaker circuit, the gain of the stage is 10,000 divided by 100, or 100.

III. SOME GENERAL A-M SIGNAL GENERATOR APPLICATIONS

10-7. Use as a Beat Frequency Oscillator for C-W Reception

Many short-wave and all wave receivers provide good reception on the short waves for radiotelephone stations, but do not contain a beat oscillator for code (c-w) reception. For such reception, a tone should be heard whenever the key is down at the transmitting station, and should stop when the key is up. This helps to distinguish dashes and dots and thus makes the code more readable. Without a tone, merely a series of clicks are heard.

A signal generator can easily be used to provide a beat oscillator for a receiver. Determine the intermediate frequency of the receiver; this will normaly be within the tuning range of nearly all regular a-m signal generators, being most frequently 455 kc or near it. Next couple the generator loosely to the antenna circuit of the receiver, or by means of a loop of wire around the mixer tube if the latter is glass. If not enough input is obtained at the antenna circuit, the mixer-tube loop may be necessary. If the mixer tube is metal and therefore shielded to prevent the generator signal from getting in, couple the generator by means of a small piece of insulated wire, one end of which is connected to the generator hot output lead and the other end shoved under the chassis near the i-f amplifier tube.

After both receiver and signal generator have warmed up, tune in a signal on the receiver. With this signal being heard, tune the signal generator through the intermediate frequency; as it aproaches that frequency, a beat note should be heard from the receiver. This beat note will start at a very high pitch and become lower in pitch as the intermediate frequency is approached. When the signal generator signal is at the intermediate frequency the beat note falls to zero. Further adjustment of the generator frequency in the same direction results in a rise in beat-note frequency until it disappears. For receiving c-w signals, simply adjust the generator frequency for desired pitch of beat signal.

The same effect can be produced by tuning the signal generator frequency to the carrier frequency of the received signal, but this requires that the generator frequency be readjusted each time the receiver is tuned to a station of different frequency. This is not necessary when the generator is tuned to the receiver's intermediate frequency.

10-8. Substituting for the Receiver Local Oscillator

In some short-wave receivers, the highest frequency bands tend to be unstable, with frequency drift and "jumpiness" of tuning. If a good stable signal generator is available, this condition can be remedied by using the signal generator output for the local oscillator signal. The signal generator is simply coupled to the oscillator grid or the signal grid of the converter or mixer tube, and the oscillator tuned circuit is shorted out, as shown in Fig. 10-7.

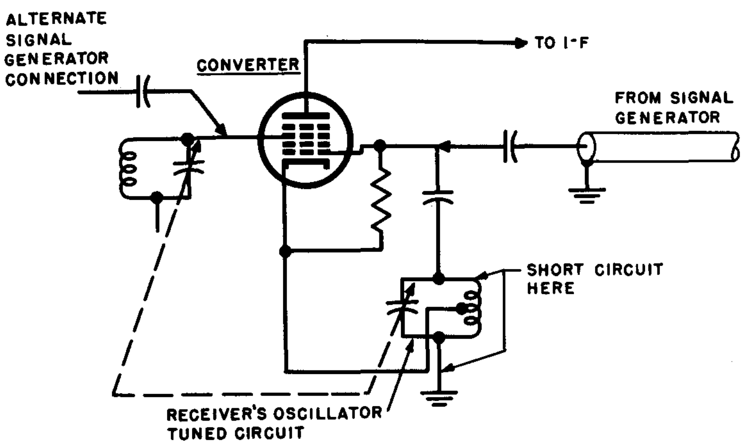


Fig. 10-7. Methods of injecting the signal generator output voltage into a receiver circuit so as to substitute for the receiver's local oscillator.

Tuning is then by means of the signal generator dial, with the receiver dial used as a "trimmer" to be tuned for maximum reception on each station. The signal generator attenuator can be adjusted for optimum injection voltage. The frequency of reception is then the signal generator frequency plus or minus the intermediate frequency, the plus or minus depending upon which the receiver dial is tuned to.

10-9. Using a Signal Generator as a Frequency Meter

The simplest way to use a signal generator as a frequency meter is to feed the signal from it into the receiver along with the signal whose

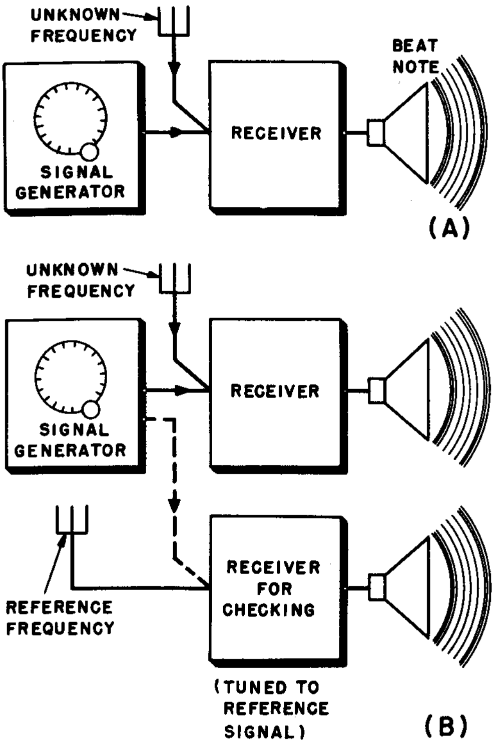


Fig. 10-8. Two ways of using a signal generator for frequency measurement.

frequency is to be determined. Then the signal generator is tuned until its signal zero beats the signal of unknown frequency. The signal generator frequency is then the same as that of the unknown signal, and, if the signal generator dial is accurately calibrated it will indicate the desired frequency. This set-up is illustrated in Fig. 10-8 (A).

Unfortunately, because of the large range of frequencies most a-m signal generators must cover, their dial calibrations are not such as to give a very close frequency reading. The signal generator is thus more useful as a frequency *standard.* In this application, the signal generator is tuned to some fixed low reference frequency, and its harmonics form "markers" through the frequency spectrum to the range in which the frequency to be measured is located. For example, if the generator is tuned to exactly 100 kc, there will be harmonics at 200 kc, 300 kc, etc. In the a-m broadcast band there will be harmonics at 600 kc, 700 kc, 800 kc, etc.; at 20 mc there will be one at 20 mc, 20.1 mc, 20.2 mc, 20.3 mc, and so on, at every tenth of a megacycle.The accuracy of each harmonic is the same in *percentage* as that of the original 100-kc fundamental. With all these harmonics present, their exact locations on the dial of the receiver can be noted. There will be a 100-kc harmonic on each side of the unknown signal. The latter's frequency can then be interpolated by its relative position between them. The set-up is shown in Fig. 10-8 (B). If there is difficulty in determining which 100-kc harmonic is which, the signal generator may be switched to 1,000 kc, to produce harmonics every 1,000 kc (every megacycle). The nearest megacycle marker can then be identified; then when the 100-kc fundamental is restored, the 100-kc points can be counted on the dial until the ones nearest the unknown signal are reached. It is desirable to set the fundamental frequency of the generator close enough to the frequency to be checked in order that the amplitude of the very high order harmonics may be sufficient to be picked up by the receiver.

The accuracy of the above method depends upon the accuracy of the fundamental frequency. Any slight variation in this fundamental frequency is multiplied by the number of times the harmonic frequency employed is as large as the fundamental frequency. In our example of the use of harmonics around the 20-mc region, 20 mc is 200 times 100 kc, so each inaccuracy of the 100-kc adjustment is multiplied by 200 in the harmonic. For instance, suppose the 100-kc adjustment is such that fundamental frequency is 250 cps (one-quarter of a kilocycle) off. The harmonic at 20 mc is then 250 x 200, or 50,000 cps (50 kc) off and completely useless as a marker.

It becomes clear that for such an application the signal generator dial calibration cannot be used for setting the fundamental frequency. Some frequency standard whose frequency is known to be very accurate beyond question must be used, and the 100-kc (or other fundamental frequency) oscillator in the generator aligned exactly with it. One good way to do this is to make use of the Bureau of Standards station WWV, which transmits signals just for this purpose.

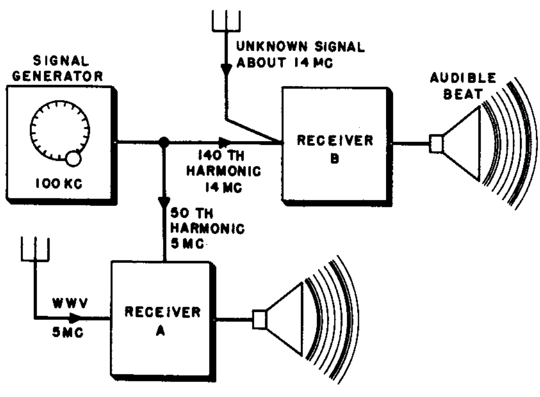


Fig. 10-9. Set-up for using the signal generator as a frequency standard.

WWV transmits with an extremely high degree of accuracy on frequencies of 2.5, 5, 10, 15, 20, 25, 30, and 35 mc. Transmissions on 5, 10, 15, and 20 mc may be received more readily due to the higher transmitting powers employed. In addition, standard audio frequencies of 440 cps and 600 cps are transmitted on all but the two higher frequencies in alternate 4-minute periods, with 1-minute pauses between, for time-signal announcements. Also, modulation by pulses spaced exactly 1 second apart may be heard.

Let us consider a practical example, illustrated by Fig. 10-9. We wish to measure the frequency of a station near 14 mc, which is being received on receiver B. The output of the signal generator is connected to both receiver A and receiver B. Receiver A is tuned to WWV at 5 mc. When the signal generator is adjusted to 100 kc, a beat note should be heard, as the 50th harmonic of the generator output heterodynes with the 5-mc signal in receiver A. The signal generator is tuned for lower and lower beat-note pitch until zero beat, or very near it, is obtained. When the frequencies are very close together, a "pulsing" effect will be heard between them, indicating that they are within several cycles per second of each other. How close this relation can be maintained depends upon how stable the signal generator is, and how clean a signal it puts out on the higher harmonics. When the frequency of the generator has been carefully adjusted as close as possible to 100 kc, the harmonics in the 14-mc region are found on receiver B, and the relative position of the unknown signal is determined accurately.

In some cases, the harmonics at the higher short-wave frequencies may be too weak and 200 kc, or 500 kc may have to be used for the fundamental. It will also be noticed that either the even or odd harmonics will be favored in some cases.

10-10. Determining Resonant Frequency of a Tuned Circuit

Sometimes it is desirable to determine the resonant frequency of a coil and capacitor combination. One way to do this with a signal generator is illustrated in Fig. 10-10 (A). The coil and capacitor are connected in parallel and the combination is connected in series with a resistor (of 1,000 to 2,000 ohms). The whole combination is then connected across the output of a signal generator. A vacuum-tube voltmeter or a volt-ohm-milliammeter with a high-frequency probe is used to measure the r-f voltage across the resistor. When the signal generator is tuned through the resonant frequency, a marked change in the voltage across the resistor takes place. Ordinarily the voltage will *dip*, due to the rise in impedance of the tuned circuit to a high value at resonance. How-

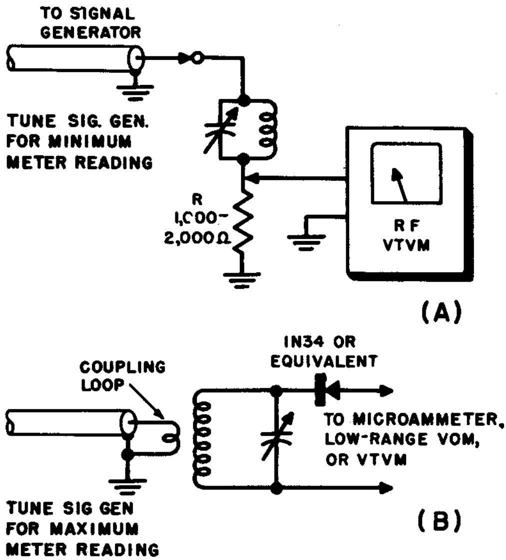


Fig. 10-10. Set-up for determining the resonant frequency of a tuned circuit.

ever, in some cases, the voltage may actually rise at resonance, because of poor regulation of the signal generator output voltage and possible capacitive effects between leads and parts of the circuit. In any event, the resonant frequency can be recognized as that at which the voltage across *R* changes suddenly, as the generator frequency is tuned through it. The meter may also be connected directly across the tuned circuit. In this case the voltage indicated by the meter will be a maximum when the generator is tuned to the frequency of the parallel circuit.

A second method is shown in Fig. 10-10 (B). Here a small coupling loop consisting of several turns of insulated wire is connected to the output of the signal generator. A microammeter, a sensitive (20,000 ohms/volt) volt-ohm-milliammeter set to its lowest d-c voltage range, or a VTVM is connected through a crystal rectifier across the tuned circuit. When the signal generator is tuned through the frequency of the circuit being checked, a noticeable peak in meter reading occurs. Peaks will also occur at harmonic frequencies of the generator; hence, the highest frequency peak should be utilized.

10-11. Using a Signal Generator as a Grid-Dip Meter

Without too much trouble, an a-m signal generator can be used as a grid-dip meter, which can then be used to check the resonant frequency of any tuned circuit within its range. In fact, with a grid-dip meter, a receiver or transmitter can be completely aligned without any power being applied.

The principle applied in the grid-dip meter is that, whenever the coil of an oscillator is loaded by the presence of a nearby circuit tuned to the same frequency, the grid current (and thus the self-bias across the grid resistor) drops to a relatively low value. Consequently, if the oscillator is brought into the presence of a tuned circuit and tuned through the resonant frequency of that circuit, the grid current of the oscillator dips quickly and returns to normal as the oscillator frequency passes through the tuned circuit frequency. The frequency of resonance of the tuned circuit is then determined by noting the point on the grid-dip oscillator dial at which the dip takes place.

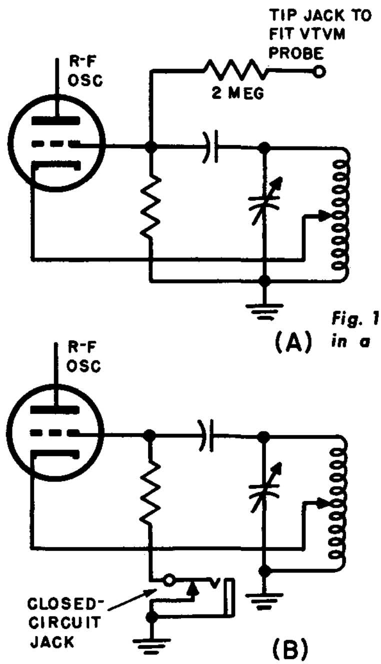


Fig. 10-11. Two methods of providing resonance indication in a signal generator circuit, when the signal generator is to be used as a grid-dip meter.

Two things are necessary to convert a signal generator to a grid-dip meter: (1) some means of coupling its output to the circuits to be tested, and (2) some way of measuring grid current or d-c grid voltage.

The coupling can be provided by a loop of wire whose ends are connected to the ends of a lead plugged into the "high output" jack of the generator. If this coupling is not sufficient, a link around the generator coil (loosely coupled) can be connected to a lead with a loop of wire at the other end, which is placed near the circuit to be tested.

Figure 10-11 shows two ways of obtaining an indication of the grid dip. In (A) a vacuum-tube voltmeter is connected through a high resistance to the grid of the oscillator. In (B) the low side of the grid resistor is disconnected from ground and a closed-circuit jack inserted. In (A) a d-c VTVM is used, in (B), a microammeter with a range of about 0-500 μa is suitable.

The above modifications are appropriate for any of the lower priced signal generators designed for servicing use. However, it is not recommended that they be attempted with any precision laboratory types in which accurate output voltage indications are possible, as the accuracy of voltage and frequency may be affected.

10-12. Use of A-M Signal Generator in Impedance Bridge

An a-m signal generator can be used as the source of signal for operation of an impedance bridge. Its wide range of frequency and control of amplitude by attenuators makes it especially suitable for this purpose. The only special requirement is that, because the output voltage of the generator is relatively low, a sensitive indicator is required for determination of the null.

Figure 10-12 shows the circuits of a Wheatstone bridge and an impedance bridge which operates on the same principle. The wheatstone

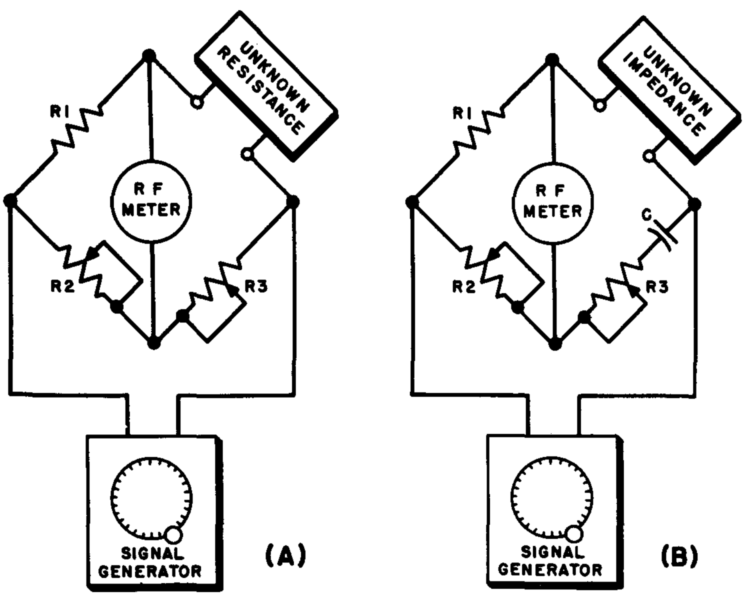


Fig. 10-12. (A) Wheatstone bridge connected to measure the r-f resistance of a component. (B) Adapting the same principle to the impedance bridge, which measures r-f impedance at the frequency of the generator.

bridge (A) in its basic form, uses a d-c source of voltage and a d-c indicating instrument to indicate d-c resistance. By changing the voltage source to an a-m unmodulated signal generator, and the indicating instrument to one sensitive to r-f, we can make the bridge measure r-f *resistance,* as shown at (A). Of course, the ratio resistors *R1 and R2,* and the standard resistor *R3* must be noninductive and be accurate for the frequency used. It is also preferable that they be shielded from each other.

The impedance bridge is the same as the resistance bridge except that the standard becomes an impedance instead of a pure resistance. At (B), the bridge becomes an impedance bridge by the addition of the standard capacitor C; *R3* is kept in the circuit to provide a sharper null by balancing out the resistance in the unknown impedance, but does not affect the impedance reading, which depends upon the reactance of C and the ratio of *R1* and *R2*[1].

It has been stated that the indicator must be a sensitive one, due to the low output voltage of the generator. A crystal rectifier and micro-ammeter will usually be found suitable. For even better sensitivity, and other advantages in some cases, a *radio receiver,* tuning to the frequency used in testing, can be employed as the indicator. If the receiver has an S-meter, an excellent indication is given. If not, it is recommended that the signal generator signal be modulated. Then the null point can be determined by listening to the receiver output.

IV. GENERAL APPLICATIONS OF SWEEP GENERATORS

10-13. R-F and I-F Transformer Response

The frequency response of individual components, as well as complete receivers and receiver sections, can be checked with a sweep generator. For example, consider such components as r-f and i-f transformers. Some kind of response curve could be obtained by feeding a sweep signal into the primary winding and connecting the oscilloscope to the secondary winding (through a detector). However, with such a direct connection, it is difficult to match the conditions of load and stray capacitance actually encountered in a circuit. For this reason, a standard circuit is usually used which is so arranged that the transformers can be connected into this circuit quite easily. The whole circuit is then checked with the sweep generator in the same way as explained in Chapter 9. Manufacturers of r-f and i-f transformers often specify their performance by stating what they will do in a given standard circuit.

[1] The basic principles of bridge operation are quite standard, and the reader is referred to any good basic book on electricity for them.

10-14. Checking Filter Response

Since the use of tv receivers has become general, the problems of interference to tv reception have been given considerable attention. This has resulted in the wide use of high-pass filters on tv receivers, and low-pass filters on radio transmitters. By the use of a sweep analysis set-up as described for the tv receiver in Chapter 9, the characteristic of such a filter can be observed on the oscilloscope screen.

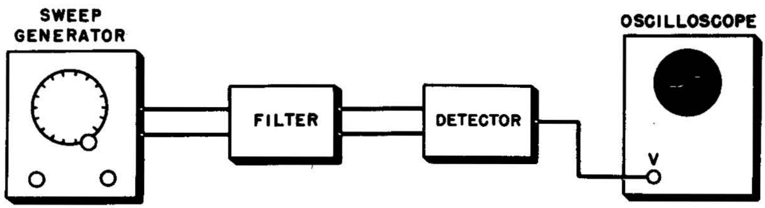
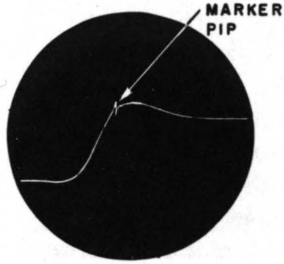


Fig. 10-13. Set-up for checking the response characteristic of a filter with a sweep generator and oscilloscope.

The arrangement is shown in Fig. 10-13. The sweep generator output is fed to the input of the filter in the same way it would be coupled to a receiver. Most of the receiver-type high-pass filters are designed for 300-ohm input, so the same termination as for a 300-ohm receiver input is appropriate. The output of the filter is then connected to a detector whose input impedance is also 300 ohms. If the detector is a high-impedance device, it is necessary to add a 300-ohm termination on the output of the detector. With an unbalanced detector (one side grounded), two 150-ohm composition resistors may be used for termination, and the detector probe is then connected across one of the two terminating resistors. The output of the detector is connected to the vertical circuit of the oscilloscope. A marker generator must be used to check the cut-off frequency. This may usually be coupled by simply holding the hot lead near the filter itself. A typical high-pass filter characteristic, showing the marker pip, is shown in Fig. 10-14.

Fig. 10-14. Typical high-pass filter response as swept out on an oscilloscope, with a marker at the cut-off frequency.



10-15. Indicating Standing Waves

With a suitable associated circuit, a sweep generator can be used to indicate, by a pattern on an oscilloscope screen, whether or not a transmission line is properly terminated, by showing whether or not there are *standing waves* present. This is very useful in checking tv and f-m receiving antennas, and in checking certain types of transmitting antennas within the limitations which will be explained.

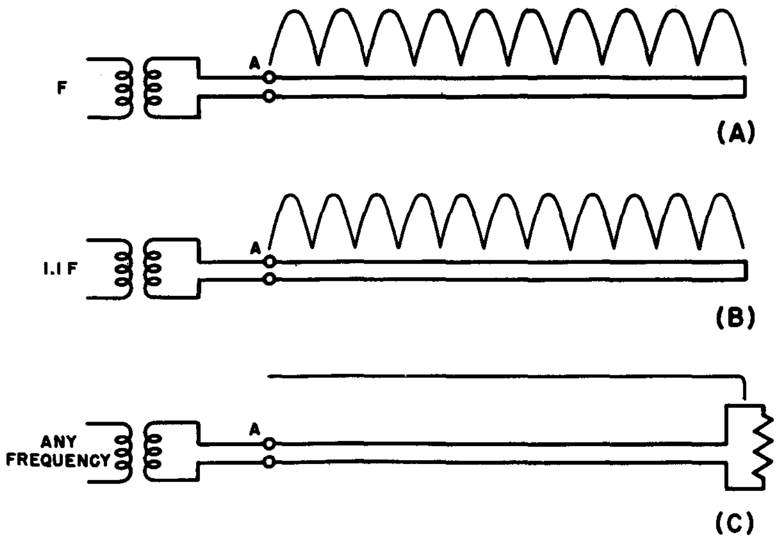


Fig. 10-15. Diagrams showing how the standing-wave distribution along an unmatched line changes as frequency changes. (A) Standing waves along a line 10 half-wavelengths long. (B) Standing waves along the same line when the frequency has been increased to make the line 11 half-wavelengths long. (C) Constant voltage without standing waves on a line which is terminated in its own characteristic impedance.

It has been previously explained how standing waves come to exist on a transmission line which is not terminated in its own characteristic impedance (Section 7-4). In Fig. 10-15 (A) is shown the representation of a transmission line into which is coupled r-f energy at frequency *f*. The line is assumed *not* to be matched at its termination, so standing waves result, as shown in the figure. In the case assumed, the mismatch is such as to produce an even 10 cycles of voltage waves along the line, so there is zero voltage (or a minimum) at point *a*. Now suppose the frequency of the signal coupled into the line is increased to 1.1*f*. Since the line is still the same length, and the voltage peaks are still one-half wavelength apart, there are now 11 cycles of standing-wave variation instead of 10. Now if the frequency had been slowly increased from *f* to 1.1*f*, the voltage at point *a* would have varied gardually from zero (or some minimum value) up to a maximum and down to zero (or minimum) again. If the frequency were varied from *f* to 1.2*f*, this variation of voltage at *a* would take place twice. Therefore, variation of frequency input at *a* causes variations in voltage at point *a*, if the line is not matched.

Now suppose the line is matched. The standing waves then disappear, and there is a constant voltage all along the line, as shown at (C). There is thus a constant voltage at point *a*, and this voltage remains the same regardless of variations in the frequency of the r-f energy coupled into the line.

With these ideas in mind, consider the set-up for checking standing waves as illustrated in Fig. 10-16. A sweep signal is coupled into the line from a sweep generator. The voltage at point *a* (input) of the line is rectified by a detector connected at that point. (Note: It is usually necessary to insert an impedance matching network at point *a* to match the output of the signal generator to the input of the transmission line. Also, if the detector is a high-impedance device that is not balanced, two equal-value composition resistors (150 ohms each for a 300-ohm line) are connected in series across the line and their junction is grounded. The detector is then connected across one of these resistors.) The output of the detector is connected to the oscilloscope vertical deflection circuit, and the oscilloscope horizontal circuit is synchronized to the sweep generator. Because of the change of r-f voltage at point *a*, the

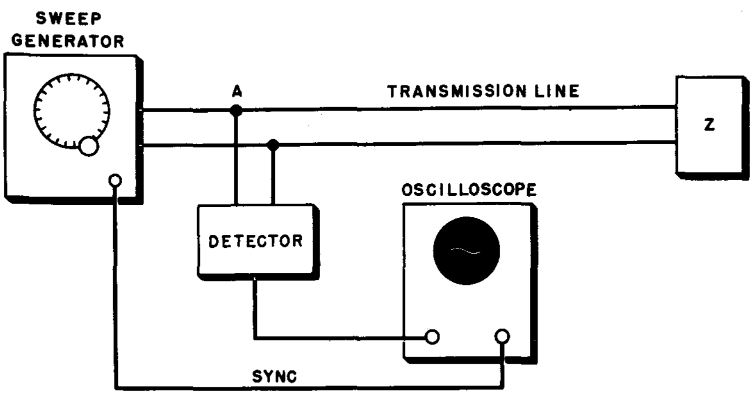


Fig. 10-16. Set-up for checking standing waves on a line with a sweep generator and an oscilloscope.

sweep line on the oscilloscope will be wavy. The number of waves across the screen will be the number of standing wave cycles passed through during the sweep frequency width. Adjustments in the terminating impedance *Z* can then be made until the wavy line on the oscilloscope screen straightens out and becomes a straight line. The straight-line trace indicates that the standing waves have disappeared and the transmission line is matched.

Certain limiting factors in this method should be noted. First, its use is limited if the terminating impedance of the line has a sharp frequency characteristic, such as would be exhibited by many transmitting antennas. With such a device, the transmission line would be matched only at or very near the frequency for which it is designed, and swinging the input frequency away from this frequency would indicate mismatch even though there is none at the operating frequency. Thus, before the above method can be useful, the terminating impedance must be determined to have an impedance which is constant over the sweep range.

The second limiting factor is that the sweep range necessary to show at least one cycle of standing waves on the oscilloscope screen depends upon the length of line used in the test. If we think of a piece of line only one-half wavelength long, which has only one-half cycle of a standing wave along it, we will realize that before the input voltage will go through a complete cycle, we must change frequency to *twice* the original value. Now if we increase the line length to one full wavelength, there will be two half cycles of standing waves, and an entire variation of standing waves will be completed when the frequency is increased to 3/2 its original value and so on for further increases. Considering these facts, we will realize that the ratio of change in frequency to produce at least one cycle of standing-wave voltage change at the input is

$$\frac{f2}{f1} = \frac{n + 1}{n}$$

where $f1$ is the lowest frequency of the sweep

$f2$ is the upper edge of the frequency sweep

n is the number half-wavelengths of standing waves along the line at the lowest frequency.

This formula is derived assuming a starting frequency at the lowest sweep value, rather than at the center, but is so close to the latter condition for a long enough line for the test that the difference is negligible.

Consider now the case of Fig. 10-15. If the starting frequency is 50 mc at (A), then the frequency at (B) is 55 mc. Therefore, to produce at least one standing wave variation cycle (at the input) on the oscilloscope, the generator frequency must sweep through at least 5 mc. If the terminating impedance of the line is an antenna whose impedance changes radically at 51 mc and 49 mc, standing waves will be indicated even though the line is matched at 50 mc, and the test is not of much use. On the other hand, if the termination is a broad-band tv receiving antenna, its impedance should not vary much over a wide range, and the test is satisfactory.

The length of line necessary for 10 half cycles of standing waves at 50 mc would be nearly 100 ft. If the line length or the frequency is doubled, the frequency change necessary to produce a cycle of variation is cut in half, or would be only 2.5 mc in this case.

10-16. Measurement of Resonant Frequency

A sweep generator may be used to check the resonant frequency of a tuned circuit in the set-up shown in Fig. 10-17. A properly terminated sweep generator is used whose output is reasonably uniform over the approximate frequency range of the tuned circuit to be checked. In part (A) of the figure, the coil and capacitor are wired in series and this combination is shunted across the output of the sweep generator. An oscilloscope is connected through a detector probe to this circuit as

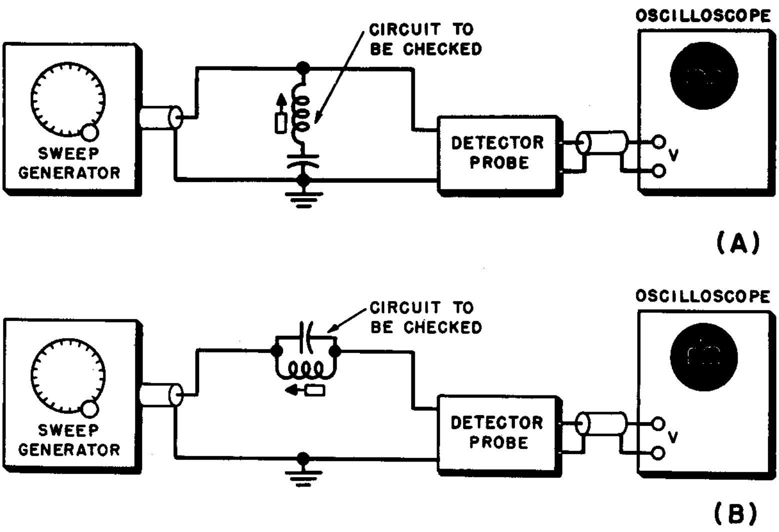


Fig. 10-17. Method used to check resonant frequency on a tuned circuit.

shown. Under these conditions a marked dip occurs in the response curve at the resonant frequency of the L-C circuit. The coil and capacitor may also be wired in parallel and this combination connected in series with the hot lead as shown in part (B) of the figure. With this arrangement, it might be thought that a reduction in response will also occur here due to the high impedance of the parallel circuit at resonance. However, in practice, a marked rise (peak) may occur at the resonant frequency of the circuit. This is probably due to the marked reduction in sweep generator loading at resonance, which causes its output to rise.

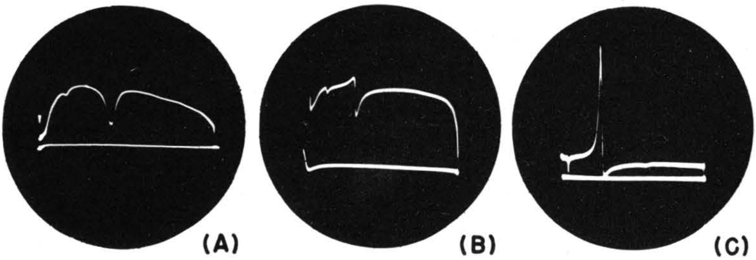

(A) (B) (C)

Fig. 10-18. Response curves produced with the set-up shown in the previous figure.

Figure 10-18 shows the response curves obtained with the set-ups of Fig. 10-17. These response curves represent sweeps from 0 mc (at the extreme left) to about 10 or 15 mc (at the extreme right). In all cases, sweep generator blanking is used to produce the straight base line below the response curve. For Fig. 10-18 (A), the coil and capacitor are wired in series and this combination is shunted across the output of the sweep generator (as shown in Fig. 10-17A). A marked dip (reduction in response) occurs at a frequency that was later marked to be about 4.5 mc. For Fig. 10-18 (B), the coil and capacitor are wired in parallel and this combination is inserted in series with the hot lead of the sweep generator (as shown in Fig. 10-17B). A slight peak in the response curve occurs at the resonant frequency (marked later with a marker generator). This peak is followed immediately by a dip that occurs at a frequency slightly above the resonant frequency of the circuit. When this same arrangement was tried with another sweep generator, the response curve shown at Fig. 10-18 (C) was produced. Here the peak, which occurred at the resonant frequency of the L-C circuit, was very marked. This peak was followed immediately by a dip at a frequency slightly above resonance.

It was found with the above set-up that the resonant frequency measured with the coil and capacitor connected together in series (as in Fig. 10-17A) was somewhat more accurate than when the parallel hook-up (as in Fig. 10-17B) was used. In the latter case, shunting capacitance effects lowered the resonant frequency slightly.

Chapter 11

SIGNAL GENERATOR MAINTENANCE AND TESTS

11-1. Limitations

The average service technician, experimenter, or radio amateur should not attempt to set himself up as a repair expert for his signal generators, no matter how well he may know their operation. Any serious deviation of performance from that specified by the manufacturer should be referred to the manufacturer himself, since he is the final authority on the equipment of his design.

However, the ordinary line of depreciation troubles due to dust, aging, corrosion, temperature, and vibration can be either avoided or remedied by the technician himself by proper routine maintenance. It will be a great saving in time and money, as well as a personal satisfaction to know that his equipment is checked and ready to go at all times.

11-2. Erratic Operation and Instability

These troubles are frequently encountered in signal generators which have undergone rugged treatment for some time. They are usually due to defective tubes, dirty or corroded capacitor rotors, loose bearings, worn bushings, or too much play in the rotor shafts of tuning capacitors. If the dial readings are all in error by the same linear distance along the dial circumference (of circular dials which rotate) the dial may have been tightened on the shaft before the frequency calibration was completely checked, or the dial may have slipped on the shaft. If the dial calibration is stationary, and a pointer moves over it, the same trouble may be due to a similar displacement of the pointer on its shaft.

Sometimes frequency readings become variable and cannot be depended upon. This condition may be the result of dial slippage due to loose set screws, defective trimmer capacitor plates, backlash in the tuning capacitor, or intermittent tube defects. Sometimes a loose connection in the tuned circuit between capacitor and coil, or loose ground connection can cause the same trouble.

If the dial readings tend to develop error only at certain spots, look for a poor connection (such as might be caused by a cold-soldered joint), a partial short circuit in the oscillator coil, or defective bypass or trimmer capacitors.

The shafts and couplings of generators should be checked for any binding, and wear in gears and other drives repaired. Carbon tetrachloride makes a good cleaning agent for shaft bearings, but *must not be used near certain plastic materials* which may dissolve in it.

It is a good idea, during periodic inspections, to blow between the plates of variable capacitors with a low pressure air hose or to slide a pipe cleaner soaked with carbon tetrachloride between them. A small amount of lubricant, such as clock oil, should be applied as a slush to the surfaces of the variable capacitors, and a very small amount to the bearings. In all cases, lubricant should be applied very *sparingly*, with the main objective to keep all parts *clean*. Variable capacitor wipers may be removed, cleaned and the metal bent very slightly to provide greater contact pressure.

11-3. Calibration of Signal Generators

After a signal generator has been in use for some time, the calibration may develop some error due to aging, dust, moisture, and other causes. If certain components are replaced, recalibration may be necessary. For these reasons, the service technician or experimenter should be prepared not only to check the calibration of his generator, but also to make small adjustments to correct it. Naturally, very radical failure of calibration should be referred to the generator manufacturer.

A very convenient and accurate source of frequency standards for checking calibration of signal generators is the a-m broadcast band. A-m broadcast stations are required by law to keep their carrier frequencies within 20 cps of specified frequency, and most of them can be depended upon to remain within 10 cps. This means that all frequencies of the generator below the low edge of the a-m broadcast band (550 kc) as well as those within the broadcast band itself, can be checked against the signals of the a-m broadcast stations whose frequencies are appropriate. Since there is a broadcast channel every 10 kc between 550 kc and 1600 kc, there are bound to be a large number of stations receivable in any one area which can be employed for frequency calibration checking.

For checking, the signal generator is coupled to the receiver enough to provide a reasonably strong signal of about the same strength as the broadcast station signals to be checked against. The antenna is left on the a-m broadcast receiver, so that broadcast station signals are received with normal strength. The set-up is shown in Fig. 11-1.

The signal generator is tuned until either its fundamental signal, or a harmonic, is zero-beat with a selected broadcast station signal. The frequency of the generator signal must then be either exactly equal to that of the broadcast station, or exactly equal to a sub-multiple of the broadcast station frequency (one-half, one-third, one-quarter, etc.). One broadcast station can be used to check a number of signal generator dial points. For example, suppose the broadcast receiver is tuned to a station on 600 kc. Then, when the signal generator is adjusted to 100 kc, the sixth harmonic beats against the broadcast station signal; when

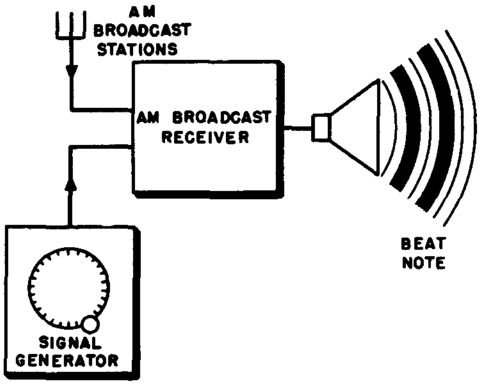


Fig. 11-1. Set-up for checking frequency calibration of signal generator in and below the a-m broadcast band.

adjusted to 120 kc, the fifth harmonic; 150 kc, the fourth harmonic; 200 kc, the third harmonic; 300 kc, the second harmonic; and 600 kc, the fundamental. All these frequencies can be checked for the generator with the receiver tuned to only one station.

One precaution must be observed; when there is modulation on the broadcast station, a false beat may be obtained by beating against the sidebands of the station, rather than the carrier. This is not a serious problem when sub-multiples are used as already described here, but does become important when a harmonic of the checking frequency is used, rather than a sub-multiple.

It may be necessary to connect a variable capacitor in series with the antenna lead if the a-m broadcast station used is too strong, but ordinarily the signal generator attenuators will provide sufficient variation of relative strength to provide the most useful beat signal.

Of particular interest to the radio service technician are the standard intermediate frequencies, 455 kc in particular. If there is a receivable broadcast station on 910 kc, this station carrier makes an excellent check point, since the second harmonic of the signal generator signal can be beat against it. If the broadcast station on 910 kc is strong enough, a quick setting of the signal generator can be made against this carrier each time a receiver is checked or aligned, thus ensuring a more exact intermediate-frequency signal than could be obtained from setting with the generator dial alone.

When generator frequencies above the a-m broadcast band are to be checked, the a-m broadcast stations cannot be used in just this way. However, what can be done is to use an additional generator or frequency meter (any good stable oscillator will do) which is tuned to an appropriate broadcast station carrier. Harmonics of this generator or oscillator can then be mixed in another receiver with the signal from the generator to be chceked. Figure 11-2 shows an example. The calibration of signal generator *A* is to be checked at 10 mc, so its dial is set for approximately that frequency, and its output is coupled to receiver *X*. The other oscillator or signal generator *B* is coupled both to receiver *X* and to another receiver, receiver *Y*. Signal generator *B* is tuned to some sub-multiple of the 10-mc calibration frequency, in the example we have chosen 1 mc (1,000 kc). A 1,000-kc broadcast station is received on receiver *Y*, along with the 1,000-kc signal from signal generator *B*.

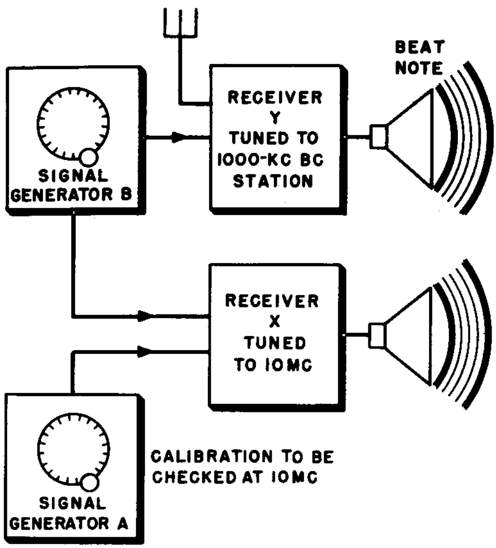


Fig. 11-2. Method for checking calibration of signal generator at frequencies above the a-m broadcast band.

Signal generator *B* is adjusted until its signal is zero-beat with the broadcast station signal. The tenth harmonic of the signal from signal generator *B* is then received on receiver *X*, which is tuned to 10 mc, along with the 10-mc signal from generator *A*. Signal generator *A* is then adjusted to zero-beat with the 10th harmonic from signal generator *B*, and is then exactly at 10 mc. The dial calibration reading can then be observed on signal generator *A*, and the amount of error determined.

If a frequency standard operating on 100 kc or 1,000 kc or other even low-frequency value is available, its regularly repeating harmonics can be used as check points right up through the short-wave range, provided a reasonably sensitive receiver is used with the standard and generator outputs fed into its antenna circuit. The process is then similar to that outlined in Section 10-9.

11-4. Compensating or Adjusting for Calibration Errors

By the methods discussed in the previous section we can determine whether or not there is dial calibration error, and about how great the error is. Now the question is "what to do about it?" There are two possible courses of action.

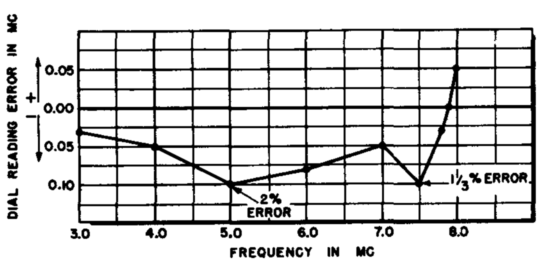


Fig. 11-3. Calibration correction curve and data taken to derive it, for one range of a signal generator.

First, we can develop a correction curve or table which will tell us just how much off the dial reading is at any particular frequency. It is seldom that the error will change very rapidly, so corrections will remain constant in most cases for up to one half of a dial coverage or more. In fact, if the frequency scale is linear, one correction may take care of a complete band coverage.

Typical dial error data taken for an actual signal generator are shown in Fig. 11-3, with a correction curve plotted from them. Note that there is a rapid change in dial accuracy at the high frequency end of the range. This is a common effect, and makes clear that it is not desirable to operate with this signal generator set at the high end of any of its ranges. This is where the tuning capacitor is at its minimum value, and errors can easily be present. Good signal generators allow a generous overlap between ranges, so there is no need to operate too closely to the high edge of any of them. Note that readings were taken much closer together when changes in the error started to take place more rapidly; this should always be done.

The second method for overcoming calibration error is by adjustment of any trimmer capacitors provided by the manufacturer for this purpose. The manufacturer's instruction manual should be consulted and only adjustments recommended by him made. Trimmer adjustment may not always provide a perfect calibration, since there is a certain allowable error due to production tolerances. For this reason, it is always desirable to make some kind of independent frequency check whenever a job which requires frequency accuracy is started.

11-5. Checking Attenuator Accuracy and Voltage Output

Step attenuators can be checked for accuracy by the set-up shown in Fig. 11-4. The modulation is turned on in the signal generator with the generator set for a convenient frequency, the generator signal is rectified by the detector and the modulation signal amplified by the vertical amplifier of the oscilloscope. With the horizontal sweep adjusted for some high value, the result will be a solid pattern whose height is proportional to the output r-f voltage of the generator. The pattern is adjusted for a size which takes up most of the screen; and then its height is measured. If the oscilloscope has a cross-hatched screen, the height can be observed in terms of squares on the screen. Now the step attenuator is reduced to the next lower position, nominally one-tenth output. The voltage should drop to one-tenth of its previous value, so the height of the oscilloscope pattern height should drop to one-tenth of its previous value. When the test on one step has been completed, the vertical amplifier of the oscilloscope and the continuous attenuator of the generator are readjusted for full height of the pattern again, and the procedure repeated for the next downward step of the step attenuator.

Microvolt readings are difficult to measure with ordinary equipment except on the higher output settings. There are vacuum-tube voltmeters

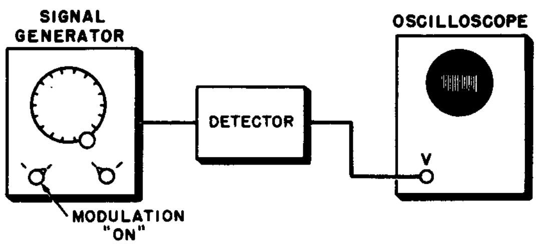


Fig. 11-4. Set-up described in the text for determining action of the step attenuator.

available with high frequency probes which will measure down to about 50,000 microvolts (0.05 v). If a field-strength meter is available, it can be used to check output voltage. The output voltage can be quite accurately checked against another generator whose output voltage indications are known to be correct. The two generators are arranged so that each can be connected in exactly the same way to a receiver. The receiver is equipped with an output meter or vacuum-tube voltmeter on the avc lead, if the receiver does not already have an S-meter. The generator known to be accurate is set successively for various values of output voltage. For each value, the generator to be checked is substituted and set for the same output indication on the receiver, at which time the output voltage indication should be the same as for the standard generator.

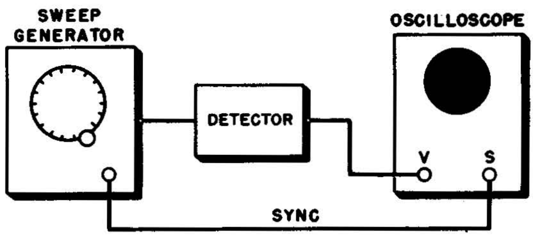


Fig. 11-5. Arrangement of equipment used to check sweep generator response.

11-6. Checking Sweep Generator Amplitude

It is of interest to know the constancy of output voltage of the r-f carrier of a sweep generator over the sweep range. This is important because in sweep response analysis, the response curve exhibited on the oscilloscope screen cannot be accurate if the voltage applied to the receiver input is not constant over the sweep range.

A typical set-up for checking sweep amplitude is shown in Fig. 11-5. The r-f output of the sweep generator is applied to a detector whose response is known to be uniform over the range to be checked. The out-

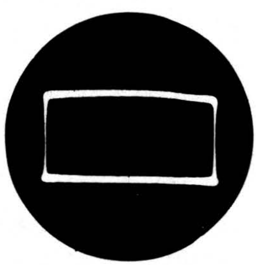


Fig. 11-6. Typical sweep generator response as observed with the set-up of Fig. 11-5.

put of the detector is applied to the vertical circuit of the oscilloscope. The horizontal deflection of the oscilloscope is controlled by the sync voltage from the sweep generator as in sweep analysis applications.

Figure 11-6 shows the type of generator response which should be obtained. Blanking should be used, since otherwise the response line will be "floating" and there will be no base line to compare it with. If the response is not flat as is shown, it may be possible to improve it by the use of isolating pads or an impedance matching network at the output end of the cable. If this cannot be done, then at least the technician should be aware of the irregularity of the output voltage so that the response curves traced on the screen with such a generator may be corrected for.

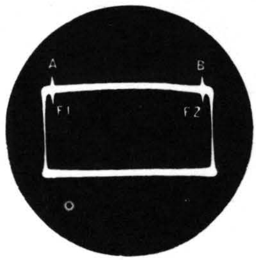


Fig. 11-7. Response of a sweep generator, with marker pips used to determine sweep width.

11-7. Checking Sweep Width

The sweep width of a generator can be checked with exactly the same set-up as described above for output, except that a marker generator is added. The marker generator is set so the marker pip is at the left end of the response line (*a* in Fig. 11-7) and the marker frequency is noted. Then the marker generator is readjusted to move the marker pip over to the right end (*b* in Fig. 11-7). If the first frequency is *f1* and the second is *f2*, then the sweep width is equal to *f2* minus *f1*.

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