CHAPTER 7

USE OF TEST EQUIPMENT

The purpose of this chapter is to acquaint the technician with the practical use of test equipment. The operation and function of several of the most common test equipments used are included. The basic operating principles of the cathode-ray oscilloscope and the echo box are stressed.

A knowledge of the proper use of these instruments is one of the most valuable tools that an ET can have. The technician will find additional helpful information in the Handbook of Test Methods and Practices (latest edition), NavShips 91828, and in the instruction books that accompany the test instruments.

OSCILLOSCOPE OS-8B/U

The cathode-ray oscilloscope is generally used to permit the technician to observe voltage waveforms in testing electronic circuits. Because voltage waveforms are observed, an ELECTROSTATIC cathode-ray tube (CRT), which employs voltage to deflect the electron beam, is used.

Some oscilloscopes may use an ELECTROMAGNETIC CRT, which employs current to deflect the electron beam. This type of oscilloscope is used for certain applications, other than general testing, where its properties make it more suitable than the electrostatic-deflection type.

In general, test oscilloscopes are used to align and test electronic equipment, to make hum measurements, to make frequency comparisons (to determine an unknown frequency), to observe complex waveforms, and to make modulation percentage measurements.

The OS-8/U series of oscilloscopes supersedes older Navy models. Improvements are also being made in the OS-8/U series. For example, the OS-8A/U has a better square-wave response than the OS-8/U, although it is slightly heavier and larger.

A simplified block diagram of the OS-8B/U oscilloscope is shown in figure 7-1; a view of the controls are shown in figure 7-2.

The VERTICAL ATTENUATOR determines the fraction of the a-c input voltage that is to be applied to the vertical amplifier via the cathode follower. The a-c input to the vertical amplifier may not be reduced at all (vertical attenuator in the 1:1 position), or it may be reduced 10:1 or 100:1, depending on the position of the vertical attenuator switch. The purpose of this arrangement is to avoid overloading the vertical deflection amplifier of the oscilloscope.

The cathode follower provides a high-input impedance and a low-output impedance, at which point the vertical Y GAIN control is inserted. The high-input impedance prevents excessive loading of the circuit under test. Inserting the gain control at the low-output impedance point avoids frequency discrimination caused by circuit distributed capacitances.

The vertical amplifiers boost the amplitude of the applied signal so that the desired vertical displacement may be obtained on the screen of the CRT. When the SYNC SELECTOR switch is in the INTERNAL position, a portion of the vertical output voltage is used to synchronize the horizontal sweep.

The horizontal amplifiers amplify the saw-tooth signal that is to be applied to the horizontal deflection plates. The length of the horizontal sweep line, as it appears on the CRT screen, is determined by the setting of the horizontal X GAIN control.

The Sync Selector switch determines the source of the synchronizing voltage. The source may be the signal applied to the vertical plates, the line voltage, or the signal applied to the external sync terminal.

The sweep generator generates a linear voltage waveform (saw-tooth waveform), which, when applied to the horizontal deflection plates

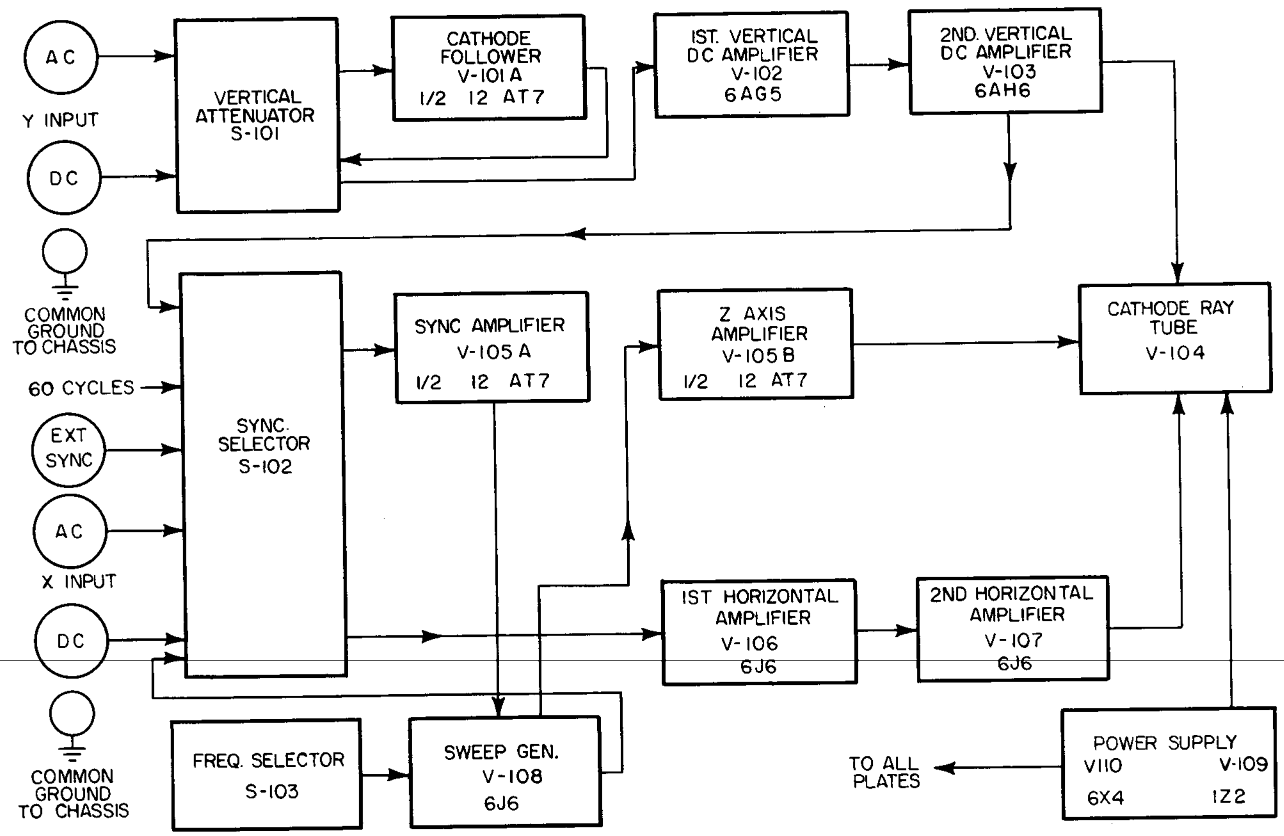

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Figure 7-1.—Simplified block diagram of the OS-8B/U oscilloscope.

of the CRT, results in a trace that progresses across the screen from left to right at a constant rate of speed. The frequency of the internally generated sweep is determined by the setting of the SWEEP RANGE switch and the SWEEP VERNIER.

The sync amplifier amplifies the sync signal and feeds it to the sweep generator.

The Z axis (blanking) amplifier and its associated circuit control the variation of the intensity of the trace throughout the sweep cycle. A jumper is normally connected across the blanking terminals of the terminal board at the CRT in order to blank the sweep return trace. If desired, the jumper may be removed and an external voltage introduced across the terminals to intensity modulate the trace throughout the cycle.

The INTENSITY control decreases or increases the bias on the grid of the CRT so that the number of electrons allowed to pass through the control grid is regulated. This control also turns off the power supply when rotated to its extreme counter-clockwise position.

The FOCUS control changes the voltage on the focusing electrode of the CRT and thus permits the sharpening of the trace on the screen.

The Y POSITION control moves the beam or trace up or down on the face of the tube; the X POSITION control moves the beam or trace horizontally on the face of the tube. By means of these controls, the trace may be positioned at any place on the screen.

The SYNC AMPLITUDE control varies the strength of the signal applied to the sweep generator. It may be set so that the sweep generator will be synchronized on either positive or negative signals.

The SWEEP RANGE control is a coarse setting for the sweep frequency desired; the

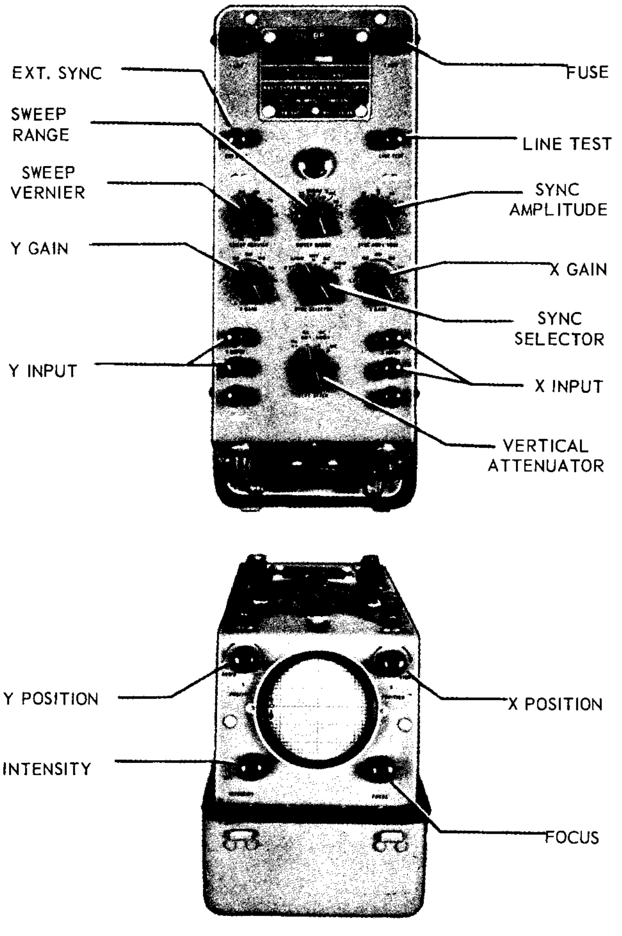

Figure 7-2.—Oscilloscope OS-8B/U controls.

sweep vernier is a fine setting for the same signal and is continuously variable within the limits set by the sweep range.

The sync selector permits different sync sources to be applied to the sync amplifier. In the EXTERNAL position, the sweep is synchronized with the voltage source connected to the external sync terminal. In the LINE position, the sweep is synchronized with the power-supply frequency; and in the INTERNAL position, the sweep is synchronized with the signal being applied to the Y INPUT. In each of these three positions the sync signal is under the control of the sync amplitude potentiometer. When the sync selector is in the A-C or D-C position, the sweep generator is cut out of the circuit, and the horizontal deflection is controlled entirely by the voltage connected to the X-INPUT terminals. A capacitor is connected in series with the a-c terminal, and the response is limited at the low-frequency end to approximately 25 cycles per second. When the d-c terminal is used, the deflection will respond to low frequencies as well as to direct current.

The Y gain controls the amplitude of the vertical amplifier output, and the X gain controls the amplitude of the horizontal amplifier output.

The Vertical Attenuator determines the fraction of the a-c input voltage that is applied to the vertical amplifier. Thus, in the 1:1 position, no reduction takes place; in the 10:1 position, the voltage is reduced to one-tenth; in the 100:1 position, the voltage is reduced to one-hundredth. In the d-c position, the attenuator and the cathode follower are bypassed. In this position, low frequencies (up to 1000 cycles) may be connected between the d-c input terminal and ground with essentially no resulting distortion.

The exact method of operating the controls is given in the instruction book that accompanies the equipment.

GENERAL INFORMATION

To obtain an accurate presentation of the voltage waveform, a few precautions must be observed. The approximate magnitude of the voltages in the circuit under test must be known so that the operator can take steps to safeguard himself from shock and the oscilloscope from a voltage breakdown.

Dependable data can be obtained from the oscilloscope only if its sensitivity and frequency characteristics are known. To make certain that the waveform will not be distorted it is essential that the manner in which distortion takes place be understood and that precautions be taken to minimize such distortion.

INPUT CIRCUIT.—The input to most oscilloscopes is between an input terminal (which is above ground potential) and the common ground terminal. The input terminal is almost always coupled to the grid of the amplifier through a capacitor. Seldom do the capacitors used have voltage ratings in excess of 450 volts. Therefore, unless the approximate magnitude of the voltage under test is known, damage to the oscilloscope through breakdown of the input capacitor may result.

VOLTAGE DIVIDERS.—In some cases, it may be necessary to observe waveforms in circuits where the voltage is much greater than the components within the oscilloscope can withstand. A voltage divider may be used in such instances to reduce the voltage to a value that will not damage the equipment. In any case, it is very important that the oscilloscope be adequately grounded. Grounding the oscilloscope is a precaution that must be taken for the protection of the operator, because a failure of some part of the voltage divider can raise the potential of the whole oscilloscope to a dangerous level if the oscilloscope case is not solidly connected to ground.

If the voltage divider used is a capacitance divider, a wise precaution is to shunt each capacitor with a high resistance in order to maintain the proper voltage distribution across each capacitor. Two voltage dividers are shown in figure 7-3. In Part A, the capacitance alone causes the voltage across C2 to be one-tenth of the voltage across C1. However, the leakage resistances, R1 and R2, may be of such values that they divide the voltage by a very different ratio. If the leakage resistance of the capacitors is high with respect to the magnitude of the X_C ohms, the leakage resistance will have negligible effect on the voltage distribution across the capacitors. However, if the leakage resistance is of the same order of magnitude as that of the X_C ohms, the leakage resistance may have a pronounced effect on the distribution of the voltage across the capacitors. This condition might cause excessive voltage across one capacitor and result in a breakdown. To prevent this unbalanced distribution of voltage, resistors R3 and R4 may be added, as in figure 7-3, B. Because the leakage resistance of a good capacitor is of the order of 1000 megohms and because R3 and R4 are relatively low in resistance, the two resistors fix the voltage division at the same ratio as do the capacitors, and the voltage divider may be easily designed to withstand the high voltage.

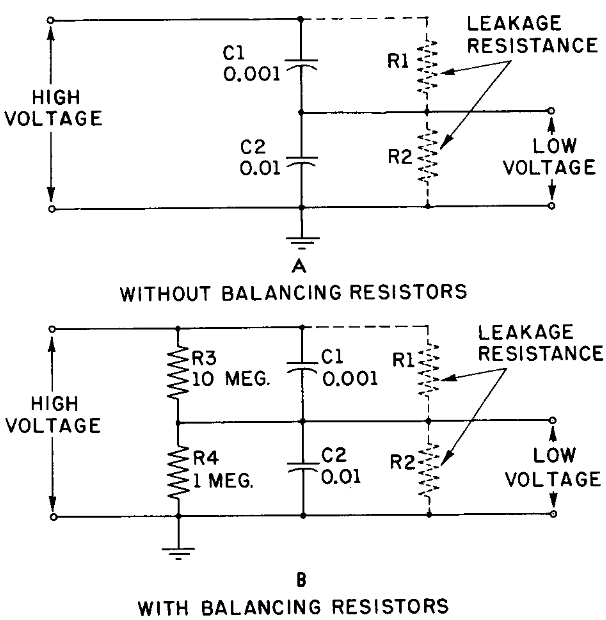

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Figure 7-3.—Capacitance voltage divider.

FREQUENCY RANGES.—The range of sweep frequencies in a given oscilloscope is usually indicated on the front panel of the instrument. The frequency range that the vertical and horizontal amplifiers are capable of amplifying properly is given in the manufacturer's instruction book. Generally, only the best oscilloscopes use amplifiers that will amplify voltages whose frequency is below 20 or above 1,000,000 cycles per second. Oscilloscopes that do not cover as wide a range of frequencies as this may be satisfactory for most uses, but distortion is likely to occur when saw-tooth or rectangular waveforms of a high recurrence rate are investigated. High performance oscilloscopes are capable of amplifying over a broader frequency range, and, accordingly, may be used on rectangular and saw-tooth waveforms of high recurrence rates without distorting the shape of the waveform.

DEFLECTION SENSITIVITY.—The deflection sensitivity of an oscilloscope may be defined as the distance in millimeters that the spot is moved on the screen when 1 volt is applied to the deflecting plates. The deflection sensitivity in this case is expressed in millimeters per volt. The most accurate way of measuring this quantity is to apply a known d-c potential directly to the deflecting plates and measure the distance that the spot is moved by this voltage. The number of millimeters that the spot moves, divided by the voltage applied, is the deflection sensitivity in millimeters per volt.

The deflection sensitivity (or factor) may also be expressed as the input voltage to the amplifier (horizontal or vertical) for a deflection of 1 inch of the spot on the CRT screen. In this case, the amplifier gain control is adjusted to a suitable value that is arbitrary (for example, midscale). The magnitude of the input sine-wave voltage is measured with an accurate a-c voltmeter. Most a-c voltmeters indicate the root-mean-square (rms) value of voltage. However, the deflection of the spot on the screen is proportional to the amplitude of the sine wave from the positive peak to the negative peak (peak-to-peak voltage). To convert the rms voltage at the input to peak-to-peak voltage, the input meter reading must be multiplied by 2.828.

Thus, the effective sensitivity (gain) of the oscilloscope in volts per inch is the peak-to-peak voltage applied at the input of the amplifier divided by the peak-to-peak amplitude of the trace in inches. For example, if the peak-to-peak voltage applied to the vertical amplifier is 2.8 millivolts and the peak-to-peak amplitude of the trace is 2.8 inches, the vertical deflection sensitivity will be $\frac{0.0028}{2.8} = 0.0001$ volt per inch. If the gain control is changed, the effective sensitivity will also change. However, the sensitivity of the CRT itself is not affected by the use of the amplifier. The only factor changed, when changing the gain control, is the amplitude of the voltage applied to the deflecting plates.

If the peak-to-peak voltage applied directly to the vertical deflection plates without going through the amplifier is 48 volts and the peak-to-peak amplitude of the trace is 1 inch, the vertical direct deflection sensitivity will be 48 volts per inch.

STRAY PICKUP.—To avoid pickup of stray signals, the leads from the circuit under test to the oscilloscope should be as short as possible. If the leads are long, a greater voltage can be induced in them by stray fields than would be induced if the leads were short. The pickup may be so disturbing in some cases that it will be almost impossible to use the oscilloscope. A few things can be done to reduce the effect that stray fields have on the oscilloscope.

First, the cathode-ray tube must be very carefully shielded from all stray fields. In most cases, this shielding is provided by the Aquadag coating on the inside of the tube, by a metallic shield outside the tube, and by the oscilloscope case.

Second, the common side of the oscilloscope circuit should be connected to a ground point in the circuit under test and to a good external ground connection. This connection will aid in eliminating most of the stray voltages that are picked up by the leads.

Third, a low-capacitance coaxial cable may be used to reduce still more the effect of stray fields.

DISTORTION.—Several sources of distortion are possible in the production of CRT display. Although distortion can be eliminated by simple precautions in some cases, it is very difficult to eliminate in other cases. A summary of some of the major factors to be considered follows.

1. Perhaps the most obvious component in which distortion can enter is the deflection amplifier. It is important, therefore, to know the frequency response of the amplifier being used. An estimate may then be made of the possibility of distortion for a given signal.

2. If the sweep is nonlinear, the shape of the wave on the screen will not be a true picture of the voltage under test. However, if the oscilloscope is not defective, the sweep will generally be linear enough for most purposes.

3. When signals of relatively high frequency are to be observed, the time of fly-back may become an appreciable fraction of the period of the signal. To avoid distortion of this type, it is well to adjust the sweep frequency so that several cycles of the signal will appear on the screen.

4. If the magnitude of the synchronizing voltage is too great, the image may be distorted because the sweep is terminated too soon. This condition may be avoided by setting the synchronization control at zero while the sweep frequency is adjusted. When the sweep frequency is some integral multiple of the signal frequency, the image will be stationary on the screen. The synchronizing voltage should then be turned up just enough to stop the apparent motion of the image on the screen.

5. In general, the input impedance of the oscilloscope will be much higher than the impedance of the circuit at the point where the test is to be made. Therefore, the input impedance of the oscilloscope will not change appreciably the circuit load nor the voltage

at the connection point, and a true picture of the voltage may be observed. In some circuits, however, the impedance may be very high (perhaps up to 100 megohms), and the input impedance of the oscilloscope may load the circuit and change the voltage so radically that it will be difficult to obtain a true picture.

6. The input shunting capacitance of an oscilloscope is generally small (of the order of 20 to 60 $\mu\mu$f), but it may be sufficient to alter the characteristics of a video amplifier or the tuning of a high-frequency oscillator.

7. When one specific type of equipment is to be maintained, many of the preceding sources of distortion may become of academic interest only. When, for example, the same oscilloscope is used with the same pair of leads to check repeatedly a given set of waveforms, the distortion will always be the same if the circuits are operating properly. If the waveforms through the system are recorded when the system is working properly, the maintenance testing need consist only of a comparison of the waveforms obtained with the recorded standard waveforms. In such a case, it is not necessary to eliminate all distortion, because the test will consist of a comparison of two sets of data that are distorted in the same way. It is desirable, however, to eliminate distortion as much as possible in order that the operation of the circuit under test may be better understood. However, successful testing may be performed regardless of distortion, if the same test equipment is used in the same way in every check.

Signal Tracing

SINE WAVEFORM.—The cathode-ray oscilloscope (CRO) is used chiefly for checking the waveform of the signal voltage in electronic circuits. The most commonly found waveform in a-c power circuits is the sine wave. Most cathode-ray oscilloscopes (for example, the OS-8B/U) have a line-test signal binding post internally connected to a low-voltage winding of the power-supply transformer so that an a-c voltage at power-line frequency (60 cycles) is available for testing purposes. A jumper may be connected between the line test signal binding post and the a-c Y input. If the sweep range is set on the line between 15 and 75 and the sweep vernier is adjusted to 60, a single cycle of sine waveform will appear on the cathode-ray screen. This pattern may be used for comparison with other sine waveforms.

OTHER WAVEFORMS.—Oscilloscope AN/USM-24 is an equipment for displaying a luminous plot of the time variation of a voltage pulse or wave, with self-contained means for measuring its duration and instantaneous magnitude. It is intended for use in testing all types of electronic equipment in the radar and communications fields. The waveforms may be square wave, saw-tooth, peaked, sinusoidal, or modifications of any or all of these.

In general, the method of obtaining the signal waveform is to adjust the horizontal sweep frequency to approximately the frequency of the signal voltage to be presented on the screen and then to apply the signal voltage to the Y input binding post, making sure that the ground terminal is returned to the ground on the equipment from which the test voltage is derived. The horizontal gain control is then adjusted for full horizontal deflection and the vertical gain control adjusted for slightly less than full scale deflection. If the pattern is not properly centered on the screen, the horizontal and vertical positioning controls should be adjusted until the desired centering is obtained.

The CRO is used in signal tracing to determine the location of a fault. The signal voltage is derived from various test points (for example, in the circuit shown in figure 7-4) and the pattern compared with the pattern for each particular check point, as indicated in the figure. The bandwidth and the sweep frequency of the test CRO are indicated for specified conditions of equipment operation. For example, at test point TP107, the sweep frequency (SF) of the test oscilloscope is designated as 60 cycles; the duration of the zero voltage condition is 15,000 μs (T), and the length of the negative-going pulse (-100 v) is 1670 μs (T). The letter, R, designates the range setting of the equipment.

As a Measuring Device

D-C VOLTMETER.—The electrostatic CRT is a voltage operated device. The amount of deflection of the spot is proportional to the magnitude of the voltage applied to the deflecting plates. If the deflection sensitivity of the CRT is known, the oscilloscope can be used as a voltmeter on either direct or alternating voltages. The oscilloscope has the advantage of

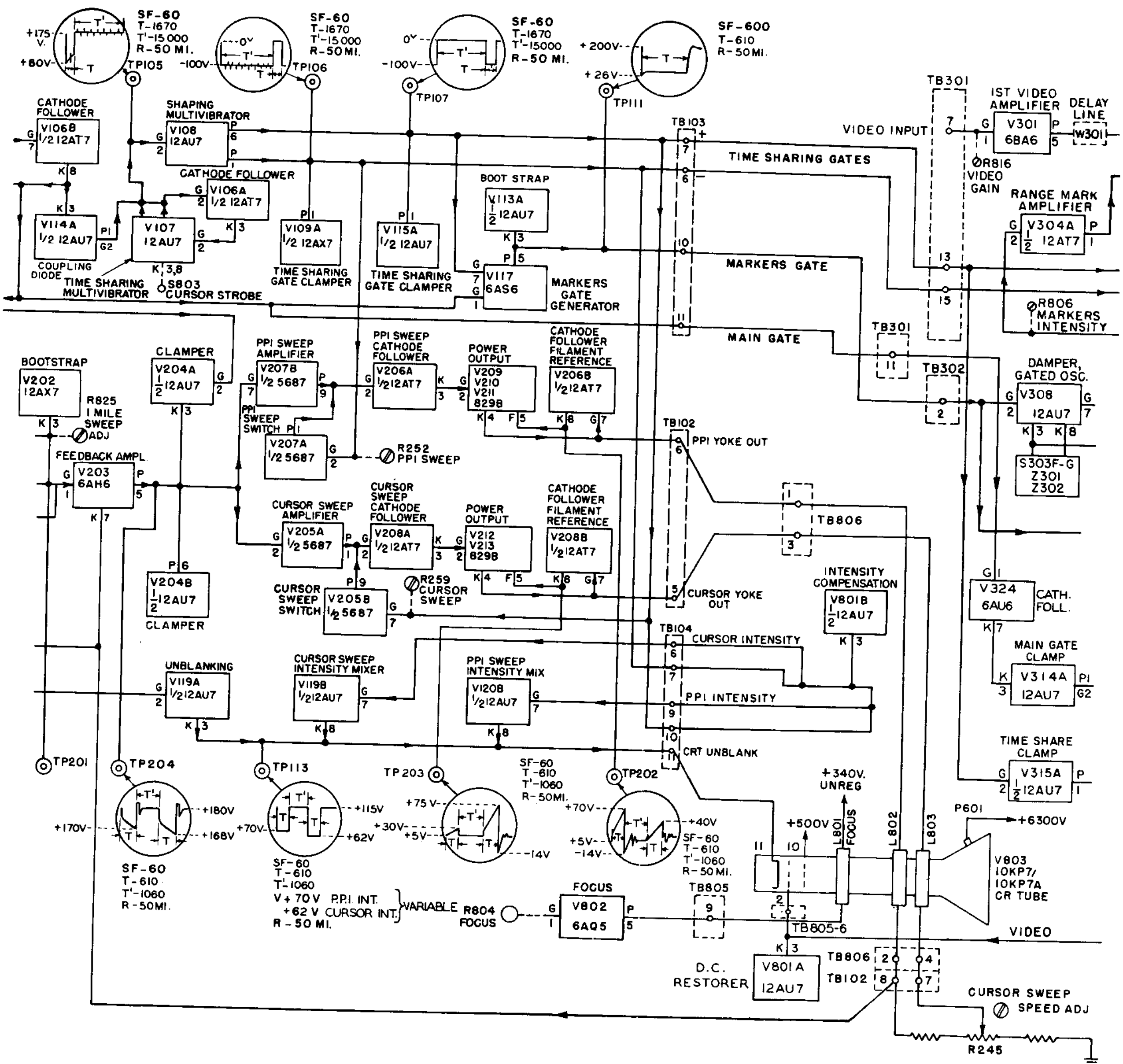

Figure 7-4.—Signal tracking with the CRO.

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having extremely high input impedance when the voltage to be measured is applied directly to the deflecting plates. However, because both the range of voltage measurements and the accuracy of indication are less than that available in commercial d-c voltmeters, the oscilloscope is not widely used for the measurement of d-c voltages.

A-C VOLTMETER.—The CRO is a better device for measuring alternating voltages than most conventional a-c voltmeters. The principal difficulty with the oscilloscope is the calibration of its deflection sensitivity. If this factor can be determined accurately, the magnitude of the alternating voltage can be determined very simply. The advantages of the oscilloscope as an a-c voltmeter are its very high input impedance, its ability to measure equally well voltages of a wide frequency range, and its ability to indicate magnitude, regardless of waveform.

The oscilloscope shows the peak value of the applied a-c voltage; whereas, standard a-c meters show the rms values of the sine-wave, a-c voltage. Peak values may be readily converted to rms values, but the results may be misleading for voltages whose waveforms are other than sinusoidal.

AMMETER.—The electromagnetic CRT is a current operated device. Accordingly, it could be used to measure current magnitudes directly if it were properly calibrated. This type of tube, however, is rarely used in test oscilloscopes. The electrostatic CRT, as mentioned previously, is widely used in test oscilloscopes, and it may be used to measure currents indirectly. If the current to be measured is passed through a calibrated resistor, the resulting voltage across the resistor may be indicated on the oscilloscope screen. By application of Ohm's law, the current may be calculated; that is, R is known, E is measured, and I can be calculated by the equation,

$$I = \frac{E}{R}.$$

WATTMETER.—The same method that is used to measure current can also be employed to measure power. The power dissipated in a resistor is equal to the product of the current through the resistor and the voltage across it. Therefore, the power dissipated in the resistor may be expressed as

$$P = E1 = \frac{E^2}{R}.$$

If the voltage measured by means of the oscilloscope is substituted in this equation, the power may be calculated (if the resistance is known).

Lissajous Figures

A Lissajous figure is a pattern created on an oscilloscope screen when sine-wave voltages (usually of differing frequencies) are applied simultaneously to both the horizontal and vertical deflecting plates. One of the principal uses of Lissajous figures is to determine an unknown frequency by comparing it with a known frequency.

DEVELOPMENT OF SIMPLE FIGURES.—The development of four types of Lissajous figures is shown in figure 7-5. Each Lissajous figure is developed by plotting a smooth curve through points formed by the intersection of horizontal and vertical lines projected from corresponding points on two sine curves (bottom and right side of Lissajous figures). Adjacent points on the sine curves at the right are separated by equal intervals (30°). Those on the sine curve at the bottom are separated by an interval of 15°. The ratio (horizontal to vertical) of the frequencies applied to the two pairs of deflecting plates is 1:2; that is, in this figure the frequency on the horizontal deflecting plates is one-half the frequency on the vertical deflecting plates. It does not matter what the actual frequencies are, as long as one of the frequencies is known.

If the two voltages are in phase; that is, if both voltages are passing through zero and going positive at the same instant, a figure eight pattern will be traced (fig. 7-5,A). As the phase changes slightly, the pattern will change, as shown in figure 7-5, B, C, and D. When the phase angle is 90°' the loops will colse, as in C. If the phase angle is greater than 180°, the pattern will be inverted, as in D.

INTERPRETATION OF PATTERNS.—One feature that all of these images have in common is that the pattern touches the horizontal lines (xx or x'x' of figure 7-5, A) at two points. This is true of the remaining patterns of the figure, even for the line tangent to the top of figure 7-5, C, because the trace passes point 1 on the figure twice during each cycle. Likewise, the vertical lines (yy or y'y') are touched by the pattern at only one point. The ratio of the number of points of tangency is equal to the ratio of the two frequencies. Expressed as and equation,

$$\frac{f_h}{f_v} = \frac{\text{number of tangent points on vertical line}}{\text{number of tangent points on horizontal line}}$$

where f_h is the frequency of the signal applied to the horizontal deflecting plates and f_v is the frequency of the signal applied to the vertical deflecting plates.

The number of tangent points on the horizontal and vertical lines is most easily counted when the Lissajous figure is stable (not moving) and when it is symmetrical. The ratio of the number of points of tangency on the vertical line to the number on the horizontal line is 1:2. If f_v = 120 cycles,

$$f_h = f_v \frac{\text{number of tangent points on vertical line}}{\text{number of tangent points on horizontal line}}$$

$$= 120 \times 1/2 = 60 \text{ cycles.}$$

MISCELLANEOUS FIGURES.—In figure 7-6, several varieties of Lissajous figures are shown. The ratio (horizontal to vertical) of the two input frequencies is indicated in each case. Unless the oscilloscope screen is very large, ratios higher than 10:1 are difficult to interpret. The circle shown in figure 7-6, A, is the simplest type of Lissajous figure. The pattern in figure 7-6, B is for a 2:1 ratio. Compare this with the pattern shown in figure 7-5, A, in which the ratio is 1:2.

Figure 7-6, C through F, indicates the increasing complexity that is encountered in ratios of higher order.

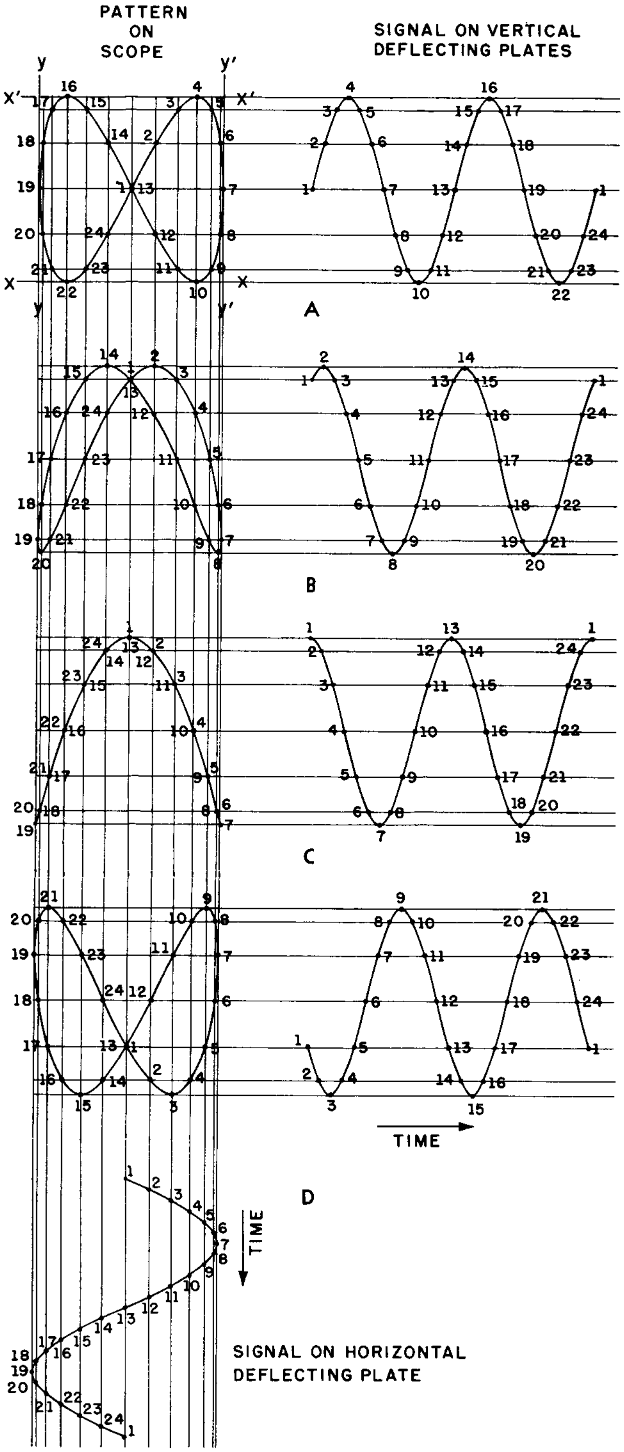

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Figure 7-5.—Lissajous figures for a 1:2 horizontal to vertical input frequency ratio.

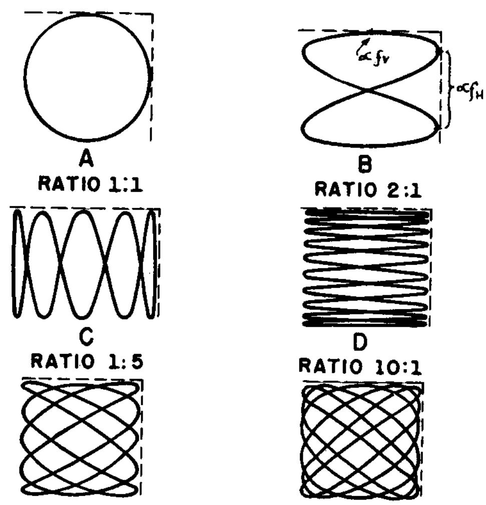

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Figure 7-6.—Lissajous figures for various frequency ratios.

INDICATION OF PHASE.—The patterns of figure 7-7 are formed by applying to the deflecting plates sine-wave voltages having the same frequency and amplitude, but having various phase differences. It can be seen in figure 7-7, A, that the resultant trace is a line at a 45° angle when the voltages are exactly in phase (0° or 360°). As the phase angle is made greater, the straight line opens into a broadening ellipse, as in figure 7-7, B and C. When the phase difference is 90°. the ellipse becomes a circle, as in figure 7-7, D. As the phase difference is increased beyond 90° (fig. 7-7, E through G), the circle begins to collapse toward another straight line, but this time the line is at 135° when the voltages are out of phase by 180°.

The patterns shown in figure 7-7 can be obtained only if the amplitude of the voltage applied to the vertical deflecting plates is the same as the amplitude of the voltage applied to the horizontal deflecting plates. If one voltage is greater than the other, the pattern will never become circular, but will always be elliptical. Therefore, if such patterns are to be used to measure the phase difference between two sine-wave voltages, care must be taken to ensure that both voltages are of the same amplitude, so that the screen can be calibrated.

Modulation Measurements

Amplitude modulation measurements are made by the observation of one of two basic patterns—the wave-envelope or the trapezoidal pattern—either of which gives a continuous, direct picture of the modulated output of the transmitter.

The WAVE ENVELOPE pattern gives a direct indication of the shape of the modulation envelope, as indicated in figure 7-8, A. A small pickup loop is coupled inductively to the final tank circuit of the transmitter and connected directly to the vertical deflection plates. The CRO saw-tooth generator is used to provide the horizontal sweep frequency.

When an audio signal generator is used in place of the microphone voice input, a voltage of sine waveform is supplied to the modulator, and the pattern on the CRT is easily stabilized by applying a portion of the audio voltage to the external sync terminal of the oscilloscope. The audio voltage is obtained from the voltage divider composed of R1, R2, and C. Capacitor C blocks the d-c component and couples the

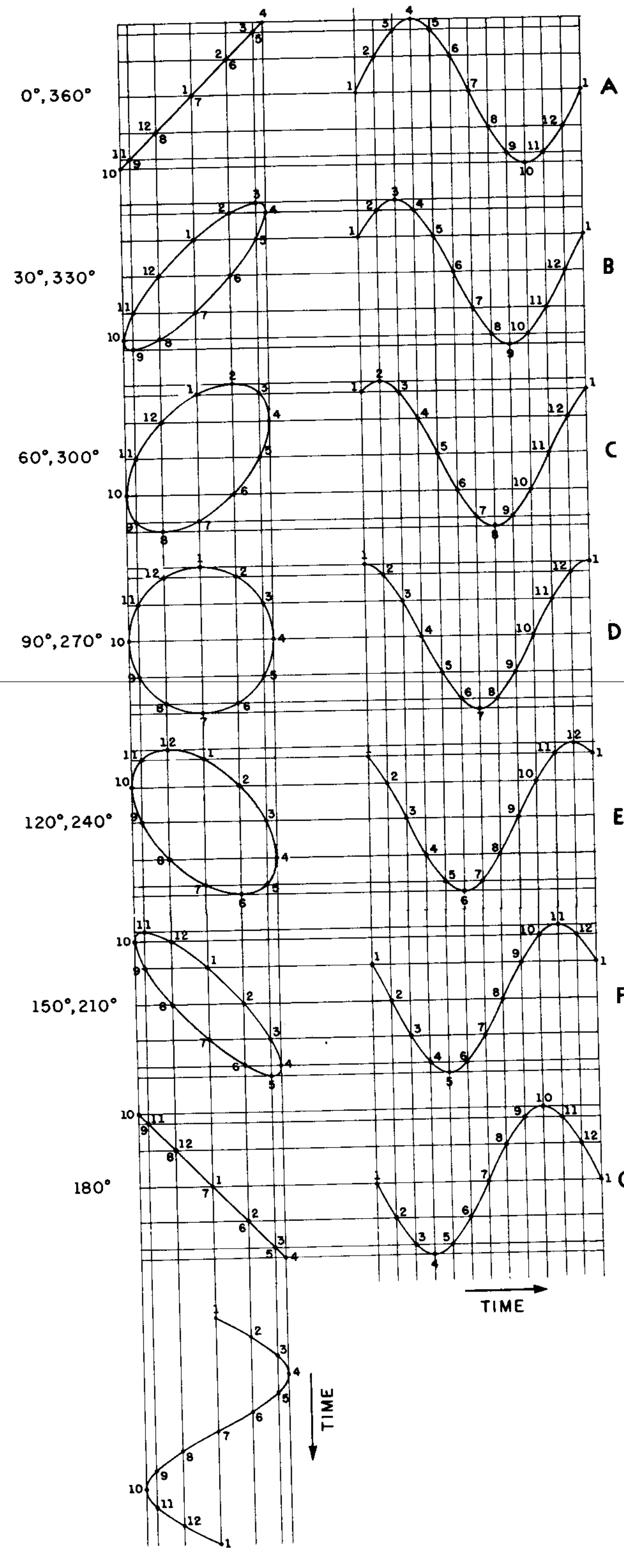

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Figure 7-7.—Lissajous figures that indicate phase difference.

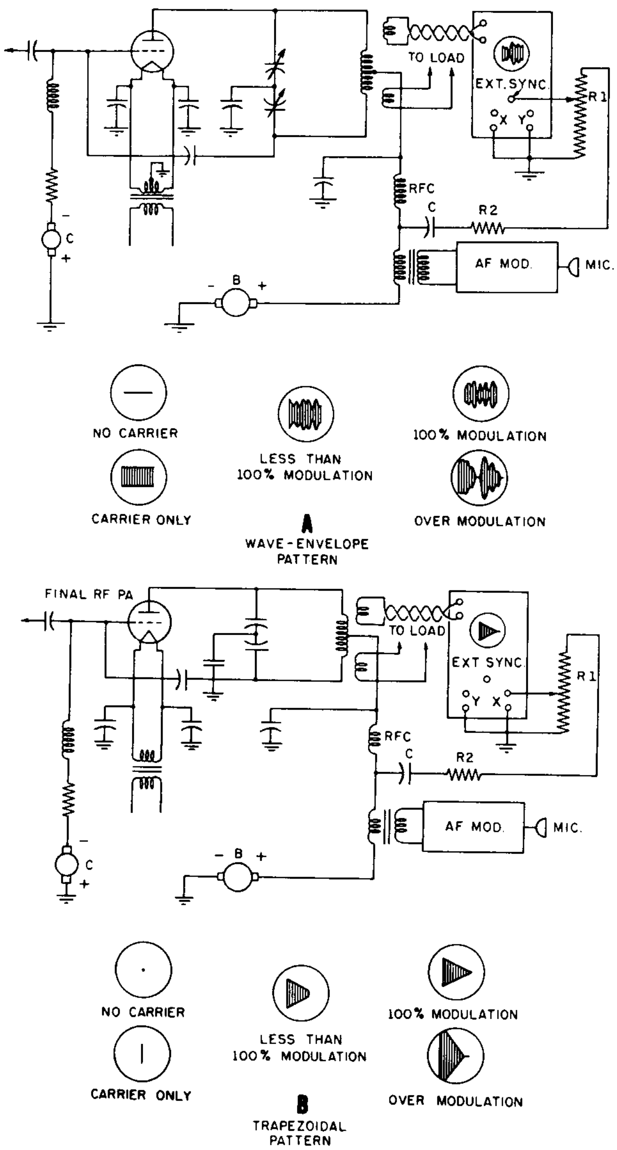

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Figure 7-8.—Modulation measurements.

a-f component to the sync input. The frequency-range vernier and sync-signal controls are adjusted until the audio component of the modulated wave is synchronized with the sweep, as indicated by a stationary pattern. When voice modulation is used, a rapidly changing pattern of varying height is obtained.

When the maximum height of the pattern is twice that of the unmodulated carrier, the carrier is modulated 100 percent. Several operating conditions are shown in figure 7-8, A. In order to determine the modulation percentage for any value below 100-percent modulation, the following procedure is followed:

The peak-to-peak height (H_2) of the unmodulated carrier is subtracted from the peak-to-peak height (H_1) of the modulated carrier, and the difference divided by the peak-to-peak height (H_2) of the unmodulated carrier. The result is then multiplied by 100 to give the percentage of modulation. As a formula,

$$\text{modulation percentage} = \frac{H_1 - H_2}{H_2} \times 100.$$

The TRAPEZOIDAL pattern is more difficult to obtain, but it gives more accurate information, particularly when nonsinusoidal waveforms are encountered. As indicated in figure 7-8, B, the vertical plates of the CRT are connected via the small pickup loop to the final tank circuit. The voltage divider, R1 and R2, across the modulation transformer secondary and the high voltage power supply provides the a-f voltage component that is applied to the horizontal input in lieu of the saw-tooth sweep frequency. Potentiometer R1 is varied until a satisfactory sweep is obtained on the screen of the CRT. The percentage of modulation is calculated in the same manner as that of the wave-envelope pattern.

THE SYNCHROSCOPE AN/USM-24

The synchroscope is a test instrument that has a wide range of applications because it includes the features of an oscilloscope plus such additional features as pulse synchronizing adaptations and markers that make it highly useful in radar testing or other testing where pulse analysis is necessary.

There are several synchroscopes available—for example, the TS-34/AP, AN/USM-32, TS-28/UPN, and AN/USM-24. Certain instruments that are, in fact, synchroscopes are sometimes designated as oscilloscopes.

A general idea of the operating characteristics of synchroscopes may be obtained from the following technical data.

For the model TS-28/UPN, the video amplifier has a frequency range of 1000 cycles to 5 megacycles.

Sweep for the oscilloscope can be internally triggered or it can be triggered by an external pulse or signal.

The internal trigger generator provides a self-generated internal triggering pulse to the apparatus under test and to the sweep and calibration mark circuits of the synchroscope when an external trigger source is not being used. The trigger frequency range is from 330 cycles to 4000 cycles.

Marker pips, synchronized with the sweep (whether internally or externally triggered), can be superimposed upon the trace of the CRT. These markers (having time ranges of 2, 10, or 25 microseconds between pips) can be used for measuring pulse width for determining pulse repetition rates, and for calibrating the sweep.

The synchroscope can also supply a synchronizing pulse of either positive or negative polarity for triggering radar or other equipment under test so that the trace appears stationary on the face of the CRT.

The following description of a representative synchroscope (oscilloscope AN/USM-24) will give the technician a general idea of the operating principles of this versatile piece of electronic test equipment. A front view of the instrument is shown in figure 7-9.

The instrument consists basically of nine channels, which are described in the following paragraphs. During the discussion, reference should be made to the block diagram of figure 7-10.

DISPLAY CHANNEL.—The heart of the display channel is the CRT. In general, the operation of the CRT is similar to those used in regular test oscilloscopes.

VERTICAL CHANNEL.—The function of the vertical channel is to transmit the signal from

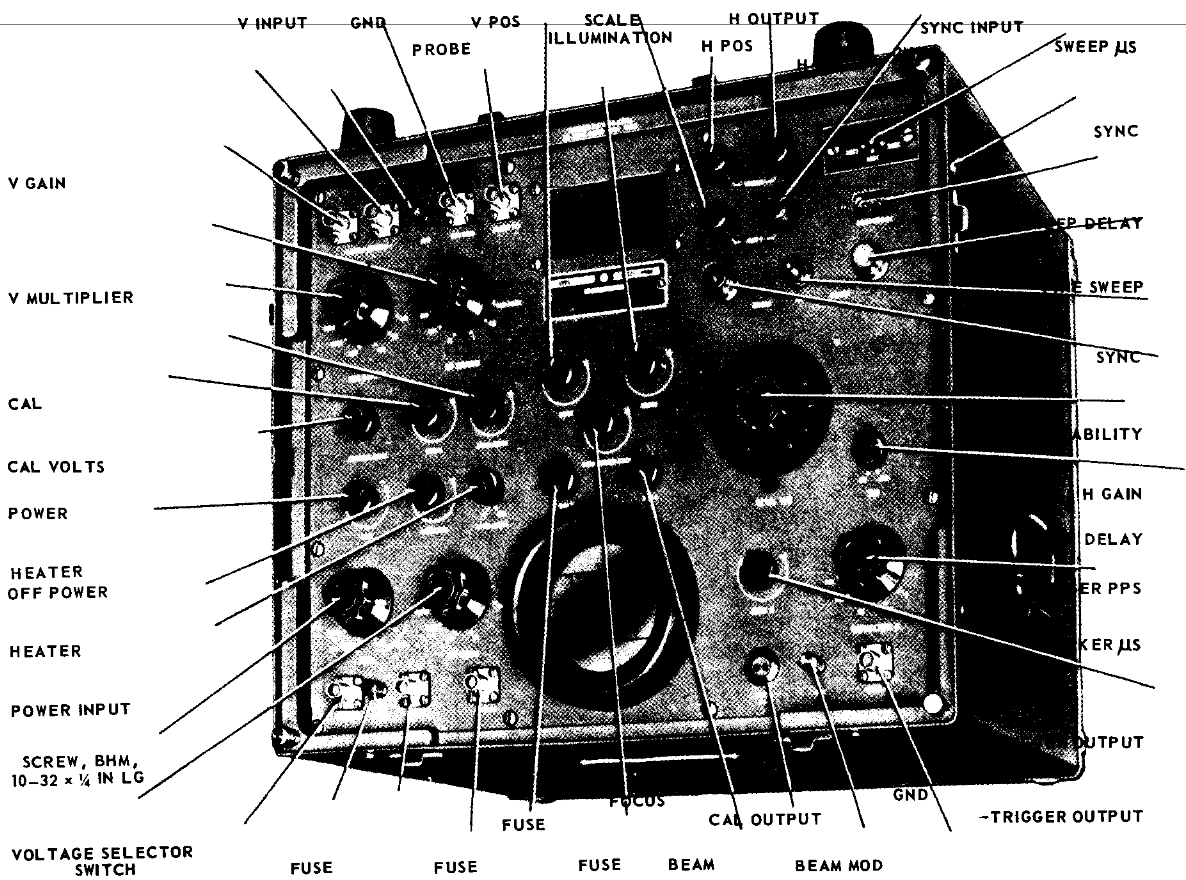

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Figure 7-9.—Front view of oscilloscope AN/USM-24.

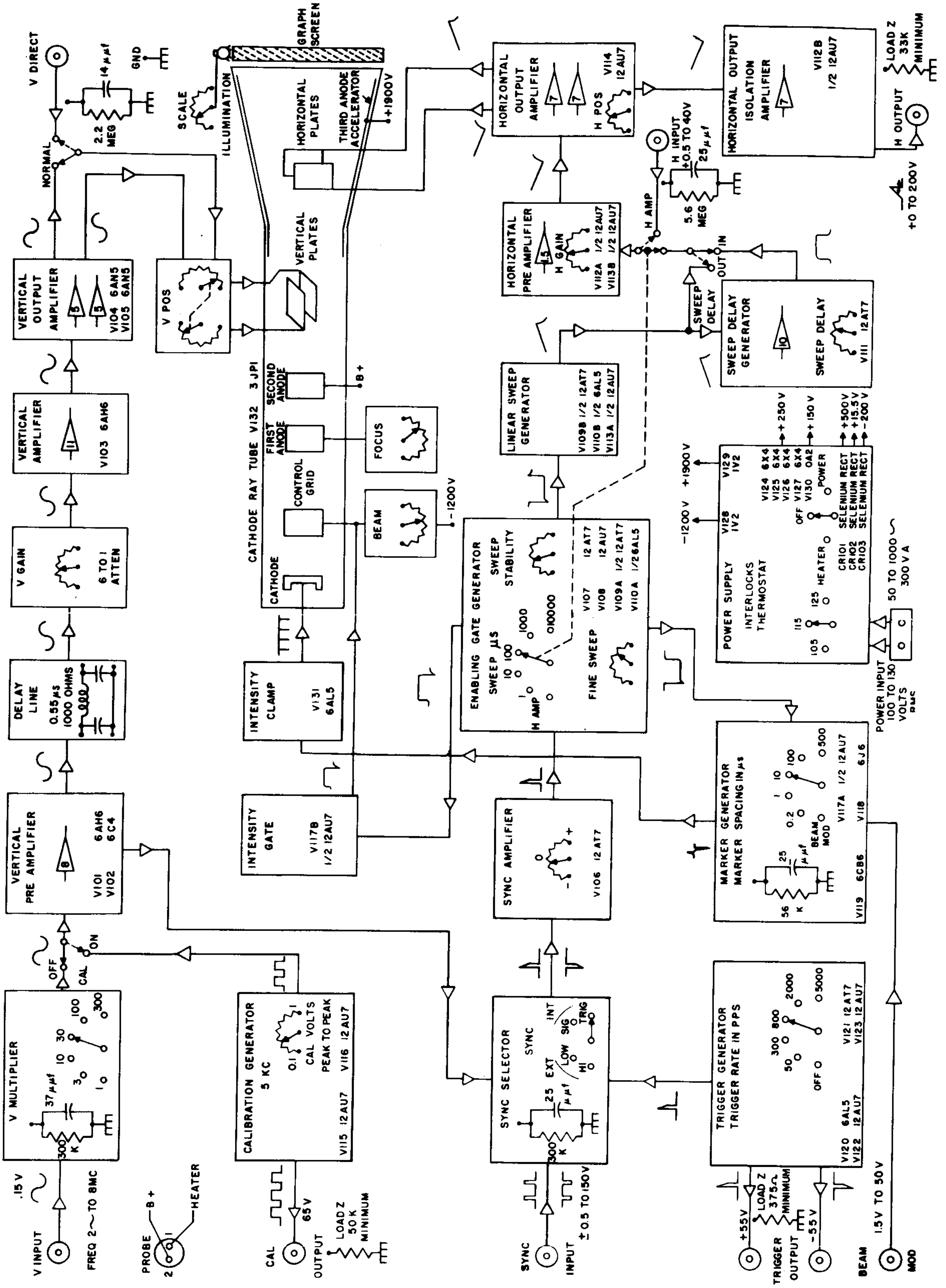

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Figure 7-10.—Block diagram of oscilloscope AN/USM-24.

the vertical input jack to the vertical plates of the CRT with the desired amplification, but with no appreciable change in its waveform. However, control over the magnitude of the signal is afforded in order to allow the instrument to handle a wide range of signal amplitudes. The signal must also be delayed sufficiently to permit the linear time base, the markers, and the intensification gate to start functioning properly before the signal reaches the vertical plates of the CRT.

Signals from 0.10 to 150 volts can be coupled directly to the input jack; signals from 9 to 300 volts may be connected to the vertical deflection plates of the CRT through the V direct terminal on the back of the oscilloscope. The frequency response curve for the vertical amplifier is essentially flat from about 30 cycles to 2 megacycles.

The R-C network in the V multiplier has a constant impedance equal to 300 k-ohms resistance shunted by 37$\mu\mu$f capacitance. The voltage divider is frequency compensated so that no distortion of the input signal results within the pass band of the vertical channel. The V multiplier switch has six positions: times 1, 3, 10, 30, 100, and 300. Voltages, as read on the CAL potentiometer (to be discussed later) are multiplied by the associated setting of the V multiplier switch for the purpose of calibrating the incoming signal. When Test Lead CG-883/USM-24 is used, the final reading is multiplied by 10.

The vertical preamplifier and delay circuit consist of a pentode amplifier and triode coupled to a delay line. The gain of the pentode is approximately 16 and the gain through the triode to the delay line (cathode-follower arrangement) is 0.5. Thus, the overall signal gain is 8, as far as the information being supplied to the vertical amplifier is concerned. The sync signal is tapped off at the plate of the triode and fed to the sync selector. For this signal, the gain of the triode stage is unity, and the gain of the preamplifier is 16.

The delay line is a pi-type filter containing 50 sections and having an overall delay of 0.55 μs. Terminating the delay line is a wire-wound potentiometer (V gain), the inductance of which provides a constant termination impedance.

The vertical amplifier is so designed that a good frequency response with a gain of approximately 10 is achieved.

The vertical output amplifier is a push-pull stage, feeding into the vertical plates of the CRT through the vertical positioning controls.

HORIZONTAL CHANNEL.—The horizontal channel consists of the horizontal preamplifier, the horizontal output amplifier, and the horizontal output isolation amplifier. Positive-going signals from the time-base channel (composed of the enabling gate generator, the linear sweep generator, and the sweep delay generator) or from the H input jack are fed to the horizontal preamplifier.

The horizontal preamplifier is resistance-coupled, with the volume control in the plate circuit. The positive-going input becomes a negative-going output.

The horizontal output amplifier is a cathode-coupled, push-pull stage. By the use of the horizontal output isolation amplifier, signals that have passed through the horizontal preamplifier and the horizontal output amplifier may be fed to an external circuit without affecting the operation of the oscilloscope.

INTENSITY CHANNEL.—The tube in the intensity-gate stage receives at its grid a positive gate pulse from the enabling gate generator. The output (positive going) from the cathode is fed to the control grid of the CRT. In the intensity-gate stage, the circuit constants are such that the tube acts as a limiter and feeds a constant-amplitude, positive-gate pulse to the grid of the CRT.

TIME-BASE CHANNEL.—The time-base channel consists of an enabling gate generator, which produces a gate pulse whose duration may be varied from 1.2 to 120,000 μs; a linear-sweep generator, which produces a linear sweep as controlled by the enabling gate generator; and a delayed sweep generator, which can be used to take any 10% portion of the linear sweep and magnify it to fill the screen of the CRT. The enabling gate generator can be operated either in a trigger (trigger supplied by the sync amplifier) or in a repetitive condition.

SYNCHRONIZATION CHANNEL.—The synchronization channel consists essentially of a selector switch (sync selector) that permits the selection of an external sync, internal trigger positive pulses from the trigger rate generator, or sync signals as developed in the vertical preamplifier.

MARKER CHANNEL.—The marker channel consists basically of a cathode-driven multivibrator, a gating tube, a marker amplifier, and a means of selecting markers.

TRIGGER CHANNEL.—The trigger channel circuit consists essentially of a free-running multivibrator (in the block marked trigger generator) for determining the repetition rate and a blocking-tube oscillator for producing trigger pulses.

CALIBRATION CHANNEL.—The calibration generator consists of a multivibrator operating at 5 kc and an out-put system. The potentiometer has a calibrated scale for adjusting voltages from 0.1 to 1 volt. The calibration switch connects either the vertical signal or the calibrated voltage to the vertical preamplifier.

DETERMINING THE AMPLITUDE AND RISE TIME OF INPUT PULSES WITH THE AN/USM-24.—These two basic measurements, the determination of (1) the amplitude and (2) rise time of a pulse, are given to illustrate the use of the equipment. The steps necessary for checking the amplitude are indicated in figure 7-11 by the circled numbers; the numbers enclosed in blocks indicate the necessary steps for checking the rise time.

The pulse amplitude may be checked as follows:

1. Set V MULTIPLIER to 1.
2. Set V GAIN half way.
3. Set SWEEP μs to H AMP.
4. Set SWEEP DELAY to OUT.
5. Set H GAIN to extreme CCW.
6. Turn HEATER-OFF POWER switch to POWER.
7. Adjust BEAM, FOCUS, H POS, and V POS for a well-defined spot located in the center of the screen.
8. Connect Test Lead CG 883/USM-24 to V input and apply to circuit under test.
9. Readjust V MULTIPLIER and V GAIN controls for a 1-inch deflection.

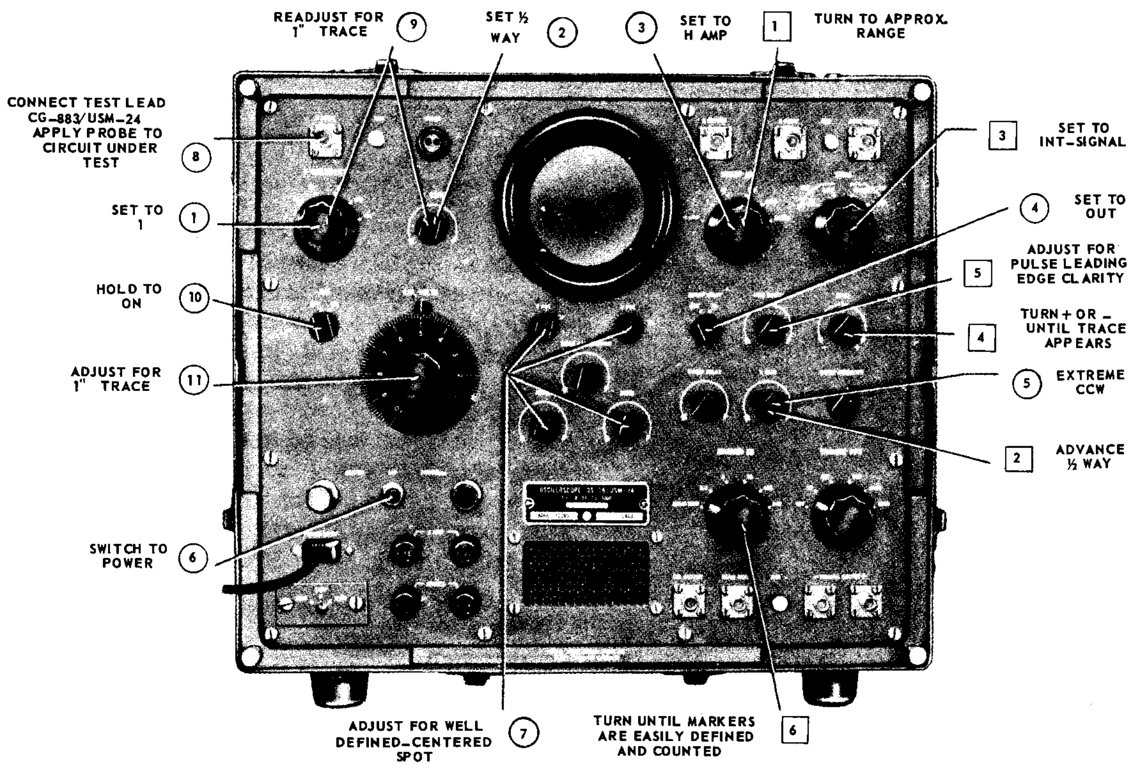

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Figure 7-11.—Control settings for basic measurements.

10. Throw and hold the CAL switch to the ON position.

11. Adjust CAL VOLTS control for a 1-inch deflection; release CAL switch.

12. Multiply the CAL VOLTS dial reading by the V MULTIPLIER setting. Multiply the product by 10 (Test Lead CG-883/USM-24 has a 10:1 attenuation factor). The product of these three figures indicates the peak-to-peak voltage of the signal.

The rise time may be checked as follows:

1. Turn SWEEP μs switch to the range most likely to encompass the duration of the signal being viewed. (Test lead CG-883/USM-24 is applied to the circuit under test.)
2. Advance the H GAIN control half way.
3. Set SYNC switch to INT signal.
4. Advance SYNC control in + or - direction (depending upon polarity of signal being viewed) until horizontal trace appears.
5. Adjust FINE SWEEP control until leading edge of pulse is clearly defined on the screen. At this point it may be necessary to readjust the SYNC control.
6. Turn MARKER μs switch until the markers that appear on the leading edge of the pulse are sufficient in number to be sharply defined and counted between 10% and 90% of the total pulse amplitude.
7. Count the number of markers and multiply by the setting number of the MARKER μs switch. The product will be an indication of the rise time (in microseconds) of the measured pulse. Rise time is illustrated in figure 7-12.

In a radar system there are certain time delays that occur within the radar equipment itself between the time the system is triggered and the time the echo pulse arrives at the indicator. Most of the delay is within the receiver; but some delay occurs in the transmitter and in the transmission line. The total delay may be equivalent to a range of 150 to 350 yards. This means that a target actually at zero range would be erroneously indicated (because of these delays) at a range of 150 to 350 yards. Zero error must be corrected after the time delay in the circuit has been determined. There are several methods of determining zero error. The most reliable is the fixed-target method in which a fixed target at a known range is used.

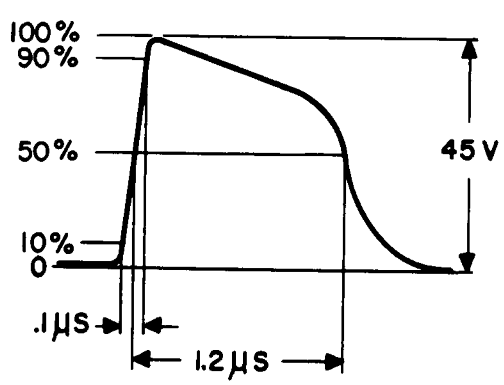

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Figure 7-12.—Trigger-generator output pulse.

The synchroscope method, however, is one of the simplest. This method does not require a fixed radar target, and fairly accurate results may be obtained.

The test setup is shown in figure 7-13. In this arrangement the synchroscope horizontal sweep is triggered by the radar system trigger. A fast sweep of about 2 μs per inch is used, and the sweep must be carefully calibrated so that the number of microseconds each inch represents is known.

Trigger pulses that are used to start the range-marker circuit in the radar indicator are fed to the synchroscope vertical amplifier input. The vertical gain is set to provide a 1/2-inch (vertical height) pulse, and the leading edge of the pulse is marked on the scope.

Next, the trigger pulses are removed, and the radar receiver output is fed to the vertical amplifier input. The radar receiver local oscillator is detuned so as not to overload the synchroscope. The radar transmitter pulse will shock-excite the local oscillator at the receiver sufficiently to produce an i-f signal. Thus the pulse from the receiver is delivered to the synchroscope shortly after the trigger pulse is initiated. The vertical gain control is adjusted to provide a 1/2-inch pulse from the receiver when the receiver gain is set to produce about 1/8 inch of noise.

The leading edge of the pulse is again carefully marked on the scope. The distance between the two marks may be converted from microseconds to yards. This interval represents the time delay between the time the system is triggered and the time the receiver pulse arrives at the indicator. This figure is the zero error. This error is corrected for by adjustments in the range-marker circuit.

Typical measurements made with the synchroscope are included in the Maintenance

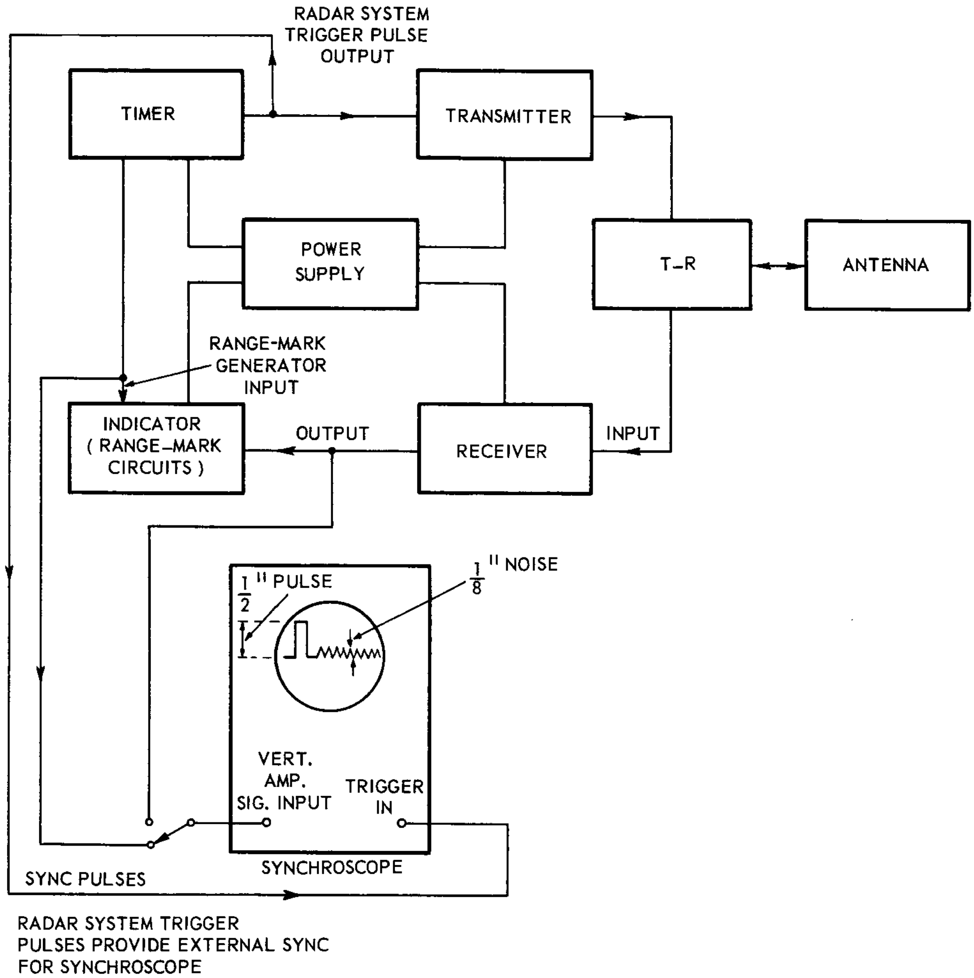

Figure 7-13.—Test setup for zero-error determination. 70.44

Standards Books for the various radar sets—for example, the AN/SPS-8. The measurements are made semiannually, or more often if necessary. Typical measurements include the amplitude and time duration of the input trigger pulses.

The amplitude and time duration of the input trigger to the trigger amplifier chassis are determined by applying the trigger to the vertical input of the oscilloscope. The amplitude and time duration of the pulses are determined by observing the waveforms on the screen and the setting of the controls on the synchroscope. The amplitude should be between 15 and 30 v, and the time duration should be between 2.5 and 3.5 μs.

The same measurements are also made of the amplified trigger. The time duration should be the same, but the amplitude of the trigger pulse should be between 45 and 60 v.

The amplitude and time duration of the modulator pulse are also determined by the synchroscope. The modulator pulse is connected to the vertical input of the synchroscope, and the amplitude and time duration of the waveform determined by observation. The time duration should be between 0.5 and 1.5 μs and the amplitude between 45 and 60 v.

The amplitude and time duration of the charging waveform (the waveform fed to the pulse network) are likewise, determined. In this case the signal is connected from the charging waveshape jack to the vertical input of the synchroscope. The time duration should be between 950 and 1050 μs and the amplitude between 15 and 35 v.

Finally, the synchroscope is used to make sensitivity time-control measurements. The function of the sensitivity time-control (STC) function of the sensitivity time-control (STC) circuit is to eliminate saturation effects caused by strong echoes from nearby targets. This circuit reduces receiver gain appreciably for a short time interval immediately after a transmitted pulse and then allows the gain to return gradually to the value normally determined by the setting of the receiver gain control. The waveform of the output signal of the STC circuit is indicated in figure 7-14. The signal is a negative voltage with a trailing edge that decays exponentially with time. This voltage is superimposed upon the negative gain-control voltage applied to the i-f amplifier portion of the radar receiver in order to control the receiver gain in accordance with the indicated waveform. The signal is obtained between terminal 6 and ground of the sensitivity time control unit (a part of the radar) and applied to the vertical input of the synchroscope. The time duration should be between 140 and 150 μs and the voltage amplitude between 5 and 10 v.

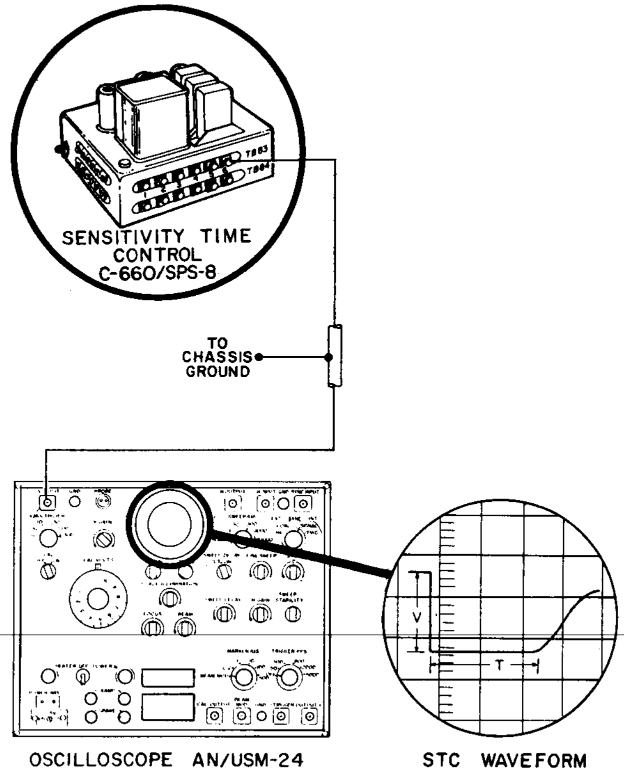

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Figure 7-14.—Radar sensitivity time-control measurements.

THE ECHO BOX TS-275/UP

Good radar performance is of vital importance because radar is the eye that the Navy depends on to detect enemy ships and planes long before they are detected by other methods. It has failed to accomplish this purpose if attacking enemy craft are detected too late for effective countermeasures to be taken. It is therefore extremely important that radar installations be maintained so that they always operate close to their maximum efficiency, and technicians should spare no effort in making this possible.

The ECHO BOX is one of the most important single test instruments for indicating the overall radar system performance. This results from the fact that the echo-box indication reflects the combined relative effectiveness of the transmitter as a transmitter of energy and the receiver as a receiver of energy.

The echo box, or resonance chamber, consists basically of a resonant cavity, as indicated in figure 7-15, A. The resonant frequency of the cavity is determined by the size of the cavity (the larger the cavity, the lower the frequency); and this, in turn, is determined by the position of the plunger. The accurately calibrated tuning mechanism controls the position of the plunger and indicates on a dial the resultant resonant frequency, or data that permits the technician to determine the frequency with great accuracy by consulting a set of curves.

Energy is coupled into the cavity from the directional coupler (or pickup dipole) by means of an r-f cable connected to the input loop. Energy is coupled out of the cavity to the rectifier and the microammeter by means of the output loop. The amount of coupling between the echo box and the crystal rectifier can be varied by changing the position of the output loop. A schematic diagram of the output circuit is shown in figure 7-15, B. The energy picked up by the loop is rectified, filtered, and applied to the meter.

A front view of a typical echo box (TS-275/UP) is shown in figure 7-15, C; the method of connecting the echo box in a radar system is shown in figure 7-15, D. An exploded view of this echo box is shown in figure 7-16. The box consists of a cast bronze cavity cylinder with removable bronze end plates. The movable plunger is actuated by means of the adjusting screw and the inner dial through the water-tight bellows. The gearing between the inner dial and

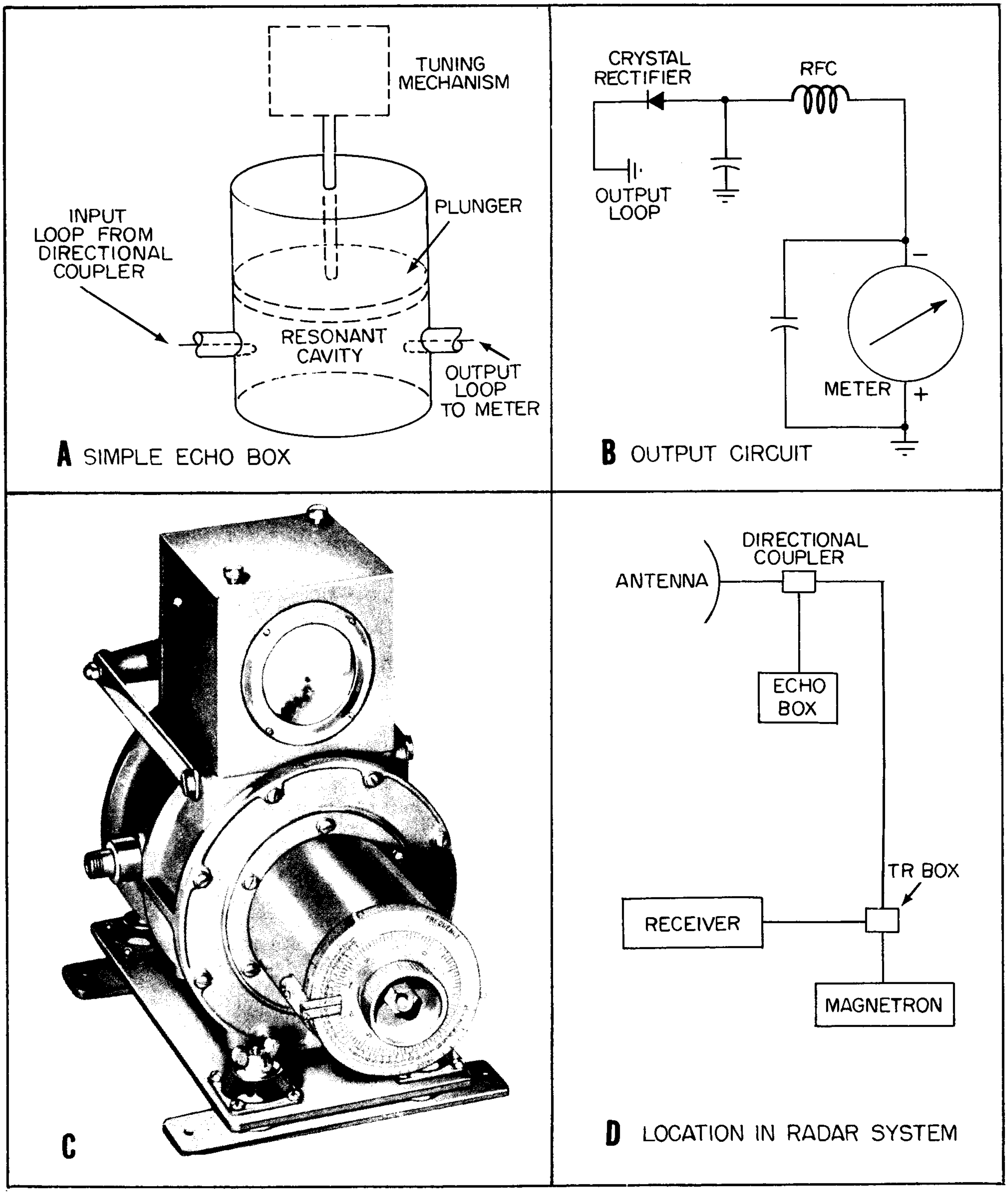

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Figure 7-15.—Echo box.

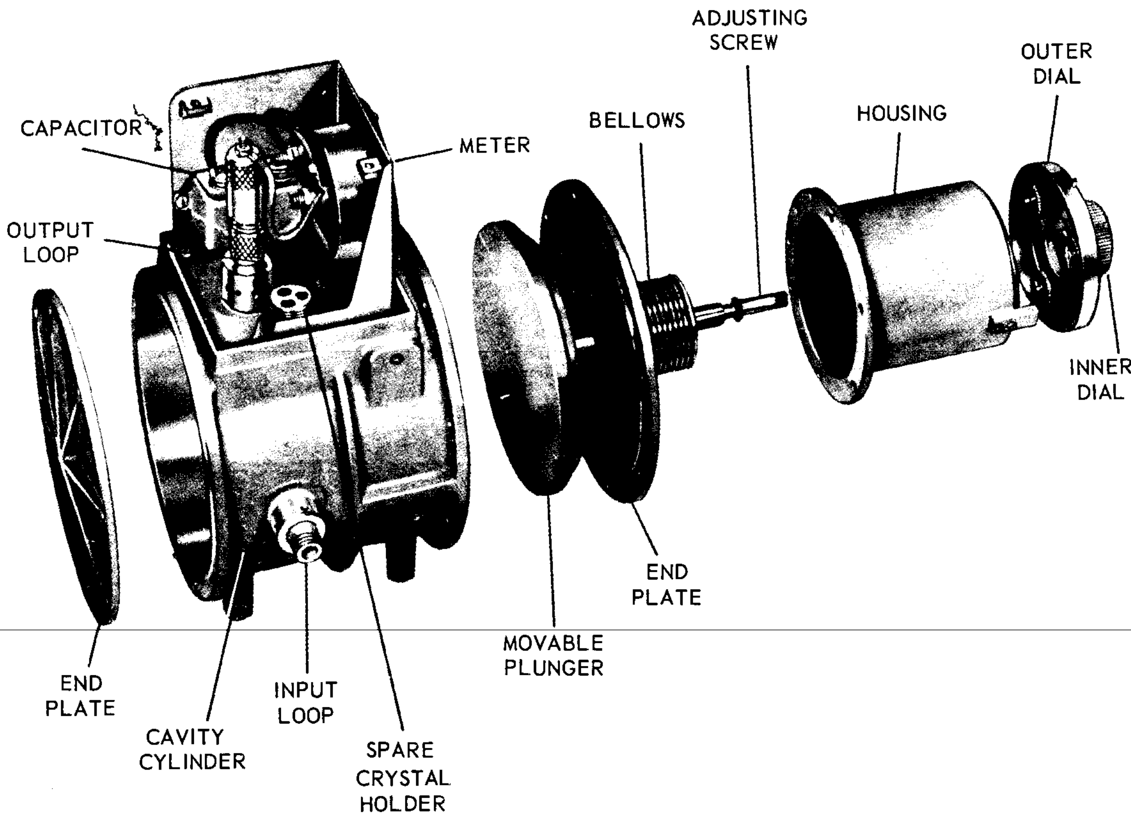

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Figure 7-16.—Exploded view of the TS-275/UP echo box.

the outer dial is so arranged that the outer dial travels the amount of one of its divisions while the inner dial makes one revolution (10 major divisions or 100 minor divisions). The gears merely operate the outer dial and have no connection with the driving of the plunger, and therefore do not cause backlash.

The indicating meter, the filter capacitor, and the spare crystal holder are mounted on top of the cavity cylinder.

The input and the output loop connectors project from the cavity cylinder.

Methods of Connecting

Either of two methods may be used to connect the echo box to the radar. A pickup dipole may be used, but more generally a directional coupler is used, as in figure 7-15, D. The method of installing the pickup dipole is described in the TS-275/UP instruction book (NavShips 900,825).

Much of the information contained in this instruction book is of a general nature and will be very helpful to anyone desiring practical information on the use of echo boxes.

A directional coupler is commonly included in the r-f plumbing of radar sets. This echo box is designed to be used with directional couplers having a coupling loss of 20 to 35 decibels on the usual radar in the frequency range covered by this echo box. The exact value depends on the radar.

Frequency Calibration

The echo box dial is read by reading the middle dial number and then the inner dial number. Figure 7-17, A, shows an example in which the reading is three two point six five (32.65). Each major division on the inner dial is one-tenth of a revolution, and each smaller division is one-hundredth of a revolution.

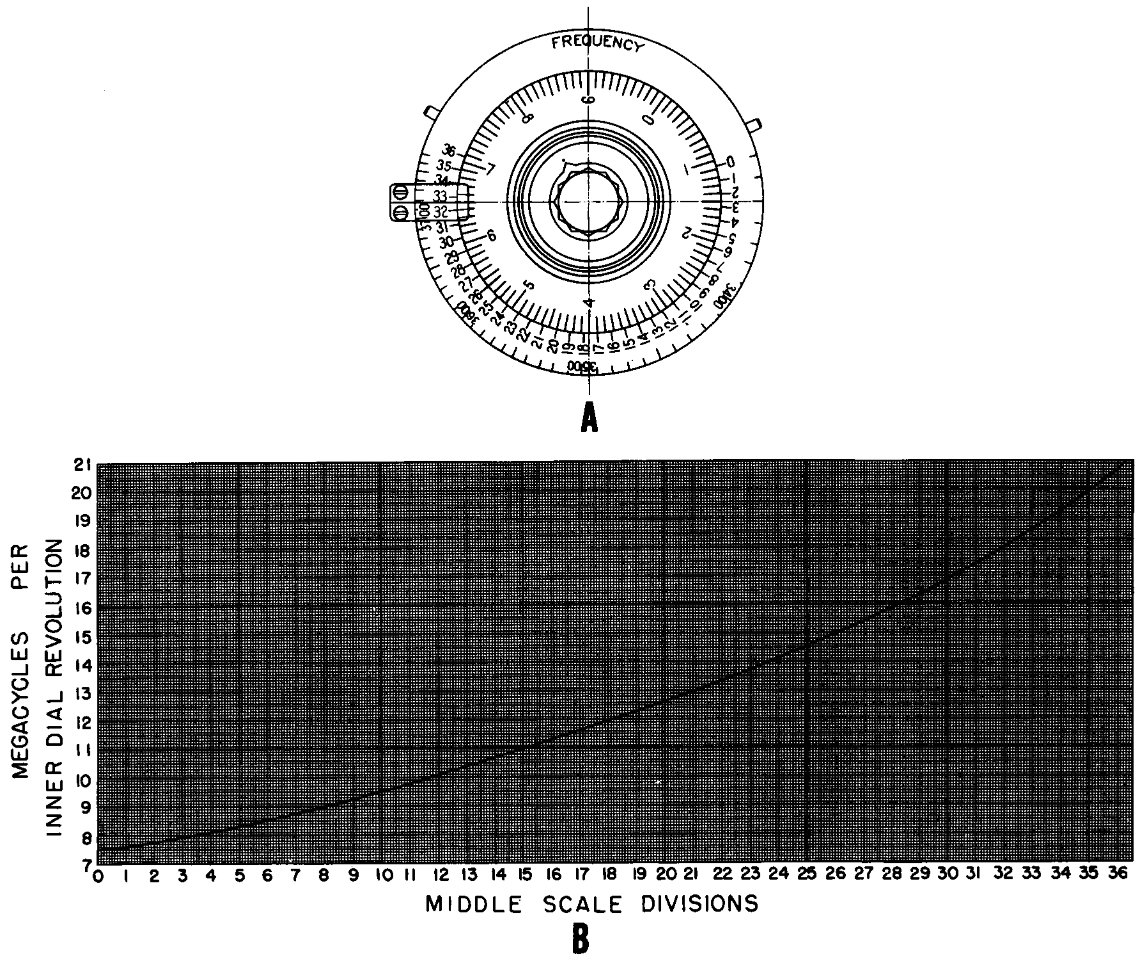

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Figure 7-17.—Reading the dial.

Each division of the middle dial represents one complete revolution of the inner dial.

The frequency calibration curve in figure 7-17, B gives the tuning rate of the echo box with any setting of the tuning dial. The method of using the curve may be best explained by giving an example. Assume that a radar under test is supposed to be tuned to a frequency of 3607 mc. (The direct frequency calibration, marked in red on the instrument, is provided on the outer portion of the outer dial.) The echo box is found to be in resonance when the tuning control is at 27.5 (middle dial divisions) rather than the expected 26 (opposite 3607 mc on outer dial). Obviously, the radar is transmitting on a frequency 1.5 inner dial revolutions higher than intended. From figure 7-17, B, the tuning rate is found to be 15.5 megacycles per (inner) dial revolution. The radar is thus transmitting on a frequency 15.5 x 1.5, or 23.25 mc too high.

Ringtime

Some of the energy generated by the radar transmitter is picked up by the echo box via the directional coupler. This energy excites oscillations in the echo box that persist for some time after the end of the radar pulse, much in the fashion of an echo that persists in a large room after a loud noise. As this echo dies down, a part of it is fed back into the radar receiving system, again via the directional coupler. This causes a saturated signal to appear on the radar indicator, which is known as RINGING. The longer this ringing extends the better the performance of the radar—that is, the more powerful the transmitter is and/or the more sensitive the receiver is.

The length of time the echo box SHOULD ring under the particular conditions of the test (called the EXPECTED RINGINGTIME, or RINGTIME) may be compared with the ringing time observed, to determine whether the radar is performing well or not.

The ringtime to be expected on a good radar depends on the particular type of radar being tested; on the way the echo box is installed—that is, for example, whether a directional coupler or a dipole is used, and on the length and type of cable used; on the individual ringing ability of the particular echo box employed; on the frequency of the radar; and on the temperature of the echo box at the time of the test. Corrections are made for all of these factors according to the procedure given in the instruction book for the echo box being used.

An echo box without correction may be used for the purpose of detecting a CHANGE in the performance of a radar. The ringtime is simply noted and compared from day to day. It should be recognized that these readings do not permit the comparison of a particular radar with a standard of performance, and thus to tell whether more may be expected from a radar than its past performance would indicate.

Ringtime Measurements

Because ringtime measurements constitute the most valuable single feature of the echo box, it is essential that they be carried out properly and with due regard for the necessary precautions. Ringtime measurements are made on the A-scope or on the PPI, both methods of which are discussed later.

In measuring the ringtime, the technician should make sure that it is the echo-box ringtime and not some fixed-target echo or block of echoes that is being received. This condition can be determined by adjusting the radar gain control and noting if there is a back and forth movement of the ringtime on the scope. The echo box echo will change in range; fixed target echoes, however, will not change in range, only in amplitude.

In order to obtain accurate results, every ringtime measurement should be repeated at least four times, and the readings averaged. Care must be taken to ensure that all readings are accurate. If two or more technicians use the same echo box, they should practice together until their ringtime measurements agree.

Radars have a tendency to drift slightly in frequency. When this occurs, the echo box becomes detuned and accurate ringtime measurement is difficult. Therefore, it is necessary when making ringtime measurements for longer than a very few minutes to retune the echo box from time to time.

The radar antenna should not be pointed at a mast or other nearby obstruction because proximity effect may cause the transmitter to change frequency.

A-scope presentation of ringtime is indicated in figure 7-18, A. The receiver gain should be set so that the 'grass' or noise is one-quarter to one-third the total saturated signal height on the A-scope. When this is done, a good pattern results, such as either of those shown in the figure. In the event that no 'grass' can be seen, the gain of the radar i-f is inadequate and repairs should be undertaken.

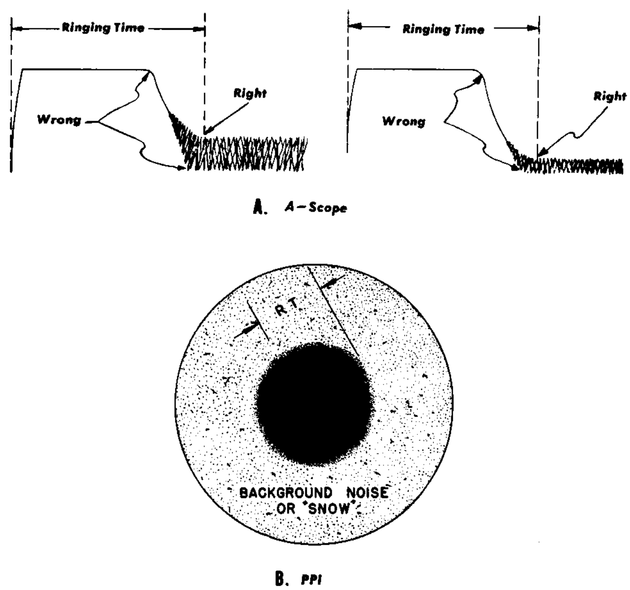

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Figure 7-18.—A-scope and PPI presentation of ringtime.

The exact end of the ringtime occurs at the furthest point to the right at which the TOP of the 'grass' is noticeably above the general level of the rest of the 'grass.' Do NOT judge ringtime by the BOTTOM of the 'grass' or by the end of the saturated portion of the ringtime because these items are influenced by the receiver gain setting and other factors.

Setting the gain too high or too low may make it difficult or impossible to read the ringtime with accuracy. (It is essential that 'grass' be present.)

An A-scope indicator measurement of ringtime is usually best performed when the radar antenna is stopped.

PPI presentation of ringtime is indicated in figure 7-18, B. In this instance, the same general principles apply as did in the case of the A-scope presentation.

The following procedure should be followed. With the radar antenna rotating, set the receiver gain at a minimum and adjust the intensity (bias) so that there is a very slight radial trace on the PPI indicator. Increase the receiver gain until the PPI-indicator area seems to be just half covered with flecks of snow.

A PPI ringtime pattern, with proper receiver gain adjustment (and the radar antenna rotating), is shown in the figure. In this case, the echo box is used with a directional coupler.

It should be emphasized that the end of the ringtime signal is NOT at the place where the bright or saturated part of the signal ends, but where the fainter portion of the signal disappears into the background noise. Therefore, when reading the ringtime on a PPI indicator, be sure to observe to the extreme edge of the grass and NOT JUST TO THE END OF THE BRIGHT PORTION OF THE PATTERN. Read to the last point at which the 'snow' is unusually bright. As indicated in figure 7-18, B ringtime (RT) is measured from the center of the pattern to the outer edge.

Spectrum Analysis

Every time a radar transmitter generates an r-f pulse, it produces a certain amount of r-f energy in the form of electromagnetic waves. Not all of these waves, however, are of the same frequency; in fact, only a small portion of them have exactly the same frequency as that to which the transmitter is tuned. The rest of the radiation is at slightly higher or slightly lower frequencies, forming the sideband frequencies. This is the natural result of pulse modulation and cannot be avoided.

Actually, the radar energy is distributed more or less symmetrically over a band of frequencies, as illustrated in figure 7-19, A. This frequency distribution of energy is known as the SPECTRUM. An analysis of its characteristics may readily be carried out with the aid of the echo box.

When properly performed and interpreted, a spectrum analysis will disclose maladjustments and troubles that would otherwise be difficult to locate. It is important, therefore, that the technician who uses the echo box be able to carry out a spectrum analysis and understand the results.

When a spectrum analysis is to be made, the tuning control of the test set (fig. 7-15, C) is first turned until a maximum output meter deflection is obtained, then the tuning control is turned slowly from a point well below this maximum to a point well above it.

While this is being done, the output meter readings are noted for various settings of the tuning control. It is good practice to cover the frequency range desired by turning the tuning knob slowly in the same direction to each new position, not by turning it back and forth. This is done to minimize any possible error due to backlash. A reading should be taken about every 0.02 revolution of the tuning knob.

Finally, an accurate graph is constructed with the meter readings plotted against the tuning control dial settings. The resulting graph should resemble one of those shown in figure 7-19.

A radar transmitter in satisfactory condition should give a spectrum curve similar to curve A or curve B. Good curves are those in which the two halves are symmetrical and contain deep, well-defined minimum points on both sides of the main peak.

A curve without deep minima, as in curve C, indicates that the transmitter output is frequency modulated during the pulse. This may be due to the application of a negative pulse to the magnetron that does not have sufficiently steep sides or flat extremities. It may also be due to a transmitter tube that is unstable or is operated with improper voltage, current, or magnetic field.

When the spectrum is extremely irregular, as in curve D, it is an indication of severe frequency modulation. This will probably cause trouble in the receiver automatic frequency

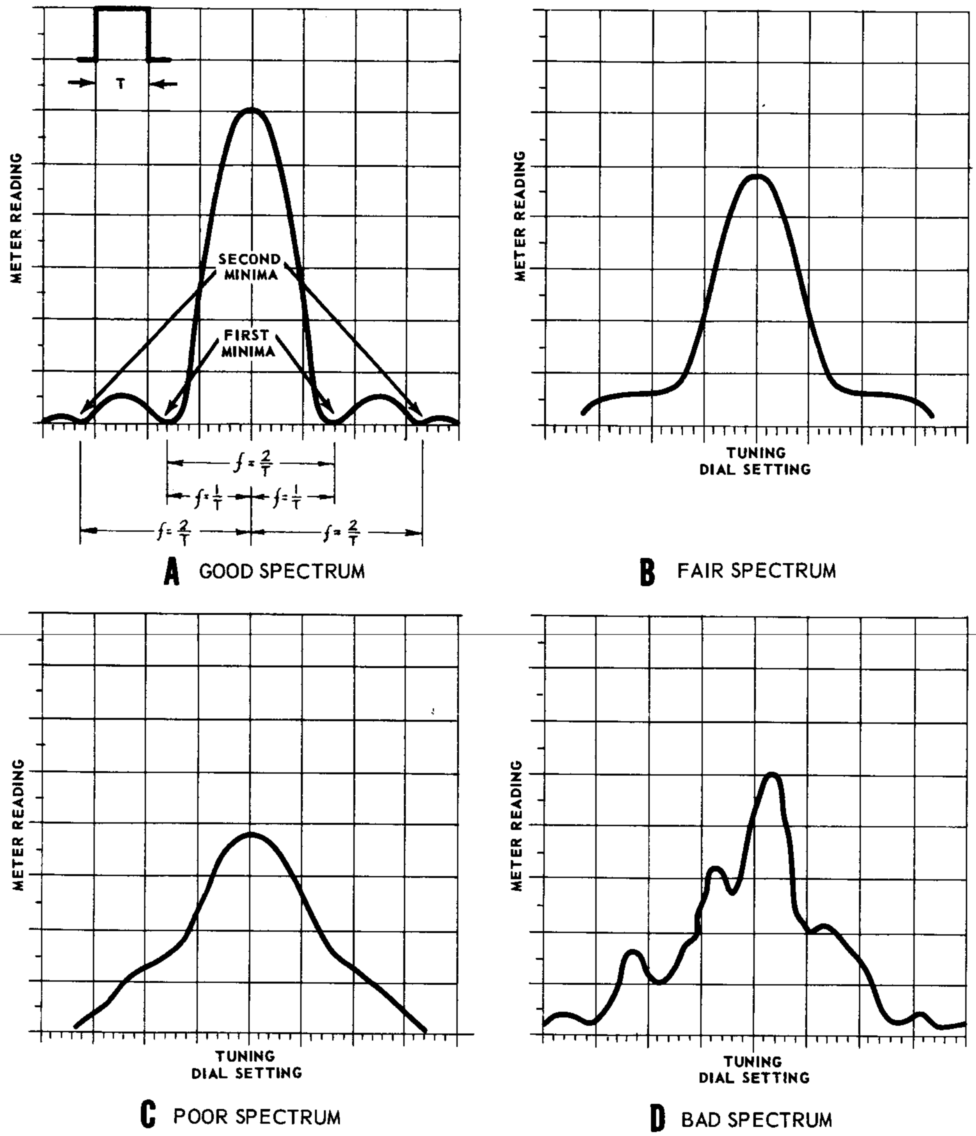

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Figure 7-19.—Typical radar spectra.

control as well as general loss of signal strength. When the spectrum has two large peaks, quite far apart, it indicates that the transmitter tube is double moding, perhaps because of unwanted standing waves in the transmission line or a bad transmitter tube. A faulty spectrum can often be improved by adjustment of the transmission line stubs or by replacement of the transmitter tube. Standing waves may be due to a faulty line connection, a bad antenna rotating joint, or obstructions in the line.

In the case of a good or fair spectrum curve with sharply defined minima on both sides of the main peak, the distance between these two minima is proportional to the duration of the transmitted pulse. Because the duration of the pulse determines the distribution of power in the sideband frequencies, the pulse length may be found from the spectrum graph. The procedure is to determine the distance in megacycles between the minima on either side of the main peak. These minima are separated by a frequency (in megacycles) equal to $\frac{2}{T}$, where T is the pulse length in megacycles and $\frac{1}{T}$ is the number of sideband frequencies contained in either upper or lower sideband (from the carrier frequency to the first minimum on either side of the carrier). Expressed as an equation,

$$\text{pulse length in microseconds} = \frac{2}{\text{distance between minima in megacycles}}.$$

Suppose, for example, that the echo box is being used to check the pulse length of a radar. The graph of the spectrum is plotted, and the tuning distance between the minima is from 17 divisions on the middle dial (fig. 7-17, A) to 17.17 divisions (17 divisions on the inner dial). From figure 7-17, B it is found that for the particular frequency range in question (3480-3490 mc) the echo box tunes at a rate of 11.65 mc per revolution (corresponding to 17 divisions on the middle dial). The frequency span between minima is

$$11.65 \times 0.17 = 1.98 \text{ mc.}$$

Applying the equation given in the last paragraph, the pulse length in microseconds $= \frac{2}{1.98} = 1.01$ microseconds. The value thus calculated can be readily compared to the standard value for a radar of the type under test by reference to the radar manual. Any great change in the test value compared to the standard value indicates an improper pulse length.

The shorter the pulse length, the wider will be the frequency band that the signals occupy. This effect will appear on the graph as a wide span between the first minima of the spectrum curve.

An abnormally narrow spectrum shows that the transmitted pulse is too long. Such a pulse could result in a long ringtime and high power reading on the echo box output meter, thus falsely indicating superior system performance.

Power Output

At the time of installation, the meter reading on the echo box, TS-275/UP, should have been set between 40 and 80 divisions (by adjusting the orientation of the output loop) while the echo box was tuned to resonance with the radar transmitter.

The output meter reading is closely proportional to the average radar power picked up by the echo box and to the transmitter pulse length, when the echo box is tuned to the maximum output signal of the spectrum. If the pulse length is long, the spectrum curve is consequently high and narrow, and the meter reading is high. Where the pulse length is shorter, the spectrum curve is flatter and the meter reading will be lower.

The power output of a radar is generally good if the transmitter current is normal. Loss in the transmission line may cause loss of power, and in the event that low power is observed at the antenna of the radar by means of a pickup dipole and echo box, the transmission line may be suspected. Because of the high initial cost of radar transmitting tubes, the echo box and its accessories should be checked carefully before discarding such a tube. Transmitter tuning stubs are NEVER adjusted for maximum power output, as indicated at the echo box. These stubs provide a transmitter frequency adjustment, the net effect of which is observed at the receiver indicator rather than at the echo box. The correct procedure for checking the radar frequency is described in this chapter.

Other Tests

GENERAL PROCEDURE.—A variety of radar equipment checks can be carried out with the aid of the echo box. The exact nature of these tests, as well as the detailed methods of procedure, may vary to some extent between different types and models of radar equipment. The typical procedures given in the following paragraphs will be useful in establishing test routines to be followed in radar maintenance. Practice and experience may suggest variations as the technician becomes more familiar with the use of the echo box.

In the testing procedures outlined in the following paragraphs it is assumed that the echo box is properly installed, and that the expected ringtime and output meter reading are known for the particular radar under test.

All measurements should be recorded in the radar log and/or on forms provided for this purpose. One such form for ringtime, from the Maintenance Standards Books, Part II Preventive Maintenance Checkoff for Radar Set AN/SPS-8, NavShips 91522.41, is included in figure 7-20. The figure includes complete instructions for making the test. Another form for listing echo box meter readings from the same publication is included in figure 7-21.

As a preliminary step in all tests, the radar equipment should be allowed to warm up fully to the normal operating temperature. The directional (or bidirectional) coupler or the pickup dipole (when used) should be correctly coupled to the echo box. All antijamming provisions (provisions to reduce the effects of the enemy jamming the radar) and the sensitivity time control, if provided, should be turned off.

OVERALL PERFORMANCE.—Adjust the echo—box tuning knob for a maximum reading of the output meter, indicating that the echo box is tuned to resonance with the radar. Then adjust the radar receiver local oscillator frequency for maximum ringtime on the indicator. Measure the ringtime as accurately as possible, preferably by taking advantage of at least four readings. Ringtime is most conveniently measured on an A-scope with the antenna stopped, and on a PPI-scope with the radar antenna rotating. Record the ringtime on the forms provided. Compare this figure with the corresponding value of the performance standard.

If the output meter and ringtime measurements are both satisfactory (compared with the expected values), the radar transmitter and receiver are both functioning well. If the meter reading is satisfactory but the ringtime is low, the radar receiver is the probable source of the trouble. Service the receiver, consulting the appropriate instruction book for the detailed procedure.

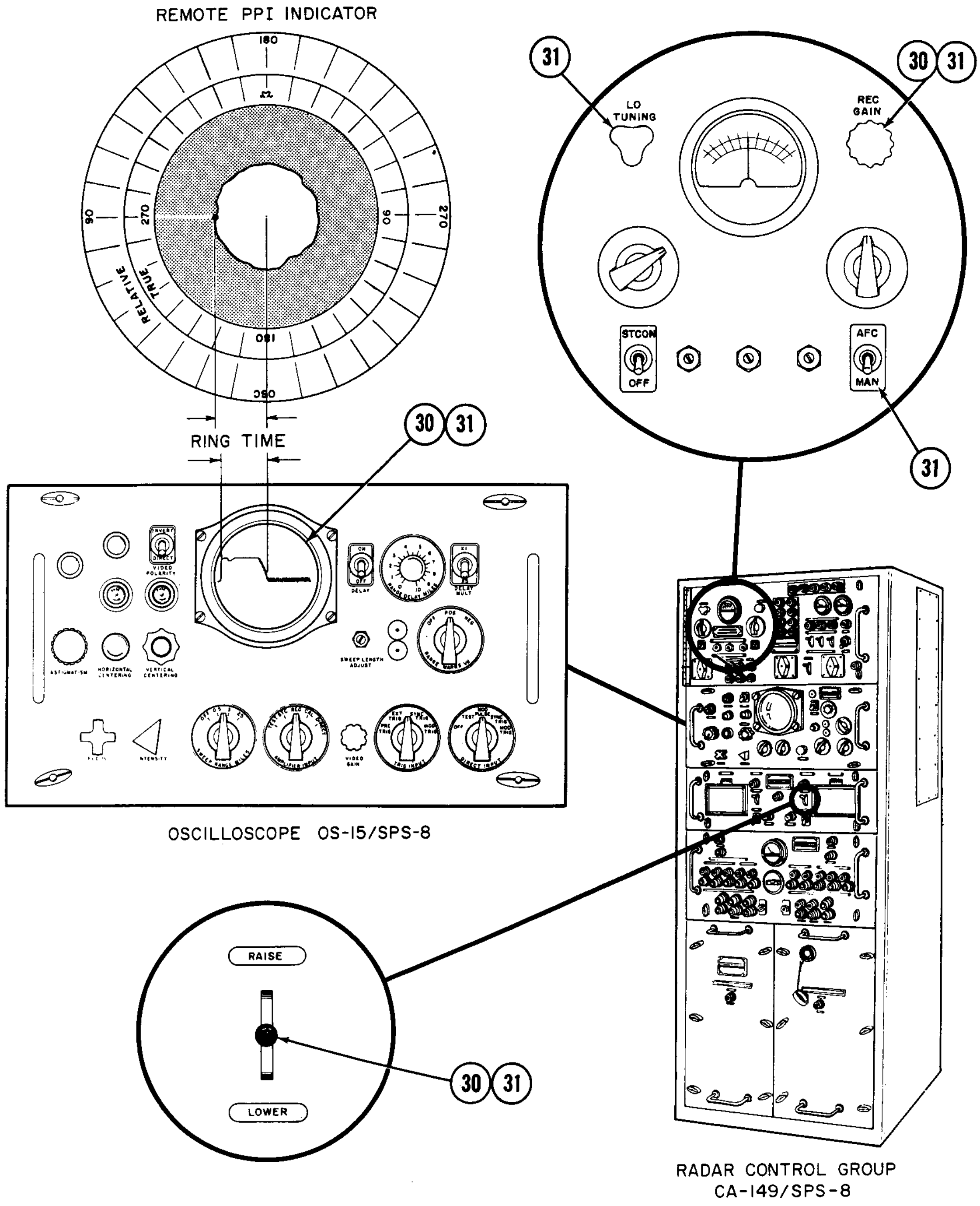
TRANSMITTER POWER.—The echo-box output meter reading is closely proportional to the average energy radiated from the radar on a particular frequency. The measurement of relative transmitter power is, therefore, a direct and simple procedure. Tune the echo box to resonance and then stop the radar antenna. Record the maximum reading on the output meter. This measurement, compared with the corresponding value on previous tests, gives an index of transmitter power. If the meter reading is satisfactory, the radar power output is good. If the meter reading and ringtime are low, the transmitter power output is low, and a spectrum analysis should be made, as previously described.

RADAR FREQUENCY.—To check the TRANSMITTER FREQUENCY, adjust the echo-box tuning knob for maximum deflection of the output meter, and stop the antenna. Read the tuning-knob scale and determine the transmitter frequency by reading the red calibration on the outer portion of the face of the outer dial, or by referring to the echo-box frequency calibration curve (fig. 7-17, B). If the transmitter frequency is found to be different from the frequency intended, the cause may be the transmitter tube or the transmitter tuning adjustments. Reference should be made to the appropriate instruction book.

To check the LOCAL OSCILLATOR FREQUENCY, the echo box is disconnected from the directional coupler (or pickup dipole). It is then coupled directly to the local oscillator output. (A special connector may have to be improvised to fit the local oscillator output of certain radars. It is desirable to insert 10 to 20 db of attenuation between the local oscillator and the echo box.) Adjust the echo-box tuning control for maximum deflection of the output meter. Read the tuning-control scale and, referring again to the echo-box calibration data, record the local oscillator frequency. The echo-box meter reading is likely to be excessive if attenuation is not inserted, and the output loop (fig. 7-15, A) should be adjusted to protect the meter (the loop may be adjusted with a wrench).

The DIFFERENCE BETWEEN THE TRANSMITTER AND THE LOCAL OSCILLATOR FREQUENCIES is easily checked by the curve in figure 7-17, B. It is necessary to have not only the correct frequency difference but also to have the local oscillator operating on the proper side (above or below) the transmitter frequency. This frequency difference is, in each case, identical with the frequency of the radar i-f amplifier. Using the tuning curve in figure 7-17, B, the technician can readily check the frequencies and determine whether the difference between them is correct.

To TUNE THE LOCAL OSCILLATOR, couple the echo box to the local oscillator. From



36.100(70)A

Figure 7-20.—Steps for recording ringtime.

STEP NO.	ACTION REQUIRED	PRELIMINARY ACTION	READ INDICATION ON	PERFORMANCE STANDARD
(30)	Record radar ring time with AFC.	Set REC GAIN (R7142) for one-half inch of grass on Oscilloscope screen. Tune Echo Box with RAISE-LOWER switch (S7404) for maximum ring time indication of Oscilloscope screen. The ring time is obtained directly in yards on the remote PPI indicator. Rotate Antenna and set the range ring slightly beyond the solid echo portion of pattern as shown on illustration page.	Range Dial Remote PPI Indicator.	____ YDS (3200 or more)
(31)	Record radar ring time in manual tuning position.	Same as Step (30) except AFC-MANUAL switch (S7104) in MANUAL position, and LO TUNING (R7138) varied for maximum ring time.	Range Dial Remote PPI Indicator.	____ YDS (3200 or more)

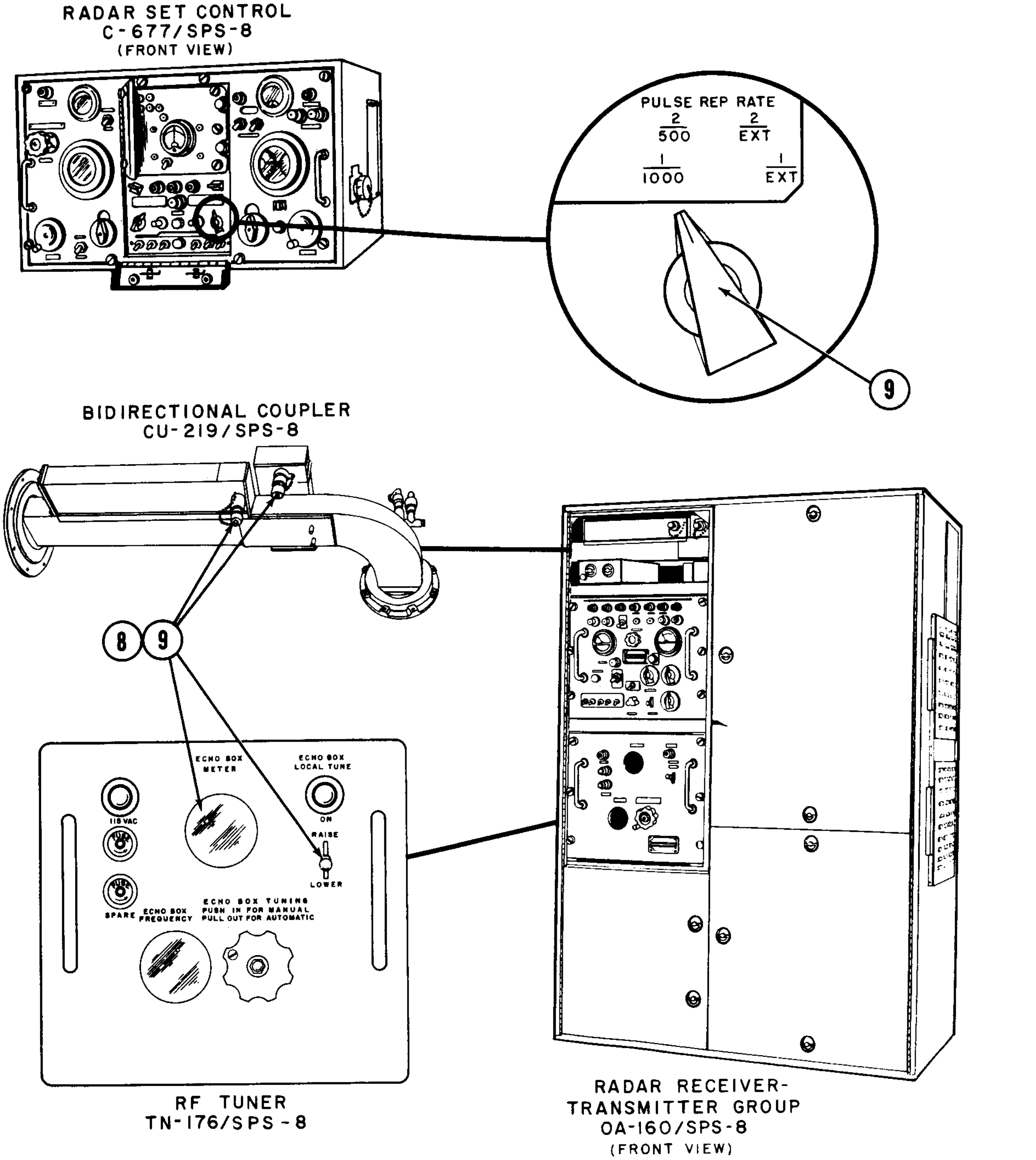
STEP NO	(30)	(31)		(30)	(31)		(30)	(31)		(30)	(31)		(30)	(31)		(30)	(31)	
Month	JAN 19_			FEB 19_			MARCH 19_			APRIL 19_			MAY 19_			JUNE 19_		
Week	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init
1																		
2																		
3																		
4																		
5																		
Month	JULY 19_			AUG 19_			SEPT 19_			OCT 19_			NOV 19_			DEC 19_		
Week	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init
1																		
2																		
3																		
4																		
5																		

36.101(70)A

Figure 7-20.—Steps for recording ringtime—Continued.

the echo-box calibration data, find the echo-box setting for the correct local oscillator frequency, and adjust the echo-box tuning control accordingly. Then adjust the local oscillator, referring to the radar manual for the correct procedure, until the echo-box output meter shows maximum deflection. The oscillator is then approximately tuned to the correct frequency. Final tuning of the oscillator should be such as to produce maximum ringtime and proper radar crystal current.

ERRATIC TRANSMITTER OPERATION.—Adjust the echo-box tuning control for maximum deflection of the output meter with the echo box connected to the directional coupler, and stop the antenna. If the transmitter is operating normally, a good ringtime pattern will be displayed on the A-scope (fig. 7-18). If the ringtime is erratic, or extra background noise traces appear in the pattern, then the transmitter may be multiple moding (transmitting on two or more distinct frequencies) or failing



36.100(70)B

Figure 7-21.—Steps for recording transmit/receive ratio.

to fire on every pulse. This may be due to faulty pulsing; transmission-line troubles, especially arcing; or other causes. Examine the spectrum in order to help localize the trouble. Refer to the appropriate instruction book for help in correcting the trouble.

TRANSMITTER PULLING.—Magnetron frequency pulling results from a change in the loading as the antenna is rotated. As a check for magnetron pulling, turn off the automatic frequency control on the radar receiver. Adjust the echo-box tuning control for maximum

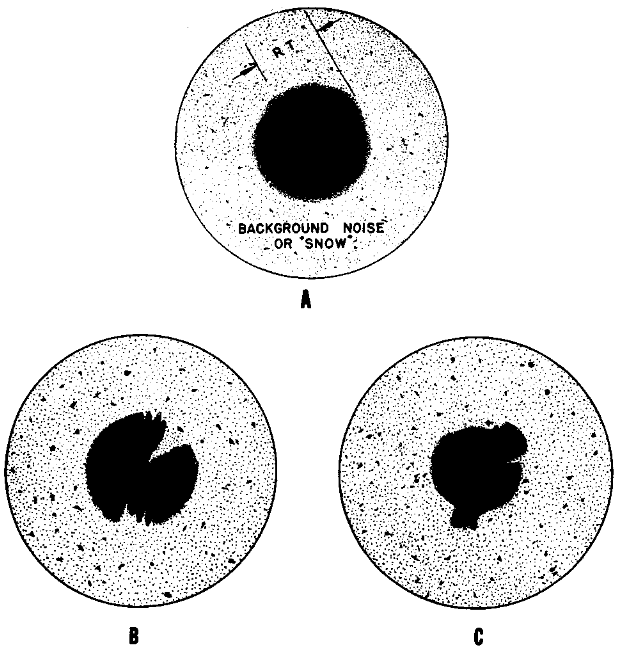
STEP NO.	ACTION REQUIRED	PRELIMINARY ACTION	READ INDICATION ON	PERFORMANCE STANDARD
(8)	Record Echo Box ratio as an indication of transmission line voltage standing wave ratio (VSWR) with a 1-microsecond pulse. (These ratios are inversely proportional; if actual VSWR is desired see interpolation curves in Section 6 of NAVSHIPS 91522 (A)).	Connect echo box to J3007 on transmitter arm of bidirectional coupler. Vary RAISE-LOWER switch (S3501) for maximum reading on Echo Box Meter. Note reading. Connect echo box cable to J3008 on receiver arm of bidirectional coupler. Vary RAISE-LOWER switch (S3501) for maximum reading on Echo Box Meter. Note reading. Divide the first reading by the second reading and record the ratio.	Echo Box Meter ____ First reading ____ Second reading	____ Ratio (1.1 or larger)
(9)	Record Echo Box ratio as an indication of transmission line voltage standing wave ratio (VSWR) with a 2-microsecond pulse. (These ratios are inversely proportional; if actual VSWR is desired see interpolation curves in Section 6 of NAVSHIPS 91522 (A)).	Throw PULSE REP RATE switch (S6205) to 2/500 and repeat Step (8).	Echo Box Meter ____ First reading ____ Second reading	____ Ratio (1.1 or larger)

STEP NO.	1st QUARTER 19__			2nd QUARTER 19__			3rd QUARTER 19__			4th QUARTER 19__		
	Ratio	Initial	Date	Ratio	Initial	Date	Ratio	Initial	Date	Ratio	Initial	Date
(8)												
(9)												

36.100(70)B

Figure 7-21.—Steps for recording transmit/receive ratio—Continued.

deflection of the output meter. With the radar antenna rotating, observe the pattern on the PPI indicator. If the transmitter is operating normally, a good ringing pattern will be seen, as in figure 7-22, A. If there are blank spaces on the PPI indicator or if the ringtime is reduced on certain azimuths, as in part B, then the transmitter is being frequency pulled. In such a case, the output meter reading will also fluctuate as the radar antenna is rotated slowly. Transmitter frequency measurements at several azimuths may also be used to confirm



55.121(70)B
Figure 7-22.—Indication of magnetron pulling.

this difficulty. The pulling may be caused by a bad rotating joint or by a reflecting surface near the antenna. Refer to the appropriate instruction book for corrective measures.

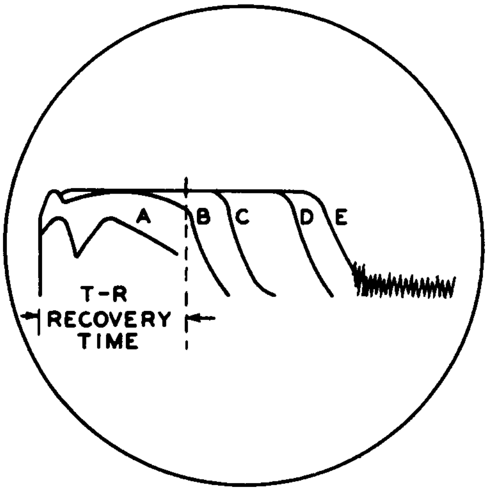
AUTOMATIC FREQUENCY CONTROL.—To determine whether the local oscillator is following the transmitter when it is pulled, first stop the antenna on an azimuth where the ringtime pattern is broken, and then retune the echo box to resonance. Rotate the radar antenna and again examine the PPI pattern. If the ringtime is now good on the azimuth at which the echo box was retuned (fig. 7-22,C), the AFC is in operation on that azimuth and the local oscillator is following when the transmitter is pulled. As may be seen in part C, the ringtime may have now decreased in those azimuths where it was originally good. If the AFC does not follow, the pulling may be excessive or the AFC may be at fault. If the ringtime is greatly decreased at certain azimuths, and the AFC does not follow, the radar must be considered inoperative at those azimuths and should be so reported.

A simple procedure will show whether the AFC is locked on the proper frequency. Stop the radar antenna and tune the echo box for maximum meter reading. Turn off the AFC switch and tune the local oscillator for maximum ringtime, thus putting the local oscillator in proper tune. Turn the AFC switch on again. If the ringtime decreases, even slightly, the AFC is locking on the wrong frequency, or is failing to lock. The proper instruction book should be consulted for corrective procedure. The probable cause of the AFC failure is a bad spectrum or the fact that the local oscillator is tuned to a frequency on the wrong side of the transmitter frequency. It is usually not advisable to tune the AFC circuit.

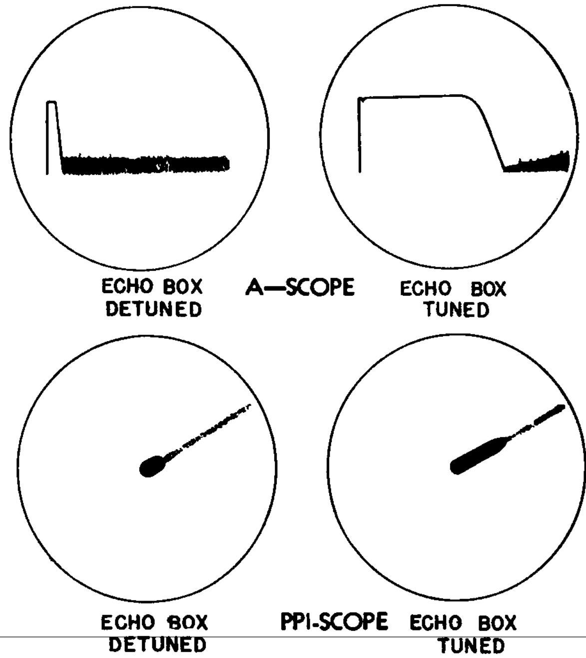
T-R BOX RECOVERY.—The time required to permit T-R (transmit-receiver switch) recovery is determined by the time it takes the T-R switch to deionize after each transmitter pulse. It is usually defined as the time required for the receiver to return to within 6 db of normal sensitivity after the end of the transmitter pulse. T-R recovery time is the factor that limits the minimum range of a radar because the radar receiver is unable to receive signals until the T-R switch is deionized. In various radar sets, the recovery time may vary from about 3 to 20 μs.

To test for T-R box recovery, adjust the echo-box tuning control for maximum deflection of the output meter, and stop the radar antenna. Adjust the A-scope for a good ringtime pattern, such as curve E in figure 7-23. Slowly and gradually reduce the radar receiver gain setting, or better, detune the local oscillator. A pattern will result, such as curve D in figure 7-23, having the same relative shape as curve E. Further slight reduction in gain setting will produce another pattern, such as curve C, again similar in shape to curve E. Continue until a change occurs in the slope of the curve, as in curve B. This point of change marks the T-R box recovery time of the radar, as indicated in the figure. For a good radar, the T-R recovery time should correspond to a range of one mile or less.

If the gain control is reduced still further, a greatly distorted pattern will appear, such as curve A in figure 7-23. This curve shows that the T-R box has not recovered. Refer to the appropriate instruction book for corrective procedures. If the above procedure does not produce a series of curves (as indicated) giving a T-R recovery point, and if the ringtime is short, then it is probable that the T-R recovery



55.123
Figure 7-23.—Checking T-R box recovery.



55.119
Figure 7-24.—Receiver nonrecovery.

time is much too high (greater than the ringtime) and a new T-R tube is needed. Check the keep-alive current. The keep-alive current should be negative and between 0.1 and 0.2 ma.

RECEIVER RECOVERY.—Adjust the echo-box tuning control for maximum deflection of the output meter, and stop the radar antenna. Then detune the echo box, and adjust the radar receiver gain control until the indicator shows a pattern similar to one of those illustrated at the left of figure 7-24. Now retune the echo box to resonance and again observe the indicator pattern. If the receiver recovery time is normal, the background noise will reappear immediately after the end of the ringtime pattern, and this noise will be approximately as strong as the noise previously observed with the echo box detuned. If the receiver recovery is slow, the noise will be weak and will not reappear for some time after the end of the ringtime pattern (see the right-hand portion of figure 7-24). In extreme cases of receiver nonrecovery, normal background noise may not reappear on the indicator at all. Receiver nonrecovery is usually an i-f tube or video defect which will make the radar susceptible to enemy jamming.

TRANSMISSION LINE LOSS.—Using the directional coupler, tune the echo box to resonance. Record the ringtime and the output meter reading. Disconnect the echo box from the coupler and connect it to the dipole (the proper location of the dipole is given in the instruction book; it is located at a position somewhere in the antenna radiation field). Again tune the echo box to resonance and again record the ringtime and the output reading. Comparing these measurements, while allowing for the normal difference due to the difference between the coupler attenuation and the antenna space loss (losses are indicated in tables in the echo box instruction book), an indication can be obtained of the loss in the radar r-f transmission line. If there is unusual loss in the radar transmission line, there will be greater differences than usual in the ringtime and also in the output meter reading. Repair or adjustments may then be undertaken.

Intermittent defects in the transmission line can often be found by rapping on the line while observing the echo box meter reading.

RAPID TROUBLESHOOTING CHART.—When the technician has become familiar with the test procedures and measurements, the echo box may be used for rapid troubleshooting.

Radar troubles may be more readily checked with the aid of the cause-and-effect chart of figure 7-25 which is essentially a summary of the information given on the use of the echo box as a test instrument.

FREQUENCY-POWER METER TS-230B/AP

Frequency-Power Meter TS-230B/AP measures the power (and frequency) of unmodulated and pulsed signals in the range from 8500 to 9600 mc ± 4 mc. It measures average power within the limits of 0.1 and 1000 mw (-10 to + 30 dbm). A front view of the meter is shown in figure 7-26.

A general idea of how the power-measuring circuit in the meter works can be obtained from the following consideration. The thermistor (fig. 7-27) is actually the heart of the power-measuring circuit. This circuit operates on the basic principle of applying the r-f power to be measured to a thermistor and observing the heating effects of that power in changing the thermistor resistance. A thermistor has a high negative temperature coefficient; that is, its resistance decreases rapidly as its temperature increases.

The thermistor is used in one arm of a balanced bridge so that any change in its resistance can be detected and measured. The thermistor is placed so that it will absorb r-f energy from the r-f field without applying r-f voltage directly to the bridge. Thus the d-c meter, M, is not subjected to an r-f voltage and the bridge is isolated electrically from the r-f source.

The power required to bring the thermistor to the right resistance for balancing the bridge varies from about 2 to 20 mw, depending on the individual thermistor and the surrounding temperature. This type of bridge is balanced when the meter reads zero. The condition of balance may be expressed mathematically as:

$$\frac{\text{thermistor resistance}}{\text{resistance of A}} = \frac{\text{resistance of B}}{\text{resistance C}}.$$

In the simplified circuit, the bridge is balanced by varying the d-c supply to the bridge, thereby heating the thermistor with enough d-c power to bring it to the right temperature so that its resistance will balance the bridge (meter reads zero). When the bridge has been balanced, the addition of power (either d-c or r-f) to the thermistor will, through the associated heating effect, unbalance the bridge and cause the meter to move up scale. The meter sensitivity is adjusted so that 1 mw of added power in the thermistor will give a meter reading of 100 (center of dial). Over a limited range (up to 1 mw) the meter reading is directly proportional to the added power.

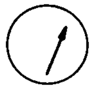
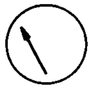
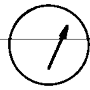
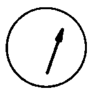
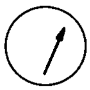
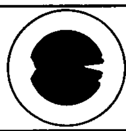
When measurements are made, the bridge is first balanced by applying the correct amount of d-c power to the thermistor; the resistance in series with the meter is then adjusted so that 1 mw of added power from the d-c supply will cause the meter to read 100. The d-c power is then reduced until the meter deflection is again zero. The r-f power to be measured is applied to the thermistor and the meter deflection again noted. One milliwatt of r-f power is equivalent to one milliwatt of d-c power and will cause the meter to read 100 divisions.

A correct impedance match between the thermistor and the waveguide in the meter is obtained so that substantially all of the r-f power will be absorbed—that is, will be converted to heat energy.

A functional block diagram of the equipment is shown in figure 7-28, A. R-f power is fed to the waveguide by means of an r-f cable adaptor.

The guillotine db input attenuator moves an energy-absorbing element (carbon-coated blade) into the waveguide. The position of the blade is calibrated on the attenuator db dial in terms of loss in decibels.

The thermistor is mounted between top and bottom faces at the center of the waveguide and parallel with the electric lines of force. The bottom end of the thermistor is grounded to the waveguide face, and the top end connects through an r-f by-pass capacitor, which consists of a plastic disc between the outside face of the waveguide and thermistor mount. The d-c power-measuring circuit is connected between this post and ground. Short-circuited coaxial stubs are in the top and bottom faces of the waveguide—one at each end of the thermistor. The bottom stub is tunable; also, the reflector plate at the end of the waveguide section can be tuned by means of a screw. The stub and reflector (in combination with the thermistor adjustment) serve to match the thermistor to the impedance of the waveguide, thus making the standing-wave ratio satisfactory.

EFFECT	APPEARANCE ON		PROBABLE CAUSE
	RADAR INDICATOR	ECHO BOX METER	
RINGTIME — NORMAL ECHO BOX METER — NORMAL			RADAR PERFORMANCE SATISFACTORY.
RINGTIME — LOW ECHO BOX METER — NORMAL			RECEIVING TROUBLE: DETUNED MIXER OR LOCAL OSCILLATOR, BAD CRYSTALS, EXCESSIVE I-F NOISE, ADJUSTMENT OF PROBES IN MIXER CAVITY, DETUNED T/R BOX.
RINGTIME — LOW ECHO BOX METER — VERY LOW			LOW POWER OUTPUT-CHECK SPECTRUM.
RINGTIME — LOW ECHO BOX METER — LOW			TROUBLE PROBABLY IN TRANSMITTER AND RECEIVER AND/OR TROUBLE IN TRANSMISSION LINE.
RINGTIME — ERRATIC ECHO BOX METER — STEADY			ECHO BOX DETUNED. BAD PULSING, DOUBLE MODING TRANSMITTER, OR LOCAL OSCILLATOR POWER SUPPLY TROUBLE. CHECK SPECTRUM.
RINGTIME — ERRATIC ECHO BOX METER — ERRATIC			FAULTY TRANSMISSION LINE OR CONNECTION — CONDITION WORSE WHEN LINE IS VIBRATED.
END OF RINGTIME SLOPES GRADUALLY, POSSIBLY EXCESSIVE RINGING. GRASS APPEARS COARSE. ECHO BOX METER-STEADY AND SATISFACTORY.			OSCILLATING I-F STAGE
PRONOUNCED DIP IN RINGTIME AT END OF PULSE.			FAULTY T/R TUBE
RINGTIME-SLIGHTLY LOW POOR OR BAD SPECTRUM.		 POOR SPECTRUM	TRANSMITTING TROUBLE
BLANK SPACES OR ROUGH PATTERN ON PPI RINGTIME INDICATOR. ECHO BOX METER READING VARIES AS ANTENNA IS ROTATED.			FREQUENCY PULLING OF TRANSMITTER DUE TO BAD ROTATING JOINT OR TO REFLECTING OBJECT NEAR RADAR ANTENNA.

55.122

Figure 7-25.—Troubleshooting chart.

The r-f gate is used for making a check of zero balance in the bridge without disturbing the setting of the attenuator. When the r-f gate plunger in the waveguide is pushed in, nearly all the r-f power will be reflected and will not reach the thermistor.

The thermistor may be heated with power from the battery in the battery case. This is

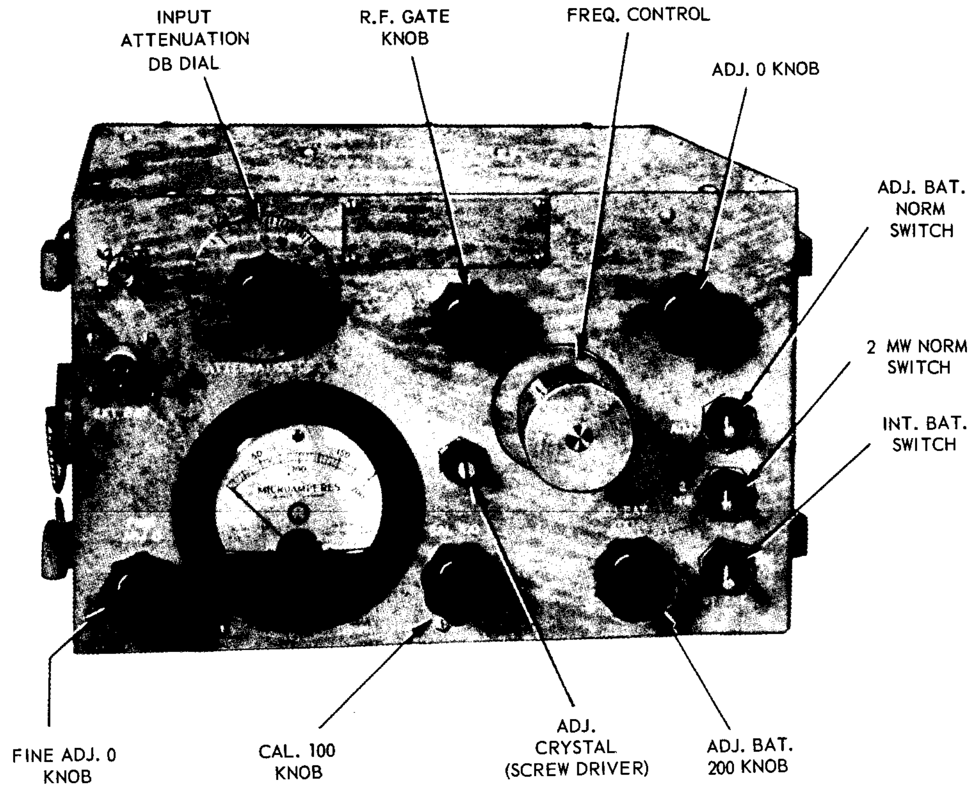


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Figure 7-26.—Front view of Frequency-Power Meter TS-230B/AP.

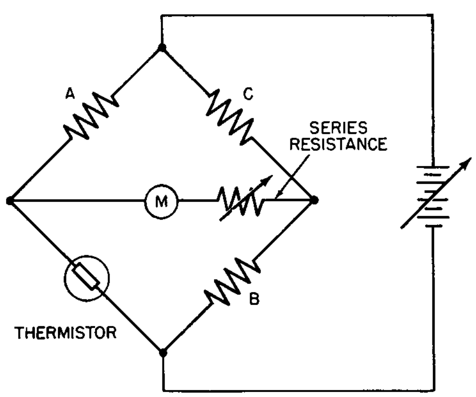

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Figure 7-27.—Thermistor bridge circuit.

the most convenient method for locations remote from external power, especially when the tests are made during a short period of time. If the internal battery is used for extended periods, its voltage decreases and frequent adjustments are needed during tests. External batteries may be connected to the external battery jack.

In order to measure power, the frequency-power meter is calibrated (as outlined in the instruction book) and the ADJ ZERO control (in the main control circuit from the battery to the bridge network) is set to the position that makes the meter read zero. The frequency-power meter is connected to the radar system; the radar transmitter is turned on and the input attenuator adjusted until a reading of 100 is obtained on microammeter, M. The input attenuator reading then represents the level in db above 1 mw at the input of the

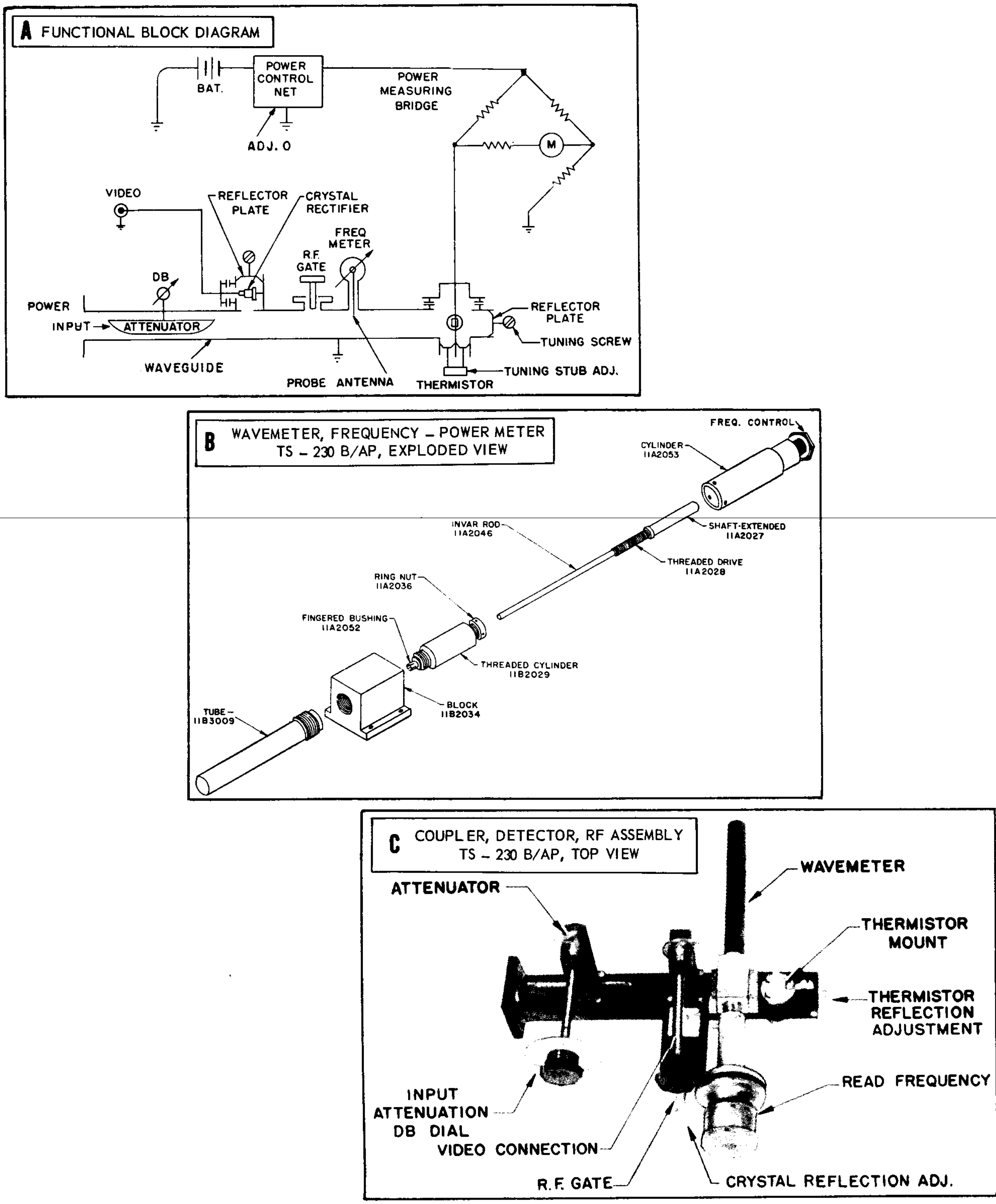

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Figure 7-28.—Functional block diagram and r-f plumbing of frequency-power meter.

waveguide. If the input attenuator dial is turned toward zero and the meter reads progressively less than 100, the meter reading will represent the power absorbed by the thermistor in hundredths of a milliwatt (one division equals 0.01 mw).

To obtain the average power output in the radar waveguide, the input attenuator reading is added to the db loss of the directional coupler (not shown in the figure) between the radar waveguide and the frequency-power meter. The loss in the directional coupler is stamped on the coupler; if a horn pickup antenna is used, the accompanying instruction book will give instructions on figuring losses. The power in watts corresponding to the total dbm (db, above 1 mw) is read directly from a table (not shown). This represents the average power of the radar output.

The meter reading indicates only the average levels of pulsed power throughout the pulse cycle. The peak power can be computed from the average power (Peak-to-Average power conversion method) if the duty cycle ratio is known. The duty cycle ratio is obtained from the radar instruction book or by assuming a rectangular pulse shape and using the following formula:

$$\text{Duty-cycle ratio} = \frac{\text{pulse length}}{\text{pulse repetition time}},$$

where pulse length is in seconds and the pulse repetition rate is given in number of pulses per second.

Representative duty-cycle ratios for radars in the band covered by this instrument are shown in table 7-1, which shows ratios in terms of decimal fractions, common fractions, and db. In table 7-1 and in the preceding formula, a perfect square-wave pulse is assumed. For this reason, duty-cycle ratios given in instruction books for particular radars may differ somewhat from these computed values. The handbook value should be used if it is available.

The peak power is obtained by dividing the average power by the duty-cycle ratio. As an example, let it be assumed that the average power of a radar transmitter, as determined by

Table 7-1.—Radar Duty Cycles.

Repetition Rate (PPS)	Pulse Length (Micro-second)	Duty Cycle Ratio		Repetition Rate (PPS)	Pulse Length (Micro-second)	Duty Cycle Ratio	
		Decimal Fraction	Common Fraction*			Decimal Fraction	Common Fraction*
2,000	0.05	0.000100	1/10,000	600	0.25	0.00015	1/6,600
1,800	0.3	0.00054	1/1,800	600	0.5	0.00030	1/3,300
1,640	0.5	0.00082	1/1,200	480	0.75	0.00036	1/2,800
1,520	0.5	0.00076	1/1,300	400	2.25	0.00090	1/1,100
1,348	0.5	0.00067	1/1,500	400	1.00	0.00040	1/2,500
1,200	0.25	0.00030	1/3,300	400	0.5	0.00020	1/5,000
1,000	2.0	0.00200	1/500	375	2.25	0.00084	1/1,200
1,000	0.75	0.00075	1/1,300	375	1.125	0.00042	1/2,400
1,000	0.5	0.00050	1/2,000	350	2.5	0.00087	1/1,100
800	2.25	0.00180	1/600	350	2.25	0.00079	1/1,300
800	1.25	0.00100	1/1,000	270	2.25	0.00061	1/1,600
800	0.6	0.00048	1/2,100	200	5.0	0.00100	1/1,000
760	1.25	0.00095	1/100	200	4.00	0.00080	1/1,300
760	0.333	0.00025	1/4,000	200	1.00	0.00020	1/5,000
750	1.125	0.00084	1/1,200	60	20.0	0.00120	1/800
600	2.0	0.00120	1/800	60	5.0	0.00030	1/3,300
600	1.0	0.00060	1/1,600	60	1.5	0.00009	1/11,000
600	0.75	0.00045	1/2,200				

*Denominator to nearest 100.

the frequency-power meter, is 25 w. Assume also that the transmitter radiates pulses 0.5 μs long 600 times per second. The calculations are as follows:

1. The duty-cycle ratio (on a square-wave basis) is the product of the pulse length in microseconds and the repetition rate in pulses per second divided by 10^6. That is,

$$\text{duty-cycle ratio} = \frac{0.5 \times 600}{10^6} = 3 \times 10^{4}.$$

2. The peak power is equal to the average power divided by the duty-cycle ratio, or

$$\text{peak power} = \frac{25}{3 \times 10^4} = 83{,}000 \text{ w.}$$

RADAR TEST SET AN/UPM-56

In general, radar test sets will perform more functions than frequency-power meters. For example, Radar Test Set AN/UPM-56 (fig. 7-29) is a portable microwave signal generator, power meter, and frequency meter; in addition, many allied functions can be performed. In this portion of the chapter we are concerned principally with its use as a power meter.

This test set can make r-f power measurements of pulsed or c-w power in the frequency range of 8500 to 9600 mc/s. The range of power that can be measured directly is from +1 to +30 dbm average (1 mw to 1000 mw). Power in excess of +30 dbm average can be measured by using an external attenuator. Power down to -9 dbm (0.126 mw) can be measured on the bridge meter, but this measurement is somewhat less accurate. Power measurements are made by attenuating the unknown power down to a reference level of 1 mw The amount of attenuation is then read on a calibrated dial. The 1-mw reference is established in a thermistor bridge circuit.

The attenuators in the test set consist of waveguide sections within which are glass strips coated with a resistive material such as carbon, which absorbs r-f energy. These

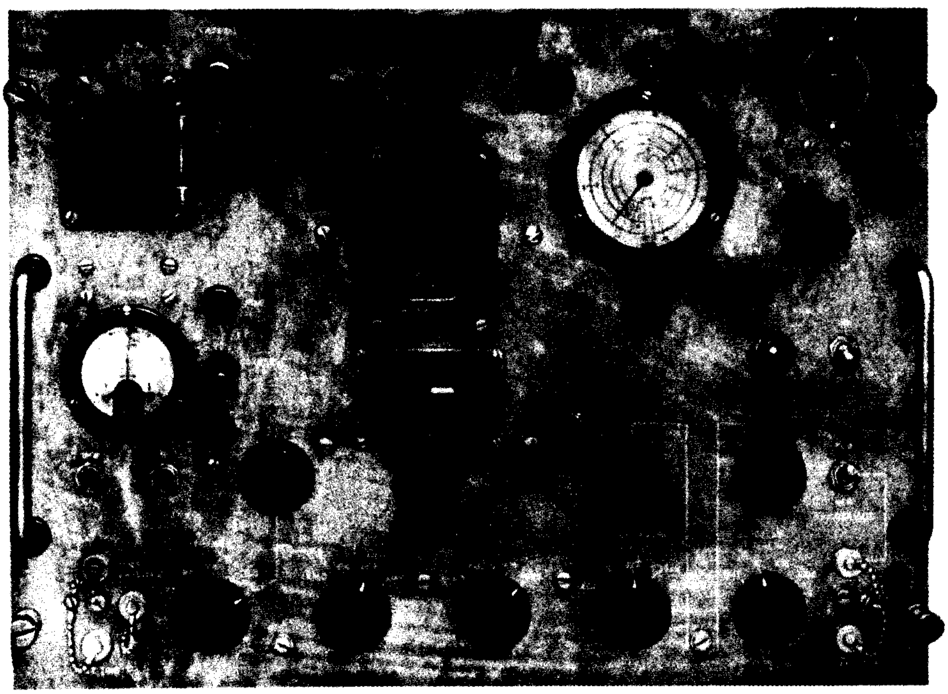

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Figure 7-29.—Front view of Radar Test Set AN/UPM-56.

attenuators are shown in the simplified phantom view of the r-f plumbing in figure 7-30. The glass strips run lengthwise in the waveguide. One of the attenuators, AT103 (calibrated attenuator) is continuously variable and has a 1 to 30 dbm calibrated range. It is the r-f level control on the panel of the test set. Attenuators AT101 and AT102 are of the step type, each having a 0-db position and a 35-db position. The step attenuators are controlled from the same knob (R-F LEVEL SELECTOR), which also controls the r-f cutoff in the T-section that connects the klystron oscillator mount to the waveguide and the T-section attenuator.

When the power of external signals is being measured AT101 and AT102 are in the 0-db position (r-f in on the r-f level selector (fig. 7-29)), the klystron oscillator is shut off, and the T-section attenuator is in a position of minimum attenuation. The calibrated r-f level control is used for adjusting attenuation. The lowest attenuation of the r-f level control is 1 dbm; this results from the attenuation inherent in the waveguide, from the attenuators in the zero position, and from other waveguide losses.

A simplified schematic diagram of the thermistor bridge wattmeter is shown in figure 7-31 A; the bead thermistor is illustrated in part B.

A bead thermistor is a temperature-sensitive device whose resistance decreases with an increase in temperature. There are three causes of temperature variations that affect the resistance of the bead thermistor—the ambient temperature (surrounding temperature), the heating effect due to an applied voltage, and the heating effect due to an applied r-f field.

The thermistor bridge wattmeter contains two bridge circuits; one is a control bridge, and the other a power-measuring bridge. The control bridge provides a means of compensating for ambient temperature changes that would normally affect the calibration of the

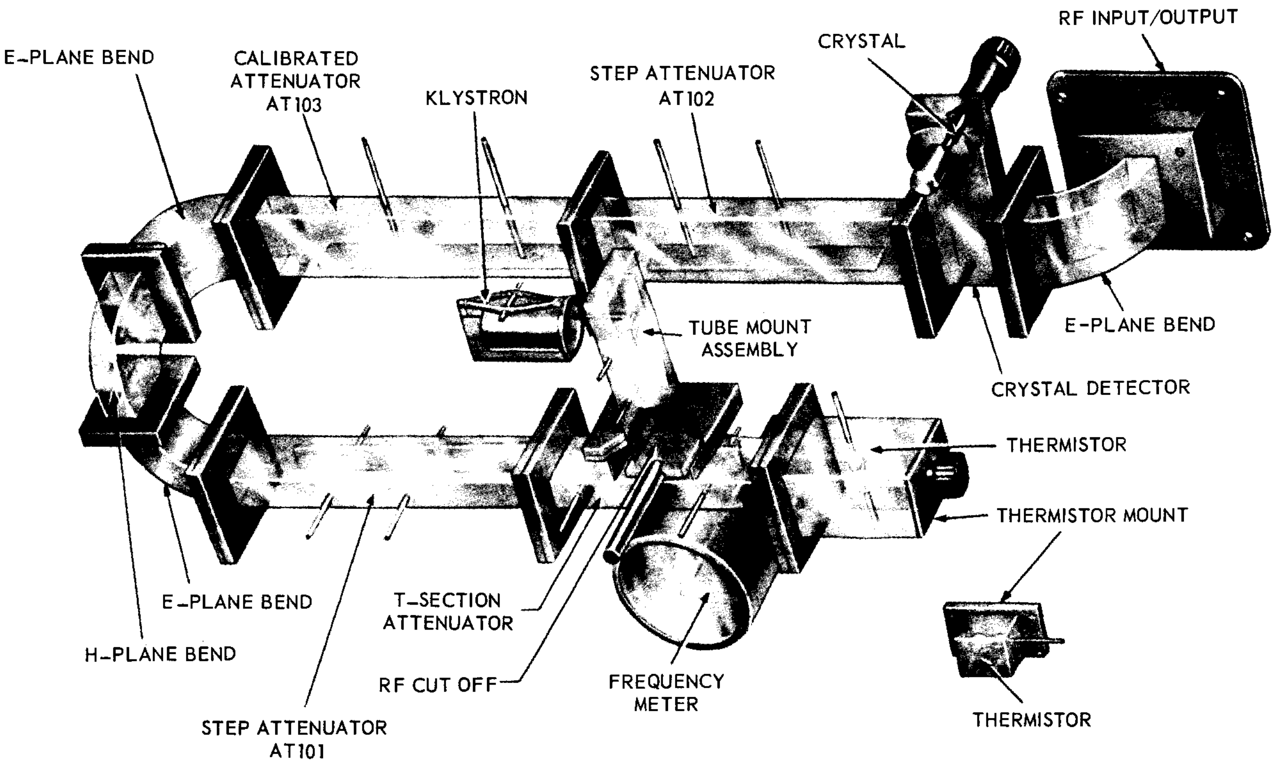

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Figure 7-30.—Simplified phantom view of r-f plumbing.

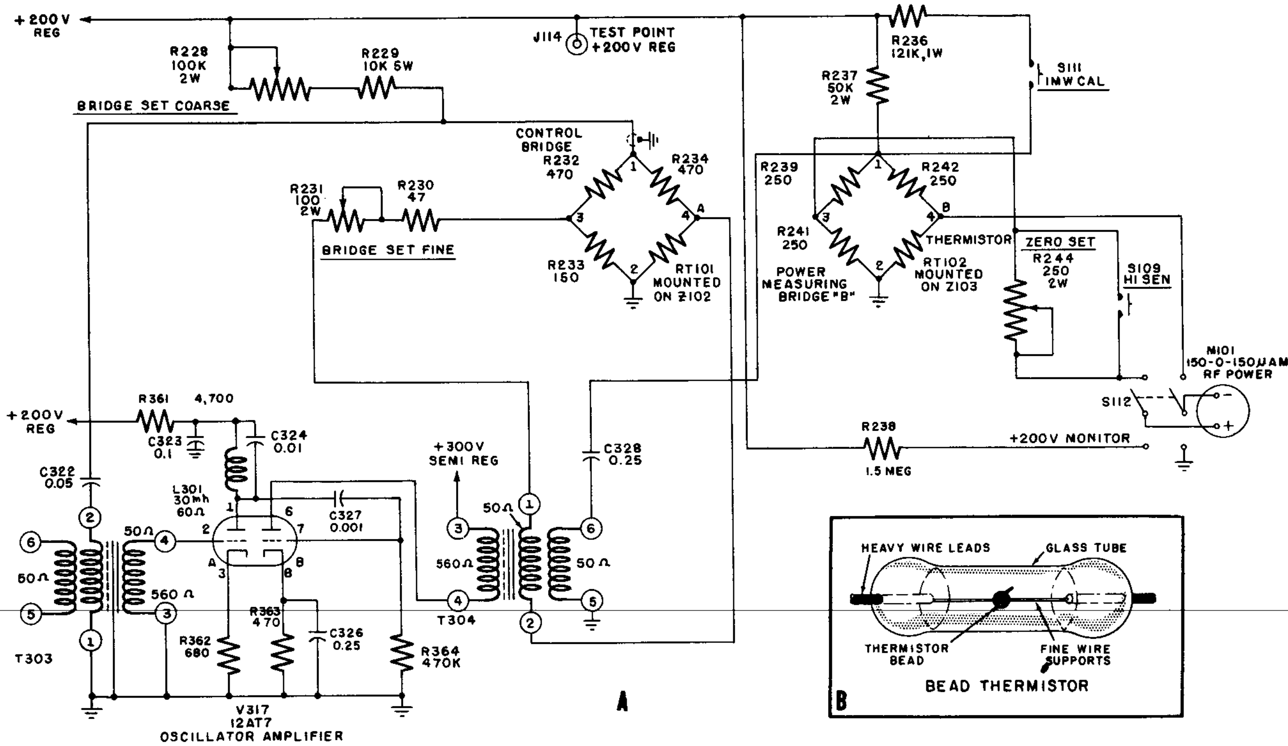

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Figure 7-31.—Simplified schematic diagram of the thermistor bridge wattmeter.

power-measuring bridge. The control bridge employs thermistor RT101 in one arm to balance a 150-ohm resistor, R233, in another arm. The remaining two arms contain 470-ohm resistors (R232 and R234).

The power-measuring bridge consists basically of bead thermistor RT102 and resistors R239, R241, and R242. Bead thermistor RT102 is mounted in waveguide section Z103 (fig. 7-30) where r-f power is applied to it from the r-f input/output connector. The resistance of thermistor RT102 at room temperature is higher than that of resistors, R239, R241, and R242, each having a resistance of 250 ohms.

The object is to obtain bridge balance (all four resistances equal) when 1 mw of r-f power is applied to thermistor RT102. In order to do this, two voltages are applied simultaneously across terminals 1-2 of the power-measuring bridge.

One voltage is a regulated +200 volts d-c applied through R237. This voltage accomplishes two purposes: first, it supplies the d-c voltage that causes the bridge meter to indicate balance or degree of unbalance; and, secondly, it reduces the resistance of thermistor RT102 by dissipating heat in it.

The other voltage is a variable a-c voltage of about 10 kc. This voltage also accomplishes two purposes: first, it dissipates heat in RT102 in varying amounts to compensate for changes in ambient temperature; and, secondly, it allows for the initial setting of the bridge. This voltage is obtained from the 10-kc oscillator, V317. The oscillator output voltage is regulated by the control bridge.

Another d-c voltage is applied to the power-measuring bridge when the 1-mw calibrated pushbutton switch, S111 is closed. This voltage exactly corresponds in temperature effect to the application of 1 mw of r-f power to RT102.

Before r-f power is applied to RT102, the BRIDGE SET FINE control, R231, is positioned (with S111 closed) so that meter M101 reads SET POWER (1-mw level). Switch S111 is then released and the ZERO SET control, R244, adjusted until the meter indicates SET ZERO (0 mw). The BRIDGE SET FINE control, R231, is again positioned (with S111 closed) so that the meter reads SET POWER (1-mw level). Switch S111 is then released again.

When 1 mw of the r-f power being measured is applied to thermistor RT102, the meter again reads SET POWER (1 mw).

The output of the oscillator-amplifier is fed through T304 to both the control bridge and the power-measuring bridge. A regulated direct voltage is applied to terminals 1-2 of the control bridge through the BRIDGE SET COURSE control and R229. The 10-kc output from T304 is applied to terminals 3-4. The amount of a-c voltage appearing across terminals 1-2 depends on the resistance of bead thermistor RT101. This voltage is applied through C322 to input transformer T303. This is the feedback loop for the oscillator. For an initial setting, the amount of feedback is determined by the resistance of thermistor RT101 and the amount of voltage applied from the output winding of T304, as controlled by the BRIDGE SET FINE adjustment.

After the initial setting, any changes in ambient temperature are reflected in resistance changes in thermistor RT101, in feedback, and in oscillator-amplifier output to the power-measuring bridge. Thus, changes in ambient temperature that normally would cause power-measuring thermistor RT102 to change resistance are compensated by adding or subtracting heat effects caused by the alternating voltage applied to its bridge. The following example will illustrate the principles of POWER MEASUREMENT. Assume that a certain radar transmitter with a built-in directional coupler having a 20-db attenuation is connected to the test set with an r-f cable having a 3.5 db loss.

The test set power-measuring bridge is first properly calibrated. When r-f power is applied, the dbm dial reads 17.5 dbm when the bridge R-F power meter indicates 1 mw. The total db attenuation with reference to 1 mw is 20 db + 3.5 db + 17.5 db = 41 dbm (1-mw reference).

The average power output of the radar transmitter in watts is 41 db above 1 mw. From the dbm-to-watts conversion chart (fig. 7-32), the corresponding average power output of the radar system in watts is approximately 12.5 w.

The peak power is equal to the average power divided by the duty-cycle ratio. The duty-cycle ratio (for a square wave) is equal to the product of the pulse length in microseconds

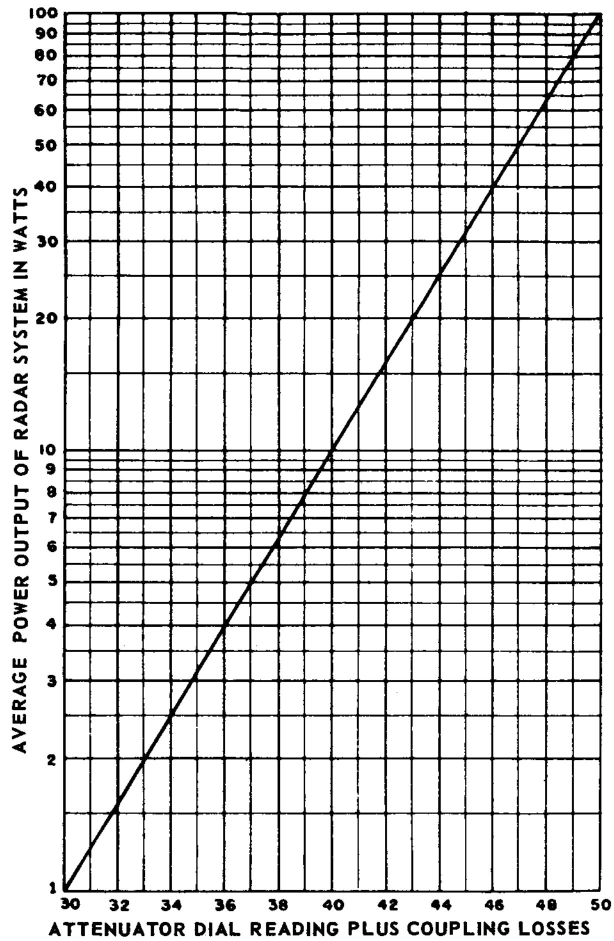

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Figure 7-32.—Dbm-to-watts conversion chart.

and the pulse repetition rate, PRF, in pulses per second, divided by 10. Expressed as a formula, the peak power is

$$\text{peak power} = \frac{\text{average power}}{\text{duty-cycle ratio}} = \frac{\text{average power}}{\text{pulse length x (PRF)}} = \frac{\text{average power x } 10^6}{\text{pulse length x (PRF)}},$$

where the peak power and the average power are in watts.

If the pulse length is 0.8 μs, the pulse repetition rate is 1706 pulses per second, and the average power is 12.5 w, the peak power will be

$$\text{peak power} = \frac{12.5 \times 10^6}{0.8 \times 1706} = 9150 \text{ w. (approx).}$$

A chart for converting average power to peak power is illustrated in figure 7-33. From this chart the db value is indicated for the example being considered as 28.65 db at point C. From this value the peak power is found from the formula,

$$\text{db} = 10 \log \frac{\text{peak power}}{\text{average power}}$$

$$28.65 = 10 \log \frac{\text{peak power}}{\text{average power}}$$

$$\frac{\text{peak power}}{\text{average power}} = 733$$

$$\text{peak power} = 733 \times 12.5 = 9150 \text{ w. (approx)}$$

RADAR TEST SET AN/UPM-99

The Radar Test Set AN/UPM-99 (fig. 7-34) consists of Radar Test Set TS-1253/UP, coder simulator SM-189/UPM-99, and power supply PP-2391/UPM-99. A variety of minor components have been designed to augment the utility of the test sets. Figure 7-35 is a simplified block diagram of Radar Test Set AN/UPM-99.

The Radar Test Set TS-1253/UP contains four modularized plug-in units; the Xtal Mark and Sync, Sweep and Inten Mark, Display, and SIF Coder units. D-c plate, bias, and a-c filament power are supplied by a power supply in the main chassis.

The pulse generator circuits of the Xtal Mark and Sync unit operate from external positive or negative, or externally generated trigger pulses. Positive suppressor, zero delay "0", and delay trigger outputs are supplied at panel connectors. The delayed trigger pulse is also provided at the input power connector of the unit for triggering the Mark X Coder in the SM-189/UPM-99, and for use within the TS-1253/UP. Internal connections supply output triggers from this unit to the Sweep and Inten Mark unit. Internal connections also supply

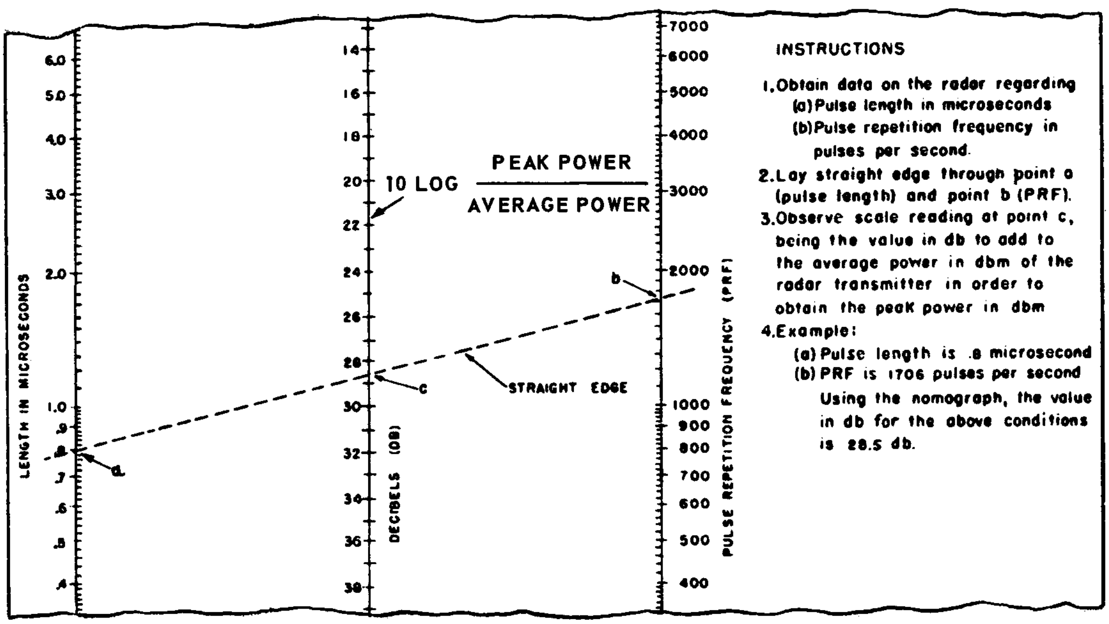

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Figure 7-33.—Average-to-peak power conversion chart.

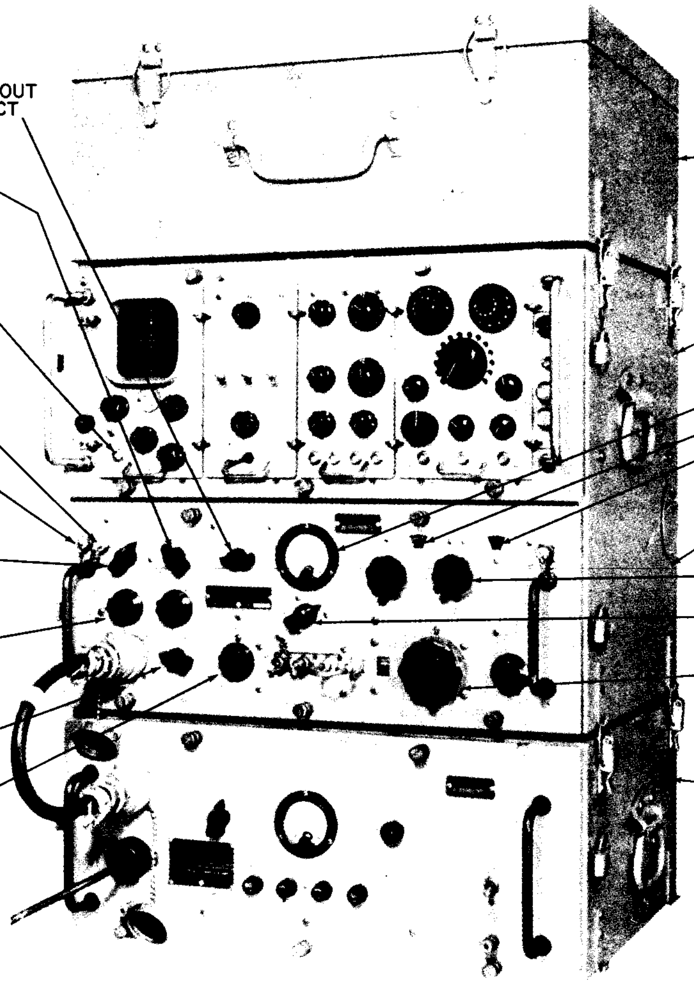

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Figure 7-34.—Radar Test Set AN/UPM-99, unit location and interconnection.

video marker output from the Xtal Mark and Sync unit to the Display unit, providing an accurate time calibration on the display sweep.

The Sweep and Inten Mark unit contains the triggered sweep generator and an intensity marker generator. Horizontal sweep output is supplied to the cathode-ray tube of the Display unit. Intensity marker output is also supplied to the cathode-ray tube and provides time-scale marks for the different sweep durations. Appropriate trigger inputs are selected by operator controls. All connections are internal.

The Display unit contains the cathode-ray tube, r-f type high voltage supply, and a video amplifier for vertical deflection. Video markers, intensity markers, horizontal sweep voltage, and power are supplied from the other units of the test set. A panel connector is provided for video input.

The SIF Coder unit requires an external positive trigger to initiate the generation of a coded pulse train. Operator controls permit code selection and output amplitude adjustment. Continuously variable, low level output is supplied at the VARI OUTPUT panel connector. High level output is supplied at the MOD DRIVE panel connector. A two-position switch controls the relative output levels from both panel connectors. The Xtal Mark and Sync unit, or other external equipment, supplies the

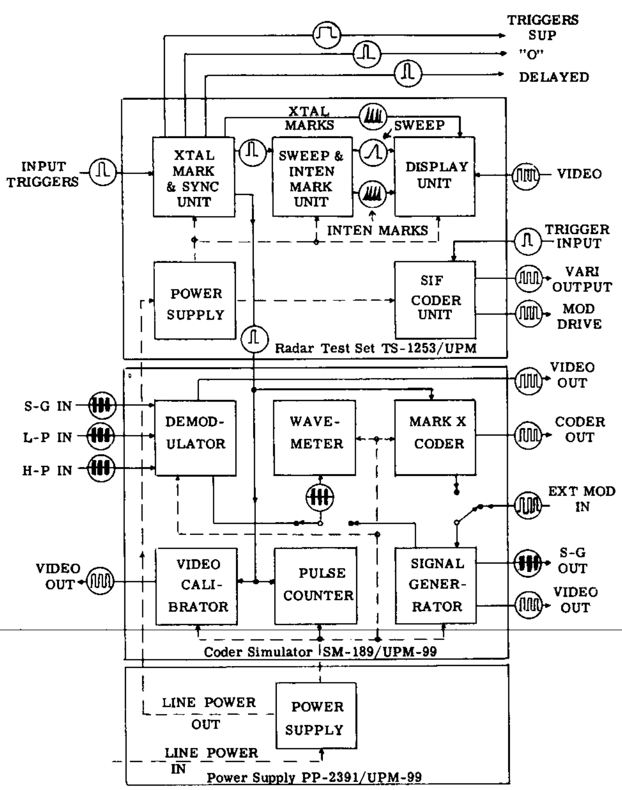

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Figure 7-35.—Radar Test Set AN/UPM-99, block diagram.

input trigger to the panel connector of the SIF Coder unit. The unit (except the power supply) is a complete coded pulse-train generator.

A drawer chassis assembly contains the power control, rectifier, and regulator circuits for Radar Test Set TS-1253/UP. It also provides mountings and interconnections for the plug-in units of the test set.

The Coder Simulator SM-189/UPM-99 component contains six sections; Mark X Coder, Pulsed R-F Signal Generator, Wavemeter, Demodulator, Pulse Counter, and Video Calibrator. These sections provide the facilities for generation of Mark X interrogations and replies, pulsed UHF signals, prf measurement, and generation of amplitude calibrated pulses.

The Mark X coder produces video pulses when internally triggered by delayed triggers from the Xtal Mark and Sync unit. These output pulses simulate the pulses used in various identification and recognition sets of the IFF system. Selection of the type of output is made by the MODE SELECTOR switch. Table 7-2 lists the types of available outputs.

To generate the six types of Mark X code pulses listed in the table, the coder circuitry can be employed in three methods of operation (fig. 7-36).

The FIRST METHOD OF OPERATION (fig. 7-36, A) generates 1-μsec wide paired Mark X challenge pulses for Modes 1, 2, and 3. The positive-polarity input trigger from the Xtal Mark and Sync unit is applied through a capacitor to the grid of trigger amplifier V301. The resulting output at the primary and secondary of T303 is a pair of identical pulses spaced approximately three, five, or eight μsec. A MODE TOLERANCE control (fig. 7-34) permits variation of approximately plus or minus one-half μsec in the pulse spacing.

In the SECOND METHOD OF OPERATION (fig. 7-36, B), a variable pulse from 0.9 to 1.3 μsec is generated to simulate a basic Mark X single pulse reply. The input trigger applied to the grid of trigger amplifier V301 causes first blocking oscillator V302 to operate. As opposed to coder operation in generating paired pulses, no delay line is connected in the grid circuit, of the first blocking oscillator. Output variation of the width of the single pulse is controlled by the MODE TOLERANCE control. When the MODE SELECTOR (fig. 7-34) is in the REPLY-SINGLE PULSE position, the maximum variation is from 0.9 to 1.3 μsec.

In the THIRD METHOD OF OPERATION (fig. 7-36, C) are generated the double and quadruple pulses Mark X replies. In this type of operation the Mark X coder produces either a pair of pulses or four pulses approximately 1 μsec each in duration with spacing between pulses variable from approximately twelve to nineteen μsec. When the MODE SELECTOR is in the REPLY-DOUBLE PULSE position the output at pulse transformer T303 consists of two identical pulses and for the REPLY-EMERGENCY position four identical pulses are produced.

The CODER OUT & S-G MOD SELECT switch (fig. 7-34) has four positions: NEG., POS., MARK X S-G MOD, and EXT S-G MOD. In the NEG. position, terminal 1 of output pulse transformer T303 is grounded and an output of negative polarity is applied to the CODER OUT connector on the front panel of the Coder Simulator SM-189/UPM-99. In the POS. position, terminal 6 of T303 is grounded

Table 7-2.—Mark X Coder Output Pulse Types.

Mode Selector Switch Position	Type Of Output	Pulse Duration (Microseconds)	Pulse Spacing (Microseconds)
CHALLENGE-MODE 1	Paired	1.0 nominal	2.5 to 3.5
CHALLENGE-MODE 2	Paired	1.0 nominal	4.5 to 5.5
CHALLENGE-MODE 3	Paired	1.0 nominal	7.5 to 8.5
REPLY-SINGLE PULSE	Single	0.9 to 1.3	- - -
REPLY-DOUBLE PULSE	Paired	1.0 nominal	12.5 to 19.5
REPLY-EMERGENCY	Quadruple	1.0 nominal	12.5 to 19.5

and an output of positive polarity is applied to the CODER OUT. In both of these cases, the Mark X coder output amplitude may be varied by operating the CODER AMPLITUDE control.

When the CODER OUT & S-G MOD SELECT switch is in the MARK X S-G MOD position, transformer T303 is disconnected from the CODER OUT connector. Terminal 1 of T303 is connected to the cathode circuit of a modulator drive stage, and terminal 6 remains grounded. The CODER AMPLITUDE control is inoperative in this case.

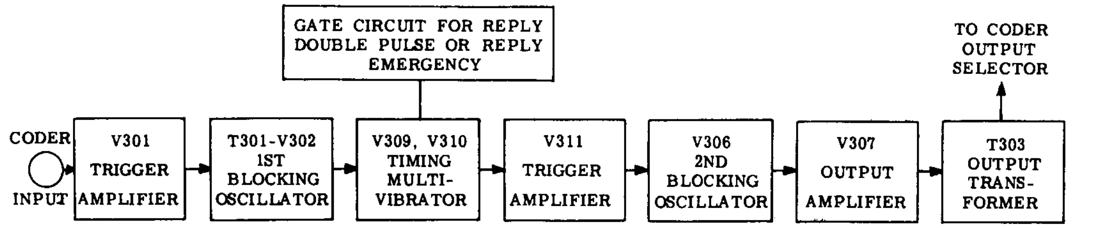
In the EXT position, terminal 1 of T303 is disconnected from the CODER OUT connector, and the EXT MODE IN connector is connected to the cathode circuit of the modulator driver stage.

The RF Signal Generator has a continuous tuning range from 925 to 1225 mc. Calibration charts are provided that can be read to within 5 mc. When greater accuracy (up to 0.2 mc) is required, the wavemeter is used to check generator frequency. The RF signal generator consists of an oscillator, and automatic level control (ALC) system, a modulator, and a variable attenuator.

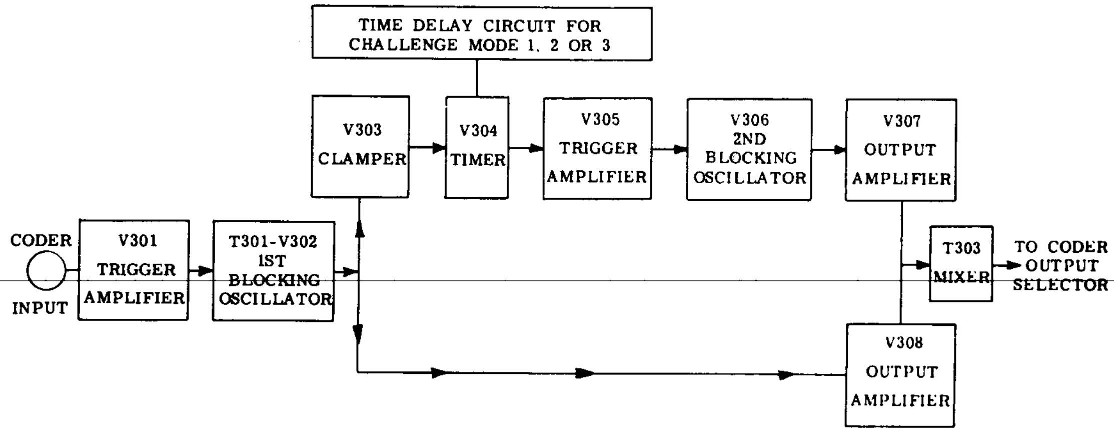
The output level can be read directly from the OUTPUT dial on the front panel and may be varied by the attenuator from 21 to 121 db below one volt rms (equivalent to 89,100 to 0.891 v) when terminated by a 53.5 ohm load. Modulation pulses are supplied by the coder to a modulator circuit. The pulsed RF output simulates the challenge and reply pulses of the equipments comprising the Mark X IFF system and equipments comprising the SIF systems. A substantially constant output reference level is maintained over the entire frequency range by means of the automatic level control system.

The Wavemeter serves to measure the frequency of pulses RF power sources and covers a range of from 925 to 1225 mc. It is necessary to use the wavemeter to determine accurately the frequency of the RF oscillator. This is done when the WAVEMETER INPUT coaxial switch is held in the SIGNAL GENERATOR position. In the DEMOD. position, the wavemeter is connected to the demodulator and the wavemeter takes a small portion of the RF power input for frequency measurement. The accuracy of the wavemeter is plus or minus 0.7 mc when measuring the frequency of the RF oscillator or external sources of 0.5 to 35 peak watts when applied to the L-P IN connector, or 35 to 3500 peak watts when applied to the H-P IN connector. Calibration charts are furnished which may be read to approximately 0.1 mc. Resonance is shown by a dip on the front panel indicating meter.

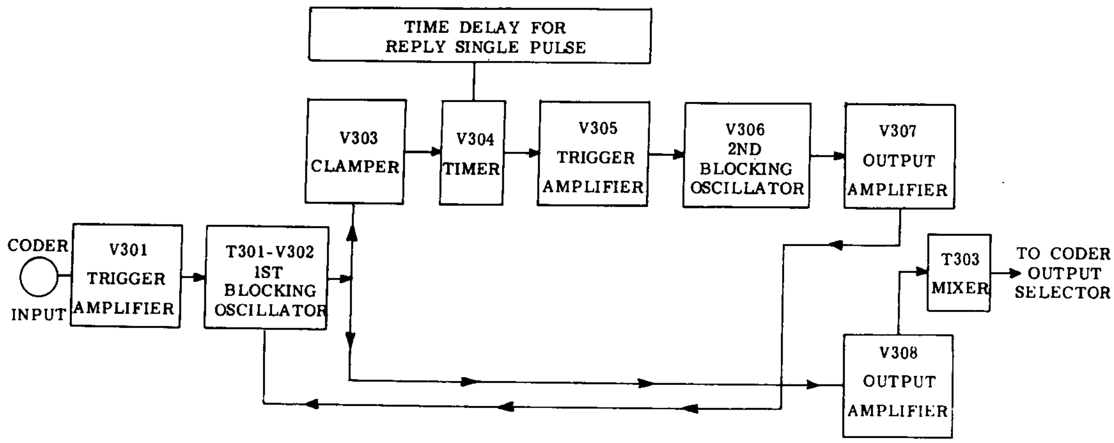
The Demodulator consists of a diode operating over the frequency range from 950 to 1215 mc and producing an output: (1) without appreciable distortion for wave-shape measurement, and (2) of peak voltages for power measurements. A small portion of the power applied to the demodulator from an external equipment is applied to the input of the wavemeter so that frequency measurements can be made. Attenuated output of the RF signal generator is available at L-P IN and H-P IN so that external equipment can be challenged or triggered.



A. OPERATION METHOD ONE, BLOCK DIAGRAM



B. OPERATION METHOD TWO, BLOCK DIAGRAM



C. OPERATION METHOD THREE, BLOCK DIAGRAM

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Figure 7-36.—Three methods of operation to generate Mark X code.

The Pulse Counter counts trigger pulses produced by the blocking oscillator V302 of the Mark X Coder. It reads the pulse recurrence frequency at which the AN/UPM-99 is operating whether self-synchronized or triggered by external pulses applied at the INPUT TRIGGERS connector (SYNC SELECT in the EXT - or EXT + position). Meter indication is given on the front panel of Coder Simulator SM-189/UPM-99; two meter scales are provided: 0 to 500 and 0 to 5000 pps.

The video Calibration unit supplies output pulses of known amplitude at the VIDEO OUT connector. One of the uses of the video calibrator is to calibrate the synchroscope in the TS-1253/UP. The output is developed across a voltage divider consisting of precision type resistors so that pulse amplitudes of 1, 2, 5, or 10 volts are available. Provision is made for self-calibration by using the front panel meter. It is possible to get video output voltages other than 1, 2, 5, or 10 volts by the setting of the CAL PULSE ADJ control. For example, if 2.5 volts are desired, the meter can be adjusted by CAL PULSE ADJ. to half scale deflection so that only 5 volts will be developed across the precision resistor voltage divider. Then if the VIDEO OUT SELECT control is set at 5, there will be 2.5 volts across that part of the divider connected to the 5 volt position.

The Power Supply is of conventional design. A time delay protection circuit is included, along with provisions for B+, bias, and filament voltages, a d-c relay supply, and a low-high input line compensation transformer network.

RADAR PERFORMANCE FIGURE

Although ringtime measurements are valuable in indicating the overall performance of a radar system, they are not as precise as Radar Performance Figure (RPF) measurements. However, neither of these measurements indicates much about how efficient the waveguide or antenna is in performing its function. Ringtime measurements are relatively easy to make; RPF measurements are more difficult to make.

The maximum range of a radar system depends on several factors—for example, (a) transmiter power, (b) receiver sensitivity, (c) the performance of the waveguide and antenna, (d) the effectiveness of the target in reflecting radar energy, and (e) atmospheric conditions.

The first two of the factors listed are especially significant in so far as equipment performance is concerned and are used in determining the RPF of a radar system. The RPF of a radar system is the ratio of the peak (pulse) power, P_p of the radar transmitter to the power of the minimum discernible signal (P_{mds}), expressed in decibels (db) or in decibels with a reference of 1 mw (that is, dbm). Expressed mathematically,

$$\text{RPF (db)} = 10 \log \frac{P_p}{P_{mds}}.$$

Because P_{mds} is a very small fraction, its log has a negative sign, and therefore

$$\text{RPF (db)} = 10 \left[\log P_p - (-\log P_{mds}\right]$$

$$\text{RPF (db)} = 10 \log P_p + 10 \log P_{mds}$$

If the power reference is 1 mw, the equation becomes

$$\text{RPF (dbm)} = P_p \text{ (dbm)} + P_{mds} \text{ (dbm)}.$$

To determine the RPF of a radar system it is necessary first to determine the transmitter average power by means of a power meter (previously discussed) and to convert the average power in dbm to peak power in dbm. The various losses must be taken into consideration in determining the power output. It is also necessary to determine the power of the minimum discernible signal.

The measurement of the minimum discernible signal (MDS) in dbm involves the use of a signal generator and an oscilloscope. The exact method of making the measurement depends on the radar set being tested. For example, the procedure for making MDS measurements on Radar Set AN/SPS-10 is given in the Maintenance Standards Book for the AN/SPS-6.

An external pulse-modulated signal and a method of viewing this signal is required. These requirements are satisfied by the use of Signal Generator TS-419/U and Oscilloscope OS-8B/U or equivalents. The test equipment is connected as shown in figure 7-37 and the correct procedures are as follows:

1. Deenergize the radar equipment (depress S102) and apply power to the signal generator and the oscilloscope.
2. Adjust the signal generator to the assigned transmitter frequency, set the FUNCTION switch to ZERO SET and adjust the ZERO SET control until the meter indication is zero.
3. Set the FUNCTION switch to CW and adjust the POWER SET control until the meter pointer is at the power set marker.
4. Set the FUNCTION SELECTOR switch to the RATE x 10 position, the PULSE WIDTH control to 2 and the PULSE RATE control to 30.

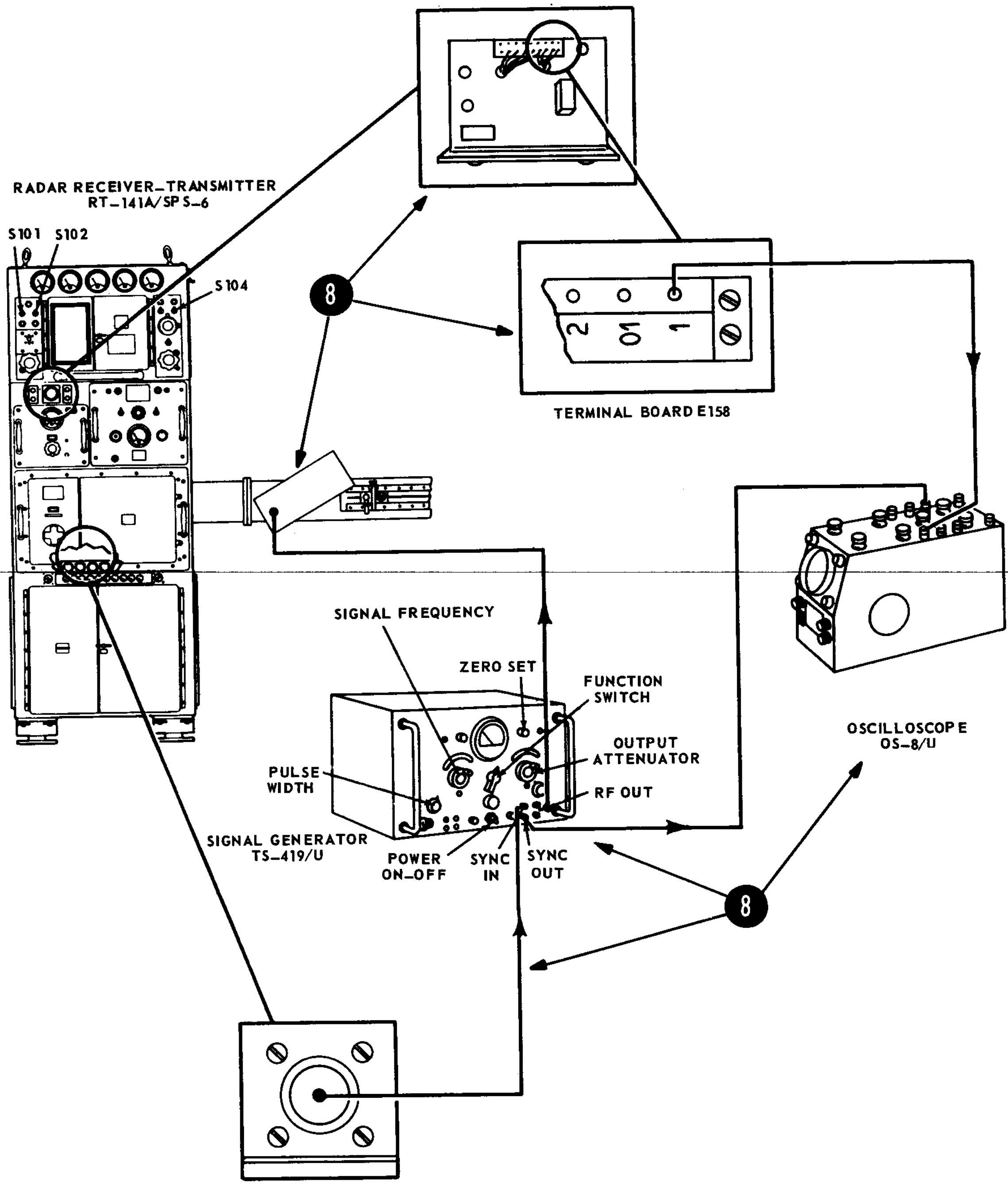

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Figure 7-37.—Test setup for making MDS measurements.

5. Make certain that all connections to the test equipment are correct, and that the oscilloscope is adjusted for maximum clarity of presentation.

6. Depress MAIN POWER ON switch (S101) on the radar set, and set MANUAL-AFC switch to MANUAL. The RADIATION switch (S104) is OFF.

7. While observing the pulse-modulated signal on the oscilloscope, slowly decrease the output of the signal generator with the OUTPUT ATTENUATOR control until the signal is barely visible in the "grass" on the oscilloscope. Read the indication on the attenuator dial in dbm.

The minimum discernible signal is the sum of the test set reading in dbm, the cable attenuation in db, and the waveguide connector in dbm. For this equipment, the power of the MDS is normally between 100 and 115 dbm.

Thus, if the peak power (Pp) output is assumed to be 90 dbm and the power of the MDS (that is P mds) assumed to be 105 dbm, the radar performance figure (RPF) is

RPF (dbm) = Pp (dbm) + Pmds (dbm)
RPF (dbm) = 90 + 105 = 195.

A graph showing the percentage loss in maximum radar range for various db losses in RPF and for various percentages of loss in ringtime is shown in figure 7-38.

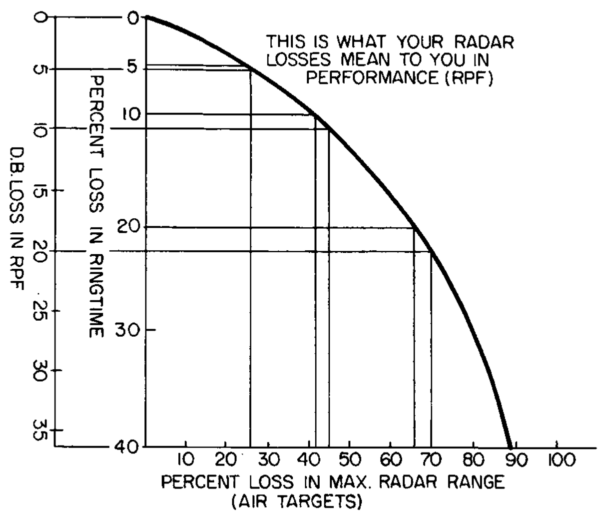

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Figure 7-38.—Effects of loss in RPF and ringtime on radar range.