CHAPTER 2

RADAR EQUIPMENT

RADAR CHAPTER

2-1 INTRODUCTION

General. Possibly one of the greatest inventions to come out of World War II is radar. The word itself is a contraction of the expression RAdio Detection And Ranging and is thus the application of radio principles to detect objects that cannot be observed visually and to determine their direction, range, and elevation.

In many cases, radar circuits are merely radio circuits which have been modified and rearranged. It is therefore not necessarily true that the radar technician's job is one of complexity and frustration. In most cases, the intelligent application of fundamental radio principles and basic circuits will contribute greatly in solving the problems encountered in the day-to-day operation and maintenance of radar equipment.

Radar depends on the transmission and reception of radio energy pulses which are controllable in strength, duration, and direction of propagation. By properly using the basic elements, the timer or synchronizer, transmitter, receiver, antenna, antenna positioner, and indicator, it is possible to determine the distance, direction, and elevation of an object which is capable of reflecting or reradiating a portion of the radio energy (radar echo). Modern radar technique, highly developed as it is, still depends on the timing, transmission, detection, and display of this energy for its intelligence.

Radar personnel should find this chapter valuable, both as a reference and as a stimulus to studying the technical manual for specific equipments. Recommendations from the field, for items to be included or corrections to be made in this chapter, are welcome and should be addressed to the Chief, Bureau of Ships, Navy Department, Washington 25, D.C.

General Maintenance. In order that maximum efficiency may be realized, it is of utmost importance that performance tests be correctly and periodically accomplished. The techniques and procedures necessary to properly test microwave-radar systems are quite different from those used in routine electronic testing. It is the purpose of this chapter to elaborate on some of these special test requirements. The description is intentionally confined to equipments, components, and circuits in general, resorting to specific cases only when necessary. (Maintenance information on specific equipments is contained in the "Service Notes" section.) Maintenance should be preventive in nature, wherein potential failures are detected and corrected before they have opportunity to develop. Timely replacement of parts exhibiting evidence of failure prevents complete breakdown. This chapter contains procedures which will aid in reducing the possibility of major breakdowns and lengthening the useful life of the equipment.

Troubleshooting of equipment as complex as the average radar set must be conducted in an orderly and systematic manner if the cause of the trouble is to be located and corrected as quickly as possible. The first logical step in a troubleshooting procedure should be an attempt to localize the trouble to a particular component or unit. Equipment operating procedures and scope and meter indications are the primary means by which a component or unit malfunction is localized. Intelligent application of these symptom indications serves to localize the trouble into one of the sectional divisions of this chapter.

Purpose of Periodic Tests. To properly monitor the operation of a radar set for optimum performance, the following measurements should be made at periodic intervals:

a. Transmitter power output.
b. Transmitter frequency.
c. Minimum discernible signal (MDS).
d. Receiver bandwidth.
e. Transmitter ring time and AFC locking.
f. TR tube recovery time.
g. Voltage standing wave ratio (VSWR).
h. Transmitter frequency spectrum width.

The purpose of the transmitter power and frequency measurement is to determine as accurately as possible the transmitter frequency and the R-F power output. The values obtained should not be less than those stipulated in the technical manual for the particular equipment.

If the power output is below the minimum acceptable value and the magnetron is operating at its rated current, replace the magnetron.

If the power output is erratic, test the modulator circuits for misfiring of the magnetron. If the magnetron firing is normal, measure the voltage standing wave ratio. If the VSWR is excessively high, test and inspect the R-F components to determine and correct the cause.

Usually, if the magnetron is outside the design frequency limits, replacement is necessary.

The purpose of the minimum discernible signal measurement is to determine the absolute sensititivity of the receiving system by measuring the smallest signal power (usually in dbm) that will provide a visual indication.

If a minimum discernible signal value higher than that contained in the technical manual is obtained, it is often due to incorrect procedure or faulty test equipment.

Minimum discernible signal readings whichare too low usually require one or more of the following corrective steps:

a. Measure recovery time and voltage of TR tubes. Change the tubes if either is excessive.

b. Test signal crystal current and change crystals if current is excessively high or low. Usually, if the TR tubes require changing, the signal crystals are also changed.

c. Test the I-F amplifier for proper operation.

The receiver bandpass width (on both wide-band and narrow-band operation, when provided) is accurately measured at the half-power points, each side of the maximum response point, to insure that the receiver is providing the optimum signal-to-noise ratio.

If the bandpass is greater than specified for a particular receiver, the receiver will have an excessively high noise figure and a correspondingly low MDS.

If the bandpass is less than required for a certain receiver, the noise figure of the receiver will be improved, but minimum discernible signal power will be lost in the suppressed sidebands.

Peak tuning of all I-F amplifiers to the same frequency precludes frequent changes in bandwidth. If this trouble is experienced, it usually indicates a defective condenser or R-F coil in the receiver.

The ring time of the radar set is measured to obtain an indication of its overall performance. The ring time duration, with the automatic frequency control in operation, is compared to ring time without the AFC in use to determine how well the AFC is functioning. There should be no appreciable difference in the ring time duration, with or without automatic frequency operation.

A shorter ring time than normal may indicate low magnetron power output, low receiver sensitivity, or both. An excessively long ring time may be caused by an oscillating I-F amplifier.

Erratic ring time usually indicates moding of the magnetron or a higher than normal voltage standing wave ratio. A pronounced dip at the beginning of the ring time pattern may be caused by a bad TR tube.

For a more detailed interpretation of ring time traces, refer to the Echo Box article in the Special Test Equipment section of this chapter.

TR tube recovery time is measured to insure against excessive recovery time and its attendant faults. Whenever a TR tube exceeds its established recovery time, it should be replaced. TR tube recovery time and voltage drop will ordinarily increase together. (The same test setup used in measuring the ring time may be used for determining the TR tube recovery time.)

The voltage standing wave ratio is measured to insure that the ratio of the power transmitted by the magnetron to the power reflected back along the transmission line is normal. A high VSWR can be caused by any of the following:

a. Moding of the magnetron.
b. Arcing in the waveguide.
c. Bad TR tubes.
d. Defective or distorted rotating joints.
e. Dents in the waveguide.
f. Corrosion in any of the R-F components.

The frequency spectrum of the magnetron is measured to insure that practically all of the transmitted power is contained in a band of frequencies no wider than the receiver bandwidth; also, to determine by the shape of the spectrum whether the pulse to the magnetron is of the proper shape and slope.

A spectrum that is too narrow usually indicates that the pulse to the magnetron is of excessive duration. A spectrum that is too wide often indicates that the pulse to the magnetron is not of sufficient width.

A spectrum containing two or more distinct peaks indicates that the modulator pulse is being frequency modulated. An indication that the modulator pulse is being amplitude modulated is failure of the spectrum pattern to fall to zero on each side of the main lobe.

Most incorrect spectra can be corrected by troubleshooting the modulator.

Section Titles. Technical manuals vary in their use of terms in describing units or components. Some manuals use the term "Transmitter" to refer to the high-power R-F oscillator. Other manuals use the same term to include the modulator and driver. Regardless of what name they are called, certain basic functions must be contained in a radar set. These requirements include a primary power source and means of regulating and controlling it, power supply to individual units, transmitter, receiver, timer, indicator, antenna, and an antenna positioning device. This chapter is divided into sections, each one devoted to a certain functional requirement of a radar set. These sectional titles were selected as divisional headings under which to list maintenance procedures and tests peculiar to certain components.

Safety Precautions. Safety precautions contained in the latest issue of Chapter 67 of Bureau of Ships Manual shall be observed in the operation, adjustment, and maintenance of radar equipment.

2-2 TIMERS, SYNCHRONIZERS, KEYERS, AND MODULATORS

General. The timer, or synchronizer, is the heart of all pulse radar systems. Its function is to insure that all circuits connected with the radar system operate in a definite time relationship with each other, and that the interval between pulses as well as the pulse itself is of the proper length. The timing device may be a separate unit by itself, or it may be included elsewhere in the equipment. In order for a radar set to give optimum performance, one of the requirements is that the transmitted pulse have the designed shape, length, and repetition rate.

Some of the more common pulses furnished by the timer include transmitter trigger, receiver gate, sweep trigger, indicator gate, marker gate, etc.

Pulse width, shape, and amplitude seriously affect range accuracy, minimum and maximum range, and resolution or definition of the target. Range accuracy requires a pulse with a sharp leading edge. Minimum range requires a pulse with a sharp trailing edge; while maximum range requires a flat-topped pulse of comparatively long duration. Accurate range resolution requires a pulse of narrow width. Pulse length and frequency determine the range of the equipment. The proper pulse repetition frequency is an insurance that echoes from targets within the equipment's range will not be obliterated by successive transmitted pulses.

The timer must be capable of establishing the pulse repetition frequency as well as forming the pulse into the desired shapes and in the proper time relations. It must possess also circuits designed to protect one component from the loading effect of another and to deliver pulses to the loads without distortion.

Various circuits and arrangements are used to accomplish the timing, or synchronizing, requirements. Some of the test procedures and maintenance hints peculiar to this type of circuit follow.

Timing Circuits. All radar applications, except search, require extremely high range accuracy. Therefore, it is very important that associated timing circuits be accurately calibrated.

The time interval between the transmitted pulse and the returning echo is the determining factor in obtaining the correct range to the target. All time delays introduced by the radar system components will result in an error in range which is equal to the total of these introduced delays.

Delays which occur in a radar system between the time the system is triggered and the time the echo pulse arrives at the indicator include: The difference in time between triggering the modulator and the modulator output pulse; time required for the transmitter to reach the proper amplitude for R-F output after application of the modulator pulse; the time consumed in the travel of the transmitted R-F energy to the radiating-collecting element, and also for the echo R-F pulse to travel to the receiver; and, the greatest delay, the time required for the R-F pulse to travel through the receiver.

Upon combining the previously described delays, it will be found that a considerable error in range would result if compensation were not made for these delays.

Zero Error. The total time delay present in a particular radar system must be calculated before the correction (zero error) can be made. Although there are several methods which may be used in making this measurement, only the fixed target, the external range calibrator, and the synchroscope methods are described here.

FIXED TARGET METHOD. The most reliable method in common use is probably the fixed target method of zero-error determination. A fixed target at an accurately known distance is required. A portable reflector will usually give more reliable results, but a natural target may be used. The known range of the target is compared with the range indicated by the radar system. The range obtained from the radar will be greater than the known distance and this difference is called the zero error.

EXTERNAL RANGE-CALIBRATOR METHOD. Connect the 50-mile marker output of an appropriate range calibrator to the input of the first marker amplifier of the range indicator. Connect the trigger output of the range calibrator to the range indicator trigger input jack or terminals. Energize the radar indicator, and adjust the horizontal and vertical centering controls for proper positioning of the range sweep. Set the range indicator to operate on the 200-mile scale.

Adjust the trigger delay control on the range calibrator until the first marker aligns with the start of the range sweep. Four markers should appear as vertical pips on the range sweep and should coincide with range marks on the tube face or with the ranging device provided. If they do not, then alignment of the circuits should be made using the adjustments provided, such as sweep rate or gate length controls.

SYNCHROSCOPE METHOD.

1. Use the radar system trigger pulse to provide external sync for the synchroscope.
2. Calibrate the sweep speed of the scope to present about 2 microseconds per inch.
3. Connect the trigger pulse which starts the range-marker circuit to the vertical amplifier, and set the scope gain to provide a 1/2-inch pulse.
4. Carefully mark the leading edge of the pulse on the scope.
5. Remove the trigger pulse and connect the radar-receiver output to the vertical amplifier. (Note: Detune the radar local oscillator; the transmitter pulse will shock-excite the R-F preamplifier sufficiently to produce an I-F signal.)
6. Adjust the scope gain to provide a 1/2-inch pulse when the receiver gain is set to produce about 1/8-inch of noise.
7. Carefully mark the leading edge on the scope, in the same manner as in step 4.
8. Measure the distance between the two marks on the scope.
9. Convert the distance between pulses into microseconds and, if desired, into yards. This figure is the zero error.

2-3 PRIMARY POWER SOURCES, REGULATORS, AND CONTROL SYSTEMS

General. The power required to operate a radar set depends upon the purpose for which it was designed and ranges anywhere from one kilowatt to many. A long range installation may require 25 or more kilowatts of power, using a 60-cycle, 3-phase, 440-volt primary source, while an airborne equipment may require only 40 amperes from a 24-volt source. The requirements are varied but precise, and measurements must be made periodically to insure that the design limits are not exceeded.

Whether the primary supply is furnished by an engine-driven generator, battery, or obtained from a commercial source, certain devices are required to convert and control this power. Rotary conversion equipment is used to change one direct current into another, direct current into alternating current, and alternating current of one frequency into alternating current of another frequency. Dynamotors are used to obtain a higher or lower voltage than is obtained from the primary source. Inverters are used in the conversion of d. c. to a. c. The primary power supply may be obtained from any of various sources, including the previously described source and the requirements will vary with the demands of different radar sets. The duty of the technician includes the responsibility of performing periodic tests and maintenance procedures to insure a primary power supply that is both correct and continuous.

The output of most all power sources varies as their load is varied and therefore the sources must contain a regulating device. The types of regulators used may vary from manually operated potentiometers, resistors, or auto transformers to the automatic mechanical or electronic type. Regardless of the type used, its function is regulatory in nature and, therefore, its effects must be measured at regular intervals to insure proper operation of the particular equipment.

Not only must a regulated primary power source be available but means must be provided also for its control. Control devices range from power relays or contactors to circuit control relays, time delay relays, circuit breakers, and fuses. Regardless of whether the device is a heavy duty power relay or a small variety of time-delay relay, its proper functioning depends upon the performance of the associated controlled units or parts.

One of the most common sources of trouble in a radar system is in the primary power supply and control circuits. The reason for this is the continuity of the circuits is not only dependent upon the fuses but also upon the interlock switches, relays, control switches, terminal boards, and connectors. All but the last two parts are mechanically moving parts, subject to wear and the effect of electrical arcs between the contacts. Interlock switches may fail to operate because a chassis is not pushed all the way back into the cabinet or because a panel has come loose or was left loose the last time it was removed. Therefore, the first step to take in locating a failure is to check the primary power and control circuits.

Motor Maintenance. The fact that all types of motors and corresponding generators have many elements in common makes the maintenance work fairly uniform. Generally, these types of equipment require only normal care to keep them operating efficiently. A periodic schedule of examining, adjusting, and servicing will usually insure continuous satisfactory operation. In the following description, insulated windings, brushes, commutators, etc., are referred to independently of the machines in which they may be used.

Malfunction may be evidenced by an unusual noise caused by metal to metal contact or the distinctive odor of scorching insulation varnish. To repair such troubles, disassembly probably will be necessary. Complete overhaul should be accomplished at least every two years whether trouble has been experienced or not. To assist in the inspection procedure during periods of disassembly, the following subsections contain information for checking and repairing certain parts of motors and generators.

Windings (Stator and Armature). Clean surfaces thoroughly. Inspect insulation surface for dry cracks, damage, and other evidence of need for coatings of insulating material. Evidence of moisture in motors or generators usually necessitates thoroughly drying, baking, and varnishing the windings. Where provided, remove the drain plugs and inspect for excessive moisture. Armature and stator should be inspected during each disassembly and overhaul for tightness of field windings and loose cable connections.

Rotors and Armatures. All air intakes, outlets, and passages must be kept free of all foreign matter which might cause clogging. Maintain air gaps at their rated opening to prevent overheating of motor bearings. Inspect rotor and armature surfaces for marks indicating the presence of foreign matter in the air gap or worn bearings. Inspect for broken and loose fan blades or bars. Clean throughly around the commutator, fan, and connections.

Brushes. Inspect brushes in holders for fit, free play, and tightness of pigtail connections. Examine brush faces for chipping or heat cracking. Check brushes for remaining wear, replacing those which are damaged or worn down to one-half their original length. Usually if one brush in a unit is replaced, all the brushes should be replaced in that unit. Inspect brushes at least every six months.

Commutators. Inspect commutator surface for scratches or roughness, high bars, and high mica. Although good commutation requires a film on the commutator, the surface should be kept clean and and smooth and have a polish. To clean the commutator, a piece of dry canvas or other hard nonlinting material may be wrapped around a stick and held against the commutator while it is turned.

In some cases, commutator roughness may be corrected by grinding the commutator with a handstone. Before using this method, remove all traces of oil or grease from the commutator and stone. When grinding, remove the associated brushes, and cause the machine to be driven by external torque. To obtain even grinding, the stone must be worked from end to end of the commutator. After grinding, smooth the commutator with a very fine grade of sandpaper; polish, using the back of the paper. Remove all copper, carbon, or other dust, preferably with a suction hose. Apply a small amount of seating compound to the commutator, reinstall the brushes, and allow the equipment to run until it is evident that even contact is being made between the brush and commutator surface. If the brushes do not seat properly, insert a piece of 00 sandpaper between the brush and commutator with the abrasive surface against the brush, and slide the sandpaper around the commutator in the direction of generator rotation. It may be necessary to adjust the holding spring for just enough pressure to hold the brush firmly against the commutator. It will be necessary to again clean the commutator. Unusual roughness or eccentricity of the commutator may not be corrected by hand grinding, requiring disassembly for more extensive repairs.

In cases of extreme roughness, the commutator should be turned down on a lathe until the rough or worn spot is just removed. Where undercutting of the mica is prescribed, the mica should be undercut approximately 1/16 inch with a file, hacksaw, or other convenient mica undercutter. The commutator must be cleaned of all copper filings, lint, and dust. The commutator may be cleaned with dry cleaning solvent 140F (FSN W6850-274-5421). Using an ohmmeter or other available continuity meter, test each segment of the commutator to each of the other segments and to the rotor core for shorts. The test should show no continuity in any case except for the commutator segment directly opposite the one being tested.

Bearings. Inspect for bearing wear and end play. If there is evidence of dirt or sludge, clean out grease caps, plugs, and grease ducts. Never clean new bearings. Packed bearings are cleaner than you can make them. Leave a new bearing packed in its container until it is to be used.

Mechanical Inspection. Inspect all motor-driven gears for signs of uneven wear. In the case of flexible couplings, if they are properly lined up there will be no noise or evidence of excessive use of the flexible part.

2-4 POWER SUPPLIES

General. To operate radar equipment, a variety of d-c voltages is required. The transmitter requires a high voltage source capable of delivering a large current for short intervals of time. The regulation or ripple content of this supply is not critical. The cathode-ray tube(s) also requires a high accelerating voltage but with very little current drain. Because of the constant small load, regulation of this source is usually no problem. The plate voltage supply for receiver and indicator requires a source of good regulation and very little ripple. In addition to these, voltages are also required for relays, blower motors, antenna control motors, etc. Suitable transformers must be included to furnish a-c voltage for heater circuits. To provide these different voltages, combinations of vacuum tubes, rectifiers, vibrators, voltage dividers, etc., are used.

The physical location of the various components in the radar system is usually such that it is impractical to install all of the power supply circuits in a single unit. For this reason power supplies vary greatly, as required to fulfill the demands of different radar sets.

Even though in some equipments the power supply may lose its identity as a separate unit, the function is still performed and must be tested and maintained at its rated performance.

2-5 TRANSMITTERS

General. The transmitter functions to provide R-F energy, often at extremely high power, for short intervals of time. The science of radar requires that the frequency of this energy be in the microwave region. The high-power oscillator that produces the R-F carrier is usually a magnetron, although some equipments use a triode oscillator or a ring oscillator for this purpose. Selection of the R-F generator is governed chiefly by carrier frequency requirements. The carrier frequency in turn depends on the tactical application of the system, effect of frequency on propagation, directivity of the antenna, etc.

The transmitter may be fired in several ways, but probably the most important are: A self-pulsing triode blocking oscillator; a low-power pulse, shaped and amplified to operate the R-F generator; and a high-power pulse applied directly to the R-F generator. The method of pulsing depends on the type of R-F generator used, required accuracy of range, and minimum range desired.

The large peak power at the extremely high frequencies involved necessitates special and peculiar procedures in maintaining and testing this unit.

Transmitter Frequency. Whether of the fixed-frequency or tunable type, the radar transmitter frequency should be checked periodically. If it is of the fixed-frequency type and found to be outside its operating band, the defective component must be replaced. It is of the tunable type, the transmitter must be tuned to its assigned frequency. Note that frequency testing instruments should not be coupled directly into the radar system. The high-power transmitter pulse would develop high voltage in the associated resonant circuits of the instrument, resulting in damage to the instrument. One way of measuring the transmitter frequency is by use of the tuned cavity or echo box. In this method, the tuned cavity is adjusted for maximum ring time on the scope and the cavity dial setting recorded as the transmitter frequency.

The transmission-type indication method also may be used. To perform this type of frequency measurement, proceed as follows: Connect an appropriate frequency meter to the radar through a power sampling device; begin with maximum attenuation and tune through the range of the frequency meter; if necessary, reduce the attenuation 10 db and tune through the meter range again until a reading is obtained; adjust frequency dial of meter for maximum reading while operating attenuator control to keep meter reading below full scale; and convert the dial setting to frequency.

Transmitter Peak Power. The radar not only must transmit pulses of the correct frequency but they also must be of optimum power. The following method of measuring the peak power of the transmitter makes use of an appropriate power meter: Connect the power measuring input of the meter through a cable and necessary attenuator to the power sampling device of the waveguide; record the power meter reading; and convert to dbm. In arriving at the transmitter peak power, the db attenuation of the coupler, connecting cable, and the duty cycle will have to be added to the converted dbm reading of the power meter.

Transmitter Ventilation. It has been determined that high ambient temperatures inside transmitter enclosures have been responsible for a large part of the component failures within this unit.

The temperature should not be allowed to exceed that specified for the individual installation. In cases where this temperature is exceeded, action should be taken to insure proper ventilation of the transmitter and to keep the heat within the specified limit.

Magnetron Double Moding. Reports indicate that double moding trouble of an intermittent nature is being experienced with some magnetrons. This is especially true in many cases where operation is satisfactory until the equipment is shut down for periodic maintenance tests. After maintenance is accomplished and the equipment reenergized, double moding trouble is experienced.

Double moding can be the result of several conditions. The following, not necessarily in order of importance, are six of the major reasons for this trouble:

a. Faulty magnetron.

b. Magnet or magnet pole weak.

c. Pulse forming network not receiving proper voltages.

d. Defective pulse forming network or pulse line.

e. Klystron, TR, or ATR improperly tuned.

f. Excessive voltage standing wave ratio.

Moding trouble of an intermittent nature usually indicates a mismatch due to misalignment in the R-F section. Such a condition may be caused by poor coupling between magnetron and waveguide which, after a few hours operation and mechanical vibration, will clear up. Care should be exercised when inserting the magnetron to insure its proper positioning. Also insure that the waveguide shutter is opening fully when the equipment is energized. A portion of this shutter protruding into the waveguide will cause standing waves to be set up, creating a mismatch and consequent pulling of the magnetron.

Incorrect Frequency. Frequency shifting, which results in loss of radar range and sensitivity, can be detected most accurately by a spectrum analysis of the output pulse. Trouble in rotating joints or the presence of large objects near the antenna are some causes of frequency shifting. One method of obtaining an analysis of the pulse frequency spectrum can be accomplished in the following manner, using an echo box and its resonant meter:

a. Plot current along the vertical line and frequency along the horizontal line of a piece of cross-section paper.

b. Rotate the echo box tuning control until the echo box resonance meter indicates a minimum current (I min.). Note current.

c. Rotate the tune control until the resonance meter indicates a maximum current (I max.). Note current.

d. Continue past this point until the current starts to decrease. Reverse the direction of rotation, and tune through the maximum and minimum point. Continue the rotation until a maximum current point is again indicated. This should be approximately the same value as the other maximum point.

e. One-half times (I max. minus I min.) plus I min. equals I set and is the correct setting for the tuning controls.

f. The difference between the two frequencies, determined by I max. and I min., is the transmitter spectrum width between the one-fourth power points.

Handling of Magnetrons. Physical handling is always a potential source of magnetron damage. This is intended as a guide for all personnel in the handling, storing, and shipping of magnetrons.

Precautions are taken by the tube manufacturer in the design of magnetron shipping containers to insure against excessive vibration, mechanical shock, and protection of the tube's magnetic properties during shipment.

In the past, shipping containers for large magnetrons have been heavy, double wooden containers which not only were awkward and unwieldly but also required considerable storage space. The latest improved design is smaller and lighter while still maintaining the basic requirements for magnetron protection. The molded styrene blocks and rubberized fiber cavities, within which the magnetron rests, not only serve as shock absorbers but also prevent interaction between the magnetic fields of adjacent magnetrons during transportation and storage.

Shipping containers for small magnetrons generally incorporate two individual cardboard boxes, one inside the other, separated by supporting members and air cells. The magnetron is located within the inner box, and the supporting members and air cells not only serve as shock absorbers but also provide the proper spacing for magnetic protection during storage of adjacent tubes.

When shipping a magnetron in a container which is not magnetically shielded, a CAUTION label must be attached to the outside of the package. This label shall warn against placing the tube within 12 inches of steel, iron, or magnets and closer than 50 feet to compass sensing devices on board ship.

A protective storage receptacle is a necessity. This need can be fulfilled by using the shipping container. Suitable storage racks or shelves must be provided to insure proper magnetron spacing from magnetic materials.

To reduce the risk of mechanical shock, unnecessary jarring of the magnetron should be avoided. Two men should be used in handling and installing the larger magnetrons.

Belying its massive appearance, the magnetron is in reality a precision instrument, composed of many parts in critical alignment. Shock to the tube can be transmitted to these parts, causing decreased efficiency or serious damage.

Dust covers and shipping guards are used to protect the magnetron high voltage cathode bushing and R-F output sections during transit, storage, and handling. These covers, removed during the course of installation, should be retained for use when the magnetron is repacked for storage or shipment.

Integral-type magnetrons must be kept at least 12 inches away from steel work bench tops, steel tools, iron, magnets, etc. The tubes usually bear a CAUTION label warning against placing them in close proximity to ferromagnetic materials.

Although tube magnets are stabilized prior to shipment, severe mechanical shock or exposure to ferromagnetic materials can cause demagnetization. Optimum performance requires that the tube magnets remain energized at the level imparted during the factory stabilization process.

Nonmagnetic tools are provided with some radar sets. Steel tools used in the vicinity of a magnetron can cause demagnetization and should not be used.

The larger magnetrons, which usually have their anode block surrounded by a cooling jack, must not be subjected to freezing until the coolant has been removed from the jacket. Not only will freezing result in physical distortion of the anode block, but it also will cause an accumulation of frost which will necessitate thoroughly drying the tube before it can be used.

Insulating oil used around the high voltage cathode bushing in most high-power magnetrons must be kept clean. Contaminated oil will increase the danger of external arcing and resultant damage to the bushing. Air in the insulating oil is also a source of trouble and contributes to external arcing. If not built-in, facilities must be provided to "bleed" off this air.

Steel wool should never be used to clean magnetrons. The use of fine sandpaper or crocus cloth will eliminate the possibility of steel particles being attracted to insulating surfaces of the tube by its strong magnetic field.

Ceramic parts of magnetrons must be kept clean. For instance, a graphite pencil mark can cause an arc path under normal operating potentials which might result in irreparable damage.

The correct heater voltage must be used if satisfactory operation is to be expected. When this value is not stamped on the tube magnet, it will be necessary to consult the technical manual for the individual equipment.

2-6 RECEIVERS

General. With the exception of some superregenerative IFF receivers, all modern radar receivers are of the superheterodyne type. The components of a typical receiver are a mixer, local oscillator, I-F amplifiers, video detector, video amplifiers, and output provisions for built-in or remote indicators. The use of R-F amplifiers becomes progressively less practical from the lower radar frequencies to the higher and therefore are not used extensively in the microwave region. In cases where R-F amplification can be used, the R-F amplifier is placed ahead of the mixer.

Improved receiver design has probably done more to improve the usefulness of radar than any other one thing. Radar receivers are quite sensitive, having been perfected to the point where they will accept signals in the order of a microvolt and will amplify and display them in many useful ways. The weaker the signal which a receiver can accept and efficiently display, the greater is the effective range of the set.

Signal-to-noise ratio as well as proper bandwidth are important properties which are designed and built into receivers.

The noise level, at microwave frequencies, is practically all within the receiver. Most of the noise is generated in the amplifier stage and includes thermal agitation, shot effect, and induced voltages. Good design reduces these unwanted noises to a minimum but a strict maintenance schedule is necessary to maintain peak performance.

Radar receiver bandwidths may vary from 1 to 10 megacycles. The noises contained within the receiver include frequency components throughout the entire frequency spectrum and are, therefore, affected by the bandwidth of the receiver. Generally, a reduction in bandwidth reduces the noise voltage but does so at the expense of pulse shape. The amount of permissible distortion of the pulse shape thus limits the reduction in noise which may be accomplished by reducing the receiver bandwidth. Audio frequency control (AFC) circuits are incorporated in receivers to help maintain the designed bandwidth.

Most of the factors which affect the performance of a receiver are established in the design and engineering of the equipment. The most important factors associated with maintenance are receiver sensitivity, which includes minimum-discernible-signal measurement, receiver bandwidth, and receiver bandpass.

Other types of circuits which are often incorporated into receivers include: Automatic gain control (AGC) and instantaneous automatic gain control (IAGC or IAVC), to maintain the output level at a particular value; detector balance-bias (DBB), to help prevent small signals from being masked by larger ones; sensitivity-time-control (STC), to reduce receiver gain immediately following transmission; fast time constant (FTC) and high-video pass (HVP), to reduce the effects of certain types of jamming.

IAGC, DBB, STC, FTC, and HVP all serve to improve target definition in the presence of clutter, sea-return, large blocks of signals, or jamming. The proper functioning of these features is vital to the efficient operation of the receiver. It is, therefore, important that they be maintained at their designed standard in order to realize the full usefulness of the receiver.

Minimum Discernible Signal. Loss of receiver sensitivity has the same effect on range as a decrease of transmitter power. A loss of 6 db in receiver sensitivity, for example, will shorten the effective range of a radar the same as a corresponding decrease in transmitter power. While a drop in transmitter power is usually evident in meter indications, a loss in receiver sensitivity is more difficult to detect. The sensitivity may be drastically reduced by a slight misadjustment of the receiver and not be known until accurate measurements are made.

A receiver's ability to accept signals of low-power level is dependent upon its sensitivity. The output noise level of a receiver tends to obscure these weak signals. A minimum discernible signal is one whose power level is just sufficient to make it visible in the receiver output. It can therefore be seen that measuring either of these qualities, MDS or receiver noise level, provides an indication of receiver sensitivity.

To measure the minimum discernible signal, the radar set should be turned on but not radiating, and special anti-jam circuits be disabled. One method of performing this test makes use of a modern pulsed signal generator and an oscilloscope and is accomplished by the following steps:

1. Connect the oscilloscope vertical input to the receiver video output.
2. Connect the signal generator R-F output to the directional coupler.
3. Connect the signal generator sync pulse to the oscilloscope sync input.
4. Turn test equipment on and allow it to warm up for 30 minutes.
5. Adjust the signal generator to provide a pulse with a width near that of the transmitter pulse and at the frequency of the magnetron.
6. Adjust the power level meter of the signal generator to 0 dbm.
7. Set signal generator output attenuator to zero.
8. Adjust the oscilloscope for optimum display of the R-F pulse.
9. Slowly increase the signal generator output attenuator, lessening the pulse until it just disappears in the grass on the scope. (Varying the signal generator pulse delay control as the attenuation is increased is an aid in determing the vanishing point).
10. Note the setting of the signal generator attenuator control.
11. Note the attenuation of the directional coupler.
12. The sum of the recordings in steps 10 and 11 is the minimum discernible signal below one milliwatt.

Receiver Bandpass. Receiver bandwidth is specified for each radar and must be maintained within its design limits. The bandwidth of a receiver can be determined by establishing the half-power points on each side of its maximum response point. One way of accomplishing this measurement is to use a signal generator and a multimeter. To properly match the output impedance of the signal generator to the receiver input impedance, it is usually necessary to fabricate an impedance adapter. The test should follow these steps:

1. Connect the signal generator (usually through an adapter) to the I-F input of the receiver.
2. Connect the multimeter to the video output of the receiver.
3. Adjust output of the signal generator to the receiver I-F frequency and peak with the receiver.
4. Adjust the signal generator for an unmodulated, 20-microvolt output at the frequency of the receiver I-F.

5. Adjust receiver gain for an indication of 1 volt on the multimeter.

6. Detune signal generator below the setting obtained in step 3 until the multimeter indicates 0.7 volt. Note this frequency.

7. Tune signal generator above the setting obtained in step 3 until the multimeter again indicates 0.7 volt. Note this frequency.

8. The bandwidth is the difference between the lower frequency and the higher frequency.

Receiver Sensitivity. Connect the receiver video output to the video input on an appropriate oscilloscope. Provide a test trigger from the radar equipment to the trigger in receptacle on the scope. Connect the output of the signal generator through an appropriate R-F cable to the probe or connector on the transmitter. Operate the signal generator output control until the signal plus the noise is twice the value of the noise alone. Add the signal generator attenuation, cable attenuation, and probe attenuation to obtain the receiver sensitivity in dbm.

Sensitivity-Time-Control (STC) Adjustment. Tests conducted on many radar installations indicate that proper adjustment of the STC circuits will greatly aid in tracking small close-in targets.

Maximum duration and about one quarter of the flat and depression controls appear to give the best results.

Care should be exercised not to use too great a setting of the depression and flat controls as this will result in the suppression of small nearby targets. The adjustments should be made on long range targets while observing small objects close-in. Settings made must be such that they will afford optimum detection of both distant and nearby targets. Maximum duration should be used in most all cases.

Crystal Care. Crystals used in radar equipment, mostly in receivers and tuned cavities, can withstand very little mechanical shock and must be carefully handled.

The static charge carried by the body can be accidentally discharged through the crystal unit in cases where the crystal is held by the base and the tip is brought in contact with grounded equipment. The same can occur when the crystal unit tip is at ground potential and a person or object, possessing a static charge, touches its base. In passing a crystal from one person to another, a static discharge may occur also. To aid in preventing crystal damage, the following precautions should be taken:

a. Before reinserting a crystal in its holder, touch the equipment with bare hand.

b. Before passing a crystal to another person, first touch his bare hand so that any static charges may be equalized.

Crystals can be damaged also by voltage shocks induced by the opening and closing of nearby electrical circuits. Careful shielding of connecting wires will aid in eliminating this potential damage. Spare crystals should be kept wrapped in metal foil or stored in a metal box.

Enough energy can be absorbed from a strong R-F field to damage or destroy a crystal. When it is necessary to remove a crystal from the spare compartment, and the unit is in the vicinity of a source of high frequency field, certain precautions must be taken.

Before opening the spare crystal compartment or crystal holder, turn the transmitter off. In replacing a crystal, remove the connecting wire and unscrew the crystal holder. Remove the old crystal with the fingernails; use pliers only if necessary. Insert the new crystal and make sure that it makes good contact with the holder. Close the spare crystal compartment before starting the transmitter.

2-7 MONITORS, INDICATORS, REPEATERS, AND CONTROL UNITS

General. The performance of the basic function of the indicator, regardless of the type(s) of scan used, requires that the following be accomplished: Measure the time required for the transmitted pulse to travel to the target and return; apply this time to measure the distance between the radar set and the target; and indicate the angular direction of the target from the radar antenna and, in some cases, the elevation of the target. The indicating device may be contained in either a monitor, a repeater, or a control unit.

The method of scope presentation depends on the purpose of the radar set. In search or early-warning applications, a PPI-scan supplemented with an S-scan may be used. As the demands on radar have grown more complex, scans have been designed to fulfill the special need, when required, of presenting all necessary data on one oscilloscope.

To accomplish this display of data, a radar indicator must possess three basic components: a cathode-ray tube of the proper persistency, a sweep circuit, and a gate circuit. The radar transmitter usually triggers the sweep circuit, which in turn-triggers the gating circuit. Precise measurement of range requires the accurate measurement of exterely short intervals. To obtain this accuracy, the sweep rate must be at a definite time relation in respect to the transmitted pulse. To prevent the scope being traced by the scanning spot on its return to the starting point, a gating pulse is required. The efficient operation of all these circuits is essential to the fulfillment of the indicator's designed purpose, which is transforming the electrical information gathered by the radar into the proper form for presenting all the information necessary to locate the target (s) on the indicator screen.

Control units, in some radar sets, may at first seem complicated because of many added controls. In some equipments, the number of controls is increased because the set design requires that many components with the same functions be paralleled at two (and sometimes more) locations. Although they bary greatly in physical makeup, they ultimately perform the same function, which is controlling the radar set from one or more remote positions.

Radar repeaters come in a variety of designs and are used in various ways. However, their basic function is to display target distance and bearing information received from a radar set.

Monitors, indicators, repeaters, and control units are valuable adjuncts to the radar set and their proper maintenance is essential.

Display Noise Level. To accomplish a measurement of the display noise level, proceed as follows:

a. Place equipment in operation.

b. Disconnect the video from the associated radar.

c. Connect the vertical lead of an oscilloscope to the video lead of display tube.

d. Record the maximum noise level appearing on the scope. This valve should not exceed 1.5 volts.

Erratic Repeater Traces. Some trouble has been experienced with repeater traces where the radar repeater and the associated radar set are operated from separate sources of power having different frequencies.

The following troubles may be experienced: The trace on the indicator tube may vary as much as one-fourth inch in length; blanking of the tube may be affected causing the trace to dim and brighten; and the servo amplifier may hunt. All these difficulties occur at a definite slow cyclic rate.

The radar set and the repeater, operating from different power sources which are furnishing ac of different frequencies, may cause these troubles. The symptoms occur at a rate equal to the difference in frequency between the two sources of power.

Calibration of Radar Indicators. Oscilloscope AN/USM-25 series (OS-4A) may be used in calibrating many radar indicators. The following method may be used to calibrate the range markers on any of the indicators whose requirements fall within the operating values of the Oscilloscope AN/USM-25 series.

Figure 2-1 provides a convenient multiple graph for converting microseconds (0 to 10,000) to yards (0 to 1,600,000) or to miles (0 to 800). The mile is based on 12.2 microseconds or 2000 yards.

The dual output of the Oscilloscope AN/USM-25 series provides two methods, marker and strobe, of indicator calibration. The marker method is considered most accurate and desirable. These calibrations may be accomplished as follows:

Marker Method.

a. Inspect the oscilloscope to insure that the marker generator crystal is installed.

(1) The 100-kc crystal will generate markers at 10-microsecond intervals or counted down (5 to 1) at 50-microsecond intervals.

(2) The 81.94-kc crystal will generate markers in 2000-yard (1-mile) intervals or counted down at 10,000-yard (5-mile) intervals.

(3) As issued, the oscilloscope has the 100-kc crystal installed. It may be used in this condition or converted to the 81.94-kc crystal which is carried in the accessories case for the oscilloscope.

b. The accuracy of the markers should be checked prior to use and at regular intervals. Adjustment procedure can be found in the appropriate technical manual.

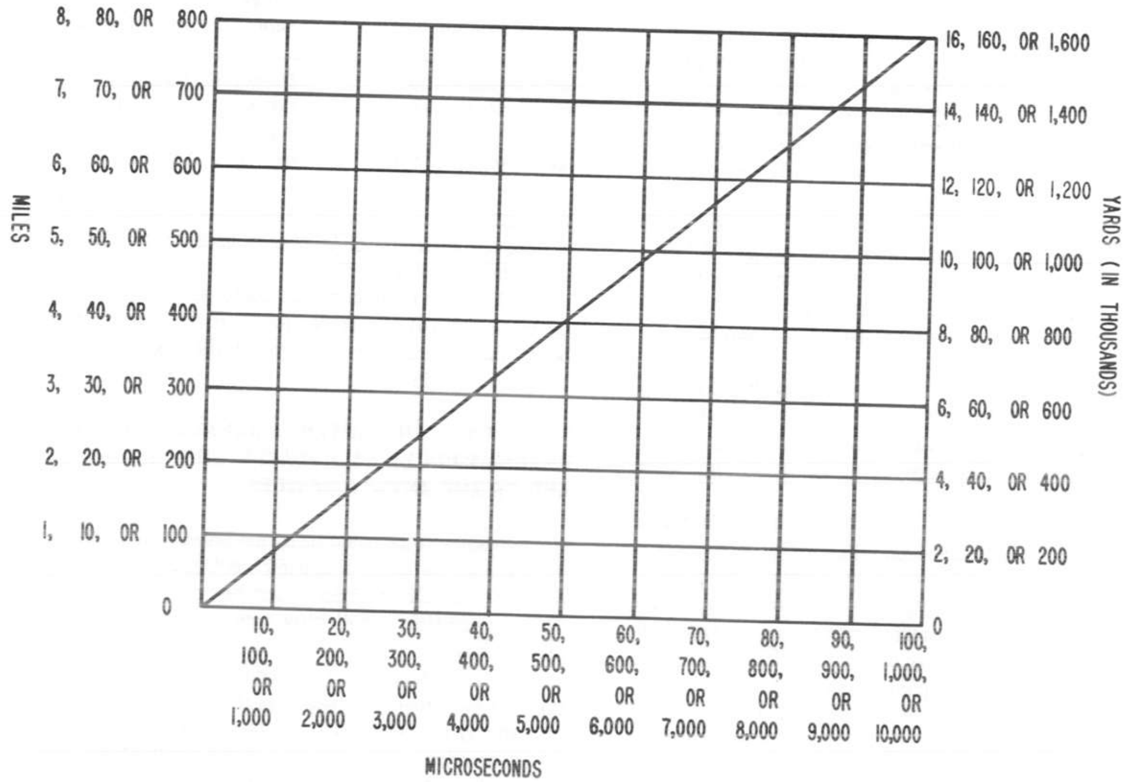


FIGURE 2-1. CONVERSION CHART, MICRO SECONDS TO YARDS AND MILES.

c. Connect the oscilloscope to a 110-volt, 60-cycle, single-phase, ac power outlet. Ground the equipment case. Turn the oscilloscope on and allow a 15-minute warmup period.

d. Disconnect the video input from the indicator to be calibrated. Connect a coaxial cable (RG-59/U) to the video input connection. The opposite end cable connection must be made with a BNC fitting (UG-260/U). Select a coaxial cable of sufficient length to reach from indicator to oscilloscope.

e. Disconnect the trigger input from the indicator. Connect a coaxial cable (RG-62/U) to the trigger input connection. The opposite end connection must be made with a BNC fitting (UG-260/U). The cable must be of sufficient length to reach the oscilloscope.

f. Set controls on the oscilloscope as follows:

(1) SYNC SELECTOR to A-R, INT.

(2) SWEEP SELECTOR to "A" sweep.

(3) A-R TRIGGER POLARITY to + or - depending on trigger requirements of the indicator being calibrated.

(4) INT TRIGGER RATE to approximate rate required by the indicator undergoing calibration.

NOTE

This control is variable from 40 to 3300 p. p. s. It is linear from about 20 per cent to 90 per cent of its rotation. The frequency between these points is approximately 50 to 3000 p.p.s.

(5) MARKER SWITCH to + or - 2 Kyds/10 microseconds, depending upon the video polarity requirements of the particular indicator.

g. Energize the indicator. Set sweep length (RANGE) to a value of between 2 and 10 miles. Turn the marker control off or to the minimum setting. Set all other controls for normal operation.

h. The opposite end of the cable connected in step d, should now be connected to the oscilloscope "A" trigger output jack. A sweep line should now be visible on the indicator (an increase in intensity may be required). After sweep is observed, turn the insensity down until sweep line is faintly visible.

i. The opposite end of the cable connected in step e, should now be connected to the oscilloscope marker output jack. Increase the video gain and/or intensity until markers from the oscilloscope are visible along the sweep line.

j. Markers from the oscilloscope should now appear as bright pips at each mile along the sweep. Adjust the indicator markers until they are just visible. Using the technical manual for the indicator being calibrated, adjust the indicator markers to coincide with proper markers from the oscilloscope. If microsecond markers from the oscilloscope are used, the proper point may be selected from figure 3-1 or the markers may be computed.

k. Beyond approximately 5 miles or when markers become difficult to distinguish, shift markers switch on the oscilloscope to 10 Kyds of proper polarity. Markers from the oscilloscope will now appear at 5-mile intervals. Align indicator markers with those from the oscilloscope.

(1) Due to difficulty in observation, this procedure is not recommended beyond 100 miles (twenty 5-mile markers from the oscilloscope). The strobe method should be used at these long ranges.

Strobe Method. This method may have errors introduced by improper observation and is not recommended for use by inexperienced personnel.

a. Accomplish steps a. and b. of the marker method.

b. Check and/or adjust accuracy of the strobe output as described in the technical manual. Also check strobe against the crystal accuracy of the oscilloscope markers. For these tests, the range selector settings should be on MS x 1/yds x 10K, MS x 10/yds x 1K, and MS x 100/yds x 10K. There is no strobe when using fast sweep.

c. Complete steps c. through h. of the marker method.

d. Connect a coaxial cable between the indicator video input and "R" trigger output on the oscilloscope.

e. Set RANGE SELECTOR to MS x 1/yds x 100 or as desired from the following calculations: Adjusting "R" delay microseconds (RANGE) will cause a traveling strobe to appear on the indicator. The range of this strobe will be the range reading of "R" delay dial times RANGE SELECTOR SWEEP RANGE, plus or minus the error found in step b. of this method. By computation or from figure 2-1, accurate points may be selected to correlate microseconds to range in yards. The ranges possible are:

Range Selector	Strobe Trigger, Yards	Microseconds
MS x 1/yds x 100	2K to 20K	1.22 to 122
MS x 10/yds x 1K	20K to 200K	122 to 1220
MS x 100/yds x 10K	200K to 2000K	1220 to 12,200

For ranges below 2000 yards (1 mile) or 10 microseconds, the strobe is not accurate.

f. Using the procedures contained in applicable technical manual, the proper indicator range mark should be adjusted to coincide with the oscilloscope range strobe as set in step a.

2-8 R-F SYSTEMS, ANTENNA ARRAYS, WAVEGUIDES, TRANSMISSION LINES, ROTATING JOINTS, COUPLERS, AND TR AND ANTI-TR DEVICES

General. In its basic form, the antenna is an electronic device used for either radiating electromagnetic energy into space or for collecting electromagnetic energy from space. This propagation or collection may be highly directional or nondirectional.

The usual function of the radar antenna system is to take the R-F energy pulses from the transmitter, channel this energy to the rotating antenna array, radiate it in a directional (or nondirectional in some applications) beam, pick up the returning echo, and pass it on to the receiver with a minimum of loss. For these reasons, the radar antenna system is considered to include transmission lines and waveguides from the transmitter and receiver to the radiating-collecting array, the antenna array, rotating joints, junctions, couplers, and protective devices. To insure the efficient performance of its function with a minimum of loss, the antenna system parts are carefully engineered and must operate within tolerable limits. Improper coupling between R-F lines and the antenna or transmitter, for instance, may produce an impedance mismatch resulting in a high standing-wave ratio, magnetron instability, and a general reduction in system performance.

Antenna Arrays. The physical dimensions, spacing between elements, etc., of present day antennas is usually accomplished at the factory and require adjustment only in case of damage. Technical manuals always contain information concerning antenna dimensions.

Duplexers, TR and ATR Switches. Since both transmitting and receiving is usually accomplished by the same antenna, the system must include a device to protect the receiver during transmission time. The duplexer, consisting of a transmit-receive (TR) switch, and usually an anti-transmit-receive (ATR) switch, is probably the most common of such devices. The extremely fast action required necessitates an electronic tube-type switch. The TR switch functions each time the transmitter pulses to prevent receiver (or crystal mixer) damage. Between pulses, the ATR switch functions to prevent the loss of returning signals in the transmitter. Thus, alternately, during pulse and reception intervals, these devices serve to properly channel the transmitter power and the received signals along their proper path with a minimum of loss.

To prevent echoes at close range being masked or blocked out, these switches must include a quick recovery time. This recovery time varies from a few microseconds to several microseconds, depending on the particular application, and will increase with use in a given type of tube. Since the recovery time of these tubes tends to increase with use, it must be checked periodically.

TR Tubes. The recovery time of TR tubes should be measured at regular intervals and replaced when this time is not fast enough for the range demands of the particular installation. Usually TR tubes should be replaced after about 500 hours of operation.

An auxiliary electrode on the TR tube is supplied with a negative d-c potential which serves as a keep-alive voltage. This keep-alive voltage is turned on before the main R-F power, furnishing sufficient ions for almost instantaneous discharge across the spark gap with small leakage power to the crystal. This keep-alive potential should be measured at regular intervals and may be accomplished by using a voltmeter having the required range and connecting the meter across the chassis ground and the keep-alive supply lead. (Caution should be exercised in observing polarity.) Some installations contain built-in meters for obtaining this measurement.

Anti-TR Tubes. The output impedance of a transmitter does not always change sufficiently during the rest period to permit the use of a resonant line for blocking received signals from the transmitter. To insure proper blocking in such cases, an anti-TR device, which operates similarly to the TR tube, is used. During firing time, the transmitted pulse causes the tube to present a high impedance to the transmission line; thus very little of the transmitted energy is used by the anti-TR tube. During the resting period of the transmitter, the anti-TR gap is effectively an open circuit and thus blocks received signals from the transmitter channel. These anti-TR devices should be maintained and kept within their operating limits in much the same manner as TR tubes.

Couplers and Slotted Line Sections. As stated previously, the antenna system, to efficiently transfer R-F energy, should have a low standing wave ratio (SWR). Two devices, couplers and slotted line sections, are used to provide points at which this ratio measurement may be made. Couplers and slotted lines may be either built into the system or come separately as test equipment.

A low standing wave ratio is maintained principally for the following reasons: Reflections occurring in the R-F line cause magnetron pulling and may result in faulty pulsing; arc-over may occur in the R-F line at maximum voltage points; mechanical breakdown in the line sometimes may occur, due to the development of hot spots. The standing wave ratio (VSWR) and should not exceed 1.5 to 1.

COUPLER. The coupler samples or couples R-F energy from the waveguide. Depending on whether the coupler is directional or bidirectional, either direct or reflected power measurements may be taken. The R-F probe (or probes) and an associated impedance are supplied with energy from within the main waveguide through properly spaced openings into the coupler section. A frequency power meter connected to the proper probe will give an indication of the transmitted power in the waveguide.

SLOTTED LINE. The slotted line is a coaxial or waveguide section of transmission line, with a longitudinal slot cut into its outer conductor, which permits the insertion of an R-F probe. The slot is constructed so as not to cause appreciable loss of energy by radiation. The probe, placed in the electrostatic field through the slot, feeds an R-F detector whose rectified output operates a meter which indicates VSWR. Slotted line sections may come separate or as an integral part of the R-F system.

HIGH VSWR. Trouble in the R-F transmission line, between the magnetron and the antenna, is usually indicated by a higher than normal voltage standing wave ratio. First check and adjust the magnetron tuning control, observing whether this improves the VSWR. If it does not, then determine if the trouble is on the antenna or transmitter side of the antenna switch in the following manner: With the magnetron operating into a dummy load, observe the voltage standing wave ratio. No marked improvement indicates that the trouble is on the magnetron side of the antenna switch, while a marked improvement indicates the trouble exists on the antenna side.

VSWR MEASUREMENT. Using the slotted line and a VSWR meter, the measurement may be performed in the following manner:

a. If the radar system has no built-in slotted line, insert a slotted section into the radar transmission line (using the adapters provided), as close to the magnetron as possible.

b. Adjust the depth of the traveling probe for a reading on the VSWR meter.

c. Slide the pickup assembly along the slot in the coupler until a maximum point is indicated on the meter. Record this as V1. (Decrease the depth of the probe as necessary to prevent arcing and to keep the meter reading on scale.)

d. Slide the pickup assembly along the slot until a minimum is reached and record this as V2.

e. The VSWR is obtained by dividing V1 by V2 and the ratio should not exceed 1.5 to 1.

VSWR Measurement, using the directional coupler method, is sometimes used but is not always accurate. To determine the standing wave ratio using this method, the coupler is inserted into the system and the direct power recorded. The coupler is then reversed and the reflected power measured and recorded. The ratio, calculated from these two values, should be less than 1.5 to 1.

VSWR Measurement, using the bidirectional coupler method, simplifies the previous procedure and has largely superseded its use. One way of applying the bidirectional method is as follows:

a. Connect an echo box to the transmitter coupler on the transmitter arm of the bidirectional coupler.

b. Vary the echo box tuning control for maximum indication and record this reading.

c. Connect the echo box to the receiver coupler on the receiver arm of the bidirectional coupler.

d. Vary the echo box tuning control for maximum indication and record this reading.

e. Divide the first reading by the second reading and, using the appropriate interpolation chart, obtain the VSWR.

Wave Guides, Transmission Lines, and Rotating Joints. The connections between sections of the R-F transmission line should be kept tight at all times. If any section of the line becomes accidentally dented or otherwise damaged, the section should be replaced.

Care of Duplexers. It is imperative that the metallic tube fins which make contact with duplexing cavities be kept clean. They must be free of grease or corrosion which would interfere with the required low-resistance contact. The newer tubes have gold-plated fins and are packaged so as not to require cleaning before installation. Tubes which have silver-plated fins will generally require cleaning before being used. One method of cleaning this type of tube fin is the gentle application of a neutral silver polish, followed by rinsing in hot water. After the excess water has been shaken off, the tube may be dried with clean tissue paper. Tubes which have lost their gold or silver plating through abrasive or chemical action were probably originally silver-plated. Such tubes should not be used except in an emergency, and then only after a thorough cleaning. After the cleaning process, care should be taken to prevent contact between the tube fins and substances which will subject them to recontamination.

DUPLEXER VIBRATION. Reports indicate that some vibrations interfere with the spark gap operation of duplexer inner conductors. This difficulty may be eliminated by insuring that the unit is rigidly mounted, thereby separating the duplexer from the harmful excitation frequencies.

Weak TR and ATR Tubes. Many cases of weak presentation of close-in targets and poor ranges on air targets are attributable to weak TR and ATR tubes and dirty duplexers. A weak crystal mixer also will contribute to this difficulty. These components should be tested for proper operation and cleaned.

Upon accomplishing the previously described maintenance, the oscillator, preamplifier, and duplexer should be tuned for maximum response.

TR TUBE TEST. A suspected TR can be tested for proper operation by measuring its current and voltage. The technical manual for each equipment contains the acceptable limits of these values. Any departure from this range indicates a defective tube. Many equipments contain built-in facilities for making these measurements. In such cases, it is necessary only to switch the built-in test meter to the desired position. When permanent provisions are not provided, the tests may be conducted as follows:

a. The TR tube voltage may be measured by connecting a d-c voltmeter of the required range across the TR tube supply. Correct polarity of the connections must be observed as well as strict compliance with all safety precautions required by Chapter 67, BuShips Manual.

b. To measure the TR tube current: Turn off the equipment, remove the keep-alive cap and the lead from the TR tube, and connect a milliammeter of the proper range in series with the keep-alive cap and the tube cap. Turn equipment on and, while it is radiating, note the meter reading.

Radioactive Tubes. Radar sets use some tubes which are slightly radioactive. The TR, ATR, and Pre-TR tubes usually fall in this category and should be handled with care.

a. Keep tube in carton until ready for installation. This will prevent tube lying around and inadvertent breakage. Tubes of this type must be destroyed in an approved manner.

WARNING

In case of accidental breakage, avoid breathing dust and vapor from the tube and do not touch broken pieces of glass with bare hands. All pieces of broken glass should be located and the area cleaned in an approved manner. If the skin is broken by a piece of glass, the wound should be immediately cleansed, using plenty of soap and water. Small cuts should be opened up to force increased bleeding before being cleaned with soap and water.

2-9 ANTENNA POSITIONING, DATA TRANSMISSION, AND SERVO SYSTEMS

General. There are many applications in radar where it is necessary for the angular motion of one shaft to be accurately repeated in another shaft some distance away.

Whether this linkage is by mechanical or electrical means is usually determined by the distance between the shafts. Due to the uneconomical and cumbersome aspects of the mechanical kind, the electrical type is more generally used. In radar, there are two major applications of repeating shaft motion: remote indicator and servo systems. These systems make use of the self-synchronous motor or selsyn, wherein the motion of one shaft is converted into electrical currents which is turn are converted back into mechanical motion in a second shaft.

Remote indicator or data transmission systems are used when the transfer of shaft motion requires very little torque energy. Reading a bearing indicator dial, temperature readings, and tuning dial controls are examples of this system.

Servo systems are necessary in applications where much more power is required in the controlled shaft than is furnished by the controlling shaft. In this system, the angular discrepancy between reference points on the shafts generates a proportional error voltage, which regulates an amplifying device. When no error exists, the amplifier is not fired. An example is when the small handwheel is turned and the angular error, between a reference point on it and one on the rotating antenna mount, controls a power amplifier, furnishing power to the antenna drive motor.

In seeking alignment with the controlling shaft, the driven shaft will sometimes oscillate about or hunt its reference point. To eliminate this effect, the shaft is equipped with an antihunt device.

To properly maintain the parts which comprise the units listed in this section heading is very important. Some of the general maintenance and test procedures which will be helpful in this work follow.

Servo Systems. There are three types of synchros: The transmitter (generator), the diffefential synchro, and the control transformer synchro. Each serves as a rotating device designed to interpret accurately the relationships between mechanical and electrical data. The electrical reference is the supply voltage from which the machine is designed to operate. The mechanical reference is a "zero" positioning of the rotor with respect to the stator. The procedures following are general and may be different for individual machines. In each case the synchro is electrically removed from the system. Do not attempt to take a synchro apart or lubricate it, these are jobs for a synchro specialist.

There are many kinds of servo systems in use: electronic, hydraulic, amplidyne, and combinations of these. The system, regardless of type, is a method of control. In the following paragraphs only the electronic type is described. Electronic amplifiers used in servo systems are classified into the following four basic types:

1. D-c input, d-c output
2. D-c input, a-c output
3. A-c input, a-c output
4. A-c input, d-c output.

Even these four basic types are varied to suit particular requirements. The scope of this section does not permit describing all the systems in detail; the section will, therefore, be confined to synchro testing in general.

By observing the action of the receivers in a synchro system, it is usually possible to locate such troubles as jamming of gears, shorted rotor or stator, open rotor or stator, etc. More complete information concerning synchros and troubleshooting synchros can be found in U. S. Navy Synchros, OP 1303. The best practice to follow regarding synchros is that if a unit is operating properly, leave it alone; if defective, replace it. (This does not include the routine cleaning and inspection of brushes and commutator.)

Overloading of the Synchro System. This is usually caused by worn bearings or defective gears in the receiving synchro. This condition allows excessive current to flow in the stator windings because of the lag between the receiver rotor and the transmitter rotor. Synchro design makes it possible for one stator lead to indicate zero volts while the other two leads may be drawing excessive current. For this reason, it is necessary to measure the current in at least two leads to detect overloading. Some synchro systems have overload indicators included in the installation which will cause a neon bulb to be fired when an unbalanced condition exists between the stator leads.

Resistance Measurement. This is the quickest way of locating opens and shorts in synchro units and their associated wiring. Within close tolerances, the resistances of rotor and stator windings should read the same. If the resistances vary greatly, the trouble may be easily localized. Do not measure resistance without first shutting off all excitation voltage to the synchro rotors.

One method of detecting open or shorted stator windings is to connect a voltmeter across any two of the stator windings. As the transmitted voltage is varied, a smooth variation between 0° and 90° should be indicated by the voltmeter. When this procedure indicates an open or short-circuited lead, the defective part may be detected by measuring its resistance.

Electrical zero between the synchros in a system is very important. Different types of synchros require different methods of zeroing and will be described individually.

Standard test synchros are available for performing operational tests on synchro systems and also may be used for troubleshooting. These precision test synchros are equipped with a braking device which permits their use as both a transmitter and as a receiver.

Zeroing Synchros. A synchro receiver may be zeroed by first disconnecting the stator leads and then connecting stator lead No. 2 to lead No. 1 on the rotor, and stator leads Nos. 1 and 3 to rotor lead No. 2. If 110 volts a. c. is applied across rotor leads Nos. 1 and 2, the receiver will rotate to 0°. The dial on the receiver shaft, if so equipped, may be loosened and set to zero. In this setup, a voltage higher than normal is connected across stator leads 1 and 3; this voltage will cause overheating if left on too long.

In cases where the stator leads cannot be disconnected easily, an alternate zeroing method may be used. In this method, the transmitter is set to zero and a jumper is connected between stator leads 1 and 3, which will hold the receiver on the zero position. Set the receiver dial to zero. Unclamp the receiver case and turn the receiver until the dial reads zero, or loosen the dial and turn the dial to zero.

After reclamping the receiver in position or tightening the dial, whichever the case, remove the jumper.

A synchro transmitter may be zeroed by connecting it in the normal manner to a receiver which has been correctly zeroed and is equipped with a dial. Set the unit, whose position the transmitter sends, to its zero position. Then unclamp the transmitter and turn the stator housing until the receiver reads zero. This will set the transmitter to approximately zero. The exact zero position can be found by momentarily connecting a jumper between stator leads 1 and 3. If the transmitter has been exactly zeroed, there will be no movement of the receiver shaft. In case of receiver shaft movement, alternately move the transmitter case slightly and momentarily connect a jumper between stator leads 1 and 3, until the receiver shaft does not move. Remove the jumper and tighten the clamp when the transmitter has been accurately zeroed.

A differential receiver may be zeroed by first disconnecting all the leads. Then connect stator lead 2 and rotor lead 2 to one side of the 115-volt, a-c line, and stator leads 1 and 3 and rotor leads 1 and 3 to the other side of the line. This will cause the shaft to turn to its electrical zero position. Set the dial to zero while the differential receiver is connected in this manner. Overheating will result if the receiver is left connected very long in this way.

One control transformer zeroing process also requires that all leads be first disconnected. Connect 115-volt a. c. between stator leads 1 and 3. Connect rotor lead 2 to stator lead 3. (No connection is made to stator lead 2.) Connect an a-c voltmeter, with its scale set on 200 volts, between rotor lead 1 and stator lead 1. Unclamp the control transformer and turn it until the voltmeter indicates minimum, usually about 40 volts. Now change all the connections. Connect stator leads 1 and 3 together. Connect the a-c voltmeter between rotor leads 1 and 2. Connect 115-volt a. c. between stator leads 1 and 2. Now turn the control transformer until the voltmeter reads minimum. Reclamp the control transformer in this position and connect all leads to their original position. If left connected in the test position too long, the unit will become overheated.

Antenna Pedestals.

Erratic Antenna Rotation. Stopping of the antenna at definite points when it is rotating may be corrected by removing the drive motor brush block and freeing the sticking brush holder arm so that the brushes will make contact on the slip rings at all times. This condition also may be caused by loose or bent arms riding on the edge of the mica insulator.

Antihunt Adjustment. In some installations, critical hunting adjustment has been materially reduced by eliminating play in the synchro gear train in the pedestal.

Binding. After several hours of operation, binding of the pedestal has developed in some installations. This prevents proper rotation of the antenna and, in many cases, has been traced to improper clearance between the stationary post and the top of the synchro housing. Maintaining the proper clearance, as contained in the technical manual, will remedy this difficulty.

Water in Antenna. Water entering antenna closed areas accounts for many of the troubles caused by decomposition of insulation, rust, and decreasing insulation resistance in motors and selsyns. All weatherproofing and sealing gaskets should be inspected periodically and maintained so as to effectively keep out all water and moisture.

2–10 IFF AND BEACONS (Unclassified)

General. Objects, even though they may be located at great distances by radar, cannot be identified as friendly or hostile. It can readily be seen that in many applications some means of identification is highly desirable. IFF (Identification-friend or foe) equipment has been developed for use as an adjunct to radar for recognition purposes. Its function is to supplement the radar system and provide the desired means of identifying radar targets.

Some form of IFF equipment is operated in conjunction with practically every U. S. Navy radar installation to identify radar pulses from friendly craft. In its basic form, the IFF system operates to receive a challenging signal by radio means from the radar location and return a reply which contains identification intelligence. The circuitry and techniques in this system are much the same as those used in radar.

One radar recognition set and at least one radar identification set comprise the IFF system. The basic functional components of a recognition set are receiver-transmitter, coder-decoder, video decoder, radar set control, and antenna. The components of an identification set include a receiver-transmitter, decoder, video decoder, radar set control and an antenna which is usually omnidirectional in nature.

In operation, the IFF system causes the electronic recognition components to transmit challenging pulse-pairs and receive coded replies from radar targets equipped with identification sets. These coded replies are received, decoded, and distributed, along with the associated radar video, to the repeater indicator(s).

The transmitter in the recognition set originates the challenging transmission. This challenge is composed of a series of coded pulse-pairs, with the interval between the leading edges coded in accordance with a preset mode. It is highly important that this interval be maintained accurate, also that the R-F power output be at its maximum and of the prescribed frequency.

The antenna used may be of either the directional or omnidirectional type, although one with directional characteristics is commonly used. Those with directional properties are usually an integral part of the radar set or, if not, they work in slave with it.

In response to challanges, the receiver section accepts a coded reply from the identification set installed in the target being challenged. The reply may be either a single pulse, a series of single pulses, or a series of pulse groups. The reply signals are received, decoded into video signals, and properly displayed. The characteristics of these displayed signals makes the identity, friend or foe, of a challenged target instantly apparent. The reply to a challenge can be properly sychronized for display only by the recognition set originating the challenging coded pulse--pairs. A particular display may contain replies triggered by other recognition sets but they will appear as random, nonsynchronous signals. Sensitivity, center frequency, and bandwidth are important factors in measuring good receiver performance.

There are several types of IFF systems, each classified according to its assigned mission. They may be any of the following: Surface-to-air system, wherein the challenge is initiated by the surface station; surface-to-surface system, in which either of the surface stations may initiate the challenge; air-to-surface system, where the challenge originates in the airborne interrogator equipment; or the air-to-air system, which is comparable to surface-to-surface operation in that either aircraft may initiate the challenge.

An IFF installation is comprised of equipments and units which have maximum capabilities designed and built into them. Location, cable runs, interconnection, and proper installation are responsibilities of personnel installing the system. Tactical requirements, adaptability, and flexibility are all the result of careful planning by design engineers and precision manufacturing methods. Preventive maintenance will insure optimum performance at IFF installations. The following pages of this section are dedicated to some procedures which will aid in detecting potential failures and correcting them before they occur.

Since objects can be located by radar, it is a form of navigational equipment or beacon. The location of these objects enables a craft to be maneuvered accordingly. Fixed nature objects used as reference points are supplemented by radar beacons. There is great similarity between a radar beacon and an IFF system, in that they both accept certain signals from a radar set and return other signals to it. Radar beacons usually will receive signals within an assigned narrow band of frequencies and of a pulse length within its design limits. Both omnidirectional and directional antennas are used by beacons. The directional characteristics are governed by the assigned mission. Some equipments use separate antennas for transmitting and receiving, while others use one. The location of each beacon installation is identified by its own assigned code. Therefore, the use of beacons is an improvement over the use of fixed objects. A valuable navigational aid is provided by the radar beacon in supplementing aircraft search. Carriers use radar beacons to assist in guiding planes attached to them back to that carrier after an operational flight. Coding facilities are provided in the beacon so that planes can distinguish between their home carrier and others in the vicinity.

There is great similarity in the operation of the electronic circuits used in beacons and recognition sets. For that reason, only those components not already covered in this chapter will be described in the maintenance procedures which follow.

Measurement of Spacing of the Transmitted Pulse. Connect the test trigger output of the coder-decoder to the trigger-in receptacle on an appropriate test set. Connect the video cable to the proper video in position on the test set. Through the required R-F cable and attenuator, connect the transmitter output to the RF in receptacle on the test set. Set the sweep delay switch on the test set to calibrator control, set the markers on, and set range and sweep delay switches to proper position for the equipment being tested. Set the transmitter selector switch for mode 1 operation. Operate the sweep vernier control until leading edge of the second (right) pulse is opposite the vertical scale on the test scope and record the vernier reading. Decrease the delay vernier control until the leading edge of the first (left) pulse is opposite the vertical scale on the scope and record the vernier reading. The first minus the second vernier reading is the transmitter pulse spacing for mode 1. Repeat the procedure for other modes.

Receiver Bandpass Center Frequency and Bandwidth. Connect the output of a signal generator to the I-F amplifier input through a crystal simulator having the proper matching characteristic impedance. Connect a multimeter across the output of the video detector. Gain-time and gating controls should be in the off position. The transmitter should not be operating and the IFF gain should be set to maximum. Set the signal generator frequency to that of the IF and adjust the generator attenuator to produce a good indication on the multimeter without overloading the amplifier. Rock the signal generator frequency dial back and forth, as necessary, to obtain a maximum reading on the multimeter. Record this as the original value. Operate the signal generator attenuator control until the multimeter indicates a signal 6 db stronger (twice voltage) than the original value. Tune the signal generator toward a lower frequency until the multimeter reads the same as the original value. Record this signal frequency as F 1. Tune the signal generator through the original point and toward a higher frequency until the multimeter again reads the same as the original value. Record this signal frequency as F2. Subtract F1 from F2; the result is the receiver bandwidth. Divide the receiver bandwidth by two and add the result to the lower frequency; this is the receiver bandpass center frequency. These two values are specified for each equipment and must be maintained within their assigned tolerance. It must be remembered that radar beacon frequency testing equipments require an absolute frequency accuracy of better than ±1 mc in the X band.

2-11 SPECIAL TEST EQUIPMENT

General. A myriad of test equipment is required to place in operation and maintain the electronic equipment in use today. This is especially true in maintaining microwave radar sets and associated systems. To efficiently perform these duties, the technican requires more than the conventional volt-ohm-milliammeter, electronic voltmeter, signal tracer, signal generator, tube tester, etc. The intelligent measurement of some electrical and electronic quantities encountered in radar requires special test equipment. It is not the purpose of this section to describe test equipments in general, but rather to mention some which are closely associated with radar maintenance. Some of the more commonly used test devices in radar applications include oscilloscope, synchroscope, and the echo box. Electrical pulses of precise duration and distinctive waveform are very important in radar timing circuits. These circuits are also used in IFF systems and radar beacons. For this reason, oscilloscopes and synchroscopes are especially valuable in the observance and measurement of these waveforms. Technical manuals contain troubleshooting charts which show the waveforms that should be viewed at special test points built into the circuits.

Oscilloscopes are manufactured in various designs to meet particular needs. Basically they contain a cathode-ray tube, sweep (sawtooth) oscillator, vertical and horizontal deflection plate amplifiers, built-in calibration potentials, internal trigger pulse generator, sweep circuit, marker and delay circuits, and any other features required for a spacial application. In general, the most important as well as the most complicated portion of the oscilloscope circuit is the sweep section, or linear time-base generator. In most oscilloscope applications, the horizontal axis is the known function, the characteristics of which are usually linear with respect to time.

The synchroscope is an adaptation of the oscilloscope. A trace is produced only when it is initiated by an input trigger, as contrasted with the continuous sawtooth sweep provided by the oscilloscope. Synchroscope circuits are similar to oscilloscope circuits except for the signal channel and sweep channel.

The usefulness of the oscilloscope and synchroscope lies in their ability to portray graphically and instantaneously the fluctuating circuit conditions. Other sections of this chapter contain tests and maintenance procedures using these two devices. However, their use in connection with microwave troubleshooting warrants listing them under this special test equipment section.

The Echo Box.* The echo box is a very important piece of special test equipment in radar applications. Its importance can be seen by the fact that many shipborne radar equipments contain this device as an integral part of the set. Separate echo boxes are available for use with others. The echo box is the chief instrument used in making the over-all radar sensitivity test. Because an understanding of echo boxes is so important to the electronics technician, they are described at length in the following paragraphs.

The echo box is one of the most facile test equipments used for measuring radar performance and for radar troubleshooting. In its basic form, it is a tunable resonant cavity which, with accessories, provides: Over-all performance measurement; an indication of relative power output; frequency spectrum analysis; frequency measurement; and a guide for troubleshooting. The accessories required are: A dipole and support or a directional coupler to pick up the R-F energy from the radar; a means of coupling the R-F to the echo box; and crystal rectifier and a microammeter to act as a tuning and relative power indicator.

The echo box is essentially a resonant cavity which is coupled to the radar transmitter output and to the radar receiver input. Connected to the resonant cavity is a microammeter which indicates relative power output, and indicates when the echo box is in resonance with the transmitter. The resonant frequency of the cavity is determined by the size of the cavity, which can be varied by means of a tuning mechanism and frequency calibrated dial. When the resonant frequency of the cavity is set to the frequency of the transmitter, oscillations are induced in the cavity by each pulse. These oscillations in the cavity produce a block of video on the radar indicator as well as an indication on the relative power meter. The block of video on the scope is measured in yards to obtain the ring time, which is the apparent duration of the oscillations set up in the echo box by each pulse.

The operation of an echo box is explained with reference to figure 2-2. Assume the echo box is excited by a transmitter pulse with a peak power of 87 dbm. The power supplied to the echo box is attenuated due to losses resulting from three causes. These are the losses due to the directional coupler, the loss in the cable connecting to the echo box, and the coupling loss at the echo box itself. Assuming, as shown in figure 2-2, that these combined losses cause a total loss in signal power of 37 db, the net power available at the echo box is approximately 50 dbm. This amount of energy is capable of being stored in the echo box, which oscillates. A definite length of time is required for the energy within the cavity to build up to its maximum value. Thus, the radar pulse may end before the echo box charge has reached the maximum value of 50 dbm.

After the radar pulse ends, the echo box continues to oscillate and this stored energy is fed to the radar receiver. The echo box operates to discharge its energy slowly, about 2-db drop per microsecond. The same losses are present during the discharge time as during the charge time. In figure 2-2, it is assumed that the saturation level of the receiver is -80 dbm. As long as the energy fed back to the receiver is greater than this value, the receiver is saturated. If the radar set has an "A"-type scope, a flat top signal appears on the scope. The sloped, lagging edge of the scope pattern represents the gradual signal decay below -80 dbm. The point at which this edge disappears into the receiver noise (-108 dbm in figure 2-2) is a minimum discernible signal level, MDS (dbm). The ring time is shown as the length of time between the start of the transmitter pulse and the point at which the signal fades into the receiver noise. In terms of range on an "A" scope, this point may be more exactly defined as that point in range at which the echo box signal, when varied slightly on either side of resonance by slowly tuning the cavity, just fails to cause a change in amplitude of noise signal. The rate of performance, figure 2-2 S (db), is shown equal to the algebraic difference or numerical sum of peak power (dbm) and minimum discernible signal (dbm). If either of these two values is increased, the length of time required for the echo box signal to disappear into the receiver noise level (that is, the ring time) also increases. Thus, the ring time is a measure of radar performance.

* Portions of this material are reprinted, by permission, from "The Echo Box" by G.B. Doty, Field Engineers' Electronics Digest, Vol. 6- No. 2.

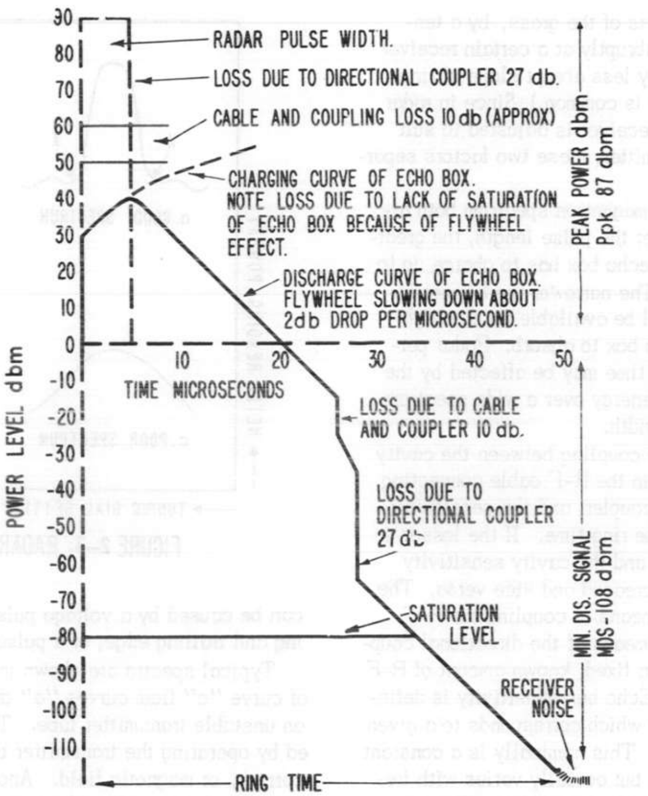


FIGURE 2-2. ECHO BOX CHARGE AND DISCHARGE CHARACTERISTICS.

Measuring the Ring Time. Adjust the gain of the radar receiver until the "A" scope shows 1/4-inch of grass. Although this height is arbitrary, it is important that the grass level should be the same in all tests of ring time if measurements are to be compared. Observe the range at which the exponential curve of the echo box signal strikes the grass line. This range is the ring time. It is the distance to the last place at which the grass appears to be elevated above the no signal level. When using the PPI in measuring the ring time, the antenna should be rotating. Adjust the gain until the PPI indicator seems to be half covered with noise. As on the "A" scope, the end of the ring time signal is determined by the place where the signal disappears into the uniform noise. If a dipole is used to pick up the energy from the radar transmitter for measuring the ring time, the space loss should be known. The simplest way of determining the space loss for a given dipole location is to compare the ring time measurement with the dipole to the ring time reading with a directional coupler. The space loss, in db, is then the coupling of the directional coupler minus 1/160 of the yards increase in ring time, measured with the dipole.

The ring time of a radar set is dependent upon the following factors:

a. Transmitter peak power
b. Receiver sensitivity (noise level)
c. Losses caused by detuned or defective TR or ATR tubes
d. Pulse length
e. Magnetron spectrum
f. Coupling losses
g. Echo box sensitivity.

Considering all the other factors to be constant, as the peak power of the transmitter increases, the amplitude of the oscillations in the cavity of the echo box will increase. Similarly, the lower the receiver input noise level, the longer the ring time signal may be seen. Since the weaker signals from the cavity are at the trailing edge, a receiver with a high noise figure would override these faint oscillations and shorten the apparent ring time.

It should be stated here that the receiver noise level can be attributed to two principal factors; the receiver noise figure and the receiver bandwidth. The noise figure, which is the general figure of merit of receivers, is the quantity which one is trying to maintain when tuning a receiver. The noise figure can be defined as the noise per unit bandwidth in the receiver, relative to that which would be present in a theoretically ideal receiver. The receiver bandwidth also contributes to the noise level. The wider the bandwidth, the more noise is permitted to pass. A large decrease in bandwidth in a receiver might impair the performance of the radar, but would give a longer ring time indication. If a receiver goes into oscillations due to interstage feedback, the bandwidth is reduced and consequently will increase ring time. (Oscillations in a receiver can be noticed by a coarseness of the grass, by a tendency of the gain to change abruptly at a certain receiver gain setting, and by a slightly less abrupt slope of ring time at the trailing edge than is common.) Since in radar design the bandwidth of the receiver is adjusted to suit the pulse length of the transmitter, these two factors separately influence the ring time.

The pulse length and the magnetron spectrum both affect the ring time. The longer the pulse length, the greater the time the cavity in the echo box has to charge up to the transmitter peak power. The narrower the magnetron spectrum, the more power will be available for the high "Q" tuned cavity of the echo box to absorb. Radar performance and, therefore, ring time may be affected by the scattering of the transmitter energy over a wide spectrum and out of the receiver bandwidth.

Other factors, such as the coupling between the cavity and the transmitter, the loss in the R-F cable connecting the cavity to the directional coupler, and the sensitivity of the echo box also affect the ring time. If the losses in the coupling devices are low and the cavity sensitivity high, the ring time will be increased and vice versa. The preferred and most efficient means of coupling the R-F energy to the echo box is by means of the directional coupler which enables the use of a fixed, known amount of R-F power for testing purposes. Echo box sensitivity is defined as the change in ring time which corresponds to a given change in radar performance. This nominally is a constant for any one type of echo box, but actually varies with frequency, temperature, and individual test sets. This necessitates a correction of the nominal value for an accurate determination of sensitivity in any particular case. The method for calculating the sensitivity of an echo box at any known frequency is given in the technical manual.

Measuring the Spectrum of a Transmitter R-F Pulse. The distribution of transmitter energy with respect to the frequency is known as the spectrum. As the cavity of the echo box is tuned through the transmitted energy frequency, the microammeter reading will be observed to rise and fall as an indication of power being radiated. Procedure for taking a measurement of the spectrum is as follows:

a. Connect the echo box to the dipole or directional coupler.

b. If the cavity tuning dial is calibrated so that the rate of megacycle change in frequency per turn is known, the spectrum can be plotted accurately by plotting power output of the transmitter vertically, and the frequency horizontally. For each setting of the cavity tuning dial, read the meter and plot this reading versus frequency or rotation of the echo box cavity tuning dial.

c. Interpretation of the spectrum. For a 2-megacycle bandwidth receiver, the distance between the two minima should not vary much greater than two megacycles or the power will be lost outside the receiver bandwidth.

A low meter reading but with good spectrum may indicate that the transmitter pulse voltage is low or that the transmitter tube needs to be replaced. A spectrum without deep minima adjacent to the main peak indicates that the transmitter tube is being frequency modulated. This can be caused by a voltage pulse which has a sloping leading and trailing edge, or a pulse with a rounded top.

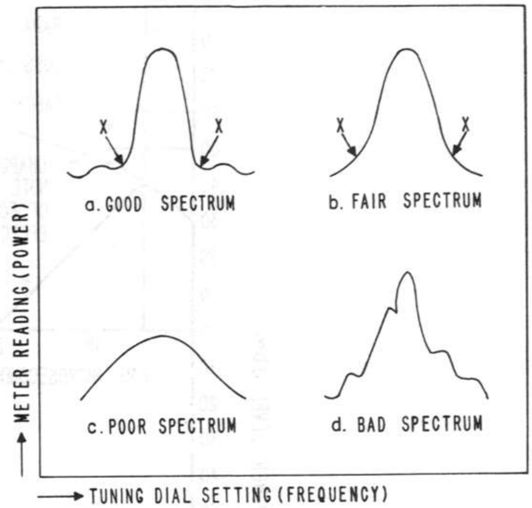


FIGURE 2-3. RADAR PULSE SPECTRA.

Typical spectra are shown in figure 2-3. The difference of curve "c" from curves "a" and "b" may be caused by an unstable transmitter tube. This instability may be caused by operating the transmitter tube with improper voltage, current, or magnetic field. Another possible cause is the application of a pulse of improper wave shape (such as sloping sides or rounded top) to the transmitter tube. A bad spectrum such as figure "d" can be caused by a large VSWR in the transmission line. A large standing wave ratio can be caused by a faulty line connection, a bad antenna rotating joint, or an obstruction in the line. Replacement of the magnetic field or the transmitter tube may be necessary.

Measuring Performance. The performance of a radar set under test can be determined easily in terms of the db below peak by the following procedure: Consult the technical manual of the radar under test for the ring time specified when the radar is operating at its optimum. Substract the measured ring time from the ring time figure given in the radar instruction book. This figure (in yards) may be divided by the sensitivity of the echo box (in yards per db) to give the number of db below peak performance of the radar. However, in most cases, the difference is calculated and the measured ring time is given in yards as a measure of the radar performance.

Transmitter Power. The meter of the echo box gives approximately the proportional average power radiated by the transmitter at a particular frequency. The echo box is tuned to the transmitter for a maximum meter reading and is compared to a previous reading at the same frequency. If the echo box is built into the radar system, the coupling devices do not change; and, therefore, the reading should be essentially the same if transmitter power, spectrum, and duty cycle are the same. If the reading is low, as differentiated from normal reading, the cause may be low transmitter output, a poor spectrum, or a shorter duty cycle.

The echo box meter may be calibrated against a power measuring device at the frequency normally operated for the transmitter, and the reading used as a power determining check. This reading should not be used as a constant method of checking power output.

Pulse Length. The length of the transmitted pulse is equal to its duration at half maximum voltage points. With a good or fair spectrum, the pulse length equals twice the reciprocal of the frequency difference between the two minima on the spectrum curve, as indicated in figure 2-3a. A narrower spectrum than usual means that the transmitted pulse is too long. This long pulse results in a long ring time and a high power reading on the echo box meter, and leads to a false indication of exceptional radar performance.

Frequency Measurement. The frequency at which the cavity of the echo box is resonant either appears on the box or can be determined from a dial setting frequency chart supplied with the equipment. By determining the resonant frequency of the cavity at maximum meter reading, the frequency of the incoming signal can be obtained.

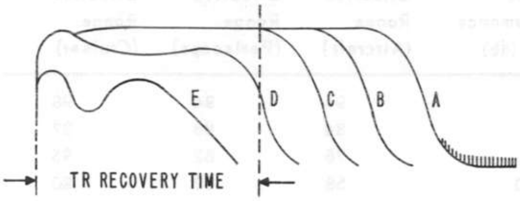


FIGURE 2-4. EFFECT OF REDUCING RECEIVER GAIN ON RADAR RING TIME.

TR Recovery. Reducing the receiver gain to any extent means shortening the apparent ring time as shown in figure 2-4, curves A, B, and C. If the ring time is shorter than the TR tube recovery time, the echo box pattern on the radar indicator is distorted as shown on curve D, the slope of which differs noticeably from receiver saturation. The TR recovery time should be less than one mile.

Receiver Recovery Time. When the recovery time of a receiver is normal, after a pulse the grass level will appear approximately the same regardless of whether the echo box is tuned or detuned, assuming the receiver gain is set the same as during radar performance measurements. When the cavity is tuned to the transmitter frequency, the grass on the radar indicator will appear immediately at the end of the ring time pattern as pointed out in a previous paragraph. When the receiver recovery time is longer than normal, the noise will be weak and will not appear for some time after the end of the ringing pattern, or in extreme cases, not at all. Receiver nonrecovery is usually an indication of a defective I-F or video stage.

Troubleshooting Notes. The following suggestions will aid the technician to use the echo box for troubleshooting. (Make sure echo box is functioning properly.)

a. If little or no indication is read on the echo box tuning meter, a power check should be made of the transmitter using the proper test equipment designated for the frequency band.

b. If the R-F power output of the transmitter is low, it should be corrected. Low power output from the antenna or directional coupler may be due to modulator or transmitter tube troubles, leaks or obstructions in the R-F lines, bad rotating joints, or damage to the antenna. Suggested procedure is as follows:

1. Check the transmitter and the modulator current and the voltage readings when the set is provided with proper meters.
2. Measure the VSWR if possible.
3. Inspect the antenna, the antenna feed, and the R-F line for leaks, damage due to serious dents or distortion, connections in coax line, excessive moisture, or foreign material in line.
4. Examine waveguide choke joints for shorts. These might be due to oil leaking out of the bearings in the antenna or to poor alignment. Bad rotating joints usually show up on radar indicators as lack of signals, reduced ring time, radial streaks on rotating PPI, and erratic readings on echo box meter. (Very close by targets or a ship's mast may also cause these indications.)
5. Listen for arcing in the line to locate trouble; the arcing can often be seen if the transmission line is inspected carefully.
6. Feel the line for hot spots.
7. Trouble can often be identified as being in the transmission line if tapping on the line causes fluctuations in the echo box reading. Do not beat the line so violently that new troubles are introduced.
8. Go over the line with a neon bulb to locate the R-F leaks.
9. Inspect waveguide choke joints for very bad alignment.
10. Examine the magnetron coupling for misalignment.
11. Test all connections for good contact.
12. Consult the radar set technical manual for methods of locating and correcting modulator and transmitter troubles.

c. If the power output is satisfactory and the echo box ring time is still low, it is indicative of trouble in the receiving system. The receiving system of the radar set includes the antenna, R-F transmission line, duplexer section, crystal mixer, local oscillator, I-F amplifiers and detector, and vice amplifiers.

A few of the common troubles and suggestions for their identification and possible adjustments are listed following:

LOSS IN R-F LINE. With noise level normal, but with poor or no signals, or poor ring time, the trouble may be in the transmission line. Receiver sensitivity should be determined before extensive troubleshooting is performed on the R-F line unless such trouble is obvious.

TR DETUNED, MISCOUPLED, OR NOT OPERATING PROPERLY, OR KEEP--ALIVE VOLTAGE WRONG. If the TR is detuned or miscoupled, poor signals and poor ring time will result. If the TR tube is worn out, a pronounced sag in the top of the ring time curve, as seen on the "A" scope, will immediately follow the transmitter pulse. This sag will be visible at low gain settings of the receiver and is caused by poor recovery time of the TR tube, or ionization of the TR tube not occurring as fast as necessary. Be sure to check keep-alive voltage. The crystal may be burned out if TR tube or keep-alive voltage is defective.

DEFECTIVE CRYSTAL MIXER OR DEFECTIVE SECOND DETECTOR. Very poor or no ring time. A bad TR tube will cause a crystal mixer to become defective. Check for a bad TR tube by inserting a used crystal with a fairly good back to front ratio for resistance. If, after turning the radar set on and off a few times, the resistance changes materially, the TR device is defective. If the crystal was not affected, try a new crystal and check if ring time has increased.

DETUNED OR DEFECTIVE MIXER, POOR ADJUSTMENT OF I-F SIGNAL AND LOCAL OSCILLATOR COUPLING TO MIXER. Low ring time and poor signals will result. Turning the mixer cavity screw may improve the ring time. Some mixers contain a line stretcher that may be out of adjustment, causing mismatch into the crystal mixer. Be sure to ground your hand before inserting a crystal into the mixer assembly. If this is not done, the crystal may burn out due to static charge in your body discharging through the crystal. In some cases where the mixer is tunable, the mixer and TR tuning are somewhat interactive; after tuning the mixer recheck the TR.

REDUCED OR NO LOCAL OSCILLATOR OUTPUT. Poor or no signals and poor ring time will result. The crystal mixer current should normally be between 0.3 to 0.6 ma. Some mixers may take up to a half hour to warm up for normal operation. If the LO is oscillating and if this power is being transferred to a good crystal, there should be crystal current. If it will not oscillate, check for proper reflector voltage. Adjust the reflector voltage and the mechanical tuning until maximum signals and maximum current appear at the same time. In some cases where the output cannot be improved by changing the reflector voltage, the cavity screw may be loose, the contracts dirty, or the tube may be bad. When the mechanical tuning is not properly set, varying the reflector voltage one way may cause the signals to fade gradually, but varying it the other way may cause signals to disappear abruptly.

MISMATCH BETWEEN CRYSTAL MIXER AND FIRST I-F TUBE MAY CAUSE REDUCED RING TIME. The alignment of the first I-F stage should never be tampered with until all other possible remedies have been tried. The adjustment is critical and difficult to make.

NOISE IN FIRST I-F TUBE. Excessive noise in the first I-F tube makes signals difficult to see and ring time appear low. Several tubes may be tried before one that matches the circuit, and has low noise, can be found.

INADEQUATE GAIN. Lack of noise on the radar indicator is the usual indication. This may be caused by bad tubes, usually in the front end of the receiver or a bad crystal mixer.

CAUTION. Since the echo box radiates on an extremely narrow frequency band as compared with the spectrum of the transmitter, no attempt should be made to try and tune the I-F stages by means of the echo box signal. If such tuning is attempted, the receiver bandwidth may be narrowed and the ring time will then increase, thus indicating an apparent improved radar performance. On the contrary, such I-F tuning will have actually impaired the radar performance. Generally, I-F tuning is not of major importance except in the first stage.

IMPORTANCE. The importance of knowing and utilizing the echo box and other test equipments to monitor radar operation can be realized if the performance of a radar can be stated in a practical application. When a radar is allowed to operate over a period of time without being checked, its performance can be expected to drop off 15 to 20 db. Experience has shown that, without test equipment, a drop of this magnitude will probably pass unnoticed by even the most experienced technicians. Table 2-1 shows the percentage loss of range for a radar system operating at various levels below peak performance.

Table 2–1. Effective Range of Radar System (3000 mc) for Various Reductions in Relative Performance.

Relative System Performance (db)	Per cent of Effective Range (Aircraft)	Per cent of Effective Range (Periscope)	Per cent of Effective Range (Cruiser)
−1.5	91	94	98
−3.0	84	88	97
−5.0	76	82	95
−10.0	58	69	90
−15.0	42	58	84
−20.0	31	49	78
−25.0	24	40	71
−30.0	18	34	62
−35.0	14	28	53
−40.0	10	24	45
−45.0	8	20	34
−50.0	6	16	21

From this table, it can be seen that a loss of 15 db means that a plane which the radar set was designed to detect at 30 miles will be detected only if it comes within 13 miles of the radar. In such a case, you are throwing away 58% or more of the detecting ability of the radar, and possibly as much as 100% of its tactical value. The column in Table 2-1 for aircraft is based on the theoretical inverse fourth power law which governs high-angle search. The column for periscope is based on experiments with an antenna about forty feet above the water. The cruiser column is based experimentally on the same type radar and the same antenna height. As further reasoning for the use of test equipment, it should be noted from Table 2-1 that the loss of range for large targets, such as cruisers, is less than that for small objects, such as planes. A radar 15 db down in performance will detect a cruiser at 84% of intended range as compared with only 42% of intended range of a plane. The cruiser that can be detected at 120,000 yards is detected by a radar 15 db down at 100,900 yards. If the ability of the radar to see a cruiser at a distance is used as the measurement of performance, the fact that the radar is 15 db down is almost certain to escape notice. It should be noted and emphasized that these results are typical, but that "unusual" weather conditions, which are of frequent occurrence, make range a poor criterion by which to judge radar performance.

2–12 NAVIGATIONAL AIDS

Radio-Direction-Finder Equipment. Radio-direction-finder equipment indicates the direction of a received wave. Special construction of its antennas permits accurate determinations of the true bearing of the received wave. This bearing is the direction of the transmitting station.

A radio-direction-finder system consists of a directional-receiving antenna, a sensitive radio receiver, and an indicating device. Often the direction-finder indicator is a cathode-ray tube encircled by a plate etched with 0 to 360 degrees of compass markings. Direction indicated is the result of rotation of the loop antenna or loop-antenna goniometer. A characteristic directional response will appear on the face of the cathode-ray tube when the antenna or its goniometer is in position to indicate station direction. The receiver only serves to detect and to amplify the antenna response.

Theory of Radio-Direction-Finder Antennas. A fundamental law of electromagnetism is that when a conductor is cut by magnetic lines of force, a voltage is induced that is proportional to the rate that the conductor is cut. This law also applies to the electric and magnetic field components of radio waves. Electric and magnetic field components of a radio wave are inseparably related. Only the magnetic component need be considered to establish combined electrical and magnetic characteristics. This rule is true for the interaction between an incident wave and a receiving antenna. In this case, the magnetic component indicates the total interaction present between the wave and antenna.

A normal or vertically polarized wave will induce voltage only in a vertical section of a conductor. A vertically polarized radio wave has a horizontal magnetic field. A vertical wire or "monopole", the simplest form of of a vertically polarized antenna, may be a part of the radio-direction-finder system. Its operation provides basic information for an understanding of direction-finder loop antennas. When a vertically polarized radio wave passes over a monopole antenna, the antenna will be cut by the horizontal lines of flux in the wave. The height of the antenna and the intensity of the alternating flux determine the induced voltage. The induced voltage is in phase with the alternating flux waves. If the flux-wave intensity is constant, a change in its azimuth direction will make no change in the values of the induced wave.

The Response of a Loop Antenna. When the horizontal lines of flux of an incident wave cut the two vertical members of a loop antenna, instantaneous voltages are produced at the two vertical members. These voltages go in the same direction. In figure 2–5, the vertical members of the loop antenna are represented by lines A and B. The arrows adjacent to A and B indicate the vertical direction of the simultaneously induced voltages. While they follow their vertical path, opposing currents circulate horizontally around the loop. These currents completely neutralize one another when voltages induced at the vertical members are equal.

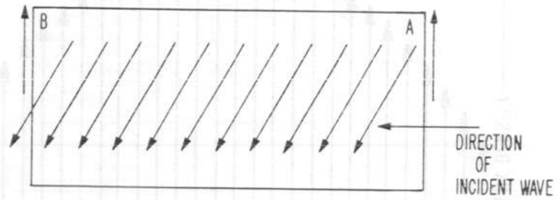


FIGURE 2–5 CURRENTS INDUCED IN A LOOP ANTENNA.

The magnetic field of an incident wave has lines of flux of various densities. They arrive at the two vertical members of the loop antenna in a sinusoidal pattern. Figure 2–6 (a) illustrates this pattern. The lengths of the flux-density lines represent the relative amounts of density. The arrow heads on the flux-density lines indicate the direction of the lines of flux.

Figures 2-6(a) and (b) combined show the relationship of the incident wave and the induced loop voltage. Note that the induced loop voltage differs in phase from the incident wave by 90°.

Size or location may prevent the rotation of a loop antenna. A goniometer combined with a pair of stationary loops at right angles produces the equivalent of a rotating loop.

Troubleshooting. Locating faults in a radio–direction-finding set should be systematic. First determine the faulty unit. If it is the receiver, determine whether the trouble is common to all frequency bands. If it is one band only, the trouble probably is in the radio frequency or oscillator unit. (Intermediate frequency, radio frequency, and indicator circuits are in use on all bands.) The main tuning capacitor and its vacuum tube and associated circuit components, the power supply, and control circuits may all be eliminated since they are common to all bands. Trouble may be an element selected by the switching operation or the actual switching device. Therefore, the coil assemblies and waveband switch should receive attention. Resistance tests of the radio-frequency amplifier and oscillator circuits will determine which one is at fault. If, in the defective circuit, the indicated resistance value changes with a slight movement of the band switch, a faulty contact may be indicated. If the abnormal resistance value remains constant, the fault probably is in the coil assembly or wiring. Examine the switch contacts and the wiring of the stage involved. If they appear to be in good operating condition, investigate the coil assembly.

A Rough Guide to Circuit Location of Faults. The amount and nature of background noise in the loudspeaker is a rough guide to the location of the fault. Absence of any sound probably would be due to power failure or to trouble in the output stage or output circuits. Normal microphonic sounds, without hiss, probably indicate a normal audio am-

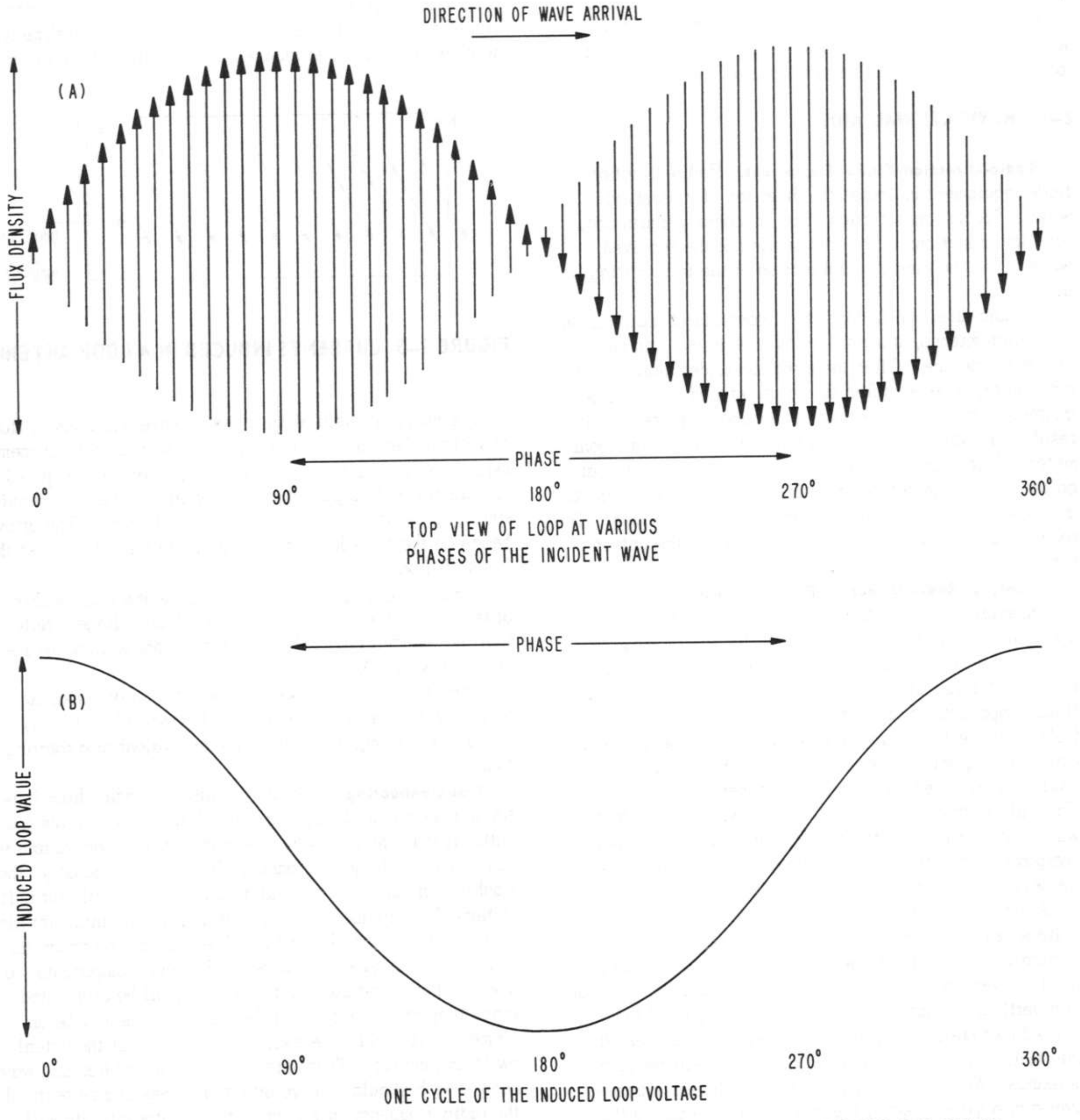


FIGURE 2–6 INDUCTION OF ALTERNATING VOLTAGE IN A LOOP ANTENNA SHOWING 90° PHASE DIFFERENCE WITH THE INCIDENT WAVE.

plifier system, but a faulty radio-frequency system. Weak signals accompanied by background noise may indicate some fault in the antenna system or transmission lines.

The indicator is an excellent guide in trouble location. If automatic bearings remain fixed at 0° and 180° or 90° and 270°, regardless of the direction of arrival, trouble in one of the directional channels and its associated cables and goniometer is indicated. Where a cathode-ray screen indicator is used, magnetized-iron parts in the automatic bearing indicator will show up as offsetting points of the usually symmetric propeller pattern.

Bearing error can be caused by refraction of the received wave. Terrain and atmosphere between the transmitter and receiver cause the wave to change direction. Bearing errors are caused also by skywave reflection and by radiation from other antennas. Two signals near the same frequency and input level will cause the indicator to shift between them. It probably will be impossible to get an accurate reading on either of them.

Shipboard transmitter radiation may cause the indicator to hunt. Deenergizing the transmitter will eliminate interference temporarily. Then it will be necessary to move the d-f antenna or the transmitter antenna to a location where transmitter radiation does not cause unstable indications.

Loran. Daylight ranges of 500 to 750 and, after sundown, ranges of up to 1400 over-water nautical miles can be expected with Loran equipment.

Loran operations start with the broadcast of short pulses from a pair of shore-based transmitters several hundred miles apart. Their signals are received by a specially designed radio receiver aboard ship. The difference in signal arrival time is displayed on a special indicator and can be measured as close as one microsecond. This time difference measurement locates the ship's position on one Loran line. The ship's position on another Loran line is established the same way, except that pulses are received from another pair of transmitters. The point at which the two Loran lines intersect is the fix of the ship's position.

A pair of Loran stations is a master station and slave station. The slave station transmits at a definite time lapse after the master station. This provides a means of distinguishing the slave pulse from the master pulse. A center line between the master and slave station is known as a "line of constant difference". Lines of constant difference are precomputed for shipping lanes throughout the world. They are made available to navigators in the form of Loran tables and Loran charts.

General Maintenance of Radio-Direction-Finder Equipments

Pilot and Dial Lamp Failure. When all pilot and dial lamps are out, the probable source of trouble is the a-c power supply or the filament circuit.

If the a-c supply is at fault, the probable cause is the power switch, a fuse, power input or output cables (possibly at the plug), or the filament-supply circuit.

No signal, Weak Signal, Or Incorrect Bearing Indication. These trouble indications can usually be traced to one of the following:

Power supply failure.
Faulty antenna connection.
Weak or burned out vacuum tube.
All d-c voltages are low.
Incorrect cable connection.
Shorted trimmer or tuning capacitor.

Power Supply Failure. When the trouble is in the power supply, the probable cause is a burned out or weak rectifier tube, faulty contact to rectifier tube pin or pins, break in continuity of power-unit cable, or shorted filter or bypass capacitor.

Faulty Antenna Connection. Poor contact between input receptacles and mating plugs or adapters may break the continuity of the antenna circuit. Other things that may create bad antenna connections are grounded or open junction-box circuits, grounded or open goniometer circuits, and grounded or open interconnecting cables.

Continuity checks will indicate open or high-resistant antenna circuits. With Multimeter AN/PSM-4 or equivalent, continuity may be measured in the following manner:

1. Disconnect the transmission line at the antenna. Connect a clip lead between the disconnected conductor and ship's ground.

2. Disconnect the transmission line at the receiver and connect one lead of the multimeter to its center conductor. Connect the other lead to ship's ground.

3. With the multimeter on the R X 1 scale, measure the continuity. It should be zero ohms.

4. With the multimeter on the R X 1 scale, perform continuity checks on any remaining antenna circuitry. This will include r-f switches and r-f cabling through junction boxes. The readings should always be zero ohms. If any reading shows an open circuit or is above zero, make a visual inspection of the faulty component for corroded or damaged switch contacts, insecure or damaged connectors, etc.

The following insulation test should be performed on the antenna transmission line:

1. Disconnect the clip lead at the antenna end of the transmission line. Using Test Set AN/PSM-2 or equivalent insulation test meter, connect one of its leads to the center conductor of the transmission line and the other to its connector shell. Measure the insulation. (It should be at least 100 megohms.)

2. Perform an insulation test on any remaining antenna cabling by measuring between the cable conductor and ground. When a reading of 100 megohms or greater is not present, check for strands of shielding between the conductor and connector shell and damaged cable insulation.

When a shorted or open circuit in the goniometer is suspected, make an ohmmeter check of its circuitry. Refer to its circuit diagram to do this. With the multimeter, determine that the stators and rotors are not shorted together or shorted to ground. A stator continuity check will require disconnecting the loop and stator at one end of the stator. The ohmmeter leads will then be connected to the two disconnected wires. Resistance should be negligible, possibly four or five ohms (the total resistance of the stator winding and loop).

All Low D-C Voltage. When all d-c voltages are low, a weak rectifier tube, an open filter capacitor, or a low resistance to ground in the B+ circuit is the probable cause.

Shorted Trimmer or Tuning Capacitor. Occasionally a drop of solder will fall on a trimmer capacitor and cause a short between plates. Solder is pried loose gently with a small screwdriver or other small implement.

CAUTION

Take care not to scar or bend the plates in the process. Bent capacitor plates cause short circuiting. Straighten a bent plate with a thin, flat implement. Press against the bent plate only. Do not wedge anything between two plates.

When the plate is straightened, rotate the capacitor control. During a complete rotation, equal spacing between plates should exist.

Noisy or Intermittent Reception. Noisy or intermittent reception may be caused by the following:

Noise pickup in the antenna system.
Faulty cable connections.

Defective control.
Defective switch.
Poor contact between a vacuum tube and its socket.
Defective vacuum tube.
Frayed or broken wiring.
Poor contact between pilot or dial lamp and socket.
Defective bypass coupling capacitor.
Loosely mounted shielding can.

Tracing a noise source. Gently shake unit components while the unit is energized. Moving the loose ground lead, poor tube and socket connection, or loose shielding can will change the noise level.

When you find one loose connection, look for others. Check all chassis connections for tightness. Press all vacuum tubes tightly in their sockets.

Change control settings. If this increases operating noise levels, look for dirty electrical contacts in the control circuits. Clean the dirty switch, relay, or other control contact with cleaning solvent Type 140F.

Tighten all cable connections. If this does not eliminate noise, look for changes in noise level when cables are shaken. Replace broken cables and clean all dirty cable connectors with dry cleaning solvent Type 140F.

If a noisy antenna circuit is suspected, short circuit or disconnect the antenna at its input to the receiver. If the noise stops, the antenna circuit is the source. Antenna circuit tests are given under the preceding topic "No Signal, Weak Signal, or Incorrect Bearing Indication".

An oscilloscope will speed discovery of a noisy coupling or bypass capacitor. With the antenna disconnected, troubleshoot the receiver from the output toward the input. Observe the waveform at each stage output. (Use a schematic and layout drawing.) Trace to the stage with a "clean" signal: where the noise distortion does not appear on the trace. The bad capacitor is in the stage previously checked or between the two stages. Replace the coupling capacitors. If the noise is still there, replace the bypass capacitors of the last noisy stage.

Fading. Fading is not always caused by circuit failure. It sometimes results from a magnetic storm. When a storm is not the cause, look for the following:

1. Defective coupling or bypass capacitors.
2. Vacuum tubes with intermittent heater operation.
3. Low sensitivity.

Procedure for determining defective coupling or bypass capacitors was given under the preceding topic "Noisy or Intermittent Reception".

Testing does not always detect a vacuum tube filament that opens intermittently. Interchanging tubes may be necessary.

The "Receiver Sensitivity Tests For Other Than Loran Navigational Equipments section describes sensitivity measurements.

Indicator Pattern Satisfactory on Direction Position, But No Pattern on Sense Position. (Or vice versa). An open deflection or sense coil will cause this. The open coil can be determined by a continuity test. A faulty brush will cause it also.

Receiver Tunes Signal Satisfactory and Circle on Bearing Indicator is Satisfactory, but No Bearings can be Obtained. The probable cause of this source of trouble is either an open input cable or no receiver-indicator channel output. To repair the latter, check the voltage output of

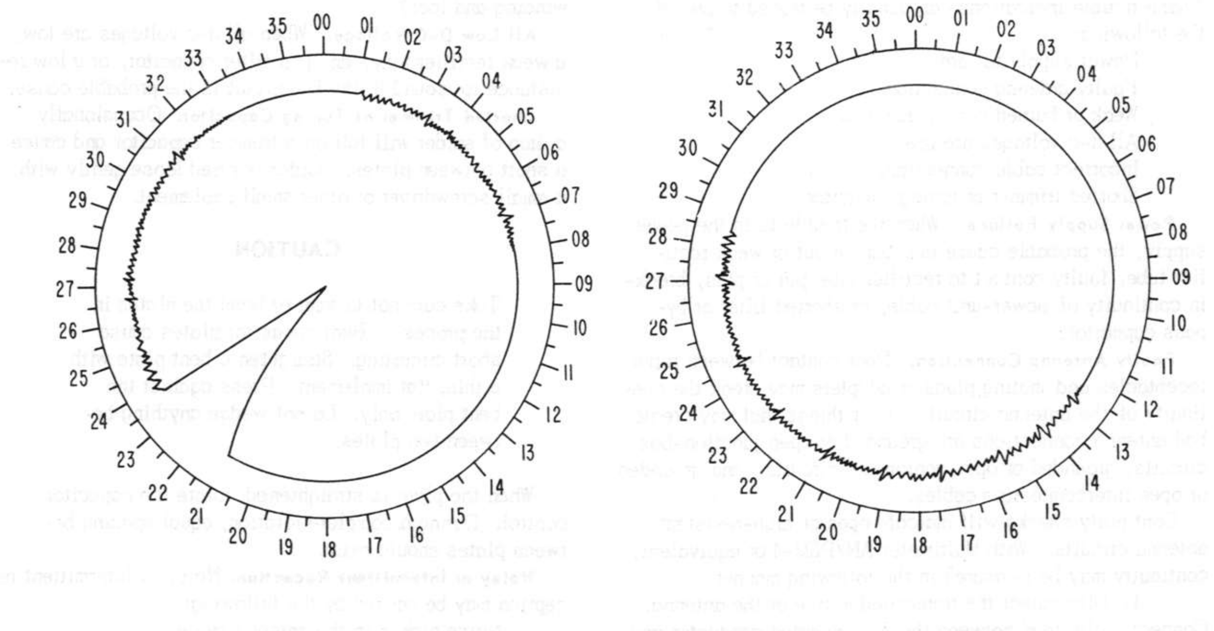


FIGURE 2–7 TYPICAL INDICATOR PATTERNS DUE TO POOR BRUSH AND SLIP-RING CONTACT.

the receiver indicator channel, and be sure that it is the same as specified in the instruction manual for the particular equipment. If there is no voltage at the output, check circuits against the applicable schematic diagrams.

With an ohmmeter, test the continuity of the input cables. Replace or repair the cables if necessary.

Sawtooth Pattern On Cathode-Ray Tube Circular Pattern. The probable cause of this sawtooth pattern is poor contact between slip rings and brushes. Cleaning and polishing of the slip rings, adjusting brush tension, or tightening the slip-ring retainer will remove the sawtooth pattern.

Loran Troubleshooting

Troubleshooting Guide. The following is a reference chart for rapid checking of equipment. Detailed maintenance is not presented; symptoms do not apply to every Loran equipment. However, it is a handy reference to show what troubles to expect when symptoms appear. It should save time by directing the technician to the general area of trouble.

Symptoms, Circuits, and Parts To Be Examined.

WARNING

High voltages are present in Loran equipments which may prove fatal to anyone coming in contact with them. Interlocks may not be provided with Loran equipments. Where interlocks are not provided, power cords should be disconnected when taking covers off equipment. Do not work on equipment while power is on unless absolutely necessary.

Symptom	Circuits and Parts to be Examined
Tube heaters are too dull or too bright.	Check line voltage. Check filament windings of power transfomer.
Poor B+ regulation or no B+ regulation.	B+ power supply. Check the B+ power supply filter capacitors. Check the vacuum tubes of the regulator circuit. Check the B+ to ground resistance: a typical satisfactory resistance range is 6500 to 8500 ohms.
No image on screen.	Power supply. Check high voltage at intensifier anode on oscilloscope tube. Check intensity and centering controls.
Vertical lines, but no horizontal trace present on slow sweep.	Slow-sweep generator.
Random or unsynchronized slow-sweep without pedestals.	Counter circuits and slow-sweep thyratron in slow-sweep generation circuit.
No slow-sweep.	Check sweep voltage on horizontal plates of oscilloscope during slow sweep. Check paraphase amplifier and slow-sweep circuit vacuum tubes and circuitry including switches.
Excessive length of traces on slow-sweep.	Counter circuits.
Slow-sweep pattern compressed or crowded into points.	Line voltage may be excessive or counter circuit may be faulty. The faulty counter circuit can be determined by inspection of pattern on fast sweep.
Sweep crowded into points at left end of trace.	Paraphase amplifier.
Length of traces on slow-sweep changes upon rotation of DRIFT control.	Check standard frequency generator to see why crystal does not control.
Traces on fast and slow sweep too short.	Check for excessive line voltage. Check fast and slow-sweep generator vacuum tubes. Check paraphase amplifier vacuum tube and circuitry.
No trace separation.	Check square-wave generator. Check switch that places trace separation in the circuit. Check "trace-shift mixer" vacuum tube and "amplitude balance" vacuum tube (indicator unit). Check adjustment of "trace separation" potentiometers.
No pedestals on trace.	Check pulses at output of "clipper tubes" in delay circuits. Check delay multivibrator circuit. Check pedestal generator circuit, including switch, generator-vacuum tube, and its cathode-follower vacuum tube.
Only one pedestal on trace.	Check clipper tubes in final delay circuits. Check pulses at output of multivibrator in first and last delay circuit.
Multiple pedestals.	Delay multivibrator circuits. Pedestal generator.
Poor pedestals or wrong length pedestals.	Check waveform at fast-sweep generator output. If faulty, check fast sweep generator tubes. Check fast sweep-slow

Symptom	Circuits and Parts to be Examined
	switches and capacitors at these switches. Check the paraphase amplifier circuit and switches.
No fast sweep.	Check fast-sweep generator tubes. Check fast-sweep switches and circitry. Check paraphase amplifier.
Distorted sweep patterns.	Check deflecting plate components of oscilloscope tube. Check slow-sweep generator tube and circuit. Check fast-sweep generator tube and circuit.
Counter circuits can not be made to count properly.	Defective storage and input capacitors in counters. Incorrect bias voltages in counters. (These are quite critical.)
Excessive horizontal jitter on fast sweep.	Check B+ power supply and voltage regulator.
No 100-kc oscillations (or no standard frequency oscillations, whatever the standard frequency may be.).	Check for sine-wave input to squaring amplifier. Check the standard frequency oscillator in the standard frequency generator circuit. Check the standard frequency drift adjustment capacitor. Check for a broken tuning slug in the standard frequency tuned circuit coil. Check the coupling capacitor that connects to the output of the standard frequency generator.
No 10-microsecond markers do not synchronize with 50-microsecond markers.	1. Check the vacuum tube in the 10-microsecond marker amplifier. 2. Check to see that the receiver load is not excessive. 3. Check adjustable and fixed value components of the 10-microsecond marker amplifier stage. 4. The standard frequency source of the 10-microsecond marker amplifier may be at fault. Look for a broken iron core in the tunable transformer of the standard frequency generator. (This would be indicated by no change in tuning when its adjustment screw is turned.) Check the output of the tunable tank circuit of the presence of output and proper frequency. If there is no output, check to see that the secondary winding is not shorted.
Symptons for absence of 10-microsecond markers only.	In addition to the preceding examinations, check the capacitor that makes the final adjustments for a clean square-wave input to counter number one. Check for a 10-microsecond pulse at the output of the 10-microsecond marker amplifier.
No 50- or 500-microsecond markers.	Check marker mixer and trace-shift mixer vacuum tubes. Check for faulty coupling capacitors and resistors between output of counter number one and the marker-mixer input. Also check them between output of counter number two and the marker mixer input.
No 50-microsecond markers or defective markers.	Check the marker mixer or trace-shift mixer circuit. Check the coupling capacitor and resistor between output of counter number one and the marker mixer input. Check for pulses at the marker mixer input if pulses are not seen on the screen.
Defective 500-microsecond markers.	Check the pulse output of the trace-shift mixer. Check the marker mixer and trace-shift mixer circuit components. Observe that the amplitude and waveform at the trace-separation control arm is as struction manual. Check required by the equipment in-waveform at trace-shift mixer input to oscilloscope-tube vertical deflecting plate. Observe that it conforms to required waveform of the equipment instruction manual.
Coarse delay ranges continuous instead of incremental.	Check trace-shift mixer, 500-microsecond marker, and coarse-delay circuit vacuum tubes. Check for required (instruction manual) pulse at output of 500-microsecond marker amplifier. Check for required pulse at input to coarse delay circuit.
Coarse delay maladjustment.	Check adjustment of coarse delay potentiometers. Check coarse delay circuitry, par-

Symptom	Circuits and Parts to be Examined
	ticularly voltage divider resistors used with the station selector switch.
Fine delay maladjustments.	Check adjustment of fine delay potentiometers. Check coarse and fine delay circuits. Check for required instruction manual pulses at fine delay-circuit output.
No feedback or feedback adjustment incorrect.	Examine the counter circuitry, checking its variable capacitors for shorted plates. Make a continuity check through the station selector switch. Check for required voltages on any pulse-limiter circuitry that may be connected to the input arm of the station-selector switch.
Excessive horizontal hum on trace.	Check hum on B+ supply. Check any vacuum tubes used as "clippers" in delay circuits. Check gas triode (if one is used) of slow-sweep circuit. Check the hum pickup on wires from delay circuit clipper stages to pedestal generator.
Excessive vertical hum on trace.	Check hum on B+ supply. Check for proper grounding of units.
Bright spots at left of trace.	In the oscilloscope grid-control circuit, check the intensity limiter vacuum tube. Also check its circuitry for proper bias. Check the continuity of fast-slow sweep switch on oscilloscope.
LEFT-RIGHT switch does not operate correctly on slow-sweep	Counter number one needs adjustment or check operation of switch itself.

Scheduled Tests and Minor Maintenance of Loran

General Loran Maintenance. The following does not replace any part of the POMSEE schedule. Listed here is general Loran maintenance that is similar to POMSEE maintenance. It shows the type of scheduled maintenance to perform to all Loran equipment.

Daily:

1. Make a visual check of operation by following the operator's alinement check of the equipment instruction book.
2. Check the line voltage of the power supply to the equipment.
3. Check the B+ regulated voltage.

Weekly:

1. Make a complete check of the indicator circuits as given in the indicator alinement procedure of the instruction book. Include a check of the B+ regulated voltage in the indicator unit.
2. Inspect the oscilloscope tube traces. The intensity should be normal.
3. Inspect traces for a-c hum.
4. Remove dust covers on the indicator and receiver units and inspect interior of the equipment. Look for loose parts and connections, evidence of corrosion, etc.

Daily Inspections.

1. Antenna: Make visual inspections of the antenna system (including transmission lines) to detect damage, fouling, excessive sagging, and other detectable conditions which might affect the antenna efficiency.
2. General Equipment: If the equipment has remained idle for a day or longer, turn it on and spot check the entire equipment using the target transmitter. Investigate any abnormal deviations. Move the target transmitter about the antenna while an operator observes the bearing indications. Bearing and sense indications are not expected to be accurate in this test as a target transmitter on the fantail is too close to the loops.

CAUTION

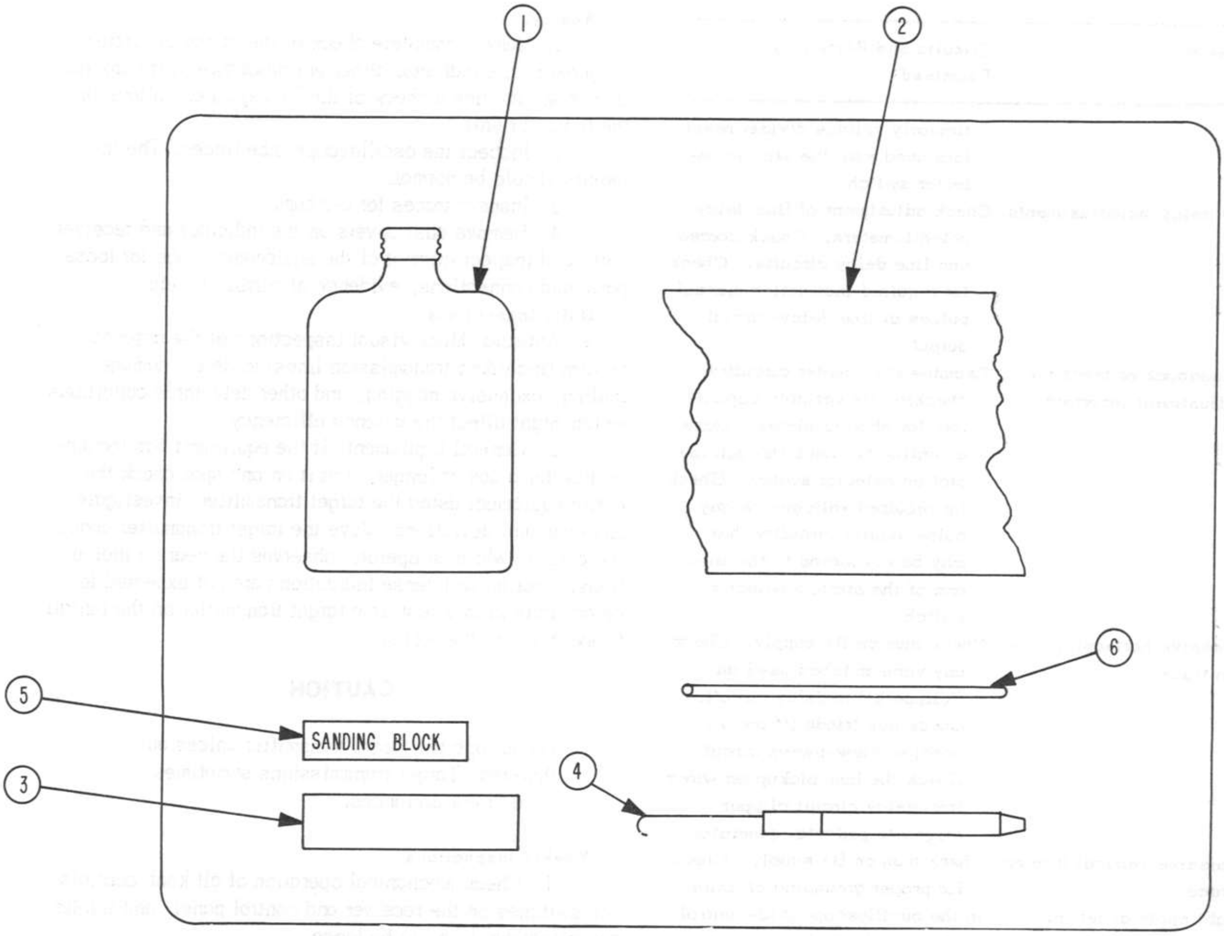
Do not use the target transmitter unless authorized. Target transmissions sometimes cover great distances.

Weekly Inspections.

1. Check mechanical operation of all knob controls and switches on the receiver and control panel, and tighten any setscrews found to be loose.
2. Tune in a signal on each frequency band and note that there is no excessive noise, weakness of signal, or distortion.
3. Observe that pilot and dial lamps function properly when control switches are turned on or off.
4. Inspect cable connections and fittings for tightness.
5. Clean bearing indicator brushes and slip rings. Clean area under slip rings. If rings are found to be pitted or scored, polish them. Check brushes for wear, freedom of motion, and pressure. See figure 2–8.
6. Clean antenna and lead-in insulators. Inspect antenna loading coil and the interconnecting power cables.

Monthly:

1. If an excessive amount of dirt has accumulated, blow dust out of equipment with bellows or air line.
2. Check the r-f alinement of the receiver with actual Loran signals.
3. If receiver is not operating correctly, substitute new tubes that have been checked in a mutual-conductance tube checker for the ones in the circuit.
4. Check DRIFT control for ample range.
5. With power supply disconnected, wipe or brush dust from parts.



1. CLEANING SOLVENT TYPE 140F.
2. 5 YARDS OF CHEESE CLOTH.
3. 6 SHEETS ARMOUR SANDPAPER WORKS CROCUS CLOTH OR EQUIVALENT.
4. 1 SPRING-TENSION GAUGE GRADUATED IN 1/2 OUNCES.
5. 1 BLOCK BAKELITE OR OTHER SMOOTH-SURFACED SUBSTANCE 2" X 3/4" X 1/8".
6. 3/8" X 5" BAKELITE ROD (OR NON-METALLIC ROD).

FIGURE 2–8. THE NECESSARY EQUIPMENT FOR SERVICING SLIP RINGS AND BRUSHES

Quarterly:

1. Check bandwidth and sensitivity of the receiver using POMSEE or Test Methods and Practices.
2. Clean external surfaces of the equipment.
3. Grease or oil control mechanism as required by the POMSEE.
4. Oil the bearing indicator in the manner prescribed by the specific equipment instruction manual or POMSEE.

NOTE

Use dry cleaning solvent Type 140F to clean. Do not use carbon tetrachloride or colored solvent supplied for fire extinguishers.

Scheduled Inspections of Radio-Direction-Finder Equipments

General Inspections. Inspections that follow pertain to all navigational aid direction finders. They are not ironbound rules; POMSEE and Test Methods and Practices are the guides for scheduled measurements. These are general procedures for scheduled inspections that can be performed to any d-f equipment. More details and more tests are necessary for specific equipments.

Monthly Inspections. Specific monthly inspections which can be performed on all radio-direction-finder equipments are as follows:

1. ANTENNAS: The antennas should be inspected while in yards (or equivalent conditions of safety) for the following:

(a) Insulators. Inspect insulators for cracks, breaks, and tightness.

(b) Elements. Check elements for alinement, vibration, and cracks in joints.

(c) Pedestals. Check pedestals for vibration, loose mounting bolts, and poor electrical and mechanical connections. Check the condition of the pedestal cables.

(d) Frame. Inspect its alinement and check for vibration.

(e) Paint. Inspect for rust spots, cracks, or peeling.

2. GENERAL. Inspect all rubber used for shock mounting, replacing where necessary because of cracking or loss of resilience

3. RECEIVER. Measure the receiver sensitivity in accordance with current instructions by Bureau of Ships. *

WARNING

Receiver alinement should not be attempted except by experienced maintenance personnel with a suitable calibrated signal generator and vacuum-tube voltmeter.

4. DIRECTION-FINDER CALIBRATION. Check the radio-direction-finder calibration curves on at least 5 points and at least 3 frequencies. Tune in transmitting stations on bearings which can be determined accurately by visual or navigational means. Vary check points and frequencies as may be practical in subsequent monthly checks.

5. INSULATION TEST. With an insulation test set, test the insulation to ground from all antennas and the insulation to ground from the control and power-supply circuits. Observe that the megger reading is 100 megs or more. Major repairs, electrical alinements, and most replacements of circuit components should not be attempted at sea, but rather at a yard equipped with laboratory equipment. A tube substitution method of replacing a suspected faulty tube with a new one known to be in good operating condition will often locate and correct the trouble. In the event that this method does not work, trouble must be located methodically through elimination processes and analyses of circuit voltages and resistances.

6. SLIP RINGS AND BRUSHES. Check slip rings for concentricity and looseness. Check brush pressure. Check brush pigtails for fatigue, flexibility, corrosion, and contact. See figure 2–8.

Quarterly Inspections.

1. ANTENNA. Clean antenna entrance, strain, and pedestal insulators, and tighten connections. Inspect, clean, and tighten, as necessary, all accessible ground connections. Antenna insulators should be cleaned more often then quarterly when dirt deposits accumulate rapidly.

2. RECEIVER.

(a) Make sensitivity measurements of the receiver in accordance with current POMSEE or Test Methods and Practices, and record results in log, prior to and after any corrective action.

(b) Check the frequency calibration of the receiver. The calibration should be checked in the manner prescribed by the particular instruction manual or POMSEE that is assigned to the equipment.

(c) Check the operation of the receiver r-f gain, audio gain, and sense-gain controls. The controls do not require any adjustment or trimming. Controlling toggle switches, potentiometers, and vacuum tubes are the usual causes of lack of or absence of gain. Frequent trouble-makers are those toggle switches which are operated so seldom that the small amount of oxide that forms on their contacts renders them inoperative. Periodic operation for ten to twenty minutes will usually permit these switches to remain in good condition. Potentiometers, however, usually become faulty from excessive use. When this occurs, the faulty potentiometer must be replaced.

Transmitters

General. Because of radiation, transmitter tuning presents problems, some of which may be eliminated by tuning while the ship is at its base. Accurate logging of dial setting during pretuning can eliminate much of the tuning at sea and speed all tuning. Frequency-dial settings based on interpolations are permitted in pretuning where exact frequencies are not required. Oscillator frequencies, which are not crystal controlled, are set by means of frequency meters.

Transmitter Frequency Testing with a Calibrated Receiver. One convenient way of checking transmitter frequency is to use a radio receiver. Since well designed receivers are accurate to better than 0.04 per cent, they can measure transmitter output frequencies quite correctly. They are most accurate when the transmissions are unmodulated. If the maximum receiver response is indicated by a carrier actuated tuning indicator, the beat-frequency oscillator in the receiver should be turned off. When a stable BFO is available, it is possible to apply it to produce greater accuracy. First the BFO is adjusted to produce a beat note of known frequency while a standard signal is applied to the receiver. For example, the BFO may be adjusted for a zero beat. If the BFO is left untouched, a signal of unknown value can now be measured by tuning the receiver until zero-beat conditions are obtained. The setting of the calibrated dial is the unknown frequency. When a nearby transmitter is being checked, the receiver antenna is disconnected. If the signal still blocks the receiver, the power amplifier of the transmitter should be turned off.

Transmitter Power Measurements.

Audio Frequency. For testing operations which require the repeated measurement of audio-frequency power, commercial power meters are available. These instruments are generally composed of a ratio transformer, a constant-resistance multiplier, and a voltmeter. The ratio transformer is compensated by various resistances which allow the effective load imposed on the output stage to be varied over

* Sensitivity tests are presented later in this section.

a number of steps. The constant-resistance multiplier acts as a range multiplier for the voltmeter while presenting a constant resistance to the secondary of the transformer. Indications are calibrated in watts with this type of instrument.

When phase angles are introduced by reactive components, power measurement by the previous method is no longer applicable and wattmeters, which are proportional to the power factor as well as the apparent power, must be used. Even wattmeters are not practical at high frequencies. Stray capacitances and inductances, skin effects, and other complications increase as frequency rises.

Power Meters. When close accuracy is not essential, compact test equipments called r-f power meters are used to furnish direct readings of r-f power. A power meter is small and portable, even when designed to measure outputs as great as 500 watts. Power meters are suitable for direct measurements from 3 mc to 300 mc.

Radio-Beacon Transmitters. Navigational-aid transmitters are restricted to radio-beacon equipments and are relatively simple. A complete transmitter may include as little as a radio-frequency oscillator, a pulse modulator, a keyer, and a power supply.

RECEIVER COUPLER TUNING IN RADIO-BEACON TRANSMITTERS.

WARNING

High voltage, dangerous to life, is present in transmitters. Before making any internal adjustments, set the high and low voltage switches to OFF.

Tune the receiver-coupler coil until the shore-station signal is of maximum amplitude, making sure that the signal on the scope is below saturation. While making this adjustment, note the antenna current. The antenna current will be somewhat reduced when the receiver coupler is far off tune. It may be necessary to slightly retune the transmitter after tuning the receiver coupler.

When the transmitter includes coil taps, set them according to the equipment instruction manuals. Other transmitter adjustments, which are peculiar to the individual equipment being tested, will have to be performed according to the appropriate equipment instruction manual.

Loran Receiver Sensitivity Tests

General. A radio-direction finder or Loran equipment requires a sensitive receiver. The following Loran tests are for general application. Sensitivity tests are preceded by voltage tests to insure that voltages are normal.

a. With all power off, remove the receiver from its dust cover. Place it on a shelf or table near the indicator. Reconnect power connections; apply power and advance the gain to full output.

b. With the negative lead of the voltmeter connected to ground and the positive lead connected to B+, measure the B+ voltage. Measure the filament and line input voltages on the a.c. scale. Filament voltages are generally 6.3 VAC for all tubes except the rectifier. They should be close to 6.3 (± 1 volt) but meter inaccuracies should be considered. B+ voltages may vary from their specified voltages without interfering with the efficiency of the set. For example, a supposedly +300 VDC B+ may be anywhere between +280 and +300 volts. However, when a B+ voltage is inaccurate, it should be corrected.

c. Place an r-f signal generator close to the Loran receiver. Connect, as shown in figure 2–9, a dummy antenna

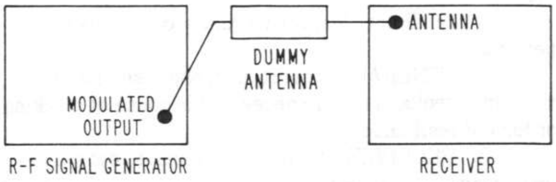


FIGURE 2–9 BLOCK DIAGRAM OF LORAN RECEIVER SENSITIVITY

between the output of the signal generator and the antenna input connector on the receiver. (The dummy-antenna resistance plus the output impedance of the signal generator should equal the normal operating antenna impedance.) With the receiver and the signal generator tuned to the same modulated frequency, adjust the signal-generator attenuator control for a very low-level output. This output will vary with equipments: for example, it is two microvolts for Radio Navigation Equipment Model DAS-4. However, the signal-generator output level must be established by the appropriate equipment POMSEE or instruction manual. If, when the signal generator output is set at its required low level, it is visible on the Loran screen, the sensitivity is satisfactory. Perform the sensitivity tests at the high, low, midfrequency points of all bands. Refer to dummy antenna (Figure 2-10). This circuit should be enclosed in a grounded shield and used with a signal generator having a resistive output of not over 50 ohms. It has the characteristics of

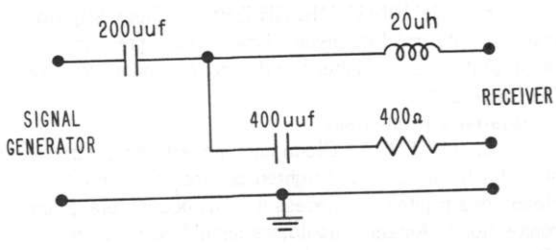


FIGURE 2–10 DUMMY ANTENNA FOR RECEIVER SENSITIVITY TEST

a 500-uuf capacitor in the 15- to 30,000-kc range, has a complex impedance in the 1-mc region, and the characteristics of a 400-ohm resistor at frequencies of 2 mc to 30 mc. To measure low-impedance-input receivers of 50 to 70 ohms, a signal generator with a 50-ohm output may be directly connected; the dummy antenna is not necessary. Other generator impedances may require special dummy--antenna networks to load the generator and receiver properly.

Receiver Sensitivity Tests for Other Than Loran Navigational Equipments

Preparatory Steps.

a. Check the power supply and line-input voltages.

b. Place a 600-ohm noninductive resistor across the output of the receiver unless another load value is specified by the instruction book for the equipment. The resistor must have a high enough wattage value to handle the maximum receiver audio output. High impedance headphones must be used if it becomes necessary to connect headsets in parallel with the output resistor.

c. Place the leads of an audio voltmeter across the output terminals of the receiver. This meter must be capable of accurate indications from 0.1 volt to 100 volts with negligible loading of the circuit. Although some receivers have audio-output meters, such meters may not indicate noise levels satisfactorily and therefore are inadequate for sensitivity tests.

d. Disconnect the antenna lead-in from the receiver. Connect the signal generator output to the antenna lead-in connector with or without a dummy antenna as the impedance matching requires.

C-W Sensitivity. A means must be provided to set the output beat note of the receiver to the standard 1000-cps frequency with an accuracy of ± 50 cps. When a receiver has a 1000 cps "Sharp audio filter, centering of the tone at the receiver resonant frequency is sufficient. The narrow bandpass frequency, created by the sharp audio filter, permits this technique. Where there is not a sharp audio filter, the 1000-cps internal tone modulation frequency of most signal generators is accurate enough and can be zero-beat against the output beatnote.

If an oscilloscope is available, the output of a calibrated audio oscillator and the output of the radio receiver can be fed independently to the deflection amplifiers of the oscilloscope to produce a Lissajous pattern of synchronization.

MCW Sensitivity. MCW sensitivity measurement requires the application of a carrier modulated 30 per cent at 1000 cps. The receiver r-f gain control should be set at maximum with the AGC on and the beat-frequency oscillator off. All other controls except the a-f gain should be set as though the receiver were adjusted for C-W reception. When the preceding adjustments have been made, progressively adjust the input signal level at the signal generator and the a-f gain on the receiver until the receiver output noise level is 0.6 milliwatt (0.6 volt) with an unmodulated input, and the signal-plus-noise output is 6 milliwatts with modulation on. When the 0.6 and 6 adjustments have been completed, receiver sensitivity in terms of input voltage is read from the signal-generator voltage calibration.

Navigational Aid Receiver Selectivity Tests, General

Procedure For Determining Receiver Selectivity.

Receivers with less than 5-kc bandwidth at 6 db down. Connect a high impedance voltmeter across the final-detector diode load of the receiver. Place a 1-megohm isolating resistor between the "high" lead of the voltmeter and the diode load (high with respect to ground). Possibly the resistor will not be necessary; its purpose is to eliminate regeneration and other undesirable effects.

Connect an r-f signal generator with an unmodulated output to the antenna input of the receiver. Beginning with the standard input voltage, increase the signal generator voltage output in steps of about 1.4, 2, 3, 5, 10, 100, and 1000 times its standard input. At each step, the frequency of the signal is adjusted to produce the same detector diode voltage as previously obtained with standard input at resonance. Procedure:

(1) Set the signal generator output at a specified low level.

(2) Tune the receiver to resonance at the same frequency as the signal generator.

(3) Increase the signal generator output until the detector output of the receiver (as indicated on the voltmeter) is 1.4 times the specified low level.

(4) Detune the receiver to one side of its center frequency until the voltmeter reading equals the specified low level and record the frequency shown on the receiver dial.

(5) Rotate the receiver dial in the opposite direction through the 1.4 point until the specified low level is again indicated on the voltmeter. Record this receiver frequency-dial setting.

(6) Subtract the lower frequency-dial setting from the higher one to obtain a bandwidth.

(7) Find a bandwidth at the next higher level by (1) increasing the signal generator until the voltmeter reads twice the original specified low level; (2) detuning the receiver until the detector output is 1.4 times the specified low level, (the first peak-voltage setting); (3) determining the 1.4 points on opposite sides of the center frequency; and (4) subtracting the lower from the higher frequency reading.

(8) Repeat similar bandwidth measurements at 3, 5, 10, 100, and 1000 times the specified low-level input; each time follow the same order of clockwise and counterclockwise approaches to frequency limits. Each time detune to the previous level to determine a bandwidth limit. A "times resonant specified input" versus "kc off resonance" curve may be plotted on semilog paper. The 6 db down and 60 db down bandwidths of this curve will show the 60 to 6 db bandwidth ratio or selectivity ratio.

Receivers with more than 5 kc bandwidths at 6 db down. In general, the selectivity of TRF and single-conversion superheterodyne receivers designed for operation above 500 kc may be measured with a carrier that is modulated 30 per cent by a 400 or 1000-cps tone. The procedure is the same as the selectivity measurements of receivers with less than 5-kc bandwidth at 6 db down. The output measurement, however, is made at the audio output terminals of the receiver and not at the final detector output load.

Bandwidth Tests at 3 db down only. Ordinarily time does not permit a complete selectivity test, but bandwidths are checked at 3 db down points at high, mid, and low portions of each band. The procedure is the same as for the selectivity tests, except that detuning is from 2.0 to 1.4 levels only. A typical POMSEE measurement requires a 2.0-ma peak adjustment at the output load of the final detector with detuning to 1.4 ma on each side of the center frequency.