CHAPTER 8

ANTENNA SYSTEM PERFORMANCE TESTS

Physical and electrical checks are required to ensure that installation specifications have been met and that the antenna system will perform within required operational limits. The recorded data from these installation inspections and tests serve to establish reference standards for future preventive and corrective maintenance actions.

Procedures for inspections and general electrical tests of antenna systems, and information on radiation and shock hazards to personnel are discussed in this chapter.

8.1 POST-INSTALLATION INSPECTIONS

Both physical and electrical inspections and tests must be performed at the time of initial antenna installation. The physical inspection of HF antenna systems should be completed before electrical tests commence. Inspections should be conducted using procedures that will detect installation deficiencies and provide reference data for future inspections and maintenance records.

8.1.1 General Inspection Procedures

The following physical checks of antenna systems, subparagraphs a. through f., below, should be conducted. In addition, for each antenna inspected, applicable parts of the antenna inspection checklist (table 8-1) should be completed and incorporated into the permanent maintenance record.

a. Structural Tower Checks. Check tower plumb with a transit at two positions, 90° apart, to determine if the top is out of plumb by more than the width of one leg. In addition,

(1) Check with transit for tower kinks.

(2) Check for loose and missing bolts.

(3) Check for missing and bent members.

(4) Check guying for improper tensioning.

(5) Check antenna-lowering davits for proper operation.

(6) Check for loose material on tower.

(7) Check for faulty lighting system.

(8) Check for corrosion or deterioration.

Table 8-1. Antenna Inspection Checklist

Antenna Type ____________________
Antenna ID ____________________
Inspected by ____________________ Date ____________________

Before Power
Annual
After Storm

Subject	Defects	Remarks	Corrective Action Taken
Antenna			
Elements			
Mounting			
Insulators			
Fastenings			
Downleads			
Connections			
Insulators			
Tie-Down			
Guys			
Tension			
Connections			
Insulators			
Anchors			
Transmission Lines			
Connections			
Tensions			
Insulators			
Poles			
Building Feedthrough Insulators			
Towers			
Plumb			
Fastenings			
Paint			
Base			
Dissipation Lines			
Connections			
Tensions			
Insulators			
Poles			
Terminating Resistors			
Connections			
Hardware			
Grounding and Lightning Protection			
Horn Gap at Building			
Horn Gap at Antennas			
Ground System			

b. Tower Support Checks. Check concrete bases for settling, cracking and tilting. In addition,

(1) Check tower anchors for loose emplacement in ground.

(2) Check guy wires for insecure clamps, clips, and turnbuckles.

(3) Check guy wires for broken strands, rusting, and excessive sagging.

(4) Check tower ground rods for broken or missing wires.

c. Antenna Installation Checks. Check antenna for installation items not in accordance with plans and specifications. In addition,

(1) Check for insecure and incorrect hardware mounting.

(2) Check insulating material for cleanliness; remove any paint or other material that may cause a loss of insulating properties.

(3) Check for bonding and grounding that is not in accordance with applicable plans and specifications.

d. Rotatable Antennas. Inspect rotatable antennas as follows:

(1) Check for proper physical clearances.

(2) Check for proper operation of mechanical and electrical stops.

(3) Check slip rings on rotating cable assemblies for electrical contact.

(4) Check for binding through entire range of travel.

(5) Check for excessive swaying during antenna rotation.

(6) Check antenna deenergizing switches, located at the antenna for proper functioning.

e. Obstruction Lights. Check power wiring at antenna structures for loose cables and conduit. In addition,

(1) Check lighting for broken glass and defective bulbs.

(2) Check photoelectric switch for proper operation. (Covering the glass front and allowing for required time delay should activate the switch.) Check for dirt on the glass which could obscure passage of light.

(3) Check flasher for correct number of flashes per minute.

(4) Check junction boxes for moisture, dirt, rust, and loose hardware, and for improperly placed gaskets, covers, and wiring.

f. Pressurized Coaxial Transmission Lines. Pressurized lines should be inspected for leaks. Leaks usually will be indicated by a decrease in normal operating pressures observed at the pressurizing system manifold line gauges and by the dehydrator unit running continuously. Since most coaxial-line pressurizing systems service several lines, it is necessary to isolate each line from the dehydrator and from the other lines, in order to identify the leaking line. As each transmission line is isolated, the pressure gauge for the isolated line is observed for a decreasing pressure reading. When the faulty line is identified and isolated in this manner, one of the following methods may be used to locate the leak:

(1) Soap-and-Water Method. This method is usually effective only on large leaks, because the soap solution will probably dry before a small leak can be detected. If it is suspected that the leak is small, the methane- or freon-gas method should be used. The procedure for detecting transmission line leaks using the soap-and-water method is as follows:

STEP 1: Apply a liberal solution of soap and water (liquid soap can also be used) to all accessible parts of the faulty line, and watch for the formation of bubbles.

STEP 2: Repeat step 1 on all highly suspect parts of the line, such as joints, connections, and fittings, until the leak is located, or until it is determined that the leak must be located by the use of other detection methods.

(2) Methane-Gas Method. This method of detecting leaks in a coaxial transmission line is particularly effective for the portions of the cable buried below ground. The suspected leak is located by charging the faulty cable with methane gas and using a special testing device to detect the gas fumes that escape to the earth's surface.

WARNING

Methane gas is flammable and must be handled with extreme caution. The procedure for locating transmission line leaks using this method is as follows:

STEP 1: Charge the transmission line with methane gas to the normal operating pressure.

STEP 2: Use a Davis Vapotester, Model D-1, to search for underground leaks by following the path of the buried cable. Escaping methane-gas fumes can be detected by the Vapotester within a relatively small area.

STEP 3: Expose the buried cable in the area where escaping gas fumes are detected to locate the leak.

STEP 4: When the leak is pinpointed, discharge remaining gas from the transmission line and make the necessary repairs.

STEP 5: Purge the transmission line with the normal pressurizing agent and test the line for residual traces of methane gas at accessible points until no fumes can be detected with the Vapotester.

STEP 6: Recharge the transmission line to the correct operating pressure with the normal pressurizing agent.

(3) Freon Gas Method

WARNING

The freon gas method of detecting leaks in pressurized transmission lines can be used only if the normal pressurizing agent is inert gas. Freon will arc in the presence of RF energy and thereby cause deterioration of the line; therefore, all power must be removed before starting the tests. The procedure for using freon gas to detect transmission line leaks is as follows:

STEP 1: Admit a small amount of freon-22 gas through the dehydrator unit intake. Allow approximately one hour for the freon to diffuse through the line.

STEP 2: Use a halide detector torch to check all accessible parts of the line for leaks. If a leak exists, the torch flame will change color from yellow or blue to bright green.

STEP 3: After the leak is located and repaired, purge the transmission line with the normal pressurizing agent. The halide detector should then be used at the escape valve farthest from the dehydrator unit to determine when all traces of freon gas have been purged.

STEP 4: Recharge the transmission line to the correct operating pressure with the normal pressurizing agent.

The foregoing physical checks for antenna systems are broad in scope and are applicable to HF antennas generally. Conscientious use of the checklists will expedite detection and correction of installation errors.

8.2 ELECTRICAL TESTS OF ANTENNA SYSTEMS

Electrical tests must be made after completion of the installation to ensure proper performance. These tests should be made after correction of the deficiencies discovered during physical inspections.

The test plan should be such that the same procedures and methods can be used for post-installation checkout and for conducting future maintenance tests.

8.2.1 General Antenna System Tests

The following test procedures were developed for HF vertically polarized LPA's. The testing format is applicable, however, to HF antennas in general. These tests should be performed when an installation has been completed, and when required during periods of routine and corrective maintenance. Additional test procedures may be found in Addendum No. 1 to DCAC 330-175-1. Significant test results should be recorded each time a test is conducted to provide a history which can be used to evaluate the operational condition of the antenna.

a. Insulation and Loop Resistance. Conduct resistance measurements of antenna systems to determine insulation resistance to ground, and insulation resistance between conductors. The following steps outline the procedure to be followed and the equipment required.

(1) Make certain that the antenna connector at the RF patch panel in the building is open. To make the measurements, an insulation resistance megger, such as the Biddle Model 7679, and an AN/URM-90 Impedance Bridge, or their equivalents, are required. Refer to figures 8-1 and 8-2 for typical test equipment arrangements and format to be used in recording the measurements.

(2) Disconnect the antenna feed line from the transformer. Disconnect the end of the antenna from any matching stubs which may be grounded. Measure the resistance of each wire of the antenna feed line to ground. The resistance reading should approach infinity.

(3) Disconnect the coaxial line from the transformer. Connect the megger to the coaxial line and measure insulation resistance. The resistance reading should approach infinity.

(4) Reconnect the end of the feed line stub to ground.

(5) Connect the impedance bridge across the ends of the antenna feed line and measure loop resistance. The resistance reading should approach zero ohms.

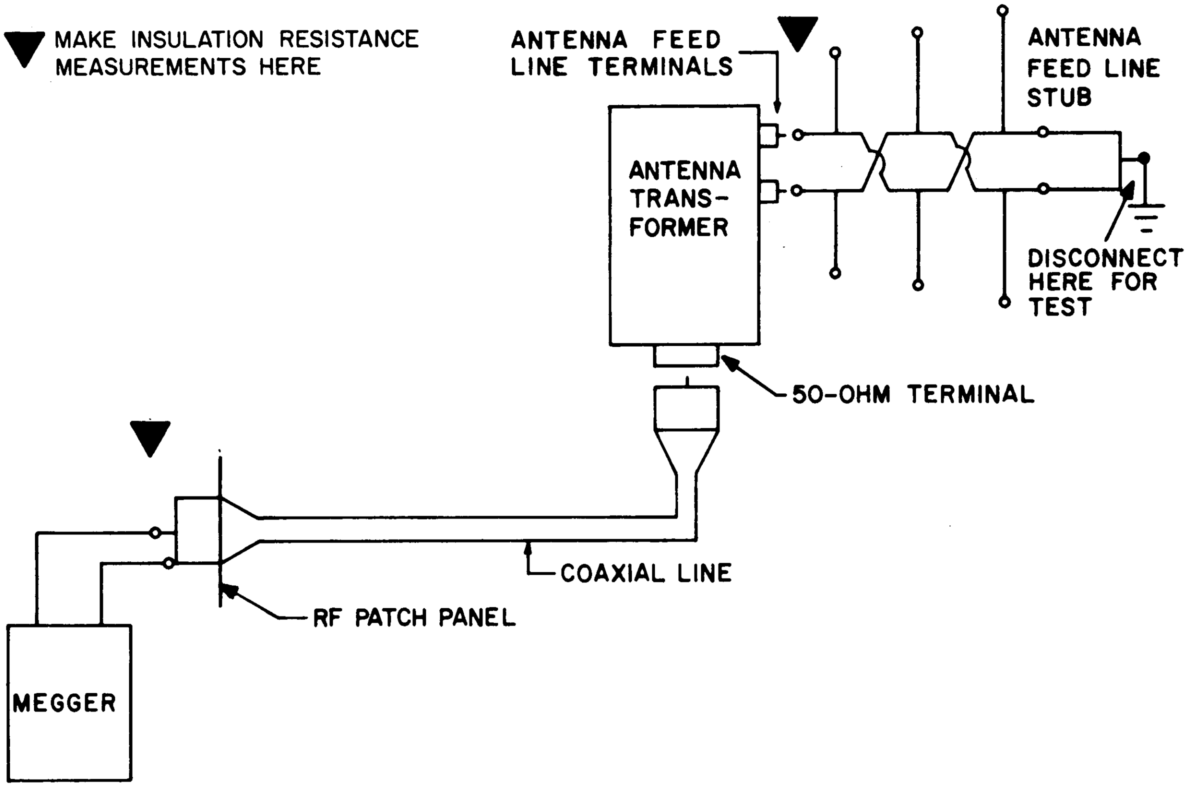
(6) Connect the impedance bridge to the 50-ohm terminal of the antenna transformer and measure loop resistance. The resistance reading should approach zero ohms.

(7) Connect the impedance bridge to the antenna transformer output terminals and measure loop resistance. The resistance reading should approach zero ohms.

(8) Connect a short jumper across the transformer end of the coaxial cable and using the impedance bridge, check loop resistance of the coaxial cable from the RF patch panel in the building. The resistance reading should approach zero ohms.

(9) Reconnect the antenna feed line to the transformer. Reconnect the coaxial cable to the transformer.

(10) Connect the impedance bridge to the coaxial connector at the building end of the coaxial cable, and measure the system loop resistance. The resistance should equal the sum of the resistances of preceding subparagraphs (6) and (8).



Insulation Resistance Measurements   Date:____________

1. Antenna feed line to ground: Left Wire ____________ megohms.

   Right Wire ____________ megohms.

2. Coaxial Cable Insulation Resistance __________ megohms.

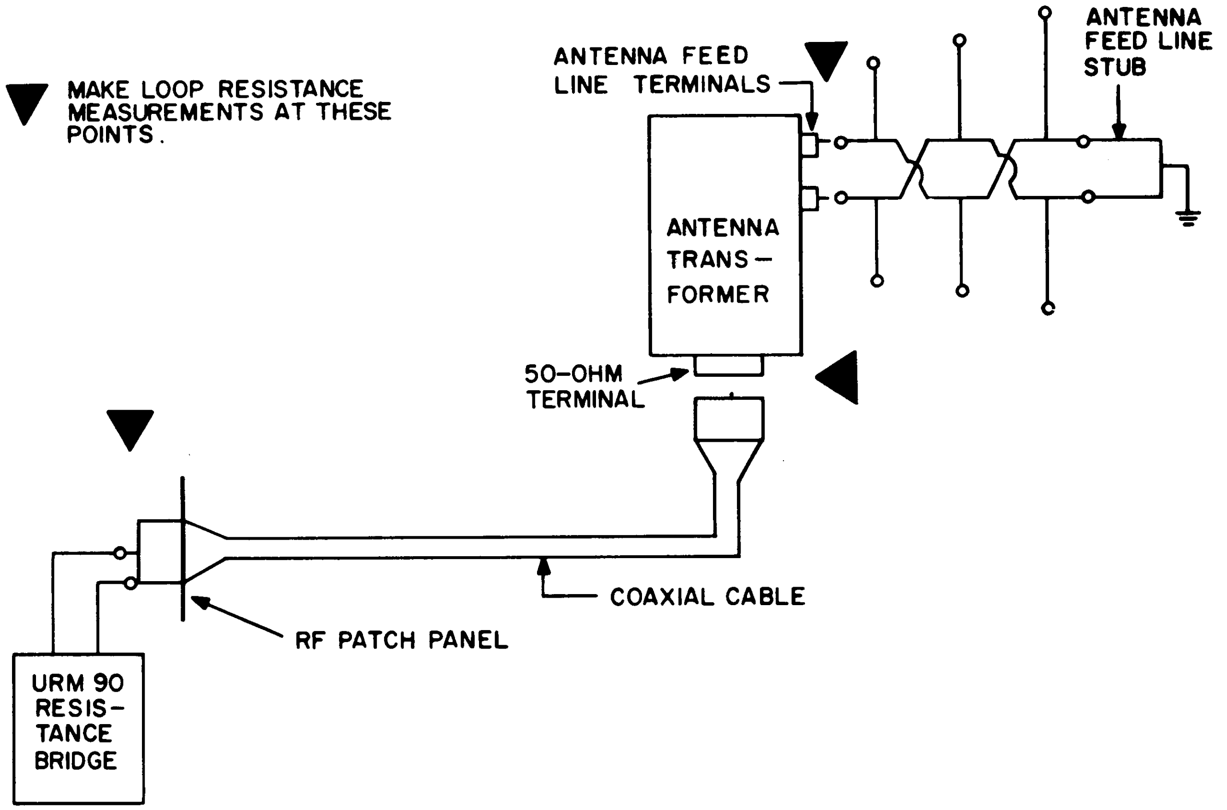
3. Equipment used: ______________________________

4. Remarks: ______________________________

   ____

5. Measurements made by: ______________________________

Figure 8-1. Insulation Resistance Measurements



Loop Resistance Measurements Date:______________

1. Antenna transformer loop resistance (50 ohm terminal)____ohms.
2. Antenna transformer loop resistance (secondary terminals) ______ ohms.
3. Antenna feed line loop resistance ___________ohms.
4. Coaxial cable loop resistance (measure from patch panel with antenna end short circuited) _________ohms.
5. Antenna system loop resistance from coaxial connector at RF patch panel with antenna and transformer connected ____________ ohms.
6. Equipment used:______________ Serial: _______________
7. Coaxial Cable Type____________ Length: ___________feet
8. Remarks: ____

Measurements by:_________________________________

Figure 8-2. Loop Resistance Measurements

(11) Record all measurements in appropriate spaces provided on figure 8-1 and figure 8-2.

b. Ground Resistance. The effectiveness of ground connections for antenna systems is determined by measuring ground resistance.

(1) Measure ground resistance with a Null-Balance Earth Megger, Evershed and Vignoles, Ltd., Model No. 1643342 or equivalent. Arrange the test equipment as shown in figure 8-3. The two 18-inch test rods are placed in the earth to establish auxiliary grounds. Distances D1 and D2 are determined by the dimensions of the ground system being tested. An alternating voltage is applied between the auxiliary grounds and the ground being tested. The voltage drop across these points, and the current between

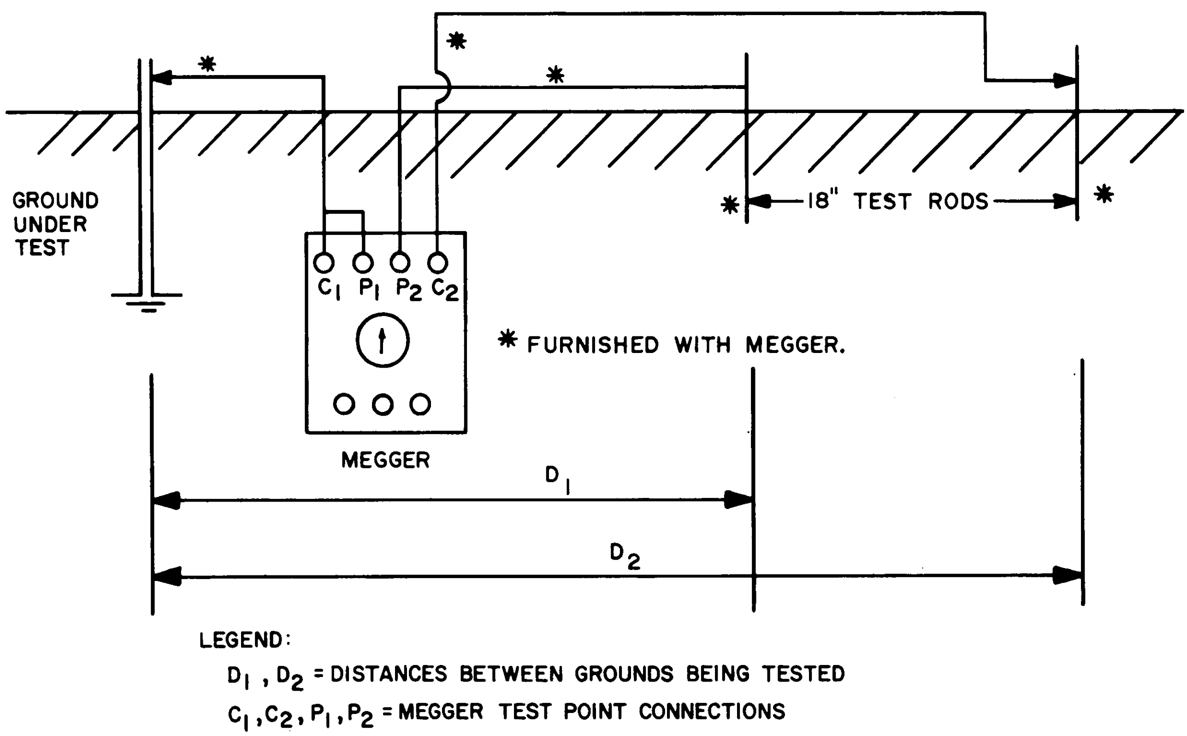


Figure 8-3. Test Arrangement for Ground Resistance

them is measured. The unknown resistance value is then determined by dividing the voltage drop by the current. Refer to the Earth Megger Pamphlet "How to Use Earth Megger Testers" for further details. Record the measurement on the form shown in figure 8-4.

c. Antenna Impedance. To determine the VSWR of an antenna, the input impedance of the antenna must be known. To measure this impedance in HF antennas, the following equipments, or acceptable substitutes, are required:

Date _______________

1. Ground Measurement Point: ____

2. D_1 ____________ feet

   D_2 ____________ feet

3. Measured resistance _______________ ohms

4. Sketch of equipment & ground stake set-up.

5. Equipment used.

6. Remarks

7. Measurements by: ______________________________

Figure 8-4. Ground Resistance Measurements

(1) RF Bridge, General Radio Type 1606A,

(2) RF Signal Generator, AN/URM-25, and

(3) RF Detector, Radio Receiver R-390A/URR.

Normally, an RF Bridge is used to measure impedances of unbalanced type antennas, whereas an admittance bridge usually is more suitable than the RF bridge for measuring the input impedance of balanced type antennas.

To determine the true impedance at the feed point of an antenna, when the measurements are made at the antenna patch panel, it is necessary to make additional measurements from the patch panel with the coaxial cable short-circuited at the antenna as shown in figure 8-5. Measurements of the shorted transmission line are necessary to determine the effect that the transmission line has on the antenna impedance measurements. Since these measurements must be made at the same frequencies at which the antenna impedance measurements are made, an accurate means of frequency calibration must be available. The built-in frequency calibrator of the R-390A/URR provides a suitable means for accomplishing this.

A test arrangement suitable for most RF impedance measurements is shown in figure 8-5. Detailed instructions on RF bridge test procedures and methods of connection for various purposes are given in the equipment instruction manual.

Measure the impedance at 1 MHz intervals across the frequency bandwidth of the antenna and at known operating frequencies. Record these impedance values for VSWR calculations.

d. VSWR. The VSWR of an antenna may be computed if the impedance is known, or may be obtained readily by plotting the measured load impedance on a Smith chart. To calculate the VSWR determine the absolute value of the reflection coefficient K as follows:

$$K = \frac{Z_k - Z_o}{Z_k + Z_o} \qquad (8\text{-}1)$$

With K determined, the VSWR can be found from the relationship:

$$VSWR = \frac{1 + K}{1 - K} \qquad (8\text{-}2)$$

where Z_k = measured impedance of load

Z_o = characteristic impedance of transmission line.

The VSWR may be determined by use of a Smith chart as shown in the following example.

Assume that the measured impedance Z_k of an antenna is 48+j38 ohms and the characteristic impedance of the associated transmission line is 50 ohms. Determine the VSWR as follows:

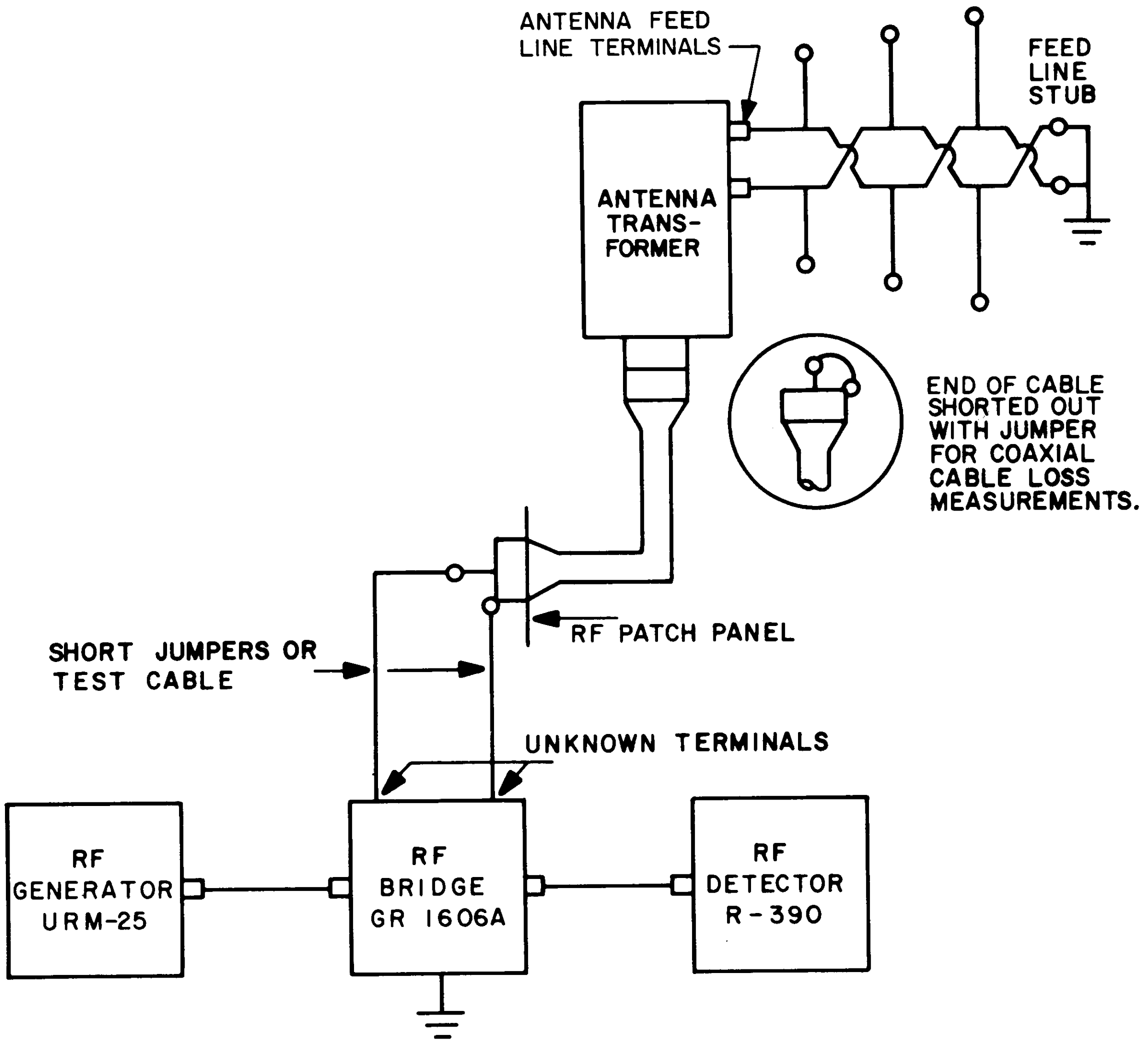


Figure 8-5. Test Arrangement for RF Impedance Measurements

(1) Normalize the measured antenna impedance to the Z_o of the transmission line.

$$Z_n = \frac{48+j38}{50} = 0.96+j0.76 \qquad (8\text{-}3)$$

(2) Plot $Z_n = 0.96 + j0.76$ on a Smith chart as shown in figure 8-6.

(3) Draw an arc of a circle with its center located at the center of the chart and passing through the plotted Z_n and the resistance axis. The intersection of the arc and the pure resistance axis indicates the value of the VSWR, 2.1:1.

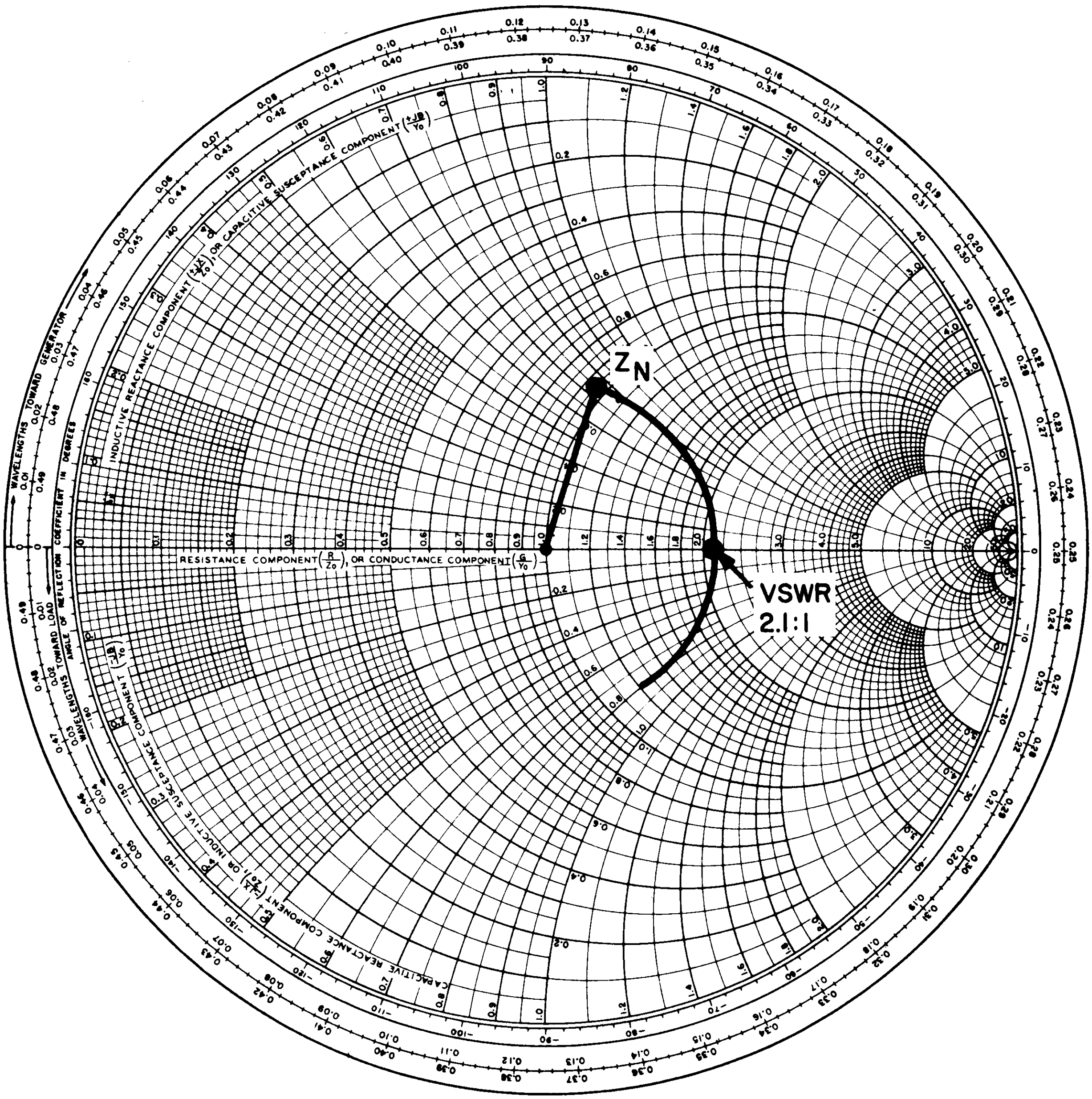


Figure 8-6. Smith Chart VSWR Calculation

Normally, the Smith chart is used to determine VSWR due to its simplicity. This method of determining antenna system characteristics is discussed in greater detail in Addendum No. 1 to DCAC 330-175-1.

e. Radiation Pattern Measurements. Radiation pattern measurements normally are not required for every antenna installation. Usually, the antenna radiation patterns provided for the particular antenna by the manufacturer are sufficient to satisfy Navy requirements. Therefore, NAVELEX determines the necessity for pattern measurements on an individual project basis.

8.3 SYSTEM TESTS AND PREVENTIVE MAINTENANCE

After an HF antenna system has been placed in service, periodic tests and inspections should be conducted to determine the operating efficiency of all components in the system. The data recorded during the post-installation physical and electrical checks provide the base line for comparison with conditions as they presently exist. The data gathered at the time of installation, used in conjunction with manufacturer's specifications, form the basis for preventive maintenance and are a valuable source of information during periods of corrective maintenance.

The individual communications activity establishes a program of system tests, and usually incorporates these tests into the preventive maintenance program.

8.4 RF RADIATION AND SHOCK HAZARDS TO PERSONNEL

RF radiation and electrical shock from HF transmitting antennas are potential hazards to personnel. The basic standards for protection of personnel against radiation hazards are contained in NAVORD 3565/NAVAIR 16-1-529. This publication also contains HERO and fuel hazard information. The application of these standards in relation to HF antennas is discussed in the following portions of this section.

8.4.1 Radiation Hazards to Personnel

Presently known detrimental effects of overexposure to RF radiation are associated with the average power of the absorbed radiation, are thermal in nature, and are observed as an increase in overall body temperature, or as a temperature rise in certain sensitive organs of the body. It has been determined that normally for any significant effect to occur, a person's height would have to correspond to at least one-tenth of a wavelength of the radiation frequency.

The Bureau of Medicine and Surgery has established safe limits based on the power density of the radiation beam and the exposure time of the human body in the radiation field as follows:

a. Continuous Exposure. Average power density is not to exceed 10 milliwatts per square centimeter.

b. Intermittent Exposure. Incident energy level is not to exceed 300 millijoules per square centimeter per 30 second interval.

c. Hazardous Areas. All areas in which the RF levels exceed prescribed safe limits are considered hazardous, and they must be identified with appropriate "RF Hazard" warning signs in accordance with NAVSO P-2455. The area in the vicinity of HF transmitting antennas is hazardous and should be restricted to prevent inadvertent entry. In all cases, entry of personnel into hazardous areas must be controlled to prevent exposure of personnel to either continuous or intermittent power levels in excess of the prescribed safe limits.

8.4.2 Electrical Shock Hazards

In addition to potential radiation hazards from HF transmitting antennas, some antennas are potential shock hazards for personnel because the antenna feed point or some of the radiating elements are located at, or near, ground level. Where ever any such installation exists, the hazardous area should be enclosed within a protective fence that will isolate the area from people unaware of the danger.

8.4.3 Protective Fences

Only non-conducting materials are suitable for constructing protective fences for antennas. Redwood or cypress is preferred. Usually, a wood fence that is from 4 to 6 feet high will provide the required degree of protection. Any gates in the fence must be designed and installed so that accidental entry into the hazardous area is not possible. Appropriate "High Voltage" warning signs must be permanently and conspicuously posted in hazardous areas in accordance with NAVSO P-2455.