NAVSHIPS 0967-177-3040 (Non-Registered)

SHIPBOARD ANTENNA SYSTEMS

VOLUME 4

TESTING AND MAINTENANCE COMMUNICATIONS ANTENNA SYSTEMS

SUPERSEDES CHAPTER 4 NAVSHIPS 900, 121(A)

DEPARTMENT OF THE NAVY

NAVAL SHIP SYSTEMS COMMAND

DECEMBER 1972

LIST OF EFFECTIVE PAGES

SECTION NUMBERS	CHANGE IN EFFECT	PAGE NUMBER
Title Page	ORIGINAL	i
List of Effective Pages	ORIGINAL	ii
Front Matter	ORIGINAL	iii to iv
1	ORIGINAL	1-1
2	ORIGINAL	2-1 to 2-13
3	ORIGINAL	3-1 to 3-31
Appendix 1	ORIGINAL	A-1 to A-3
Alphabetical Index	ORIGINAL	Index 1 Index 2

TABLE OF CONTENTS

SECTION 1 - INTRODUCTION

SECTION 2 - SHIPS FORCE TESTING AND MAINTENANCE

SECTION 3 - SUPPORT ACTIVITIES TESTING AND MAINTENANCE

LIST OF ILLUSTRATIONS

SECTION 1

INTRODUCTION

1.1 PURPOSE

This publication is Volume 4 in the series of Shipboard Antenna Systems published by the Navy. Its purpose is to provide information relative to testing and maintenance. The performing of test requirements has been divided into two categories: first, tests that may be accomplished by ship's personnel and secondly, tests that require instrumentation and engineering support from activities such as the U.S. Naval Laboratories and Shipyards.

1.2 GENERAL

The material in this volume is based on information obtained from reports submitted by ships, naval industrial activities, field support activities and laboratories. The model range tests and procedures were developed by Naval Ships System Command as a part of the active fleet Antenna Improvement Program (AIP). The information is intended for use by ship and shore personnel in the maintenance of shipboard communications antenna systems. The performance of a communication transmitting or receiving system is highly dependent on the condition of its associated antenna. The antenna is the point in the system where the rf energy is transferred to or from the radiation field. If the antenna is not in good operating condition physically or electrically, optimum performance cannot be expected from the transmitter or receiver. To ensure the system is operating at maximum design capability, mechanical and electrical tests are required for preventative and corrective maintenance. An individual antenna system consists of the antenna, insulators, hardware, matching devices, coaxial transmission lines, antenna patching systems, multicouplers and tuning units. The information in this volume is confined to testing and maintenance of antennas and ancillary components such as matching devices and feed lines. These requirements for nomenclatured antennas such as the AS-390/SRC are also outlined in their respective technical manuals.

SECTION 2

SHIP'S FORCE TESTING AND MAINTENANCE

2.1 GENERAL

The ship's force is responsible for the day-to-day mechanical and electrical condition of the communications antenna system. The operational capabilities of the system can be realized only if the ship's force has an adequate preventative and corrective maintenance program. Regularly scheduled inspections and tests are necessary to maintain the system at its maximum capabilities; test procedures involve physical inspection, mechanical maintenance and repair, and instrumentation to perform electrical tests. Proper evaluation of system performance requires each antenna system to have a set of standard operating conditions developed from information accumulated during initial tune-up and operation. Any deviation from these values is an indication of probable system degradation.

A naval ship operates in an environment that is greatly conducive to the deterioration of antenna components. Salt deposits and stack gases are major contributors to corrosion and the formation of low impedance paths across insulators. Continual ship's motion tends to increase the possibility of loose connections and excessive stresses on antennas and mountings. A shipboard antenna system is shown in Figure 2-1.

The frequency of tests required to maintain maximum operational capability should be based on the ship's mission, duration of time at sea, and the area of operation. The Planned Maintenance System (PMS) and Maintenance Repair Cards (MRCs) define specific preventative maintenance tasks in step-by-step procedures. Appendix 1 contains samples of MRCs for communications antennas. Routine tests should be scheduled on a quarterly basis. Tests must be performed immediately when there is any degradation of service. This is extremely important to prevent damage to the antenna and associated equipment of high power transmitting systems.

2.2 MECHANICAL TESTING AND MAINTENANCE

Mechanical testing and maintenance involves a visual inspection of the system for indications of physical deterioration and mechanical discrepancies such as broken insulators and loose connections. Maintenance procedures generally consist of the replacement of broken or worn parts, cleaning, and tightening of mechanical and electrical connections. Since physical defects generally result in changes in the electrical characteristics, mechanical testing and maintenance should take place prior to electrical tests.

2.2.1 VISUAL INSPECTION

Visual inspection requires that all parts of the system be viewed. The ship's personnel should be cognizant of the location of all system components including the routing of coaxial cable transmission lines. Visual inspection should also be directed to the topside area in the vicinity of the antennas especially if structural changes have been made. Structural changes often vary the impedance and pattern characteristics thus affecting the operation of the antenna. The temporary stowage of equipment and material in proximity to the antennas affects operation in the same manner. The ship's rigging and fittings in the antenna area should be inspected for proper bonding and grounding in accordance with NAVSHIPS 0967-266-1010, HULL GENERATED INTERMODULATION INTERFERENCE REDUCTION TECHNIQUES FOR FORCES AFLOAT, October 1971.

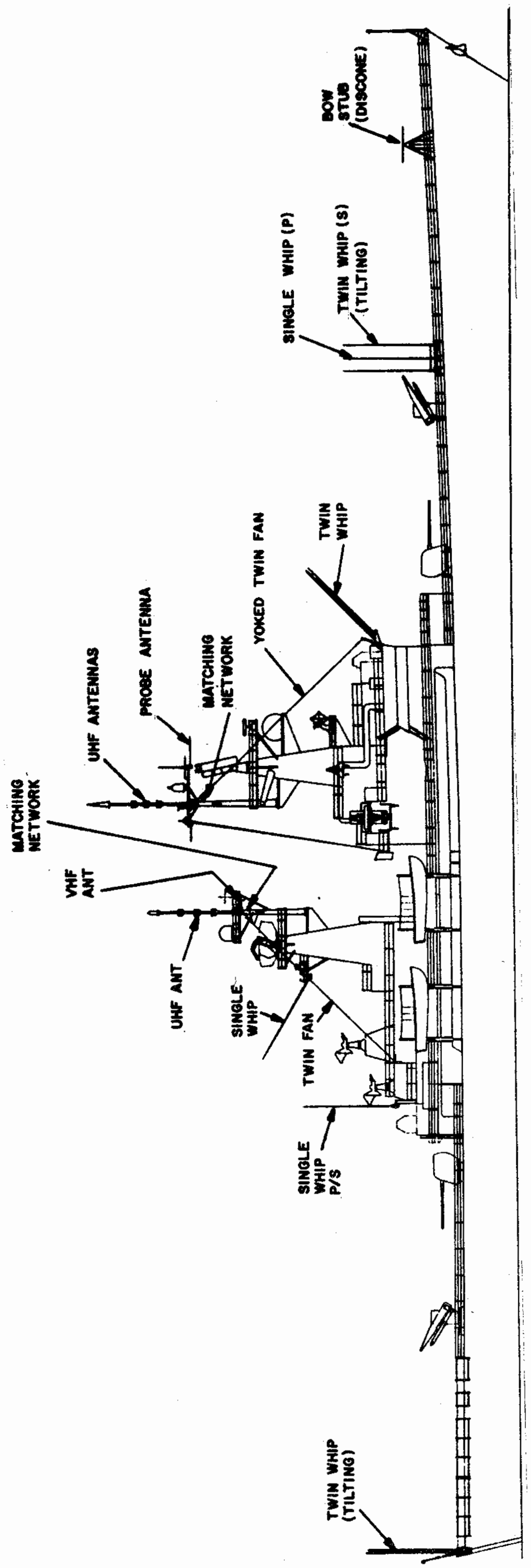

Figure 2-1. Shipboard Antenna Systems

SHIP'S FORCE TESTING AND MAINTENANCE

2.2.2 COAXIAL CABLE TRANSMISSION LINES

Coaxial cable transmission lines should be inspected for physical abrasions and cuts, deformation at watertight fittings, excessive heat in the vicinity of the cable, cable sag and possible stretching caused by hanging objects on the cable, moisture and corrosion, loose connectors and end seals, and to ensure that the specified bending radius has not been exceeded.

Particular attention should be given to cuts or holes in the outer jacket of flexible coaxial cables wherever they are exposed to the weather. Moisture entering the cable seeps under the jacket and eventually shorts the cable at a connector. Salt water reacts with the copper braid outer conductor causing corrosion and possible complete deterioration. This often occurs at bulkhead fittings and in areas where the water flow is restricted by pressure on the outer sheath. .The same situation exists with semi-flexible cables; however, the outer conductor is solid and not subjected to as rapid deterioration as is braid. Semi-flexible lines should be inspected for dents and crimps in the outer conductor that might affect the characteristic impedance of the cable. Defective coaxial cable lines should be replaced with complete runs without splices or connectors. In an emergency lines may be spliced, but they should be replaced at the first opportunity. If the line is pressurized it should be checked to determine that the specified pressure is being maintained. Loss of pressure indicates a leakage from loose fittings or holes in the outer conductor.

Connectors should be inspected for indications of arcing or burning. If either of these conditions is noted; or if testing indicates a fault, the connectors must be replaced. RF connectors exposed to the weather should be moisture proofed as outlined in MIL-HDBK-216—RF TRANSMISSION LINES AND FITTINGS, Section 3A. In this manual the third method outlined is most applicable to connectors used in the VHF/UHF coaxial transmission lines where a transposition is made from a larger to a smaller cable at the antenna. These junctions should be inspected for indications of loose tape and moisture. If the tape must be removed, it should be unwrapped rather than cut with a knife to avoid possible damage to the cable sheath.

2.2.3 WIRE ROPE ANTENNAS

Wire antennas should be inspected for corrosion, kinks, frayed strands and loose hardware. Kinked and frayed wire with broken strands should be replaced because they reduce overall tensile strength and tend to create RFI problems due to arcing and corona discharges when exposed to high energy rf fields. All antenna hardware, including patented terminating devices, turnbuckles and shackles, should be inspected for tightness, corrosion and wear. The bonding across mechanical junctions should be inspected for corrosion and tightness. The requirements for bonding are contained in MIL-STD-001310B (Ships)— SHIPBOARD BONDING AND GROUNDING AND OTHER TECHNIQUES FOR ELECTROMAGNETIC COMPATIbility and Safety, and in NAVSHIPS 0967-266-1010.

The dress of wire antennas is important. If the antenna is stressed too tightly it is subject to damage from ship movement. Excessive slack can introduce sufficient variations in the capacitance of the antenna to detune the system during ship's motion in a seaway.

Feed wires from coupler units or termination boxes to tuned antennas should be a minimum of 48 inches from metal surfaces. Feed wires from HF broadband fan type antennas should be installed in such a manner that insulators are not required to maintain separation from metallic mast structures. Insulators should be inspected for cleanliness, surface damage, and cracks in the insulating surfaces. If the insulators show evidence of soot or salt deposits they should be cleaned by washing with a dishwashing compound in a solution of fresh hot water until all surface dirt has been removed. A thin coat of Dow-Corning compound

No. 4 should be applied to the surface of the insulator. This compound forms a film which sheds water and reduces the formation of salt deposits and the accumulation of dirt. Similarly, threaded portions of antenna hardware should be coated with an anti-seizing compound.

Insulators with cracks and chips in the porcelain indicate possible failure and are depositories for dirt. They should be replaced.

2.2.4 WHIP ANTENNAS

Both fiberglass and metal whip antennas are currently installed on board ship. The metal types, made of aluminum, are mounted on a base insulator by means of a cast aluminum adapter piece. Some fiberglass types are mounted in this same manner; others are furnished with an integral fiberglass base insulator.

The metal types should be inspected for indications of metal fatigue, due to vibrations and flexing caused by ship's motion, loose section joints, and corrosion. Cracked or peeling paint accelerates corrosion especially on antennas that are subject to high temperatures and stack gases. Before repainting, the entire area should be cleaned thoroughly of old paint and corrosion. The area should be repainted in accordance with the procedures outlined in NAVSHIPS 0967-177-3020—SHIPBOARD ANTENNA SYSTEMS, ANTENNA INSTALLATION DETAILS for preparation and painting of aluminum surfaces.

Each metal whip must have a 1/8- to 3/8-inch drain hole at the base of the antenna to prevent moisture from accumulating within the antenna. In addition to accelerated corrosion due to entrapment of water, serious damage can result if water is allowed to collect and freeze during operations in cold climates.

The fiberglass types are subject to chips and cracks in the fiberglass which permit moisture to collect within the laminations. Moisture within the antenna, especially salt water, can cause corrosion of the metal strips of the antenna. In cold climates there is a possibility of lamination separation due to freezing. These antennas cannot be repaired in the field and should be replaced if severe cracks and lamination separation are experienced.

Particular attention should be given to the hold-down bolts on the base insulator and the aluminum adapter piece. The mounting surface of the base insulator is either bronze or a corrosion resistant metal that is compatible with the adapter piece. However, care must be exercised in selecting mounting hardware not to use metals which would be conducive to electrolytic action between the various components. A small magnet may be used to insure that mounting bolts are not manufactured from ferrous metals. Complete information on the correct assembly procedures and materials for the installation of whip antennas is outlined in NAVSHIPS 0967-177-3020.

The insulating surfaces of the base insulator should be inspected for dirt, salt crystal encrustation, paint and other foreign matter. If these conditions exist the insulator should be cleaned thoroughly as previously outlined for insulators. The insulator should be examined for cracks and chips; if cracks are evident, replacement is necessary since early failure can be expected due to the large mechanical loads placed on the insulator by ship's motion. The rf connection to the base insulator should be tight and free from corrosion. The insulator should also be inspected for entrapped moisture due to leakage around the mounting flange gasket.

The area in the vicinity of whip antennas should be examined to ensure the antennas are not fouled by ship's rigging and that antenna flexing in a seaway does not cause contact with ship's structures. Trussed whip and discone/cage broadband antennas are physically constructed of a support pole and wires. The mechanical tests for these antennas are similar to those described in the preceding paragraphs. However, due to the large number of mechanical and electrical joints in these antennas particular attention must be given to loose fittings and corrosion. The dress and stressing of the wire sections of these antennas are important in maintaining mechanical and electrical symmetry.

2.2.5 VHF/UHF AND PROBE ANTENNAS

VHF/UHF antenna assemblies and probe antennas such as those supplied with the AN/SRA-17 Antenna Coupler Group should be inspected for corrosion, dirt on the insulating surfaces, and loose mounting hardware. Particular attention should be given to the VHF/UHF antennas for indications of moisture leakage around the coaxial cable connector and assembly gaskets. Some antenna assemblies such as the AS-390/SRC are equipped with a pipe plug that may be removed to check for the presence of moisture. The antennas are subject to severe damage from freezing if moisture is allowed to collect within the assembly; therefore, if moisture is detected, the antenna must be disassembled, thoroughly dried out, all corrosion removed, and then reassembled with proper gaskets and sealants.

The probe antennas are supplied as an integral part of an assembly that consists of a mounting box containing a tuning unit and cable terminations. The whip should be inspected for corrosion and metal fatigue, the base insulator for dirt and cracks, and the mounting for loose hardware. The method of cleaning the base insulator is the same as for whip antennas.

2.2.6 MATCHING DEVICES

Narrowband antennas (single whips) are matched to their transmission lines by the tuning units in antenna coupler groups. These units are installed as close as possible to the antenna base insulator and are usually pressurized with nitrogen or dry air to prevent moisture condensation within the enclosure. A pressure indicator is installed on the outside of the unit to monitor the pressure. The external housing should be inspected for corrosion, dirty insulators, loose connectors and proper pressurization; however, this enclosure should not be opened unless difficulties within the unit are suspected. Careful attention must be given to the ground strap to make certain that it is free from corrosion and its terminations are tight. If opened, the unit should be inspected for corrosion, moisture, evidence of arcing or burning, especially on switches and rotary inductors, and loose connections. The unit should be cleaned thoroughly and any defective parts replaced. The unit must be resealed and pressurized prior to return to operational status. Shipboard broadband transmitting antennas generally require some method of matching the transmission line to the antenna so as to present no more than a 3:1 VSWR at the transmitter or multicoupler output. Many hf broadband transmitting antennas cannot satisfy the 3:1 VSWR criterion over the entire design bandwidth, without the aid of a matching network. The inductors and capacitors used in these networks are mounted in a metal box located as near as possible to the antenna feed point. Network enclosures generally are not pressurized because a box that can be pressurized is difficult to design with the large rectangular openings required for access to the components and the manipulation of tools within the box. It is also difficult to reestablish the seal once the access has been broken. Therefore network enclosures are designed to be splash proof but not airtight. A drain hole is provided in the bottom of the box to drain off any moisture that might accumulate from condensation due to cyclic temperature and pressure changes. If this drain becomes clogged, moisture will accumulate and eventually cause failure of the network.

The exterior of the unit should be inspected for corrosion, cracked and dirty insulators, and loose connections. The interior should be inspected for moisture, loose and corroded connections, and indications of arcing expecially across inductors and end seals. All signs of corrosion should be removed and all connections cleaned and tightened. Care must be exercised not to disturb the settings of the network components since the special instrumentation required for correct adjustment of the system is not always available on board ship.

2.2.7 ANTENNA TILTING DEVICES

Aircraft, VERTREP, helicopter, and ordnance operations require that antennas installed in certain areas be equipped with tilting devices to reduce their vertical height so as not to interfere with the aircraft. There are several designs for tilting devices; some are operated manually while others are operated hydraulically or electrically. Manual types must be counterbalanced to operate properly. Both types require positive locking devices in the horizontal and vertical positions. All moving joints must be fitted with electrical bonding straps. The tilting mechanisms should be inspected for rust and corrosion, worn or damaged parts, proper lubrication on all moving parts, and loose fittings and connections. The connection between the matching network or coaxial cable line termination and the base insulator must be free from kinking or stretching during operation. The area in the vicinity of the tilting mechanism must be kept free of any temporarily stowed items or other obstructions that would prevent raising or lowering the antenna.

2.3 ELECTRICAL TESTING AND MAINTENANCE

Ship's force electrical testing includes VSWR, continuity, and resistance measurements. Shipboard test equipment allowance lists do not include instrumentation for measuring antenna system impedances, patterns or gain.

2.3.1 INSTRUMENTATION AND PROCEDURES

The VSWR indicators installed in transmitters and multicouplers are used for equipment adjustment and monitoring. The ship should keep a log of VSWR readings near the transmitter or multicoupler terminal of the system coaxial transmission line. The readings should be obtained using an in-line SWR indicator at approximately five evenly spaced frequencies in the design band of each antenna. The log will indicate any changes to the antenna and its associated coaxial transmission line and coupling or matching networks. An increase in VSWR is usually the first indication of a system malfunction. (In certain instances an increase in VSWR may be caused by energy coupled from adjacent antennas.)

Variations in a narrowband, e.g. single whip antenna, system may be attributed to the transmission line, coupler or the antenna; therefore, each individual section must be checked to determine the problem.

Ship's force action in the case of failure is normally limited to the replacement of coaxial cables, connectors, tightening loose connections and the replacement of antenna fittings.

The instrument used for continuity and resistance measurements on coaxial cables and antenna insulators is a constant voltage megohmmeter (Megger) such as the AN/PSM-2 shown in Figure 2-2.

This instrument develops an output voltage of approximately 500 volts and is capable of measuring resistance values from zero to several hundred megohms. Because of the output level of this instrument it must not be connected to any

SHIP'S FORCE TESTING AND MAINTENANCE

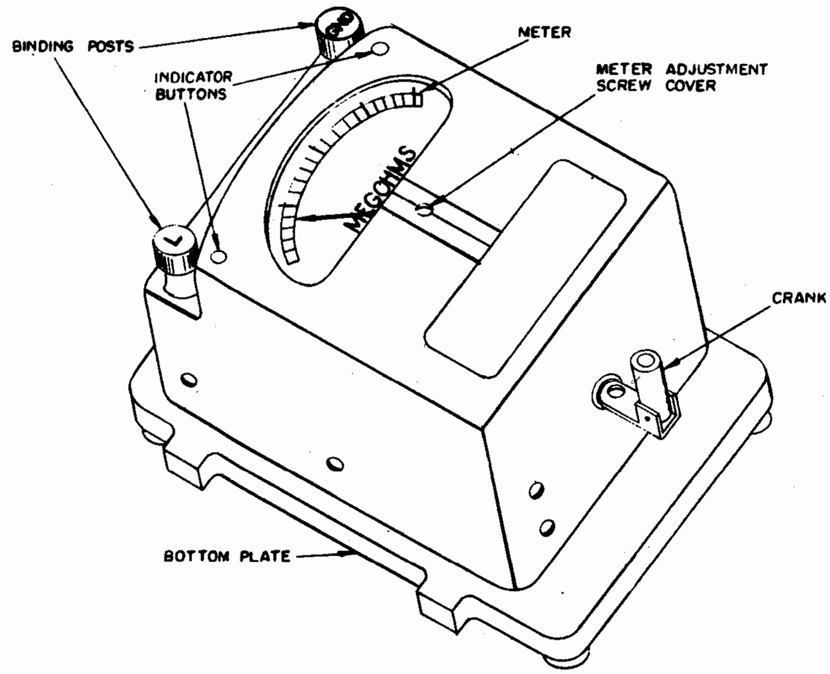

Figure 2-2. AN/PSM-2 Constant Voltage Megger

equipment. Prior to use the Megger must be checked and adjusted in accordance with its technical manual. During use the crank should be operated at a constant rate until the output level indicators are actuated. Care should be exercised that all test lead connections are making good contact. Safety precautions must be observed to prevent personnel from coming in contact with the test leads or the circuit under test while the Megger is in operation.

Power measurements are generally limited to the VHF/UHF ranges and may be accomplished with a power meter such as the AN/URM-43. A portable dummy load may be used for insertion at various points in the system to check coaxial transmission lines. When the dummy load is used the power output of the transmitter must not exceed the capabilities of the device. The AN/URM-43 RF WATTMETER shown in Figure 2-3 is a typical instrument used to perform power measurements.

All test data should be logged so comparisons can be made with previous data to show any abnormal deviations. Large variations in any system should be investigated to determine the cause and the corrective action necessary to prevent possible failure.

2.3.2 COAXIAL CABLE TRANSMISSION LINES

Prior to performing electrical tests on a coaxial cable it is necessary to isolate the line by disconnecting it at both ends since some antennas operate at dc ground potential. Care must be exercised to ensure that all equipment, including matching networks, static drain resistors, and chokes used in receiving antenna systems, have been isolated from the cable.

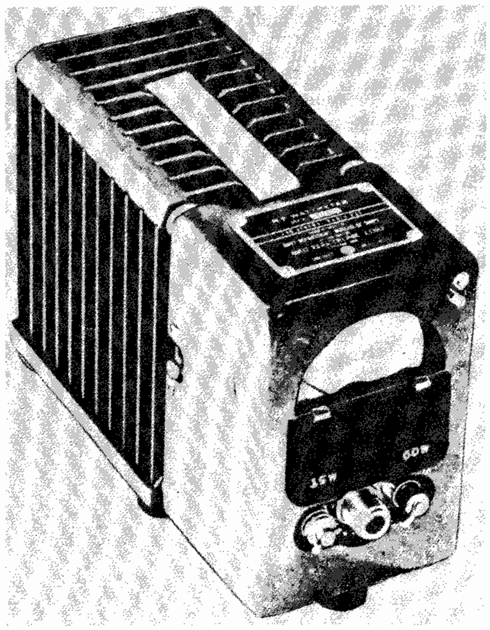

Figure 2-3. AN/URM-43 RF WATTMETER

Continuity measurements are made in the following manner: (See Figure 2-4.)

1. Disconnect the cable at both ends.

2. Connect a shorting bar between the inner and outer conductors at one end of the cable.

3. Measure the resistance between the inner and outer conductors at the other end.

This value should be less than one ohm depending on the cross section and length of the cable. A high resistance or open reading indicates a faulty inner or outer conductor or defective connectors. A check of the individual conductors may be made as follows:

1. Remove the shorting bar.

2. Short the inner conductor to ground, (ship's hull).

3. Connect the instrument to the inner conductor and the ship's hull at the other end of the cable.

4. Measure the resistance.

5. Repeat with the outer conductor.

Resistance readings should be less than three or four ohms depending on the cross section and length of the cable and the ship's hull resistance. If high resistance readings exist and are not remedied by connector repair or replacement, the line is defective and must be replaced. Figure 2-5 demonstrates the instrument connections for resistance tests.

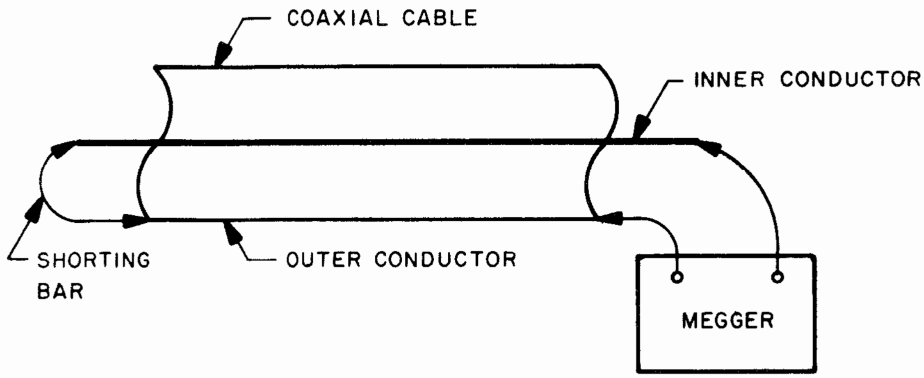

Figure 2-4. Continuity Test Instrument Connections

The condition of the cable dielectric and the insulation in the connectors is determined by resistance tests. Resistance tests may be accomplished in the following manner:

1. Disconnect the cable at both ends.

2. With the cable open at both ends, connect the Megger between the inner and outer conductors.

3. Measure the resistance between the conductors.

Readings in excess of 40 megohms indicate that the dielectric and the connectors are in good condition. If resistance readings of less than this value are experienced, the connectors should be examined for signs of arcing and burned insulation.

Defective connectors must be replaced. Care should be exercised in the assembly of coaxial connectors. The correct assembly procedures for all types of coaxial connectors is outlined in MIL-HDBK-216. If low readings persist after determining that the connectors are satisfactory and test equipment is not malfunctioning, then the line is defective and must be replaced.

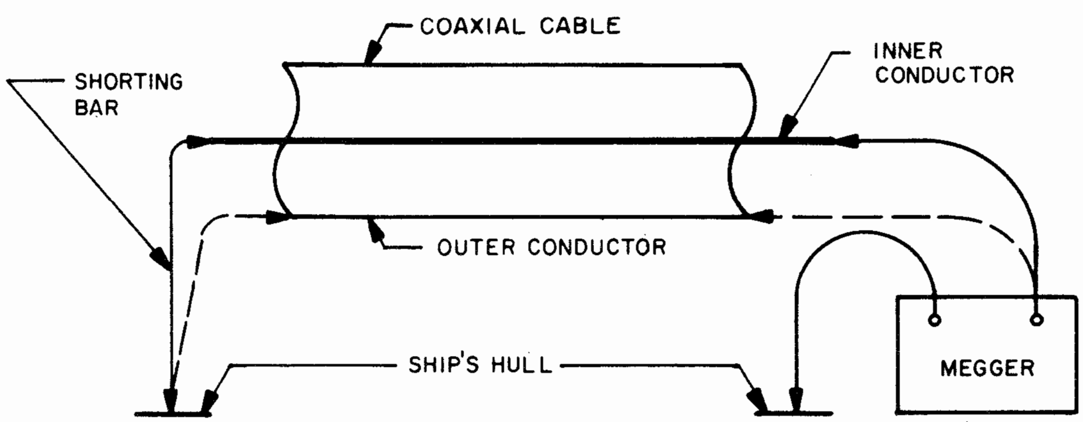

Figure 2-5. Resistance Test Instrument Connections

Resistance and continuity tests are conducted using the dc voltages and do not provide an indication of the cable's operating condition at radio frequencies. Coaxial cables normally operate at rf and are designed with a characteristic impedance. Variations of this impedance caused by discontinuities such as fluctuations in diameter, ellipticity of the core or centering of the inner conductor and connectors along the line can result in reflections or standing waves on the line. If the cable has been determined satisfactory as far as continuity and resistance measurements are concerned, it can be tested for operation at rf if a dummy load is available. The load should first be connected to the output of the transmitter or multicoupler and the equipment tuned for minimum VSWR. The dummy load is then disconnected and the line connected to the transmitting equipment. The dummy load is then connected to the other end of the line and VSWR readings are taken without changing the tuning of the transmitting equipment. If the line is in good condition there will be no appreciable change in the VSWR readings. While testing, the transmitter output power must not be allowed to exceed the capability of the dummy load.

2.3.3 WIRE ANTENNAS

Wire antennas insulated from ground are tested electrically by connecting the Megger across the input connection and ground. The antenna must be isolated by disconnecting it from the system. This test establishes the leakage across the insulators. A resistance of 100 megohms or greater indicates that the insulators are in good condition. Lower readings can be expected on wet or humid days; since this is not a good indication of the condition of the insulator, Megger tests should be conducted on dry days. Assuming that the insulators have been cleaned thoroughly and treated as outlined in paragraph 2.2.3, resistance values of less than 35 megohms indicate defective insulators. Each insulator in the antenna must then be checked individually and defective insulators replaced. The insulated sections of wire antennas operated at dc ground potential must be tested individually. It may be necessary to disconnect each insulator and test by connecting the Megger across it. The resistance values should be 100 megohms or greater. If the insulators have been cleaned and treated, those with resistance values of less than 35 megohms should be replaced. All mechanical and electrical connections disturbed during testing must be redone with care so no discontinuities will be introduced into the antenna. Figure 2-6 shows a typical wire rope insulator arrangement.

2.3.4 WHIP ANTENNAS

The base insulator of a whip antenna is tested for leakage by connecting the Megger between the input connection and ground. Prior to testing, the input connection must be disconnected from the system. Resistance values of 100 megohms or greater indicate that the insulator is in satisfactory condition. If readings of less than 35 megohms are experienced after the insulator has been cleaned and checked for entrapped moisture, it should be replaced. Trussed and twin whip antenna base insulators are tested in the same manner.

2.3.5 VHF/UHF AND PROBE ANTENNAS

VHF/UHF antenna assemblies, such as the AT-150/SRC and AS-390/SRC, are designed to operate at dc ground potential. Electrical tests on this type of antenna are limited to continuity tests between the inner and outer conductors of the coaxial cable input connector. The instrument should indicate zero ohms, a short, if the antenna is in good condition. Resistance measurements on this type of antenna should be made with an ohmmeter rather than a Megger because of possible damage to matching networks from high voltage developed by the Megger.

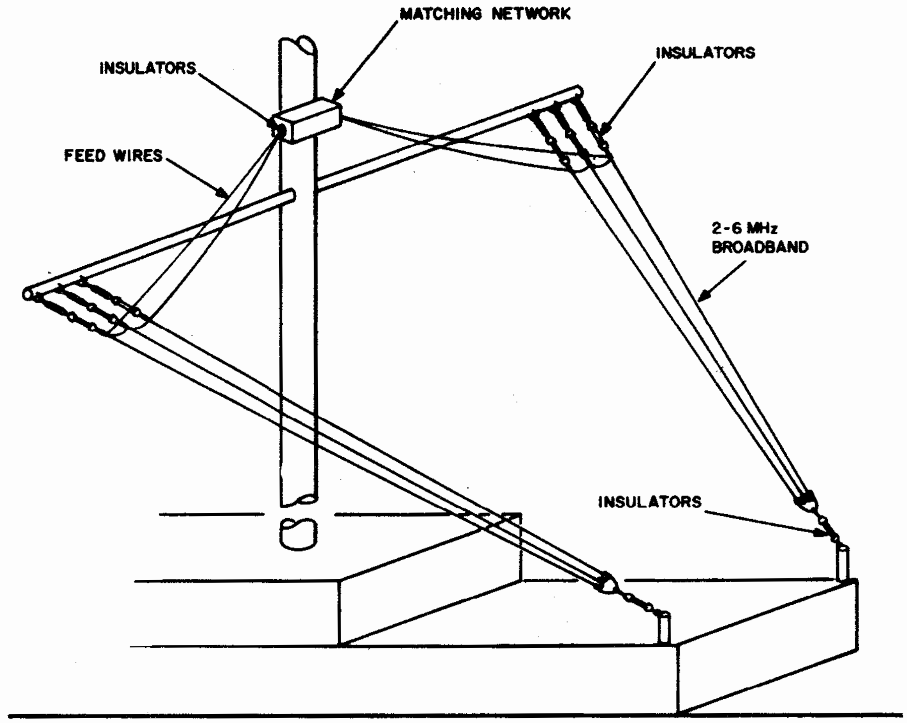

Figure 2-6. Typical Wire Rope Insulator Arrangement

VHF/UHF dipole antennas not operated at dc ground potential are tested by connecting the Megger across the inner and outer conductors of the coaxial cable input connector. This test establishes the leakage value across the insulator on the radiating element and the insulating spacers within the body of the antenna. These antennas normally have one dipole section at dc ground potential. The resistance readings should be 100 megohms or greater. A continuity test should be made between the inner conductor of the coaxial connector and the insulated dipole to insure that the mechanical and electrical connections within the antenna are in good condition.

These tests determine that the antennas are satisfactory insofar as continuity and insulator properties are concerned. They do not provide assurance that the antennas will operate satisfactorily on their designed operating frequencies. If difficulties are experienced in loading an antenna, or high VSWR readings are noted, the system may be tested using an rf power meter such as the AN/URM-43. This instrument is essentially a 50-ohm dummy load with an indicating meter calibrated to read in watts. The procedure for this test is similar to the method outlined for testing coaxial cables with a dummy load. The power meter is connected to the output of the transmitter or multicoupler and the system is tuned to maximum power output reading. Since the load is 50 ohms, low VSWR reading (less than 2:1) should be indicated. The power meter is then disconnected from the transmitting equipment and the coaxial transmission line is connected in its place. The power meter is then connected to the other end of the transmission line, and, without changing the transmitting equipment tuning, power meter and VSWR readings are noted. Assuming that the transmission line is in good condition, the power meter readings should be approximately the same as indicated at the transmitting equipment end. Any loss may be attributed to the length of the line. The VSWR readings should remain the same. The power meter is now removed; the antenna is connected to the transmission line and VSWR readings are noted. The VSWR should be approximately the same as with the power meter if the antenna is in good operating condition. These antennas are broadband types and some variation of VSWR may be expected depending on the frequency used during the tests. To minimize variations during testing, a frequency close to the center of the antenna design bandwidth should be selected. If large VSWR variations are noted, the antenna is defective and requires repair or replacement. The power meter may be connected into the system as shown in Figure 2-7.

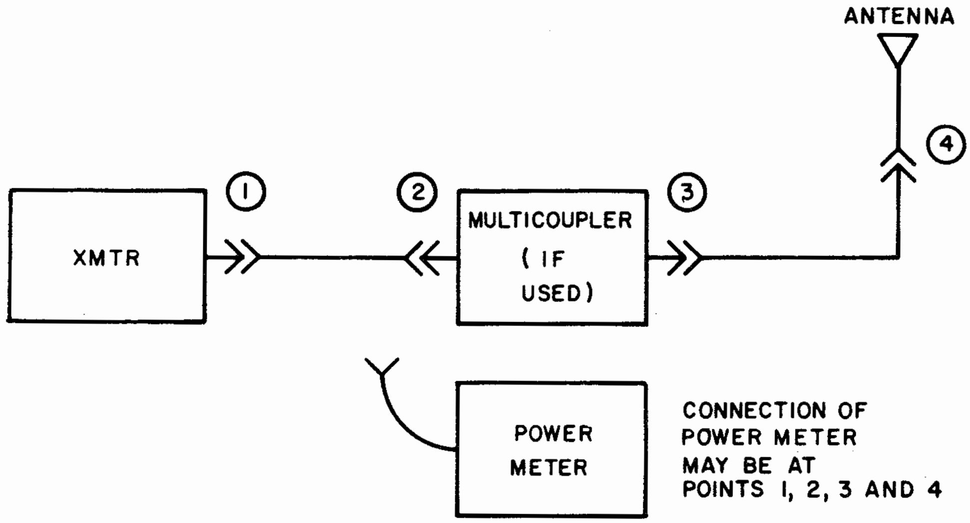

Figure 2-7. Power Measurement Instrument Connections

If the base insulator of a probe antenna is suspected of being faulty it may be tested for leakage by connecting a Megger between the antenna connection and ground. The antenna connection must be disconnected from the remainder of the system prior to connecting the Megger. The insulator should have a resistance reading of 100 megohms or greater for a satisfactory condition. Readings of 35 mehohms or less indicate that replacement is required.

2.3.6 COUPLING AND MATCHING DEVICES

Electrical tests for antenna couplers that are components of a system such as the AN/URA-38 are outlined in the technical manual and MRC for the specific equipment. The antenna feed through insulator should be tested for leakage with a Megger as outlined for probe antennas only if the insulator is suspected of being faulty.

Matching networks used with broadband antennas may be tested for continuity and leakage. The feedthrough insulator on the output side of the network is tested for leakage by connecting a Megger between the antenna connection and ground. The connection must be isolated from the antenna and the network circuitry prior to performing this test. The resistance values should compare with those noted for base insulators listed in the preceding section.

The circuit configuration of the network will determine the type and method of performing any additional electrical tests. The circuitry may provide dc paths to ground through inductors or it may be insulated from ground by capacitors. There may be inductors in series with the transmission line and the antenna terminal that permit continuity between these points. Inductors should be tested for continuity and capacitors for short circuits with an ohmmeter.

All stand-off insulators and insulating material should be checked for leakage with a Megger. Defective parts should be replaced. However, replacement parts may be limited since each network is developed for a specific antenna and may contain parts that are not normally included in the ship's spare parts allowance list. Ship's personnel are cautioned not to disturb the tuning adjustments of matching network components because the test equipment necessary for adjustment is not available on board ship. All connections disturbed during testing must be carefully redone. Care must be taken not to replace nuts, bolts or washers with ferrous types.

2.3.7 ANTENNA TILTING DEVICES

Electrical tests for antenna tilting devices are confined to those that are electrically operated. The electric drive motors and control circuits should be tested with a Megger or ohmmeter for grounds caused by moisture and vibration. Prior to performing any tests, the power must be disconnected at the distribution panel and the switch tagged in accordance with standard safety procedures. Defective motors, wiring and switches should be repaired or replaced.

SECTION 3

SUPPORT ACTIVITIES TESTING AND MAINTENANCE

3.1 GENERAL.

Testing and maintenance services available from support activities augment the efforts of ship's force in maintaining the ship's communication antenna system at its maximum operational capability. This support is available from facilities of industrial activities, field engineering services, and model range studies. Industrial activities are utilized for mechanical maintenance and repair requirements beyond the capabilities of the ship's force. Field engineering services provide assistance in solving technical problems and performing tests and calibrations that require instrumentation not available to ship's force. Model range studies are used to determine the effects of ship's structure changes in the vicinity of the antennas, to test antennas and matching networks, and to develop antenna systems to satisfy expanded operational requirements of the fleet.

The HF portion of the spectrum is used by naval ships to satisfy a major part of communication requirements. The space available on board ship is not sufficient to provide a one-equipment one-antenna configuration within this band. Broadband antennas in conjunction with multicouplers furnish an adequate number of antenna connections having the required channel isolation, impedance, and radiation patterns. The use of broadband antennas with their specific requirements for installation, tuning and maintenance necessitates an understanding of these systems and associated matching networks. (Broadband antenna design is covered in NAVSHIPS 0967-177-3010 SHIPBOARD ANTENNA SYSTEMS, COMMUNICATION ANTENNA FUNDAMENTALS.) The following sections will outline HF broadband antenna systems.

3.2 BROADBAND ANTENNA SYSTEMS.

The number and range of frequencies required and the limited space available on board ship make it desirable to use broadband antennas wherever possible. (VHF/UHF antenna assemblies are designed for a 2:1 bandwidth.) Fleet use of VHF communications is generally on a one-antenna one-equipment basis. However on amphibious class ships multicouplers are used to allow as many as four transmitters to be operated into single or arrayed antennas. In the UHF range multicouplers are nearly always used because of the limited number of antennas available for the number of operational frequency channels required.

Typical HF transmitting, broadband, multicoupled systems allow up to eight transmitters to be coupled to a single antenna in a 3:1 bandwidth. Typical HF receiving broadband antenna systems allow as many as twenty receivers to be connected to a single antenna for a variety of frequency bands within VSWR limits of 5:1. At the lower frequencies (2-3.5 MHz) the VSWR for receiving broadbands will exceed 5:1 because of the limitations in the size of the antennas. However, this can usually be tolerated because of the high noise levels in this frequency range.

HF broadband antennas usually occupy the most desirable available antenna locations on the ship and are capable of carrying most of the HF circuits critical to efficient ship operation with a marginal backup capability if the broadband system fails. Therefore, every effort must be made to keep the broadband system in good operating condition. Since ship's topside structures are of the size and shape to become part of the HF radiators, every ship class must be custom fitted with its own broadband antenna suit.

Many HF broadband transmitting antennas on ships do not satisfy inherently the 3:1 VSWR criterion over the entire design band, so a broadband matching network is required between the transmission line and the antenna feed point.

3.2.1 BROADBAND ANTENNA MATCHING DEVICES.

If the impedance of an antenna does not equal the impedance of the transmission line supplying power to it, the antenna is mismatched. When a mismatch occurs some of the energy is reflected back along the line creating standing waves. Standing waves represent power losses; therefore, VSWR must be kept to a minimum.

An impedance match is not difficult to obtain when the antenna is designed to operate on one frequency; however, in shipboard broadband systems some compromise must be made to permit operation over a broad bandwidth and still keep the VSWR within the specified limitations. This is accomplished by allowing the VSWR to increase to within a predetermined value, usually on the order of 3:1 for transmitting antennas. VSWRs no greater than 3:1 are generally obtainable over a 3:1 frequency range by the use of an antenna matching network, and this variation is compatible with multicoupler output impedance requirements.

A 3:1 VSWR over each frequency range will be used in the examples describing the development and application of matching broadband antennas. The design requirements will involve shifting or warping the impedance curves as plotted on a Smith Chart, within a circle representing a 3:1 VSWR. (The use of Smith Charts is described in NAVSHIPS 0967-177-3010, Appendix C.)

Two impedances are matched when they have the same magnitude and phase. In Figure 3-1(a) the load impedance Z_L is matched to the generator impedance Z_S if the load impedance equals the generator impedance. If the two impedances are not equal, it is possible to obtain a match by using a network having $Zi_1 = Z_s$ $Zi_2 = Z_L$ and near zero attenuation, as shown in Figure 3-1(b).

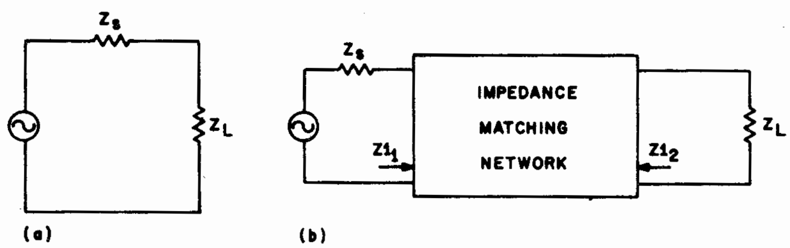

Figure 3-1. Impedance Matching

There are several types of matching networks. Lumped constant networks, consisting of either capacitors or inductors, or combinations of both, are the most commonly used in shipboard broadband systems and can be calculated with reasonable accuracy. The simplest method of matching with lumped constants is to use either an inductor or a capacitor in series with the antenna. If a match is not obtainable with a series configuration it may be necessary to use an "L", "T", or "PI" network. These types are shown in Figure 3-2.

In applications involving extreme bandwidth, care must be taken to avoid selectivity in the antenna matching network. The smaller the amount of stored energy in all the reactive elements, the less selectivity the network will have. It is for this reason that series configurations should be considered first, then the "L", as stored energy is kept low. However, the completed network may have to be finalized as a "T" or "PI" due to impracticability of using values arrived at in the development of the series or "L" types.

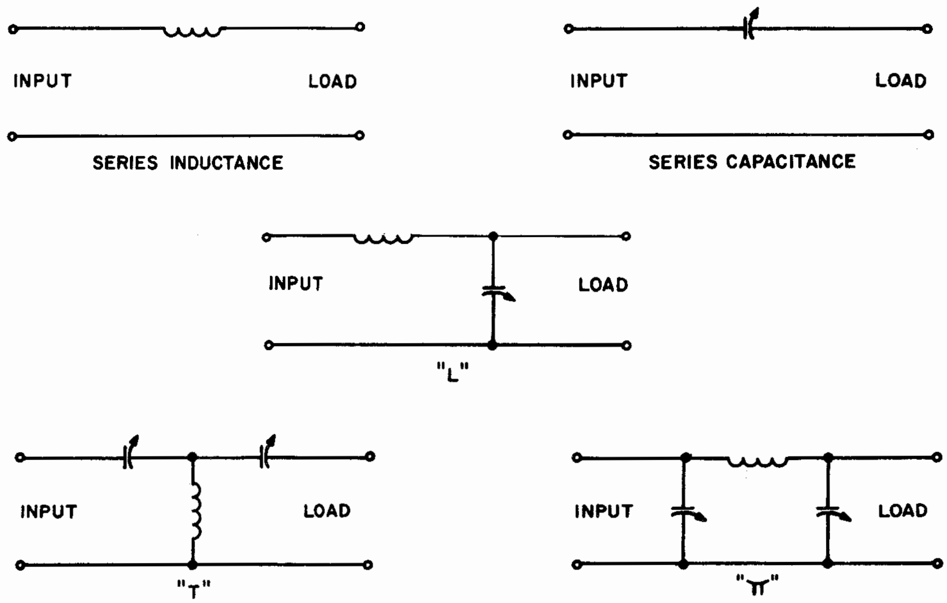

Figure 3-2. Typical Matching Networks

3.2.1.1 DEVELOPMENT OF MATCHING NETWORKS.

The range of frequencies covered by a broadband antenna presents difficulties in developing a network because there is no set procedure for establishing a frequency point from which to start in the calculation of the network. Each antenna has its own inherent characteristics and the impedance plots will be different.

The antenna impedance at a specific frequency may be expressed as a complex number R+jX and may be plotted on an R-X diagram having abscissa R and ordinate X. The antenna impedance, Z_a, determined at each frequency, may be plotted and connected with a curve as in Figure 3-3.

When an antenna impedance must be matched over a broadband of frequencies a complete match may not be feasible. However, compensation may be accomplished to keep within the predetermined VSWR. This limit is shown graphically and is called a definition circle as depicted in Figure 3-3. Assuming a transmission line impedance, Z_o, of 50 ohms is to be used with a VSWR limit of 3:1, the R intercepts are at 16.6 and 150. This is given by:

$$Z_o/\text{VSWR} = 50/3 = 16.6$$

and,

$$Z_o(\text{VSWR}) = 50 \times 3 = 150$$

It can be seen from Figure 3-3 that by adding inductance or capacitance in series with the antenna the impedance curve can be moved up or down through the definition circle. Thus the dotted lines represent the series boundaries, i.e., if the impedance curve falls within these lines, by adding a series component, the curve can be shifted to come within the definition circle, and therefore, within the allowable VSWR. In the case of Figure 3-3, by adding inductance in series with the antenna, the capacitive reactive component will be balanced out and the curve will shift upwards. It can also be seen from this figure that if the antenna impedance curve should lie outside the series boundary lines the adding of inductance or capacitance will have no effect on transforming the

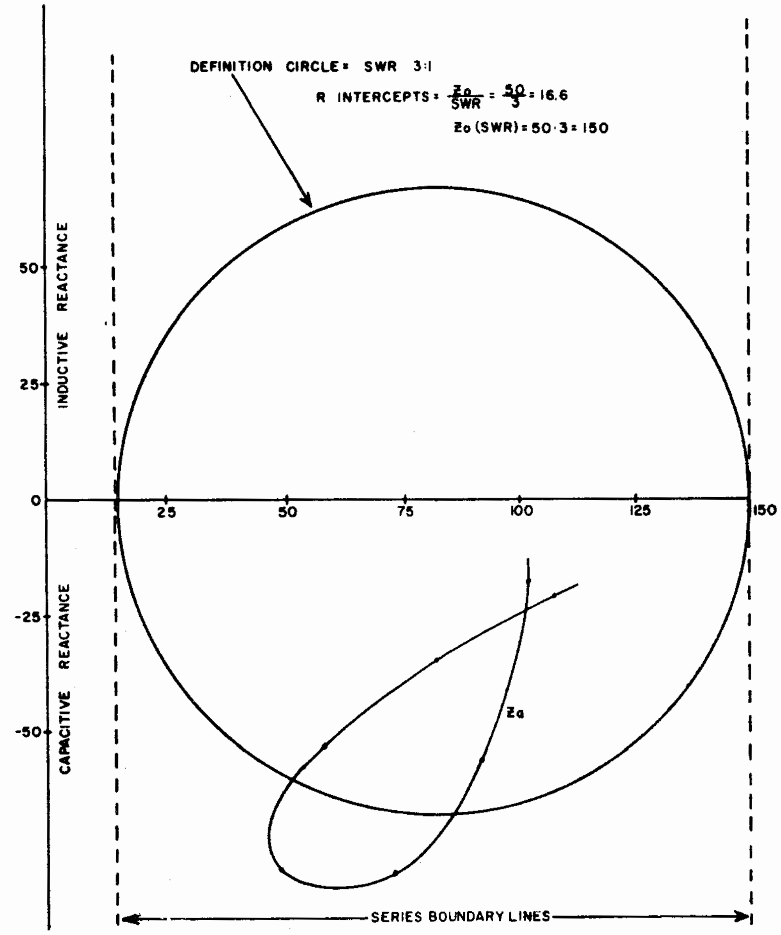

Figure 3-3. R-X Diagram Showing Definition Circle and Series Boundaries

curve to come within the definition circle. In these cases it may be necessary to use parallel components to make the transformation.

In Figure 3-4, a definition circle is shown representing a VSWR of 3:1. This circle is constructed by using 1.0 on the resistance component scale as a center and a radius of 3.0. Circle A is constructed by locating its center on the resistance component line, R/Zo, and is tangent to the definition circle at the maximum R value and passes through the point of infinity. Circle B is constructed by locating its center on the resistance component line, R/Zo, and is tangent to the definition circle at the minimum R value and passes through the point of infinity. The area between the circumferences of these two circles represents the series boundaries. If the antenna impedance curve falls within the definition circle or the shaded area, as shown in Figure 3-4, the curve can be transformed, within certain frequency limitations, to come within the circle using series components. Various points of the impedance curve that may lie outside the shaded area may be transformed to come within the definition circle through the use of parallel reactance components. These cases are covered in the latter part of this section. It can be seen in Figure 3-5 that by adding an inductive reactance in series with the antenna, the impedance curve can be made to shift in a clockwise direction to come within the definition circle. The value of inductance necessary to accomplish this shift can best be determined by selecting one frequency point and determining the amount of inductance required to

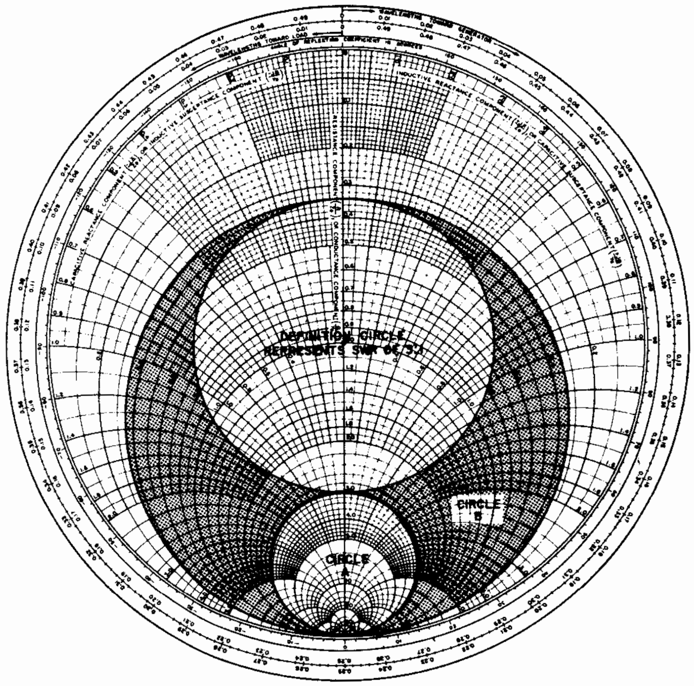

Figure 3-4. Smith Chart Showing Definition Circle and Series Boundaries

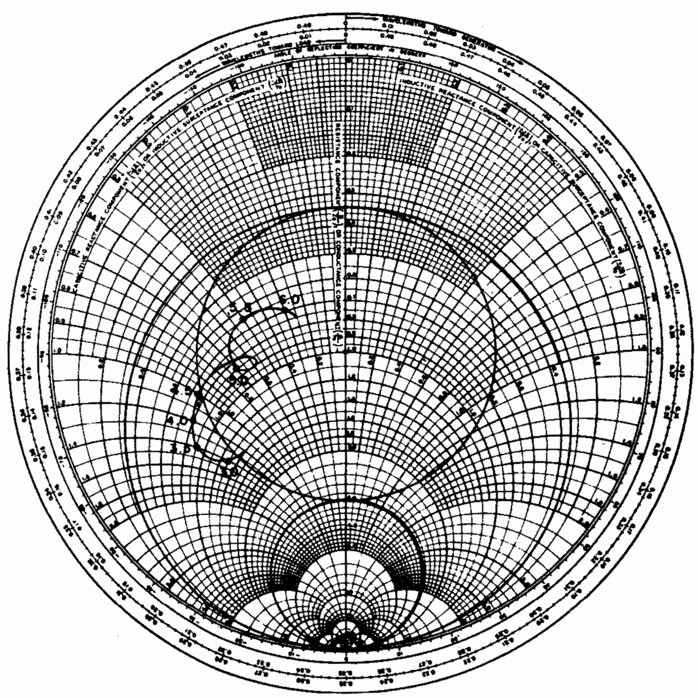

Figure 3-5. Antenna Impedance Curve

shift it to fall within the definition circle. It can be determined, using the same value of inductance, what effect it has on the points at the other frequencies. The following examples explain how several points may have to be tried before complete transformation can be realized.

Example 1:

Figure 3-6 shows the impedance curve of an antenna designed to operate between 3 and 6 MHz. The measured impedance is shown as Curve (a). This antenna is to be matched to a transmission line having a characteristic impedance, Zo, equal to 50 ohms.

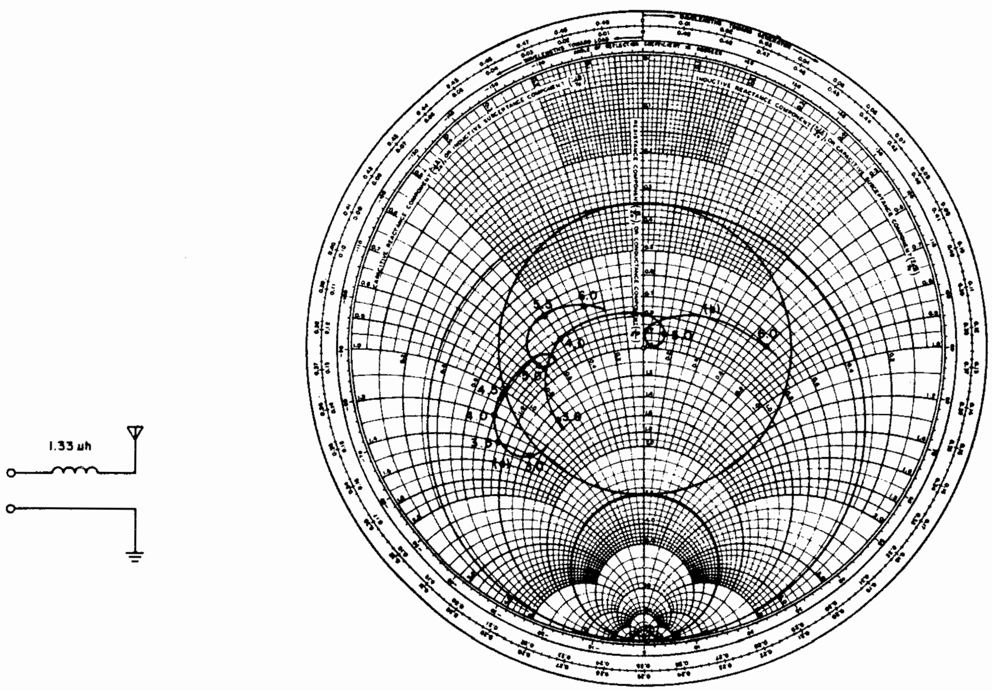

Figure 3-6. Curves for Example 1

It may be seen from this curve that the 3 to 4.5 MHz portion of the impedance curve does not fall within the 3 to 1 VSWR definition circle. The objective is to bring the entire curve, as nearly as possible, within the definition circle.

Referring to Figure 3-4, the portion falling outside the definition circle is well within the series boundaries. In this particular case the adding of inductance in series will create a shift in a clockwise direction. It must be remembered, however, that any change in the impedance at a particular frequency will affect the curve at all other frequencies.

If the point representing 6 MHz is moved along the R/Zo value of 0.7 from the -jX/Zo = 0.3 to the point jX/Zo = 0.7, it would have the resultant effect of adding inductive reactance in series with the antenna. This may be shown as follows:

$$\text{Distance moved} = \text{Final point} - \text{Initial point or,}$$
$$jX/Zo = j0.7 - (-j0.3) = j1.0$$

$$\text{Since } Zo = 50 \text{ ohms,}$$
$$jX = 50\ (j1.0) = j50 \text{ ohms}$$

The required inductance is found as follows:

$$X_L = 2\pi f L = 2\pi(6\text{x}10^6)(L) = 50$$

$$L = \frac{50}{2\pi(6 \times 10^6)} = 1.33\mu h$$

The effect of this inductance at the other frequencies may be found by calculating X_L and jX/Zo at these frequencies and adding them (with proper respect for signs) as was done for the 6 MHz point. However, since inductive reactance, and hence jX/Zo, is proportional to frequency, a proportion may be established to yield the other points. To illustrate, the normalized reactance at 4 MHz will be calculated by this method:

$$\frac{\frac{jX_2}{Zo}}{\frac{jX_1}{Zo}} = \frac{f_2}{f_1}$$

$$\frac{jX_2}{Zo} = \frac{f_2}{f_1}\frac{jX_1}{Zo} = \frac{4 \times 10^6}{6 \times 10^6}(1.0) = .667$$

If desired, a conversion chart such as that shown in Figure 3-7 can be constructed from the data calculated thus far. The horizontal axis represents frequency and the vertical axis represents jX/Zo. Having the points (f=6 MHz, jX/Zo=1.0) (f=4 MHz, jX/Zo=.667), a line is drawn connecting them as shown. Values of jX/Zo can then be determined from the chart for as many points as desired.

To determine the new impedance curve, it is now merely necessary to add the values of jX/Zo as read from the chart to the value as plotted on the Smith Chart (observing the proper sign).

The new point representing 5.5 MHz is -0.5 + 0.916 = 0.416. (Note that the sign has changed indicating that the R/Zo axis has been crossed.) In a similar manner all other points are determined. A smooth curve is then drawn so as to include these points. This is shown as Curve (b) in Figure 3-6. It may be seen that the entire curve is now within the 3 to 1 VSWR definition circle, thus accomplishing the match. It may be noted at this point that if it had been decided initially to move the point representing 4.0 MHz inside the definition circle but it had been moved too far, it would have forced the high end of the curve outside the definition circle, thus defeating the objective. A circuit diagram of the matching network is also shown in Figure 3-6.

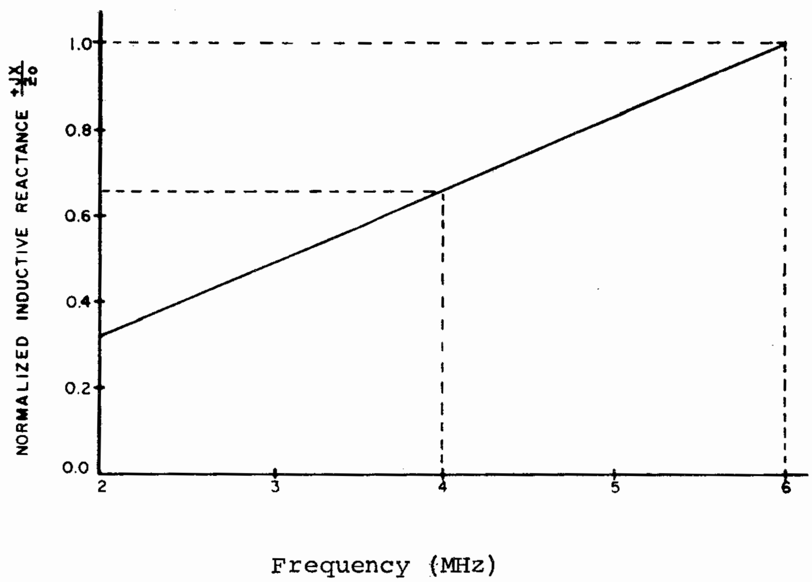

Figure 3-7. Frequency-Reactance Chart

It must be remembered that this resultant curve is only a prediction. Only an impedance measurement of the antenna after a matching device has been designed and installed will reveal whether or not an acceptable impedance match has been obtained. The components used in matching networks will usually be made variable to provide some adjustment.

Example 2:

Figure 3-8 shows the impedance of an antenna designed to operate between 7 and 12 MHz. The measured impedance is shown as Curve (a). This antenna is to be matched to a transmission line having a characteristic impedance, Zo, of 50 ohms.

It may be seen that the entire impedance curve lies outside the 3:1 VSWR definition circle. Again, the objective is to bring the entire curve, as near as possible, inside the definition circle. Since the impedance curve lies inside the series boundary (refer to Figure 3-4), it is possible to make this shift in impedance by a single series element. It must be again remembered, however, that any change in impedance at a particular frequency will also affect the curve at all other frequencies.

If the point representing 7 MHz is moved along the line R/Zo = 0.8, from jX/Zo = 2.0 to jX/Zo = 0.2, the effect is that of adding capacitive reactance in series with the antenna. This may be shown as follows:

$$\text{Distance moved} = \text{Final point} - \text{Initial point or,}$$
$$jX/Zo = j0.2 - j2.0 = j1.8$$

$$\text{Since } Zo = 50 \text{ ohms;}$$
$$jX = j1.8(50) = -j90 \text{ ohms}$$

The required capacitance is found as follows:

$$Xc = \frac{1}{2\pi fC} = \frac{1}{2\pi\ (7\text{x}10^6)C} = 90$$

$$C = \frac{1}{2\pi(7\text{x}10^6)(90)} = 253 \text{ pf}$$

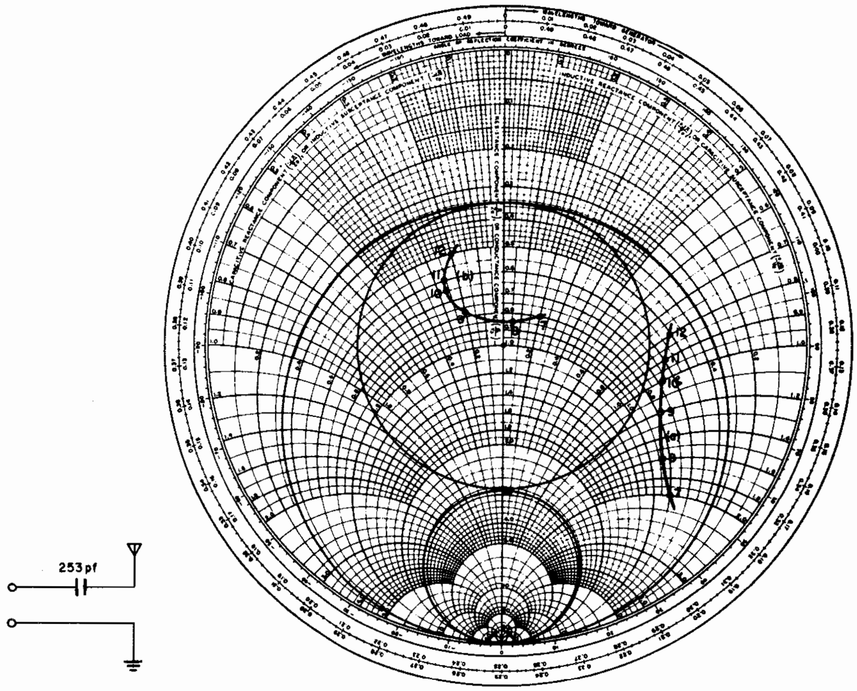

Figure 3-8. Curves for Example 2

To find the effect of this capacitance at the other frequencies, it is necessary to calculate X_c and jX_c/Zo at these frequencies and add them, with proper respect for sign, as was done for the 7 MHz point. However, since capacitive reactance, and hence jX_c/Xo, is inversely proportional to frequency, a proportion may be established which will yield the other points. To illustrate, the normalized reactance at 12 MHz will be calculated by this method.

$$\frac{\frac{jX_2}{Zo}}{\frac{jX_1}{Zo}} = \frac{f_1}{f_2}, \quad \frac{jX_2}{Zo} = \frac{f_1}{f_2} \quad \frac{jX_1}{Zo} \doteq \frac{7\ (1.8)}{12} = 1.07$$

If desired, a conversion chart such as that shown in Figure 3-9, can be constructed from the data calculated so far. The horizontal axis again represents frequency and the vertical axis represents jX/Zo. Having the two points (f = 7 MHz, jX/Zo = 1.8) (f = 12 MHz, jX/Zo = 1.07), they are connected with a straight line as shown. Values of jX/Zo can be determined for as many frequencies as desired.

To determine the new impedance curve, it is now merely necessary to add values of jX/Zo as read from the chart to the value as measured on the Smith Chart (with careful attention to sign).

The new point representing 10 MHz is 1.0 + (-1.28) = 1.0 - 1.28 = -0.28. Since the sign is negative, the point lies to the left of the R/Zo axis. In a like manner, as many other points as desired may be established. A smooth curve drawn to include these points is the new predicted impedance curve. This is illustrated by Curve (b) in Figure 3-8. Experience or trial and error may

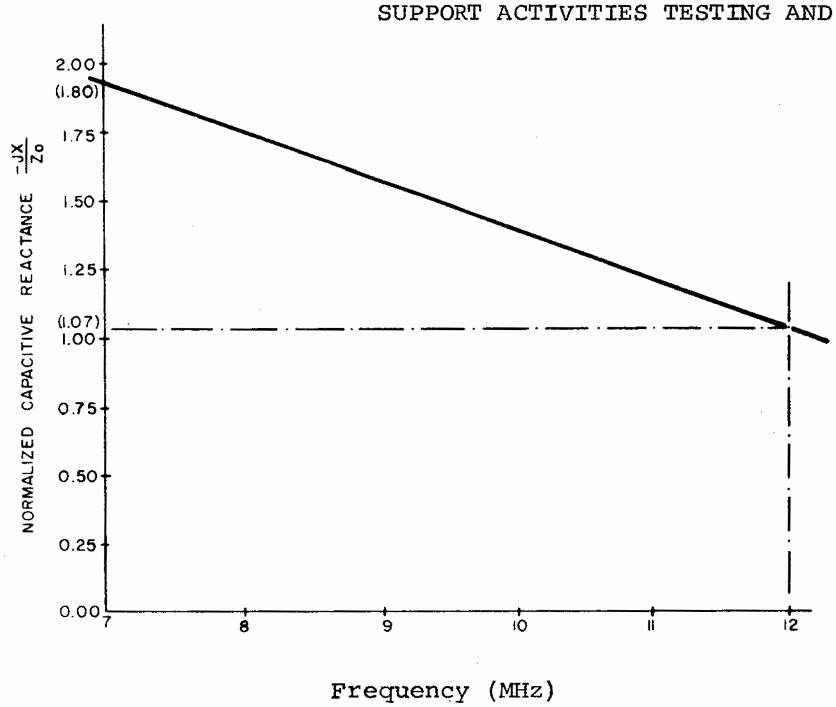

Figure 3-9. Frequency Reactance Chart

be relied upon to determine the optimum value of capacitance to achieve the lowest possible VSWR. Note, however, that the entire curve has now been shifted within the 3:1 VSWR definition circle.

A circuit diagram of the matching network is also shown in Figure 3-8. Figure 3-10 shows an impedance curve, a portion of which falls outside the series boundary. It can be seen that adding either capacitance or inductance in series will accomplish nothing more than shifting this curve back and forth inside the limit circle "A". In such cases it may be possible to move the impedance curve within the 3:1 VSWR definition circle by the use of a parallel component.

When working with parallel components, it is advantageous to convert the impedance curve to an admittance curve. This can be done by transforming the impedance curve, point by point, using the relations $G/Y_o = Z_o/R$ and $jB/Y_o = Z_o/-jX$. To illustrate, points 1 and 4 of the impedance curve in Figure 3-10 will be converted to admittance. Draw a line from point 1 on the impedance curve through the center and extend it in length. Now, using the center of the chart, strike an arc through the impedance point (distance R) and through the equivalent admittance point. This point is labeled 1 on the admittance curve. In a similar manner, a line is drawn from point 4 on the impedance curve, through the center and extended. An arc is drawn intersecting this extension at a distance from the center equal to the distance from the center to the impedance point. This locates the equivalent admittance point and is thus labeled 4 on the admittance curve. In a similar manner, as many other points as desired can be located and a curve drawn as shown in Figure 3-10. It may be noted that the limit circles have been moved also. The same procedure as was used for the curve may be employed to move these circles.

From the Smith Chart, it may be seen that the capacitive reactance component region may become the inductive susceptance region and the inductive reactance region becomes the capacitive susceptance region. Thus, using a capacitance as a parallel component will have the same effect on the admittance curve as an inductance used as a series component would have on an impedance curve located

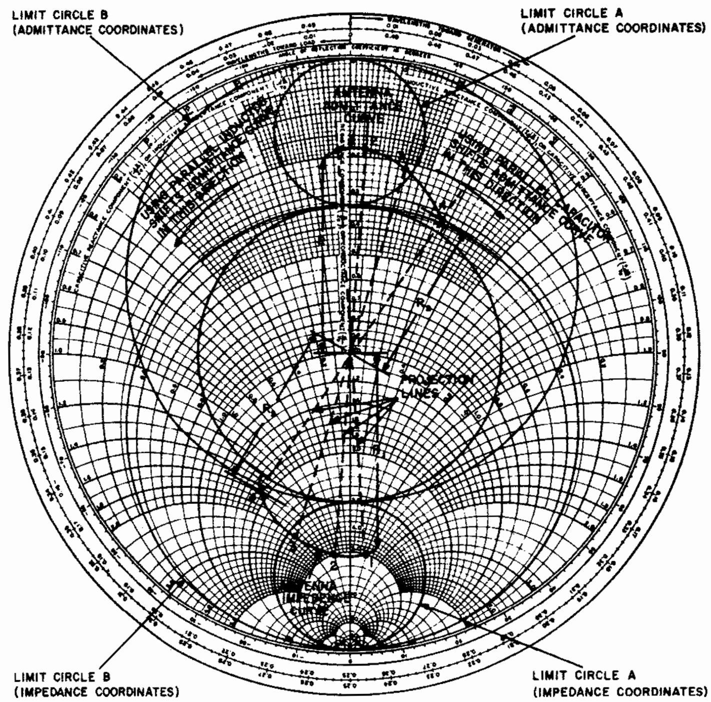

Figure 3-10. Smith Chart Showing Method of Converting an Impedance Curve to an Admittance Curve

in the same position as the admittance curve. Therefore it may be possible, in this case, to use a capacitor as a parallel component and shift the admittance curve clockwise to a point inside the parallel boundary. If this is done, the curve will fall inside the series boundary when it is reconverted to impedance. A series inductance component could then be used to shift the impedance curve within the 3:1 VSWR definition circle.

Example 3:

This example is given to illustrate the case of a parallel element to aid in obtaining VSWR of less than 3:1. Figures 3-11 and 3-12 show such a case. The measured impedance of an antenna designed to operate over the range of 2 to 6 MHz is shown as Curve (a). The antenna impedance curve is transformed to an admittance curve as outlined previously. Lines are drawn from the 2- 3- 4- 5- and 6-MHz point on the impedance curve through the center of the chart and extended a distance equal to the distance of the original point from the center. These points, when connected as shown in Curve (b), represent the admittance of the antenna. Thus, Curve (b) is the reciprocal of Curve (a). Limit circles must also be constructed, as shown, for admittance. The admittance curve may now be shifted either clockwise or counterclockwise by adding a parallel element. If capacitance is chosen as the parallel component, it will cause the admittance curve to rotate in a clockwise direction. Susceptance is proportional to frequency ($jB = 1/X_c = 2\pi fC$); therefore, a given capacitance will have the greatest effect at the highest frequency. For this reason, the 6 MHz point will be moved first to insure that it does not move too far.

By moving the point representing 6 MHz along the line G/Yo = 0.13, from -jB/Yo = 0.30 to jB/Yo = 0.28, it has the effect of adding a parallel capacitance. This may be shown as follows:

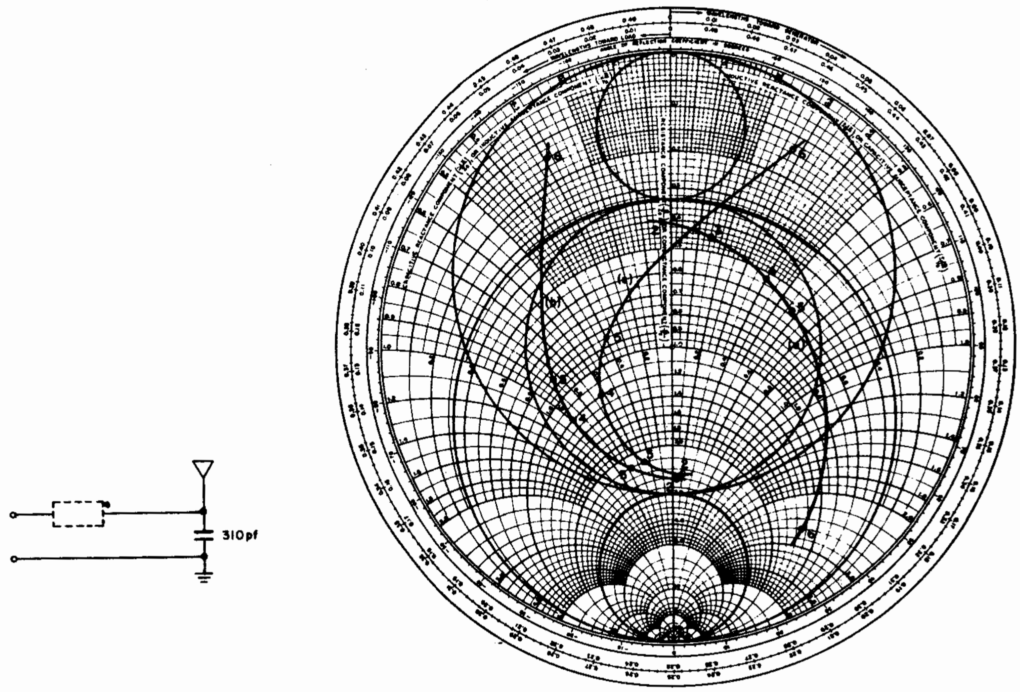

Figure 3-11. Curves for Example 3

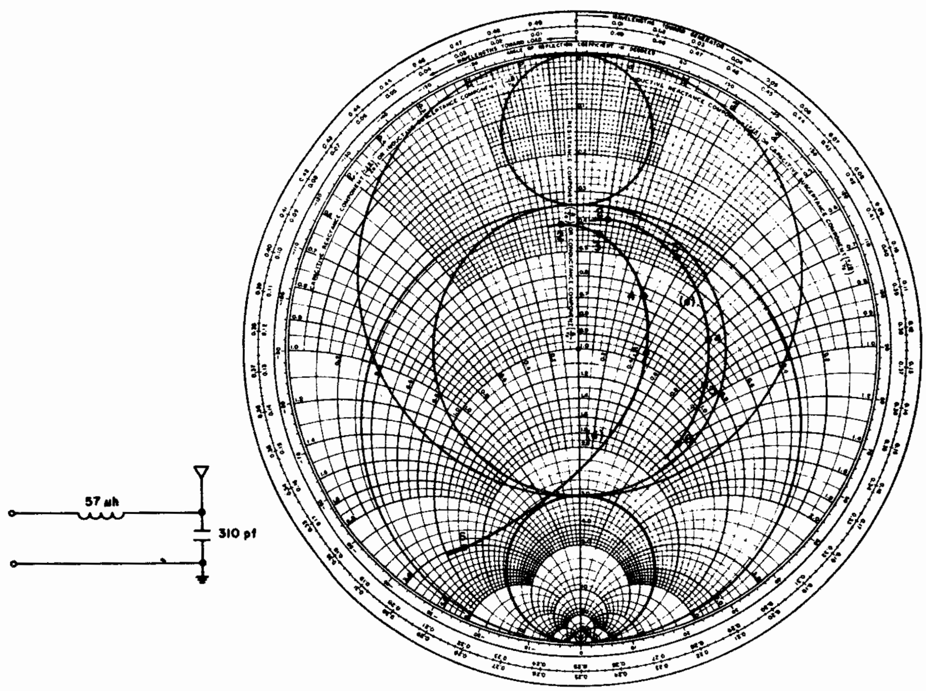

Figure 3-12. Curves for Example 3

SUPPORT ACTIVITIES TESTING AND MAINTENANCE

Distance moved = Final Point - Initial Point or
$jB/Yo = j0.28 - (-j0.30) = j0.28 + j0.30 = j0.58$

Since, as usual Zo = 50 ohms or Yo 1/50 ohms then,

$$jB = j0.58\ (1/50) = j0.0116 \text{ ohms}$$

The required capacitance is found as follows:

$$B = \frac{1}{X} = \frac{1}{X_C} = 2\pi fC$$

$$0.0116 = 2\pi(6 \times 10^6)C$$

$$C = \frac{0.116}{2\pi(6 \times 10^6} = 310 \text{ pf}$$

To find the effect of this capacitance at the remaining frequencies jB and jB/Yo may be calculated at these frequencies and added, with the proper respect to sign, to the original admittance curve. However, employing the method of proportionality as in previous examples, this may be accomplished by the following calculations. The normalized admittance is calculated at 2 MHz.

$$\frac{\frac{jB_1}{Yo}}{\frac{jB_2}{Yo}} = \frac{f_1}{f_2},\ \frac{.058}{B_2} = \frac{6}{2} \text{ or } \frac{jB_2}{Yo} = \frac{2(0.58)}{6} = 0.193 \text{ mhos}$$

As in previous examples, a chart is constructed as shown in Figure 3-13 by drawing a straight line between the points (f= 6 MHz, jB/Y_O = 0.58) and (f = 2 MHz, jB/Y_O = 0.193). Values of jB/Y_O can be determined from this chart for as many frequencies as desired.

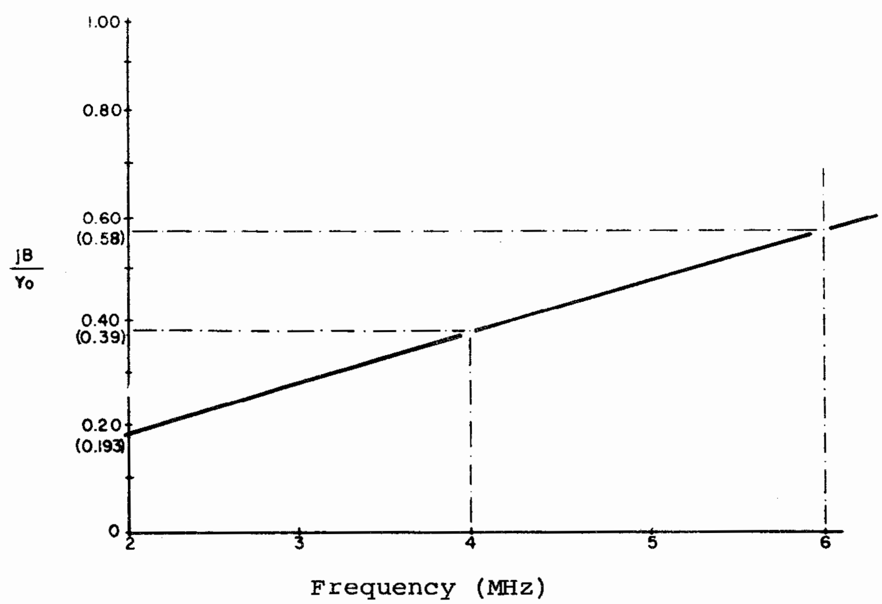

Figure 3-13. Frequency Reactance Chart

To determine the new admittance curve, it is now merely necessary to add the values of jB/Yo to the values given on the Smith Chart (with careful attention to sign). The susceptance at 4 MHz is 0.39 read from Figure 3-13, plus 1.0 read from Figure 3-11. Or

$$jB4\ MHz/Y_o = -1.0 + 0.39 = -0.61$$

This procedure is repeated until a curve, shown as Curve (c) in Figure 3-11, can be drawn.

The conversion from admittance back to impedance uses the same technique as did the previously described conversion to admittance. A line is drawn from a point on the admittance curve, through the center of the chart and extended a distance equal to its original distance from the center. This determines the new impedance points. Repeating this procedure and drawing a smooth curve through them results in the curve shown as Curve (d) in Figure 3-12. Note that Curves (c) and (d) are shown on separate figures to avoid confusion due to overlapping lines. This curve is the impedance of the antenna using a parallel capacitive component of 310 pf. Since this curve lies partially within the definition circle and the series boundary it may be possible to transform the curve to become completely within the definition circle with the aid of a series reactance. The procedure for this was explained in Example 1. In this particular case, a series inductance of .57 microhenrys shifts this curve to the position as Curve (e) in Figure 3-12. This is within the 3:1 VSWR definition circle; thus, an acceptable matching network for this particular antenna and frequency range is reached.

Example 4:

This example illustrates the use of an "L" type network. The measured impedance of the antenna is shown as Curve (a) in Figure 3-14 and lies outside the large circle which defines the series boundary. Accordingly, as in the previous example, it is not possible to achieve a 3:1 VSWR by the use of a simple series element. The curve is converted to admittance as explained previously in Example 3. This is shown as Curve (b) in Figure 3-14. As $1X_C = jB$, and $1/X_L = jB$, choosing capacitance as the parallel component, the curve can be shifted upward to position (c) in Figure 3-14. The highest frequency will be affected most, so movement of the 19 MHz point is made first to insure that too great a shift is not made. It is found that 300 pf in parallel with the antenna results in Curve (c). Note that when this curve is converted to impedance, Curve (d), it lies inside the series boundary. This is the end to which admittance is always used. Since Curve (d) is to be shifted in a -jX direction, capacitance is added in series. It is found, in this particular case, that 200 pf added in series as shown in the figure results in Curve (e). This is within the 3:1 VSWR definition circle and is thus an acceptable matching network for this antenna.

Example 5:

This example illustrates the necessity of using a "T" network. Curve (a) in Figure 3-15 represents the measured impedance of the antenna. It would appear at first that by simply adding a series capacitor we might swing the curve counterclockwise to become within the definition circle. Trying a few values of capacitance will prove that this is not possible. Although a series component which has a value of 88 pf was chosen to shift the curve to that of Curve (b), it is pointed out that this does not limit the values that could be chosen. A rule that might be followed at this point would be to try to pick a value that will allow most of the curve to become within the definition circle.

It is now necessary to convert the impedance to admittance. Using the same procedures as previously covered develops the admittance plot of Curve (c). The object now is to shift the curve counterclockwise to a position that when it

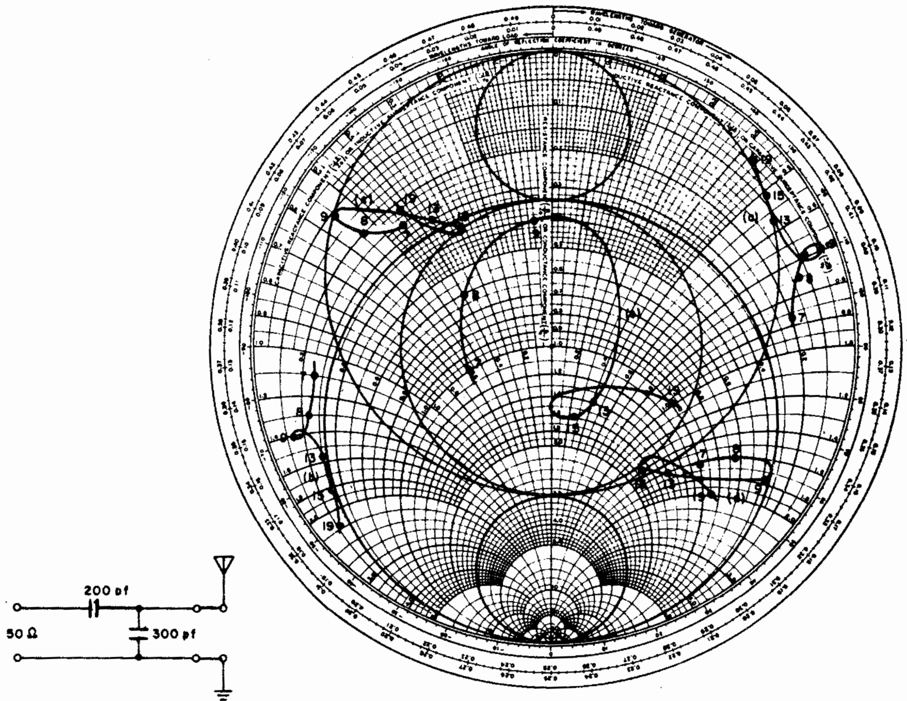

Figure 3-14. Curves for Example 4

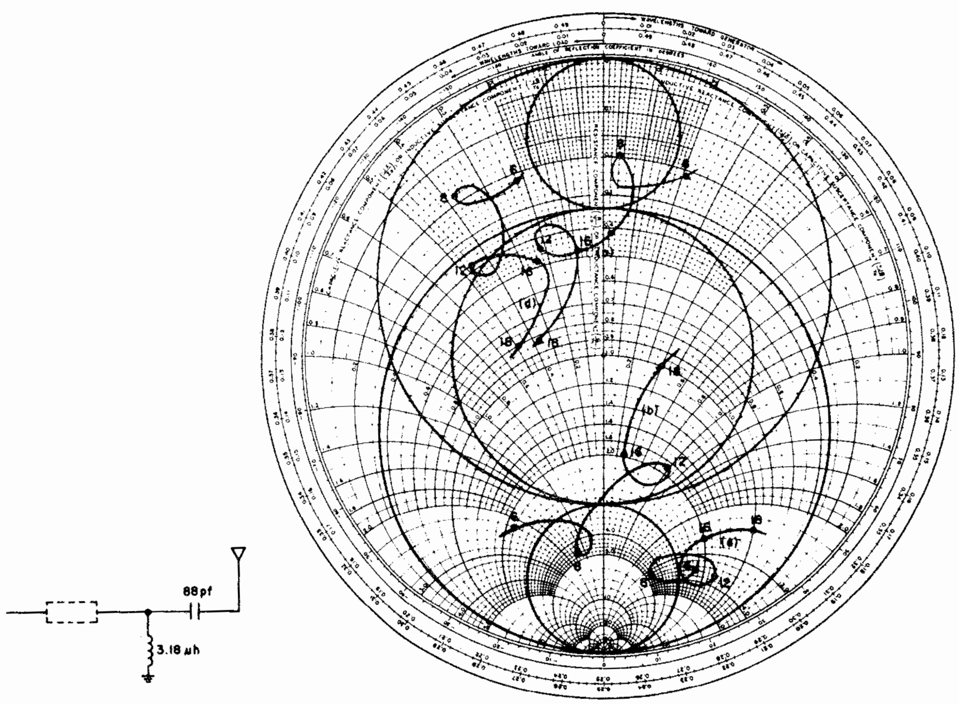

Figure 3-15. Curves for Example 5

is reconverted to impedance it will be entirely within the series boundary. A parallel component whose value is 3.18 microhenrys will accomplish this and Curve (d) will result. Reconverting to impedance yields Curve (e) in Figure 3-16. These curves are shown on separate figures to avoid confusion due to overlapping lines. It can be seen that by adding another series component the curve can be shifted counterclockwise to become within the 3:1 VSWR definition circle. A series component of 375 pf will accomplish this and yield Curve (f). The foregoing examples have shown that in each case the approach is the same. Trial and error, backed by experience, are the only governing factors in obtaining optimum results.

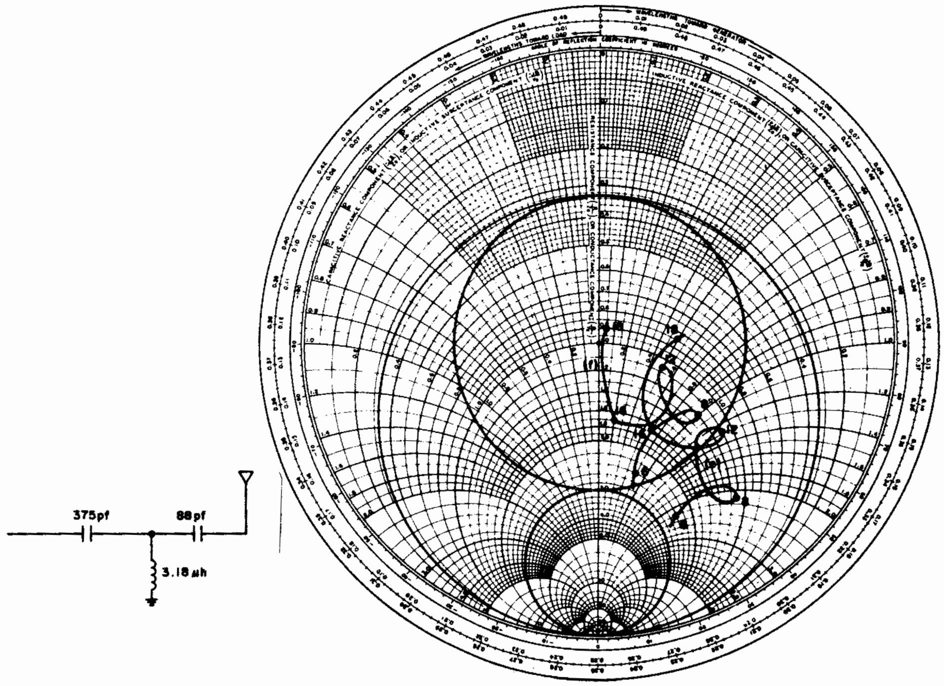

Figure 3-16. Curves for Example 5

3.2.1.2 MATCHING NETWORK CONSTRUCTION AND INSTALLATION.

Once the values of the components have been theoretically determined, construction of the matching network can be undertaken. It must be remembered that there will be variations between the calculated impedance and the values of the installed system. Therefore, the elements must be adjustable to compensate for these variations.

The components should have loss characteristics as low as possible for maximum efficiency. Variable vacuum capacitors with ceramic envelopes have excellent loss factors and are also shock and vibration resistant. Inductors should be designed for maximum Q. Inductors manufactured from No. 6 AWG copper wire or 1/4-inch copper tubing approximately 3 inches in diameter have proven satisfactory.

The components must be mounted on firm supports to prevent movement or dislocation during high shock and vibration periods. The dielectric material used for supports must have adequate insulating properties to prevent burns or arcovers during operation. Since the material will be exposed to moisture laden atmosphere it must be immune to water absorption.

The location of the elements within the enclosure is important in achieving the desired final matched antenna impedance. The components must be mounted in such a manner as to keep interaction between the elements to a minimum. Inductors should be mounted on opposites sides of the enclosure not less than one diameter away from one side of the enclosure, and, if possible, with their axes at right angles. Capacitors should be mounted so no excessive strain will be placed on their envelopes. The output power of the transmitting equipment and the reactance values of the network will determine the voltage rating of the capacitor elements. Generally a rating of 10 kv is sufficient. Where low reactance is used, that is, a high value of capacitance, a lower voltage of 5 kv will be adequate.

Stray reactances within the enclosure, especially from interconnecting leads will have considerable effect on the final matched impedance. This is more pronounced as the operating frequency is increased. The connecting leads between elements should be one-inch copper strap to keep the inductance of these connections low. The connections should be routed as direct as possible. The mutual coupling between inductors and connecting leads must also be considered. Leads should be positioned to cross a minimum number of flux lines of an inductor; that is, leads should go directly away from the inductor to the next element.

The enclosure should be manufactured with seamless construction and a rectangular opening of sufficient size to permit installation of the components and adjustment. The cover must be gasketed to be watertight. A drain hole or tube is required in the bottom of the enclosure to prevent the collection of moisture within the unit due to cyclic temperature and humidity variations. Studs for mounting the element support plates should be welded to the inside of the enclosure. These studs will provide ground connections for the elements where required. The matching network enclosure should be welded to the ship's structure to assure a positive ground connection. If it is impracticable to weld the enclosure to the ship it should be bolted to the structure and fitted with a ground strap welded to the enclosure and to the nearest point of the ship's structure. The matching network should be installed as close as possible to the antenna terminal.

3.3 MODEL RANGE TESTING.

An antenna model range provides facilities to design, test and evaluate complete shipboard communications antenna systems for specific ships or classes, to determine the effects of topside structural changes on existing systems, to test multicouplers, matching networks, filters and RF distribution systems, and to perform research and development of antenna systems to meet specific needs. Model range tests involve determination of antenna impedance, pattern, gain, system EMI and EMC, and electromagnetic radiation hazards.

A scaled model study is the most useful and efficient method of determining the design and operational characteristics of a complete system in a shipboard environment. The greatest effect on the antenna system operational characteristics is from the environment in which the system must operate. The communications antenna system is not an isolated, independent system. As a matter of fact the entire ship from the top of the mast to the waterline is an antenna system. It is a whole complex of interacting antennas radiating and reradiating electromagnetic energy, some of which is unintentional and unwanted. Testing on the model under shipboard conditions is far more economical than on board ship. Years of experience at model ranges show that data gathered by model range testing will parallel very closely actual shipboard testing.

The U.S. Navy maintains an antenna model range at the Naval Electronics Laboratory Center (NELC), San Diego, California. This range is equipped and staffed to provide services for antenna system development, scale model testing and field engineering. The description of the physical plant and services related to scale model testing and field engineering services in this volume is based on the facilities and activities at NELC.

A model study requires the building of a scale model, usually to 1/48 scale, of the ship with complete topside configuration. This includes all communications antennas, fire control directors, ordnance, structures and other equipment that might influence the antenna patterns. Brass is normally used to model conducting surfaces since it is easy to machine, corrosion resistant, easily soldered and is a good conductor. All models are constructed from actual ship drawings with the topside reproduced only after verification of all structural details. Copies of plans, sketches and photos illustrating topside configuration should be forwarded to NELC. All measurement data from broadband antenna systems should be included. This data is used to update the model ships and aid NELC in providing quick responses to antenna problems encountered in the fleet.

The model range, Figure 3-17, consists of a 160-foot diameter cement base and a 22-foot diameter turntable in the center. The concrete base is coated with lead, and the turntable is covered with brass plate to simulate sea water. Reflections from the edge of the artificial ocean are reduced by triangular seriations of the outer edge of the lead surface. A large wooden arch located at the perimeter of the cement base is fitted with an antenna which can traverse the arch from 3 to 65 degrees above the horizontal.

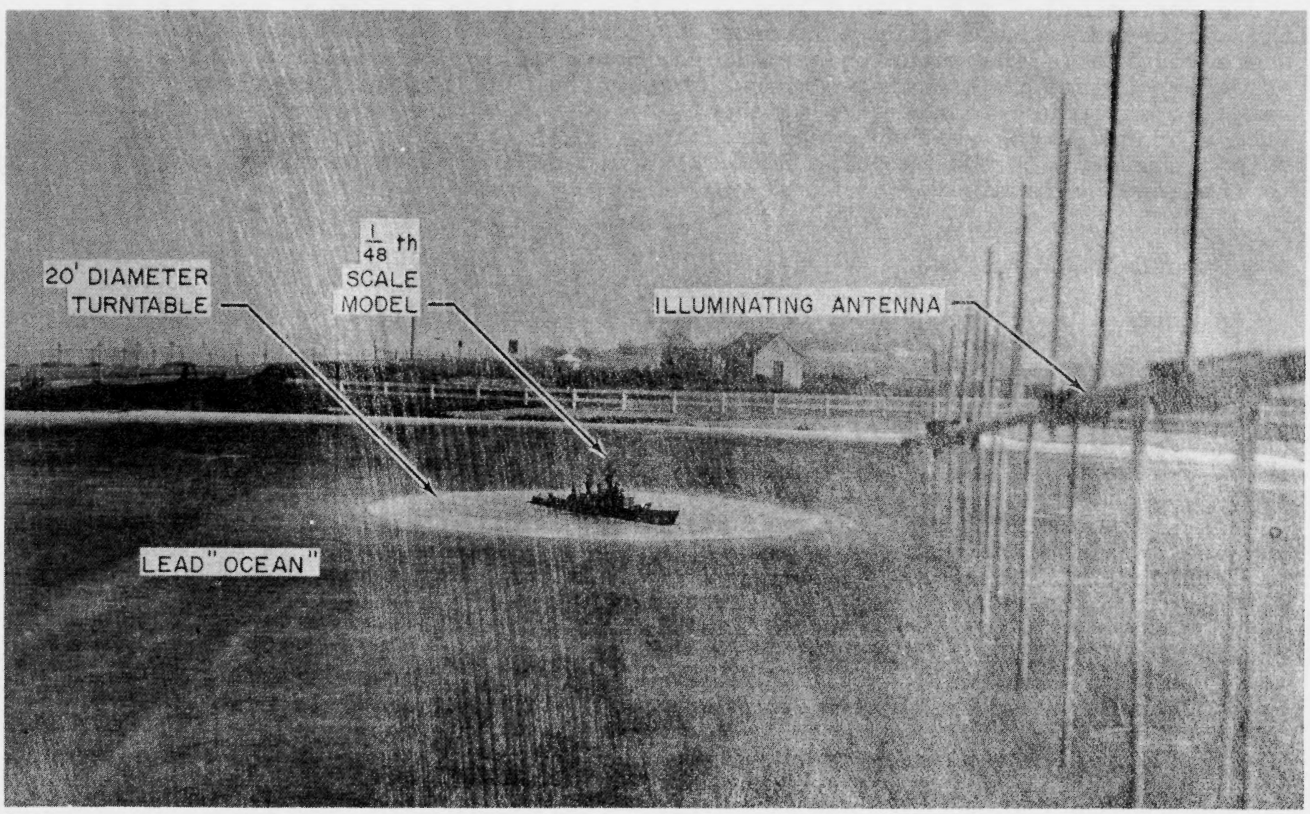

Figure 3-17. NELC Pattern Range

SUPPORT ACTIVITIES TESTING AND MAINTENANCE

Illumination of the range (usually from 96 to 1440 MHz to simulate at 1/48 scale the 2- to 30-MHz band) is accomplished by the use of fixed monopoles inside parabolic reflectors at ground level and a planar log periodic antenna, Figure 3-18, mounted on a track attached to the inside face of the arch. The fixed monopoles excite the range for vertically polarized ground waves only. The arch mounted log periodic can be rotated remotely for vertically and horizontally polarized measurements in azimuthal and vertical planes.

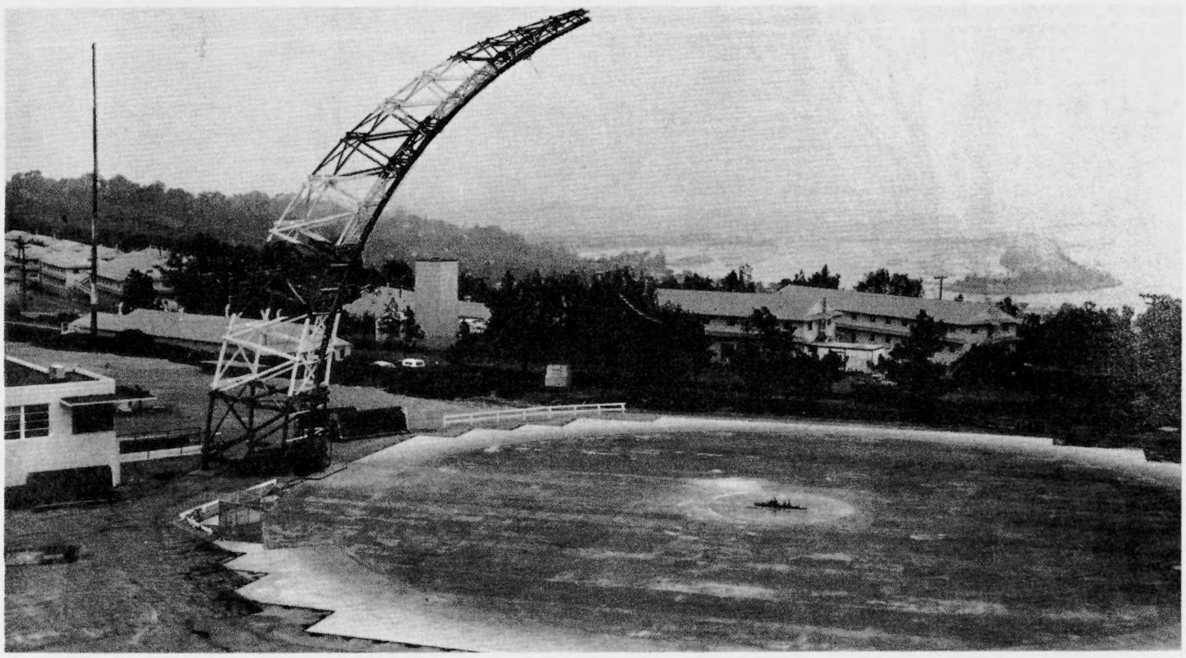

Figure 3-18. NELC Model Range

Brass plate ships, Figure 3-19, modeled to the waterline are placed over a slot in the turntable for measurements. Access to the model ship's antennas is from underneath.

The receiving equipment, located in a nearby control room, Figure 3-20, is connected by coaxial cable to the antennas on the model. A polar plotter or a radiation distribution printer is used to record the data. Data gathered is stored on paper and magnetic tape for use in the center's computer. This information is retained for future use in comparing and evaluating any subsequent changes to the particular system.

The model range has four underground test rooms available, and they are equipped to measure full or reduced scale antennas to determine functional characteristics such as susceptance and mutual coupling at frequency ranges from 2 to 12 GHz. The model ship and antenna under test are placed directly over the test equipment on a wire mesh screen which forms a continuous ground plane or counterpoise. The antenna is connected to the test equipment in the room below by low-loss coaxial cable. This configuration permits antenna measurements without disturbing the electrical field of the antenna.

One of the underground test rooms is used primarily for full scale antenna testing. Testing is normally limited to 2 to 400 MHz with facilities to measure up to 12 GHz. This room has been used for analysis of full scale VHF

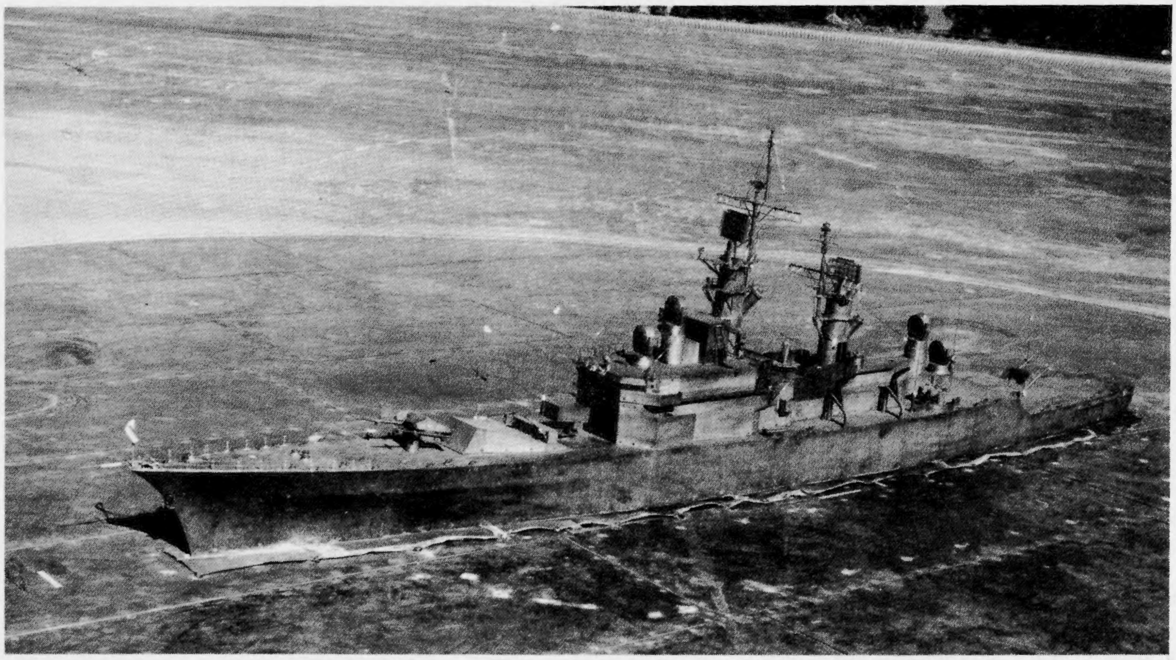

Figure 3-19. Model on Turntable

Figure 3-20. Model Range Control Room

broadband dipoles, checking wire fan antennas and in the design of 35-foot fiberglass whip antennas.

The ship models, stored at the facility, are updated periodically to reflect changes to the actual ship. They are readily available for use in determining the effects of structural changes or new topside installations and providing solutions to antenna problems that may be experienced in the field. All data accumulated during tests is retained for future reference.

3.3.1 IMPEDANCE MEASUREMENTS.

The impedance of an antenna at the input terminal affects the interaction between the antenna and its associated equipment. Antenna impedance is an important factor in the consideration of power transfer, noise, and bandwidth. In broadband antenna systems it is the antenna impedance that limits the useful bandwidth of the antenna. Since shipboard broadband antennas are limited to presenting a 3:1 VSWR to the transmitting equipment it is essential that the impedance be known for use in the design of matching networks. The antenna is modified by the environment in which it operates, especially from nearby structures and antennas. For this reason the antenna is placed in a replica of its operating environment. When the model has been configured to conform with the specifications for the test it is placed on the test platform and connected to the test equipment. Figure 3-21 shows a typical test instrumentation setup for determining antenna input impedance. There may be variations in the instrument setup depending on test requirements.

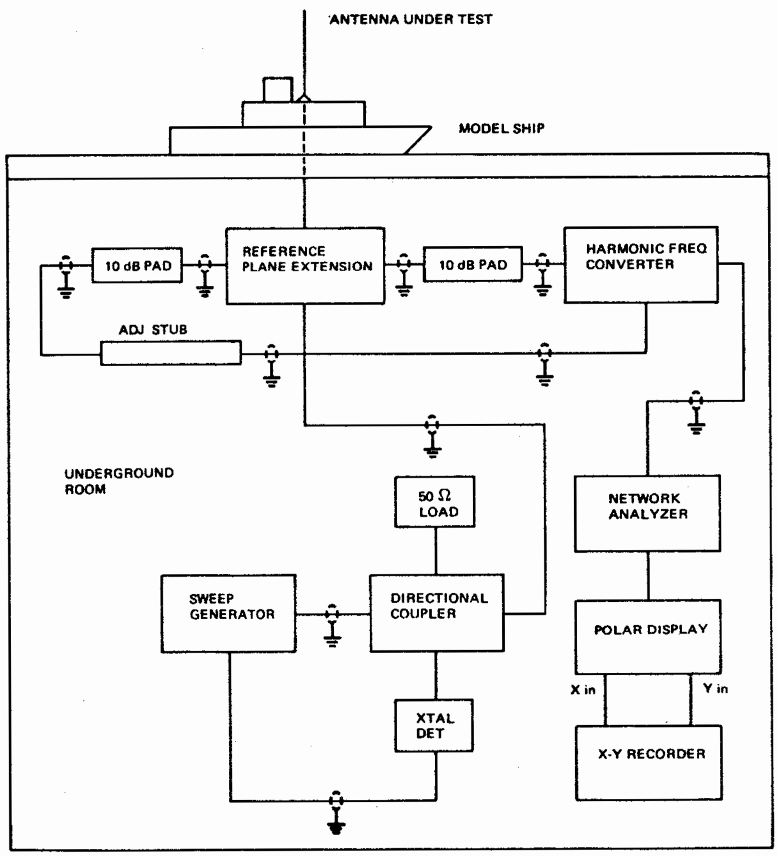

Figure 3-21. Model Range Test Setup for HF Impedance Measurements

The antenna is tested over its design bandwidth. From the data it can be determined if the antenna can be satisfactorily matched to the system transmission line over its bandwidth. If the antenna does not provide an adequate match the data can be used in the design of matching networks to improve the match. The data may also be used in determining the practicality of modifying the ship's structure or relocating antennas or other equipment to bring the impedance within specified boundaries. The impedance data obtained from model tests will assist in the alignment of the shipboard system.

3.3.2 PATTERN AND GAIN MEASUREMENTS.

Scale model radiation pattern and gain measurements provide important information that may be used in determining some of the expected operational characteristics of the shipboard antenna system. This information includes radiation distribution which predicts the expected coverage of the antenna, gain, depth of nulls for a given set of conditions, mismatch losses, and statistical data that may be used to determine other system losses such as whether the system will become noise limited. Since it is more economical and convenient to perform model measurements in the receive mode, the tests are conducted with the model being illuminated from an external source. The information recorded in this mode is applicable to transmitting antennas by the principle of reciprocity.

The radiation pattern measurements are conducted on the pattern range. The model is positioned on the turntable and the interconnecting cables terminated to the model and the control room. A typical test setup for measuring antenna patterns is shown schematically in Figure 3-22.

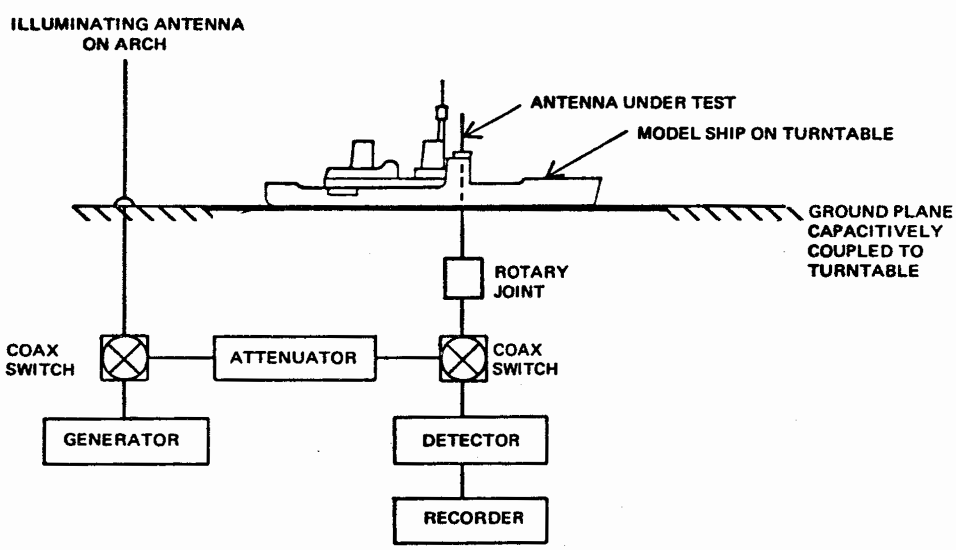

Figure 3-22. Model Range Test Setup for Antenna Radiation Patterns

The model is illuminated by the antennas at ground level and on the arch. The patterns are recorded over full 360 degrees in azimuth and the illuminating antenna on the arch is capable of furnishing angles of incidence from 3 to 65 degrees from the horizontal. The illuminating frequencies are determined by the bandwidth of the antenna under test. Patterns are recorded on a polar recorder and statistical data recorded on a radiation distribution printer. Radiation pattern measurements may be on either a relative or an absolute field intensity basis.

A typical polar recorder pattern is shown in Figure 3-23; variations in power levels and azimuth coverage for various angles of incidence are clearly shown. Since the model data is closely duplicated on board ship this will be the expected coverage when the full scale antenna is installed on the specific ship. Energy levels are determined by comparing the level of the received signal with the output level of the illuminating antenna. The reference levels are determined by measuring the levels of a quarterwave monopole.

Once the initial radiation pattern measurements have been recorded for the complete system, the data is analyzed to ascertain whether the configuration may be expected to fulfill the operational requirements. If there are discrepancies, such as lack of coverage, excessive radiation losses, or mutual interference with other antennas, the model is reconfigured and additional patterns are made. This process is continued until the best possible design, within the constraints imposed by the ship's structure, has been obtained. The design is then considered satisfactory for full scale installation.

The data obtained from these measurements is retained for future use and is especially useful in determining the effects on the antenna system of future structural changes on a specific ship or class.

3.4 SHIPBOARD TESTING AND MAINTENANCE.

Engineering and technical personnel assigned to laboratories and industrial activities are available to support the fleet in the installation and maintenance of shipboard communications antenna systems. These services include initial adjustments of the antennas and matching devices, calibration and adjustment after structural or other changes that affect antenna operation, inspections, and response to requests for assistance in solving specific problems beyond the capabilities of the ships force on an emergency or "quick fix basis." The support activities are equipped to provide instrumentation not normally available on ship to conduct specific tests.

3.4.1 IMPEDANCE MEASUREMENTS.

The most important characteristic of a shipboard antenna is the input impedance. The impedance will determine the bandwidth of the antenna, the design and adjustment of matching and coupling devices and the VSWR on the transmission line. The impedance of an antenna may be measured on board ship by the use of an RF bridge to measure the antenna input admittance from which the impedance can be calculated. Figure 3-24 shows a typical setup of the equipment required for this measurement.

The accuracy and repeatability of data and the safety of personnel and test equipment are dependent on the control of the topside area during the measurements. Strict attention must be given to the following:

a. The ship must be docked in a clear location with no other ships nested alongside.

b. All RF emissions in the immediate area must be eliminated.

c. Stack and exhaust emissions must be controlled.

d. All nearby hf antennas should be shorted to ground at their feedpoint. Tuned probes such as the AS-1857/SRA-43 used with the AN/SRA-43 Antenna Group are exempted from this requirement.

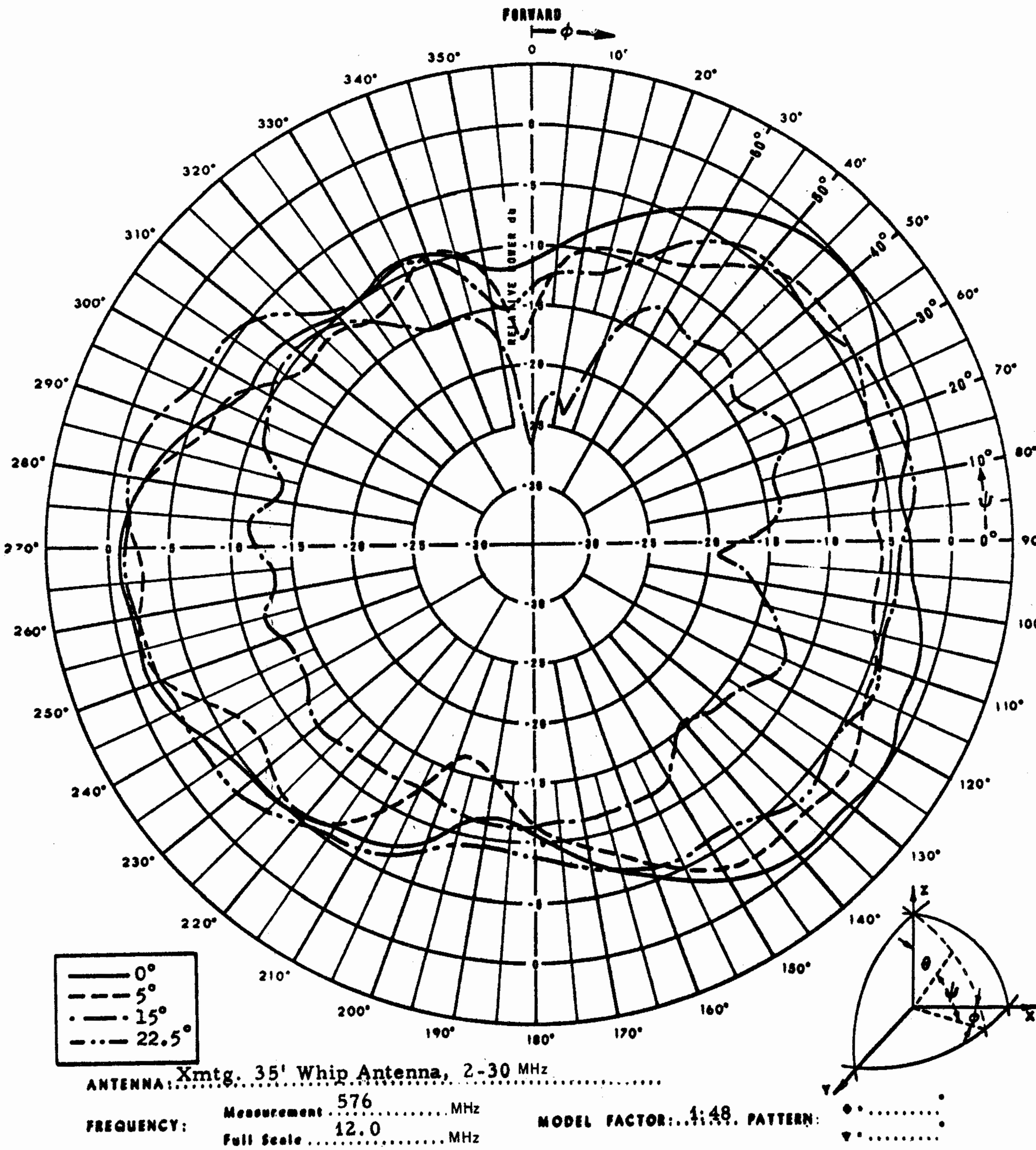

Figure 3-23. Model Range Radiation Pattern 35' Whip at 12 MHz

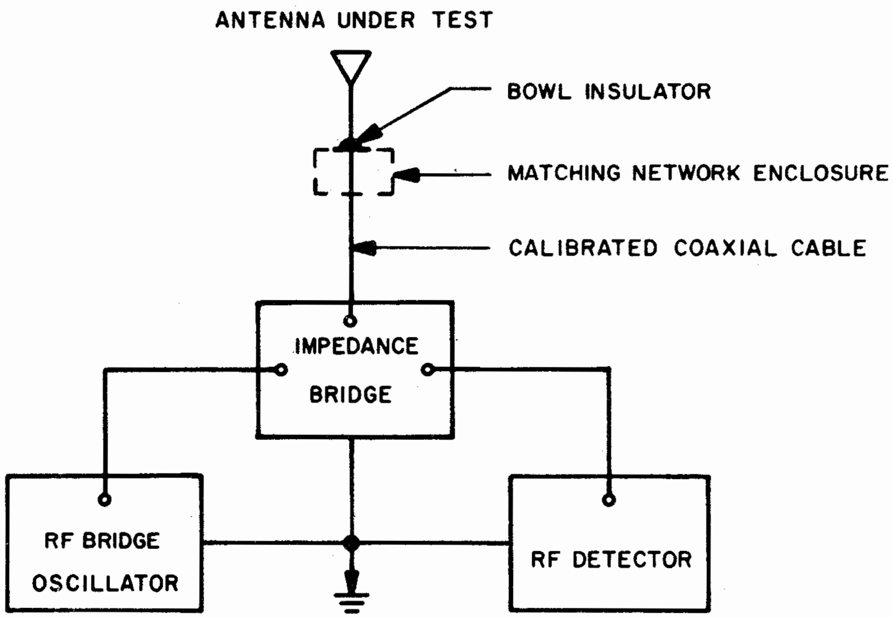

Figure 3-24. Instrumentation for Antenna Impedance Measurements

e. The ship must be in an at-sea configuration without dressing lines or mast staging.

f. Any tuned antenna suspected of causing undesirable coupling with a broadband antenna may be tuned and the effect monitored.

The accuracy of the test data is dependent on the care exercised in setting up the test equipment and maintaining these conditions throughout the tests. The procedure outlined in this section is time consuming; for each antenna as many as 12 hours may be required to complete all measurements and install matching networks. The number of individual readings on a specific antenna will depend on the frequency and bandwidth of the antenna. The measurement intervals should be as follows:

2 MHz to 6 MHz	---	200 kHz
6 MHz to 12 MHz	---	500 kHz
12 MHz to 18 MHz	---	800 kHz
18 MHz to 30 MHz	---	1 MHz

If excessive variations are noted within a narrow frequency range, the measurement intervals may be reduced to detect and identify any discrepancies. The measurement of antenna impedances requires the following test items:

a. RF Impedance Bridge equivalent to AN/URM-39.

b. Signal Generator equivalent to AN/URM-25.

c. A well shielded communications receiver equivalent to R-1051/URR series.

d. Calibrated portable coaxial cables such as RG-213/U. Three cables, 10, 50, and 100 feet should be sufficient to cover most measurement requirements.

e. Special connectors for connecting the test cables to the antenna.

f. Ground and bonding straps and hardware for making ground connections.

The proper calibration and use of the impedance bridge and its connection to the antenna are the most critical of the operations for accurate impedance measurement and matching. The technical manual and operating instructions for the bridge should be thoroughly understood by test personnel.

The signal generator should be well shielded and should cover the frequency range of 2 to 30 MHz. The maximum output should be at least 2 volts. The generator should have a modulation capability of at least two tones to facilitate null detection. An important requirement on the signal generator is a vernier dial that allows close resetability of the test frequencies. For accurate impedance measurements, the vernier dial should be calibrated with a frequency counter. The use of the vernier for frequency resetability is especially important for the higher frequencies and longer test cables. For example, a 100-foot cable at 10 MHz is 1.40 λ . A one percent error in frequency setting will result in a line-length error of 0.015λ.

The detector should cover the frequency range of 2 to 30 MHz with both a visual and an audio indicator to determine the null point. When there is interference the null of the generator's modulated tone can be heard in most cases although it may be difficult to pinpoint with a visual indicator.

The test cable should have loss characteristics as low as possible and should be uniform over its length without cuts, kinks and other deformities. The test cable selected for impedance measurements should be as short as possible to reduce the effects of cable loss and line length errors on the observed impedance measurements. The test cable should not be shorter than 10 feet so the presence of the observers and the test equipment do not affect the antenna impedance characteristics. The test cable should be dressed in such a way that it lies closely along the ship's structure. Cables draped across open spaces will alter the electromagnetic environment surrounding the antenna and will result in serious measurement errors.

A typical connection from the test cable to the antenna consists of an alligator clamp connected to the center conductor of a specially made fitting. This fitting may be manufactured from standard Navy type coaxial connectors. The outer conductor should be connected to a copper strap at least 12 inches long and approximately two inches wide for a good ground connection. If a matching network is installed on the antenna under test, the connection to the antenna should be made through the matching network bowl insulator to take into account its shunt capacitance.

The equipment in the test setup should have a common ground. Ideally, the generator, bridge and detector should be mounted on the metal deck with each equipment well grounded to bare metal at a point convenient for using a "C" clamp. The shortest possible lengths of solid strap connected from the base of each equipment to the common ground gives the best results. Thoroughly tighten all grounding connections.

To perform impedance measurements connect the test equipment as shown in Figure 3-24. For example: the impedance of a broadband discone antenna is to be measured. This particular antenna is designed to cover the frequency range of 4 to 12 MHz. The impedance measurements may be performed in the following manner:

1. Tune the signal generator and receiver to 4 MHz.

2. The bridge is adjusted for a null. In this case the reactance value is read as 30 ohms capacitive (-jX), and the resistance as 29 ohms.

SUPPORT ACTIVITIES TESTING AND MAINTENANCE

3. Record the frequency, 4 MHz, and the values 29 ohms and $30X_c$ on a prepared form as shown in Figure 3-25. This form is typical. The activities performing antenna impedance measurements will prepare data sheets to satisfy their particular requirements.

4. Repeat steps 1 through 3 with frequency intervals of 500 kHz and increasing to 800 kHz above 12 MHz. During tests it is desirable to make measurements at smaller intervals where it is noted that there are large variations in reactance values. More frequent measurements will also result in smoother curves when the data is plotted on a Smith Chart.

The information recorded on Figure 3-25 can be transferred to a Smith Chart to plot graphically the antenna impedance. The impedance curves are normally drawn on a Smith Chart using normalized impedance coordinates.

The Smith Chart is shown in Figure 3-26 with the antenna impedance of the data recorded in Figure 3-25 plotted. The scaled vertical line represents the ratio of R to Zo, where R equals the resistive component of an antenna measured at a particular frequency and Zo equals the characteristic impedance of the transmission line. The circle centered at 1.0 on the resistance scale passing through 3.0 on the same scale encloses all values of impedance which will cause a 3:1 VSWR or less when it terminates a transmission line with a characteristic impedance of Zo.

Moving counterclockwise from the resistance component line locates the negative (capacitive) reactance component, which is the ratio of the -jX component to Zo, measured at a particular frequency. Similarly, moving clockwise locates the positive (inductive) reactance component, which is the ratio of the jX component to Zo, measured at a particular frequency.

To illustrate, two of the points on Figure 3-26 will be plotted.

Referring to Figure 3-25, observe that at 5 MHz, the measured impedance of the antenna is 27.5-j20. A transmission line with a characteristic impedance of 50 ohms will be used. The resistance component equals:

$$\frac{R}{Zo} = \frac{27.5}{50} = 0.55$$

and the reactance component equals:

$$\frac{-jX}{Zo} = \frac{20}{50} = 0.40$$

and is negative (capacitive).

The point representing the impedance measured at 5 MHz is found by locating 0.55 on the resistance component line and moving counterclockwise along its arc until it intercepts the 0.40 capacitive reactance arc. At 12 MHz the measured antenna impedance equals 20.0 + j11.0. From the first equation the resistance equals 0.40. From the second equation the reactance component equals 0.22 and is positive (inductive); this impedance point is found by locating 0.40 along the resistance component line and moving clockwise to the point of intercept with the 0.22 inductive reactance arc.

Other points are located in the same manner and would represent the curve shown on the chart. It will be noted from Figure 3-26 that the majority of the plotted points are within the allowable 3:1 VSWR circle. The requirement for a matching network to bring all points within the 3:1 circle will be predicated on the expected frequencies to be used by the antenna. If frequencies between 8.5 to 10.5 MHz are of prime interest, a matching device should be considered to improve the match at these frequencies.

ANTENNA IMPEDANCE MEASUREMENTS

SHIP OR STATION ____________ TYPE Discone

ANTENNA LOCATION ____________

RANGE 4 to 12 MHz DATE ____________

FREQUENCY f	RESISTANCE R	INDUCTIVE REACTANCE jx	CAPACITIVE REACTANCE −jx	INDUCTANCE L	CAPACITY C
4.0	29.0		30.0		
4.5	28.0		25.0		
5.0	27.5		20.0		
5.5	27.5		10.0		
6.0	30.0	5.0			
6.5	50.0	32.5			
7.0	85.0	32.5			
7.5	110.0	2.0			
8.0	110.0		20.0		
8.5	70.0		60.0		
9.0	50.0		60.0		
9.5	35.0		50.0		
10.0	25.0		37.5		
10.5	20.0		20.0		
11.0	20.0		20.0		
11.5	20.0	0	0		
12.0	20.0	11.0			

Figure 3-25. Antenna Impedance Tabulation Form

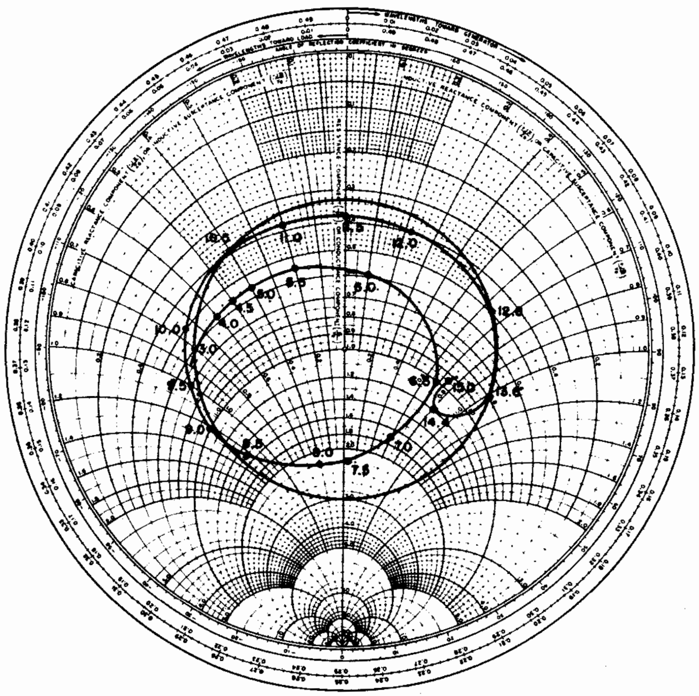

Figure 3-26. Impedance Curve of a Discone Antenna Normalized to 50 Ohms.

It is recommended that the impedance characteristics be plotted on a Smith Chart while the measurements are being conducted. This will show immediately any erratic operation of the test equipment or the antenna. It is difficult to ascertain this information from the raw numerical data until it has been plotted. Two persons should work together; one to operate the equipment and the other to record data, make calculations, and plot the data. In this way an impedance plot on a Smith Chart is available as the reading for each frequency is obtained. Considerable time and effort may be saved if any discrepancies are recognized during measurements, permitting investigation and correction of any discrepancies and preventing the collection of poor data.

3.5 TIME DOMAIN REFLECTOMETER TESTING.

A time domain reflectometer (TDR) is used to locate faults such as shorts, opens, defective connectors, mismatched terminations and physical deformities in coaxial wideband transmission systems and components. The equipment consists of an oscilloscope and a time domain reflectometer plug-in unit. The TDR develops a very rapid step voltage that is applied to the transmission line. The reflected voltage is measured on the high-speed sampling oscilloscope. By analyzing the pattern on the oscilloscope, displaying magnitude, shape and duration of the reflected waveform, the position and the nature of the discontinuity can be determined. This information may also be recorded on an X-Y recorder. The TDR method cannot be used on narrow-band devices and filters which appear as high impedances in the line. Long or lossy lines cause greater attenuation of the high frequency component of the "step" thus reducing the TDR's ability to resolve closely spaced discontinuities. The TDR has a time distance scale calibrated in a centimeter or foot line per division display, and in round trip time in nanoseconds. The distance scale reads directly in distance to the discontinuity while the time scale expresses the electrical length of the cable in round trip time. The true electrical length of the cable is then one half of that displayed on the oscilloscope. The system may be calibrated so one division on the horizontal axis is equivalent to a certain length of transmission line.

If no discontinuities exist on the transmission line and it is terminated in its characteristic impedance, $Z_L = Zo$, only the outgoing step will be indicated on the oscilloscope. A single discontinuity produces a reflection with a peculiar shape depending on the type and impedance. It will be displaced along the time base in accordance with its location along the line.

Two or more discontinuities or mismatches produce reflections that can be analyzed separately. However there are complications in analyzing the oscilloscope display. The reflections from the first discontinuity are unaffected by the presence of others. The succeeding discontinuities tend to become masked and distorted. As reflections are analyzed and cleaned up from the TDR end of the cable, the complications introduced by reflections are eliminated successively.

Each individual type of TDR has its own peculiar waveforms displaying specific discontinuities. The equipment technical manual supplies the waveforms that may be expected for the various forms of discontinuities. A treatment of TDR setups and measurements is outlined in NAVSHIPS 0969-120-7010—ANTENNA AND TRANSMISSION LINE REFLECTOMETER MEASUREMENTS, dated January 1971.

The system is tested by connecting the TDR to the transmission line at the transmitting or receiving equipment end. Prior to performing TDR measurements the transmission line should be visually inspected for any obvious mechanical faults. After the equipment has been set up for measurements in accordance with the technical manual the system is tested for mismatches and other faults.

When discrepancies are indicated on the TDR display they must be analyzed to determine the type and the location along the line. Usually, the faults are loose or defective connectors, physical damage to the cable not detectable by visual inspection, moisture in the cable or connectors, and shorted antennas. If multiple reflections are shown, the first discrepancy down the line from the instrument must be corrected before proceeding to the next. Corrective measures include connector replacement, drying out and resealing connectors and end seals, complete cable replacement, and antenna overhaul or replacement. Sections of the line may be isolated by disconnecting and terminating the line with a dummy load equal to the characteristics impedance of the line. In this manner successive sections may be progressively isolated from source to load, thus isolating any discrepancy that might appear in a specific section of the line.

The TDR is especially useful in testing transmission lines that have several connectors or transitions. The conditions of VHF/UHF antenna assemblies may be tested by the TDR method for discontinuities such as moisture, internal shorts and loose mechanical connections. A typical TDR test setup is shown in Figure 3-27.

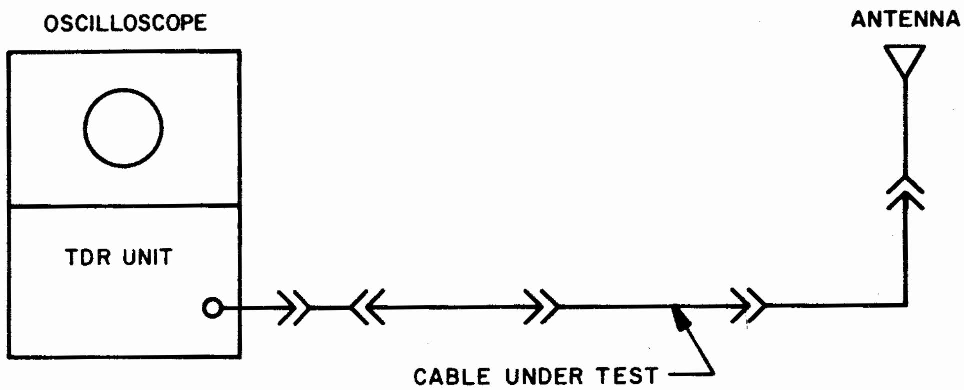

Figure 3-27. Time Domain Reflectometer Test Setup

SYSTEM	COMPONENT	MRC CODE	
Communications	Wire, Whip, and Dipole Antennas	C-405 Q-1	
SUBSYSTEM	**RELATED MAINTENANCE**	**RATES**	**M/H**
Antennas	N-1	2RMSN	1.0

MAINTENANCE REQUIREMENT DESCRIPTION

1. Wash down whip and dipole communication antennas.

TOTAL M/H 1.0
ELAPSED TIME 0.5

SAFETY PRECAUTIONS

1. Observe standard safety precautions.
2. Turn OFF and tag transmitter power switch
3. Comply with ship's regulations for working aloft.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Warning tags
2. Clean, dry rags
3. Fresh water hose

PROCEDURE

Preliminary
a. Turn OFF and tag transmitter power switches.
b. Comply with ship's regulations for working aloft.

1. Wash Down Whip and Dipole Communication Antennas.
a. Wash antenna, using fresh water to remove soot and salt residue.
b. Wipe insulator dry, using clean rag.
c. Return equipment to desired condition.
d. Comply with ship's regulations for completing work aloft.

PAGE 1 OF 1 A9 CD53 Q

LOCATION

DATE October 1969

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4790-1 (E) (REV. 11/66)

SYSTEM	COMPONENT	MRC CODE	
Communications	Wire, Whip, and Dipole Antennas	C-405 M-1	
SUBSYSTEM	**RELATED MAINTENANCE**	**RATES**	**M/H**
Antenna	None	RM3 RMSN	2.0 2.0

MAINTENANCE REQUIREMENT DESCRIPTION

1. Inspect wire, whip, and dipole communication antennas and associated hardware.
2. Clean antenna insulators.
3. Measure antenna insulation resistance.
4. Measure antenna continuity

TOTAL M/H 4.0
ELAPSED TIME 2.0

SAFETY PRECAUTIONS

1. Observe standard safety precautions.
2. Turn OFF and tag transmitter power switch.
3. Comply with ship's regulations for working aloft.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Clean rags
2. Wire brush
3. Vinyl tape
4. Rubber tape
5. Safety belts
6. Warning tags
7. Bucket of warm, fresh water
8. Multimeter, AN/PSM-4 or equivalent
9. Insulation test set, AN/PSM-2 or equivalent
10. Insulating varnish
11. Dow-Corning compound
12. 8" Adjustable wrench
13. Soap and water solution
14. Solvent FSN 6810-184-4794
15. 6" Normal duty screwdriver
16. Grounding strap

PROCEDURE

Preliminary
a. Turn OFF and tag transmitter power switches.
b. Comply with ship's regulations for working aloft.

1. Inspect Wire, Whip, and Dipole Communication Antennas and Associated Hardware.
a. Inspect wire, whip, and dipole antennas and related hardware for security, corrosion, and pitting. Antennas mounted in the vicinity of the stacks require particular attention. If antennas require cleaning and preservation, perform applicable sections of MRC A-1R.
b. Tighten loose grounding lugs and bolts. Replace broken grounding straps; clean grounding area thoroughly with wire brush.
c. Ensure coaxial connectors exposed to weather are watertight. If a connector is found that is not watertight, or a connection has been disconnected, the following steps should be taken.

PAGE 1 OF 2 A9 CD52 M

LOCATION Equipment Guide List

DATE October 1969

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4790-1 (E) (REV. 11/66)

Procedure (Cont'd)

(1) Ensure the coaxial connectors are clean and dry.
(2) Coat threads of connectors with Dow-Corning compound.
(3) Reconnect connectors.
(4) Wrap rubber tape around connectors and around cable 4" on both sides of connectors.
(5) Wrap vinyl tape on top of rubber tape 6" on both sides of connectors.
(6) Apply insulating varnish liberally over the taped area.

2. Clean Antenna Insulators.

CAUTION: Do not use any metal objects to clean or scrape insulators.

a. Remove foreign material such as paint, salt, and soot deposits from insulators with a clean rag saturated with solvent. Wash with soap and water, followed by several rinsings with clean, fresh water.
b. Inspect insulators; replace any insulators found to be cracked or chipped.

3. Measure Antenna Insulation Resistance.
a. Disconnect static leak resistors from ground on wire receiving antennas.
b. Measure insulation resistance of each antenna, using appropriate test instrument connected between transmission line center conductor and ground on antenna side of coupler-tuners or antenna patch panel.
(1) For open antenna, any reading below 100 megohms should be investigated.
(2) For shorted antenna, any reading above 2 ohms should be investigated.
c. Disconnect insulation test set or multimeter from transmission line coaxial connectors.
d. Reconnect static leak resistors to ground on wire receiving antennas.

4. Measure Antenna Continuity.
a. Measure continuity of each antenna.
(1) Connect grounding strap between antenna and ground.
(2) Connect multimeter leads between antenna cable center conductor and ground; multimeter should indicate 2 ohms or less.
(3) Disconnect multimeter and grounding strap.
b. Reconnect transmission line to associated equipment.
c. Remove warning tags.
d. Return equipment to desired condition.
e. Comply with ship's regulations for completing work aloft.

PAGE 2 OF 2 A9 CD52 M

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4790-1 (E) (REV. 11/66)

Figure A-1 Maintenance Requirement Card (MRC) Antenna Test and Maintenance

SYSTEM	COMPONENT	MRC CODE	
Communications	Wire, Whip, and Dipole Antennas	C-405	A-1R
SUBSYSTEM	RELATED MAINTENANCE	RATES	M/H
Antennas	None	2RMSN	2.0

MAINTENANCE REQUIREMENT DESCRIPTION

1. Clean and preserve wire, whip, and dipole communication antennas.

TOTAL M/H 2.0
ELAPSED TIME 1.0

SAFETY PRECAUTIONS

1. Observe standard safety precautions.
2. Turn OFF and tag transmitter power switches.
3. Comply with ship's regulations for working aloft.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Wire brush
2. Clean rags
3. Safety belt
4. Warning tags
5. Bucket of fresh water
6. Primer treatment, FSN G 8030-165-8577
7. Dow-Corning compound, FSN 5970-159-1598
8. Zinc chromate primer, FSN KZ-8010-161-7419
9. Haze gray paint (No. 27), FSN G 8010-285-8298
10. Gun slushing compound Type B, or hard film corrosion preventive
11. Strap wrench (2)
12. 8" Adjustable wrench
13. Coil 1/2" nylon line
14. 1", 3" Paintbrush (2)
15. Solvent, FSN 6810-184-4794

PROCEDURE

NOTE 1: Perform annually or when directed as a result of antenna inspection.

<u>Preliminary</u>

a. Turn OFF and tag transmitter power switches.
b. Comply with ship's regulations for working aloft.

1. <u>Clean and Preserve Wire, Whip, and Dipole Communication Antennas.</u>
   a. Clean and preserve wire antennas:
      (1) Disconnect and lower wire antenna to the deck, using nylon line; exercise care not to damage the insulators.
      (2) Clean insulators by wiping with a clean rag and fresh water. Replace cracked or chipped insulators.
      (3) Wirebrush metal fittings and hardware to remove dirt, salt, and corrosion.

PAGE 1 OF 3 | A9 | CD55 | A

LOCATION

DATE October 1969

MAINTENANCE REQUIREMENT CARD (MRC)

Procedure (Cont'd)

(4) Where antenna is uncoated, brush with wire brush.
(5) Where antenna is coated, clean with rag saturated with solvent.
(6) Inspect shackles and shackle pins for evidence of wear; replace badly worn shackle pins.
(7) Use brush to paint cleaned hardware and fittings with gun slushing compound or hard film corrosion preventive.
(8) Return antenna to its original location. Ensure shackle pins, clamps, and fittings are tight, and that insulators are not in a position which places an unnatural strain on them. If safety links are installed, ensure that they are properly formed and that seizing is secure.

b. Clean and preserve whip antennas:
   (1) Remove antenna from bowl insulator.
   (2) Lower whip to the deck; exercise caution not to damage the antenna.
   (3) Use strap wrenches to disconnect antenna sections.
   (4) Inspect whip closely for cracks and corrosion; remove flaking or blistered paint, salt deposits, dirt, oxidation powder, and rust from the antenna and base casting with a wire brush.
   (5) Clean threads with wire brush.
   (6) Wash antenna with fresh water.
   (7) Wipe antenna with dry rag.
   (8) Apply Dow-Corning compound to threaded sections.
   (9) Reconnect antenna sections.
   (10) Preserve cleaned antenna if required; allow ample time for drying between coats:

NOTE 2: Fiber glass whip antennas do not require painting.

(a) Apply 1 coat of primer treatment. FSN G 8030-165-8577.
(b) Apply 1 coat of zinc chromate primer, FSN KZ-8010-161-7419.
(c) Apply 2 coats of haze gray paint (No. 27), FSN G 8010-285-8298.

CAUTION: Under no circumstances will metallic paint be used.

(11) Clean and inspect bowl insulators; remove paint and other foreign material with clean rag and water; inspect bowl closely for cracks. Cracked or badly chipped bowls must be replaced.
(12) Return whip to its original position; tighten all associated hardware. If connection box is mounted below whip antenna, ensure drain hole is clear.

PAGE 2 OF 3 | A9 | CD55 | A

MAINTENANCE REQUIREMENT CARD (MRC)

Procedure (Cont'd)

c. Inspect and preserve dipole antennas:
   (1) Inspect condition of Teflon separators. Remove paint, soot, and salt deposits with a clean rag and water.
   (2) Inspect metallic elements for corrosion; remove all corrosion with a wire brush; preserve cleaned surfaces as described in step 1.b.(10).

NOTE 3: Brass dipoles need not be painted with zinc chromate.

d. Return antennas to desired condition.
e. Comply with ship's regulations for completing work aloft.

PAGE 3 OF 3 | A9 | CD55 | A

MAINTENANCE REQUIREMENT CARD (MRC)

Figure A-2 Maintenance Requirement Card (MRC) Antenna Cleaning and Preservation

SYSTEM	COMPONENT	MRC CODE
Communications	Wire, Whip, and Dipole Antennas	C-405 Q-2

SUBSYSTEM	RELATED MAINTENANCE	RATES	M/H
Antenna	M-1	[illegible]	0.3
		FN	0.3

TOTAL M/H: 0.6
ELAPSED TIME: 0.3

MAINTENANCE REQUIREMENT DESCRIPTION

1. Inspect, clean, and lubricate whip antenna tilting platform.

SAFETY PRECAUTIONS

1. Observe standard safety precautions
2. Turn OFF and tag transmitter main power switch.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Oil, Symbol 5190
2. Solvent, P-D-680
3. Hydraulic fluid, MIL-H-5606
4. Hydraulic pump handle
5. 10" Adjustable wrench
6. Grease gun with grease, MIL-G-7711A
7. Gun slushing compound, Type B or hard film corrosion preventative
8. Funnel
9. Sash brush
10. Clean rags
11. Wire brush
12. Diesel fuel
13. 1" Paintbrush

PROCEDURE

Preliminary

a. Turn OFF and tag transmitter main power switch.

1. Inspect, Clean, and Lubricate Whip Antenna Tilting Platform.
   a. Manual tilting platform
      (1) Inspect tilting mechanism and related hardware for corrosion and pitting.
      (2) Tighten loose bolts and nuts.
      (3) Inspect ground strap for security.
      (4) Wirebrush and preserve corroded areas as required.
      (5) Wipe off grease fittings with clean rag prior to, and after, lubrication.
      (6) Inject grease through fitting until new grease appears at faying surfaces.
      (7) Remove excess grease.
      (8) Remove locking pin.
      (9) Lower and raise antenna through complete cycle.
      (10) Observe mechanism for freedom of movement.
      (11) Install locking pin with antenna in the vertical position.
      (12) Return equipment to desired condition.

PAGE 1 OF 3 | 60 | CD54

LOCATION | DATE June 1979

MAINTENANCE REQUIREMENT CARD (MRC)

Procedure (Cont'd)

b. Hydraulic operated tilting platform
   (1) Inspect hydraulic lines, connections and fittings for security.
   (2) Tighten loose bolts and nuts.
   (3) Inspect grounding strap for security.
   (4) Remove corrosion from hydraulic selector valve and antenna platform with wire brush and preserve as required.
   (5) Remove corrosion from hydraulic piston rod, using wire brush and wiping clean with a rag saturated with solvent.
   (6) Apply a light coat of grease on all moving parts of the hydraulic system.
   (7) Apply a light coat of gun slushing compound or hard film corrosion preventative on stationary parts of the hydraulic unit, using 1" brush.
   (8) Wipe off grease fittings with clean rag prior to, and after lubrication.
   (9) Inject grease through fittings until new grease appears at faying surface.
   (10) Remove excess grease.
   (11) Remove locking pin.
   (12) Turn hydraulic selector valve to the position to lower the antenna.
   (13) Lower the antenna with hydraulic pump handle, observing freedom of movement.
   (14) Remove filler plug and inspect hydraulic oil level. Fluid should be visible in filler plug hole.
   (15) Reinstall and tighten filler plug.
   (16) Turn hydraulic selector valve to the position to raise the antenna.
   (17) Raise the antenna to the vertical position, observing freedom of movement.
   (18) Inspect locking pin.
   (19) Reapply a light coat of grease on hydraulic piston rod.
   (20) Return equipment to desired condition.
c. Electric operated tilting platform
   (1) Inspect tilting mechanism and platform for corrosion and pitting.
   (2) Tighten loose bolts and nuts.
   (3) Inspect ground straps for security.
   (4) Wipe off grease fittings with a clean rag prior to, and after lubrication.
   (5) Inject grease through pillow block bearing fittings until new grease appears at faying surfaces.
   (6) At the gear reducer coupling, remove 2 screws and install zerk fitting in 1 screw hole.
   (7) Inject grease through fitting until new grease appears at other screw hole.

PAGE 2 OF 3 | 60 | CD54

MAINTENANCE REQUIREMENT CARD (MRC)

Procedure (Cont'd)

   (8) Remove zerk fitting; reinstall 2 screws.
   (9) Inject 1 stroke of grease in gear reducer shaft bearing zerk fittings.
   (10) Remove high level inspection plug from gear reduction box; oil level should be at bottom of hole. Reinstall plug.
   (11) Remove top half of housing from drive chain.
   (12) Clean chain, gears, and bottom half of housing, using diesel fuel and sash brush.
   (13) Inspect chain for damaged links, wear, and misalignment.
   (14) Fill bottom half of housing with 5190 oil until oil level is 1" below lower end of housing.
   (15) Reinstall top half of housing.
   (16) Remove locking pin.
   (17) Lower and raise antenna through complete cycle, from local and remote position.
   (18) Observe mechanism for freedom of movement.
   (19) Return equipment to normal readiness condition.

PAGE 3 OF 3 | 60 | CD54

MAINTENANCE REQUIREMENT CARD (MRC)

Figure A-3 Maintenance Requirement Card (MRC) Antenna Tilting Platform Maintenance

ALPHABETICAL INDEX

ALPHABETICAL INDEX (Continued)