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MILITARY STANDARD

EFFECTIVENESS OF CABLE, CONNECTOR, AND WEAPON ENCLOSURE SHIELDING AND FILTERS IN PRECLUDING HAZARDS OF ELECTOMAGNETIC RADIATION TO ORDNANCE; MEASUREMENT OF

FSC MISC

DEPARTMENT OF THE NAVY

NAVAL ORDNANCE SYSTEMS COMMAND

WASHINGTON, D. C. 20360

Effectiveness of Cable, Connector, and Weapon Enclosure Shielding and Filters in Precluding Hazards of Electromagnetic Radiation to Ordnance; Measurement of

MIL-STD-1377 (NAVY)

1. This Military Standard is mandatory for use by the Department of the Navy.

2. Recommended corrections, additions, or deletions should be addressed to the Commanding Officer, Naval Ordnance Station, Indian Head, Md. 20640, Attn: Standardization Division, FS6.

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EFFECTIVENESS OF CABLE, CONNECTOR, AND WEAPON ENCLOSURE SHIELDING AND FILTERS IN PRECLUDING HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE; MEASUREMENT OF

1. SCOPE

1.1 This standard is intended to provide a weapon developer or designer with shielding and filter effectiveness test methods for determining whether the particular weapon design requirements of MIL-P-24014 have been properly implemented. It is not intended to be a substitute for full-scale electromagnetic hazards evaluation tests of the weapon system, but rather an aid in developing a weapon system with a high probability of successfully passing such environmental tests.

1.2 This standard covers the methods of shielding effectiveness of weapon enclosures, cables, and cable connectors over the frequency ranges of from 100 kilohertz (kHz) to 30 megahertz (MHz) and from 1000 MHz to 10 gigahertz (GHz). The shielding effectiveness test methods are conducted at two separate frequency ranges because of hardware limitations. It is unnecessary to measure shielding effectiveness between 30 MHz and 1000 MHz because of the Navy's limited use of these frequencies and because experience has indicated that shielding deficiencies in this range will probably appear in either of the two measured frequency ranges. The upper frequency for the test methods in paragraphs 4.4 and 4.5 may be increased to 40 GHz when applicable. This standard also covers the methods of measuring the filtering effectiveness of radio frequency (RF) suppression devices (filters) for weapon firing circuits over the frequency range of from 100 kHz to 10 GHz.

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2. REFERENCED DOCUMENTS

2.1 The following document of the issue in effect on date of invitation for bids or request for proposal, form a part of the standard to the extent specified herein.

MIL-P-24014(WEP)	Preclusion of Hazards from Electromagnetic Radiation to Ordnance, General Requirements for

3. DEFINITIONS

3.1 The terminology used in this standard is in accordance with the definitions of MIL-P-24014(WEP). In addition, the following terms are used throughout this standard, and their interpretation shall be in accordance with the following definitions.

3.1.1 Octave. The interval between any two frequencies having the ratio of 2:1.

3.1.2 Weapon enclosure. The metal shell surrounding a weapon circuit, such as the weapon skin.

3.1.3 Weapon cable. Any wiring outside of the weapon enclosure designed to be connected to circuits inside the enclosure.

3.1.4 Weapon enclosure discontinuity. Any break or joint in the metal weapon enclosure.

3.1.5 Surface transfer impedance. The ratio of the magnitudes of the longitudinal voltage drop on the outer surface of the shield to the current on the inside of the shield.

3.1.6 Shielding effectiveness. A measure of the quality of shielding.

3.1.7 Filter effectiveness. The minimum attenuation of a filter.

4. REQUIREMENTS

4.1 Shielding effectiveness measurements on cables (100 kHz to 30 MHz).

4.1.1 Test apparatus. The test apparatus shall be arranged as shown in figure 1.

4.1.1.1 Signal generator. The signal source shall be any RF signal generator or power oscillator with a current output capability compatible with the ammeter and voltmeter specified by 4.1.1.2 and 4.1.1.5, respectively.

4.1.1.2 Ammeter. Any shielded RF current measuring device which can measure the center conductor current of a coaxial cable over the desired frequency range shall be used. Such a device can be constructed from a small metal box and an RF panel ammeter as shown in figure 2. The ammeter, mounted inside the box, is connected to the center conductors of two bulkhead connectors mounted on opposite sides of the box. A small screen-shielded window in front of the box is used for viewing the meter. The sensitivity of the ammeter shall be compatible with the signal generator output current capability.

4.1.1.3 Cable adapter. It is generally necessary to construct an adapter to link the signal source and ammeter to the test cable. This can be constructed by placing the appropriate connectors on opposite sides of a small metal box and joining the proper center conductors inside. (A similar construction is shown in figure 3.) If a multiconductor cable is to be tested, the selection of the conductor(s) to be connected to the signal source is arbitrary.

4.1.1.4 Shielded short. One end of the test cable shall be terminated with a short that provides shield integrity.

4.1.1.5 RF voltmeter. An RF voltage measuring device or balanced or near balanced input design shall be used. The voltmeter probe should be fitted with balanced probe leads, each approximately 3 inches in length. The voltmeter shall be coordinated with the signal generator such that it is capable of measuring RF voltages as small as 1 millivolt per ampere of signal generator output current capability.

4.1.1.6 Shielding. To avoid direct coupling to the voltmeter probe, the circuit from the signal source to the cable under test should be shielded. The effectiveness of this shield should be greater than that of the cable under test. This can be determined by shorting the cable adapter and measuring the voltage and the center conducting current with the signal generator on. The surface transfer impedance (STI) calculated (see 4.1.4) from this arrangement shall be at least 20 decibels (db) below the STI of the test cable when calculated in accordance with 4.1.4.

4.1.2 Preparation for test.

4.1.2.1 Cable connectors. The cable under test should include both parts of any attached connectors, which shall be in a fully mated condition.

4.1.2.2 Long cables. If the cable to be tested has an electrical length greater than one-tenth wavelength at the test frequency, it must be divided into shorter lengths (test cables) and each length tested separately.

4.1.2.3 Branch cables. When the test cable has branches, the signal generator shall be connected to the branch having the most conductors. One branch shall be provided with the shielded short. Each remaining branch shall be left open-circuited but shall be provided with a cap to maintain shield integrity.

4.1.2.4 RF environment. Determine the RF environment by shorting the cable adapter and measure the voltage with the signal generator off. If any voltage is measured, identify the source and either terminate the source, shield the test apparatus, or compensate the calculations.

4.1.3 Measurement technique. The arrangement of the signal source, measuring equipment, and the test cable shall be in accordance with figure 1.

4.1.3.1 With the ouput of the signal source applied to the test cable, the center conductor current and the voltage on the outer surface of the shield between the ends of the test cable shall be measured. The cable shall be bent to permit the ends to be reached by the probe leads. These corresponding measurements shall be made at frequencies not more than 1 octave apart from 100 kHz to 30 MHz.

4.1.3.2 When the cable under test has been divided (4.1.2.2), the measurements shall be repeated on each section.

4.1.3.3 For branch cables, the measurements shall be repeated for the short on each branch except the branch to which the signal generator is connected.

4.1.4 Calculating the STI. The STI shall be calculated at each test frequency by dividing the voltage measurement by the current measurement. For long cables or branch cables, the STI for the total cable is the arithmetic sum of the STI's of the individual sections or branches.

4.2 Shielding effectiveness measurements on connectors (100 kHz to 30 MHz). The shielding effectiveness of cable connectors in the mated condition is normally measured as part of the cable measurement under 4.1. If the application requires a connector to provide shielding during mating, shielding effectiveness measurements shall be made as follows.

4.2.1 Test apparatus. The signal source and measuring equipment shall be as specified in 4.1.1.

4.2.2 Preparation of test connector.

4.2.2.1 Adapter cables. The two parts of the connectors to be tested should be attached to short lengths of shielded cable with one cable terminated in a short as specified in 4.1.1.4 and the other provided with the cable adapter as specified in 4.1.1.3.

4.2.2.2 Pin extension insert. A special pin extension insert, as shown in figure 4, shall be used. The purpose of the insert is to provide a path for the center conductor current and a method of positioning the connectors relative to each other. The insert shall be of a conducting material and of such length that the ends of the original mating pins will be held at least one-tenth inch apart. If a multipin connector is being tested, one of the outermost pins should be selected for extension. The conductor leading to this pin shall be the one to which the signal is applied.

4.2.3 Measurement technique. The arrangement of the apparatus shall be in accordance with figure 1, with the exception that the test connector pair with adapter cables shall be substituted for the test cable.

4.2.3.1 With the output of the signal source applied, the center conductor current and the maximum voltage between the two connector shells shall be measured at frequencies not more than 1 octave apart from 100 kHz to 30 MHz. The connectors should be manipulated relative to each other to obtain the maximum voltage. This should be done with a nonconductive handling device.

4.2.4 Calculation of the STI. The STI shall be calculated at each test frequency by dividing the voltage measurement by the current measurement. Each calculation shall be reported separately.

4.3 Shielding effectiveness measurements on weapon enclosures (100 kHz to 30 MHz).

4.3.1 Test apparatus. The signal source and measuring equipment shall be as specified in 4.1.1.1, 4.1.1.2, and 4.1.1.5. The test apparatus shall be arranged as shown in figure 5. It may be necessary to add extensions to the voltmeter probes; however, probe length shall be as short as practicable.

4.3.2 Preparation of test enclosure. The enclosure shall first be inspected for potential electrical discontinuities. Each discontinuity that is suspected shall be tested separately. A coaxial bulkhead connector shall be mounted on the outer surface of the enclosure on one side of the discontinuity. A wire shall be connected between the center conductor of the bulkhead connector and the inside surface of the opposite side of the discontinuity. The point of termination for the wire shall be such that the shortest line on the enclosure surface connecting the termination point and the bulkhead connector is perpendicular to the discontinuity. The length of the wire shall be less than 1 meter.

4.3.3 Measurement technique. The arrangement of the signal source, measuring equipment, and the test enclosure shall be in accordance with figure 5.

4.3.3.1 With the output of the signal source applied, the voltage across the discontinuity on the outer surface of the enclosure and the input center conductor current shall be measured for each discontinuity. The voltage and current measurements shall be made at frequencies not more than 1 octave apart from 100 kHz to 30 MHz.

4.3.4 Calculation of STI. The STI shall be calculated at each test frequency by dividing the voltage measurement by the current measurement. Each calculation shall be reported separately.

4.4 Shielding effectiveness measurements on cables (1000 MHz to 10 GHz).

4.4.1 Test apparatus. The test apparatus shall be arranged as shown in figure 6.

4.4.1.1 Signal generator. The signal source shall be any RF signal generator or power oscillator with a power output capability which is 80 db above the sensitivity of the power measuring devices specified in 4.4.1.5.

4.4.1.2 Double stub tuners. Any low loss impedance matching devices capable of matching the input and output impedance of the test cabinet to the 50-ohm measurement system shall be used.

4.4.1.3 Directional coupler. This shall be any device capable of providing a signal proportional to the forward power from the signal generator. It shall have a coupling of greater than 15 db (i.e., the signal povided by the directional coupler shall be more than 15 db below the forward power to be monitored) and a directivity of greater than 20 db.

4.4.1.4 Isolator. This shall be any type of isolator that will isolate the signal generator by providing a 50-ohm load for the signal generator and a 50-ohm source impedance for the input part of the cabinet.

4.4.1.5 Power meters. These can be any devices which will measure the power dissipated in a 50-ohm load.

4.4.1.6 Test cabinet. The test cabinet shall be in accordance with figure 7 and the following paragraphs.

4.4.1.6.1 Cabinet enclosure. This shall be a continuous metal enclosure. Its dimensions shall be such as to accommodate the weapon cable to be tested with a minimum distance between the weapon cable and the cabinet walls (except the wall to which it is affixed) of 1 foot. The shielding effectiveness of the cabinet should be greater than 60 db.

4.4.1.6.2 Input antenna. A type N bulkhead connector shall be mounted in one wall of the cabinet enclosure. The center conductor shall be connected to an antenna placed inside the cabinet. The antenna shall consist of a wire running from the connector to one corner of the cabinet, then diagonally across the end of the cabinet, and then the length of the cabinet parallel to one edge. It shall be at a spacing of approximately 1 inch from the cabinet walls. Standoff insulators of low loss shall be used to support the antenna.

4.4.1.6.3 Output antenna. A type N feed-through bulkhead connector shall be mounted in the cabinet wall forming the top of the cabinet. An antenna consisting of a length of wire shall be placed inside the cabinet so that it runs from the connector to one corner of the cabinet, then diagonally across the end of the cabinet, and then the length of the cabinet parallel to one edge. This places the output antenna opposite the input antenna in the cabinet enclosure. The antenna shall be approximately 1 inch from the cabinet walls at all points. Standoff insulators of low loss shall support the antenna. A provision shall be made to connect and disconnect the antenna to the bulkhead connector.

4.4.1.6.4 Access door. An access door or panel shall be placed in one wall of the cabinet. This door shall be large enough to allow entry of the weapon cable to be tested and shall provide easy access to the weapon cable. The shield integrity of the cabinet shall be maintained at 60 db or greater.

4.4.1.6.5 Paddle wheel tuner. A paddle wheel tuner, as shown in figure 8, shall be installed in the space between the cabinet wall and the weapon cable to be tested. The paddle wheel shall consist of three dipoles, 8, 6.5, and 5.25 inches long and each 1 inch wide. The dipoles shall be attached at their centers to one end of a nonconducting rod and shall be equally spaced (angularly) about the rod axis. The diameter of the rod shall be less than 0.5 inch. The length of the rod shall be such as to permit a 10-inch travel of the dipoles in the space between the weapon cable and cabinet wall. A metal tube shall be placed in the cabinet wall for the rod to exit the cabinet. The tube shall have a maximum inside diameter of 0.5 inch and a length of greater than 3 inches. The tube shall be bonded electrically to the cabinet wall at the exit point. This bond shall preserve the shield integrity of the cabinet enclosure.

4.4.2 Preparation of test cable. The test cable shall be of the same construction and materials as the final production cable.

4.4.2.1 Short termination. The test cable shall be shorted at one end. This short may be constructed from an opposite jack or plug connector by connecting all the pins of the connector together and to the connector's shell. The shielding effectiveness of this short shall be much greater than that of the cable to be tested.

4.4.2.2 Connector adapter. An adapter shall be constructed to adapt the connector at the unshorted end of the test cable to a standard type N connector. One or more of the pins connected to the conductors of the test cable shall be connected to the center conductor of the type N connector. The shielding of the connectors shall be maintained through the adapter. Figure 3 shows a preferred construction.

4.4.3 Measurement technique. The following measurements shall be conducted at 500-MHz intervals from 1000 MHz through 10 GHz.

4.4.3.1 Shield loss measurement. With the signal source power applied to the input of the cabinet, the matching devices shall be adjusted for maximum power as measured by the output power meter. The paddle wheel tuner is then used by rotating the rod and moving it back and forth. During this procedure, the paddle wheel tuner position must be adjusted at a number of positions until an absolute maximum is found. Once the absolute maximum is found the smaller relative maxima are disregarded, and the tuner is placed at the position for maximum power output. The remaining stub tuning is then performed. With the matching devices tuned, the maximum output power (P_{OS}) and the forward input power (P_{IS}) to the cabinet shall be measured.

4.4.3.1.1 A recommended method to insure that the paddle wheel tuner is placed in the position for maximum output is as follows. With the paddle wheel tuner fully extended, move it longitudinally inward until a relative maximum is reached. Rotate the tuner until the maximum is firmed up. Return the tuner to its original angular position and continue to move it inward until a second relative maximum is reached. Firm up relative maximum. Continue until tuner is completely in the cabinet. Pull tuner until it is fully extended and rotate it 20 degrees and proceed as above. Continue to repeat the procedures at each 20-degree interval until the tuner has been rotated 180 degrees.

4.4.3.2 Calibration measurement. The test cable shall be disconnected from the bulkhead connector in the cabinet wall and the output antenna in the cabinet shall be connected to the bulkhead connector's center conductor. With this configuration, the signal source power shall be applied to the input of the cabinet. The matching devices shall be adjusted for a maximum power in the load as measured by the output power meter. This tuning is accomplished as described in 4.4.3.1. With the matching devices tuned, the maximum output power (P_{OC}) and forward input power (P_{IC}) to the cabinet are measured.

4.4.4 Calculating shielding effectiveness. At each test frequency, shielding effectiveness may be computed from the measured values of forward input power (P_{IS}) and maximum output power (P_{OS}) for the shield loss measurement, and forward input power (P_{IC}) and maximum output power (P_{OC}) for the calibration measurement by using the following formula:

$$\text{Shielding effectiveness} = 10 \log (P_{IS} \cdot P_{OC})/(P_{OS} \cdot P_{IC}).$$

4.5 Shielding effectiveness measurements on weapon enclosures (1000 MHz to 10 GHz).

4.5.1 Test apparatus. The test apparatus shall be arranged as shown in figure 6.

4.5.1.1 Signal generator. The signal generator shall be in accordance with 4.4.1.1.

4.5.1.2 Double stub tuners. These shall be in accordance with 4.4.1.2.

4.5.1.3 Directional coupler. This shall be in accordance with 4.4.1.3.

4.5.1.4 Isolator. This shall be in accordance with 4.4.1.4.

4.5.1.5 Power meters. These shall be in accordance with 4.4.1.5.

4.5.1.6 Test cabinet. This shall be in accordance with figure 9 and 4.4.1.6.1, 4.4.1.6.2, 4.4.1.6.4, and 4.4.1.6.5. (In these paragraphs, the term "weapon cable" shall be replaced by "weapon enclosure.")

4.5.2 Preparation of the weapon enclosure. The internal components of the weapon shall be removed so that only the weapon's shell or exterior skin remains. The weapon enclosure shall be supported inside the cabinet by low loss insulating material.

4.5.2.1 Reference discontinuity. A type N feed-through bulkhead connector shall be installed in one wall of the weapon enclosure. The point chosen for this installation should be centrally located or near a suspected discontinuity. An antenna shall be fitted to each side of the bulkhead connector. These antennas shall consist of a 1-foot length of wire connected to the connector's center conductor. Provision shall be made to remove the antenna outside the weapon enclosure and replace it with a standard type N short termination.

4.5.2.2 Output antenna. A type N feed-through bulkhead connector shall be installed in the weapon enclosure. The point chosen for this installation should be centrally located. A wire running the length of the weapon enclosure on the inside shall be connected to the connector's center conductor. The other ends of this wire shall be electrically connected to the inside of the weapon enclosure. A double shielded coaxial cable shall connect the other side of this connector to another feed-through connector located in the cabinet wall.

4.5.2.3 Paddle wheel tuner. A paddle wheel tuner shall be installed inside the weapon enclosure. The tuner shall be in accordance with 4.4.1.6.5. However, if the dimensions of the paddle wheel tuner are too large for the enclosure, it shall be scaled down proportionally. Provisions for tuning from a position external to the cabinet shall be made by passing the rod through the weapon enclosure and cabinet walls. At the exit points, the rod shall pass through a tube which is less than 0.5 inch in diameter and greater than 3 inches in length. The tubes shall be electrically bonded to their respective surfaces at the exit points in such a manner as to maintain the shield integrity of each enclosure.

4.5.2.4 Access panel. An access panel can be placed in the weapon enclosure if necessary to facilitate the test. The panel shall be as small as practical. The panel shall be bonded to the weapon enclosure by fasteners not more than 2 centimeters apart around the periphery of the panel. Standard RF gasket material shall be used to seal the panel.

4.5.3 Measurement technique. The following measurements shall be conducted at 500-MHz intervals from 1000 MHz through 10 GHz.

4.5.3.1 Shield loss measurement. The reference discontinuity shall be short circuited. With the signal source power applied to the input of the cabinet, the matching devices shall be tuned for maximum ouput power. The tuning procedure for each paddle wheel tuner shall be as specified in 4.4.3.1. The paddle wheel tuners should be tuned before the stub tuners. With the matching devices tuned, the maximum ouput power and forward input power to the cabinet are measured.

4.5.3.2 Calibration measurement. The short termination shall be removed from the reference discontinuity and replaced by the reference discontinuity antenna. With this configuration, the signal source power shall be applied to the input of the cabinet and the matching devices adjusted for maximum output power. This tuning is accomplished as specified in 4.5.3.1. With the tuning devices tuned, the maximum output power and forward input power to the cabinet are measured.

4.5.4 Calculating shielding effectiveness. Shielding effectiveness is computed from the measured values by using the equation specified in 4.4.4.

4.6 Effectiveness measurements below 30 MHz on filters for load known. Filter effectiveness can be determined as specified in 4.7 rather than 4.6, if desired.

4.6.1 Test apparatus. The test apparatus shall be in accordance with figure 10.

4.6.1.1 RF voltmeter. Any RF voltage measuring device(s) which has the desired frequency range and sensitivity shall be used. The input impedance of the voltmeter shall be high enough such that the impedances in the transmission lines being monitored are not significantly changed.

4.6.1.2 Signal generator. The signal source shall be any signal generator or power oscillator capable of providing sufficient power output to permit a filter effectiveness of 60 db to be measured with the voltage measuring device described in 4.6.1.1.

4.6.1.3 Impedance measuring device. Any RF bridge or other device or arrangement capable of measuring impedances in the range encountered shall be used.

4.6.2 Preparation of test filter. The filter shall be mounted in its final production configuration with the load (circuit to be protected) unattached.

4.6.3 Measurement technique. A low loss filter generally is not suitable for protection of a load when not all the circuit impedances are known and a meaningful filter effectiveness cannot be measured. Therefore, a preliminary test shall be required to determine whether the filter under test is a high or low loss device.

4.6.3.1 Determination of filter loss. The input impedance of the filter shall be measured with the ouput of the filter terminated in a short circuit and again with it terminated in an open circuit. The terminations shall be placed at the same point in the output circuit. These measurements shall be made at frequencies not more than 1 octave apart over the specified frequency range. The following formula shall be used to determine filter loss:

$$\text{Filter loss} = \left| \frac{Z_{SC} + \sqrt{Z_{SC} Z_{OC}}}{Z_{SC} - \sqrt{Z_{SC} Z_{OC}}} \right|$$

where Z_{SC} is the filter input impedance with the output shorted and Z_{OC} is the filter input impedance with the output open. If the filter loss is less than 10, filter effectiveness measurements are not meaningful. If the filter loss is greater than 10, filter effectiveness can be determined using the method in 4.6.3.2.

4.6.3.2 Filter effectiveness measurement technique. The arrangement of the measuring equipment and test apparatus shall be in accordance with figure 10.

4.6.3.2.1 Impedance measurements. The input impedance shall be measured at the input terminals of the filter with the load attached. The load impedance shall be measured by removing the filter from the circuit and measuring the impedance between the load terminals. The values of the input and load impedances shall be measured at frequencies not more than 1 octave apart from 100 kHz to 30 MHz.

4.6.3.2.2 Voltage measurements. The input voltage and the output voltage of the filter under loaded conditions shall be measured. With the filter properly installed in the circuit, the signal source voltage shall be applied to the input terminals of the filter and shall be measured with the RF voltage measuring device. The voltage measurement shall be made at the point in the input circuit where the impedance was measured. The output load voltage shall be measured simultaneously in a similar manner. If the weapon enclosure provides the circuit shield for the filter's output circuit, the voltage measuring device should be placed outside the weapon with the probe and probe cable penetrating the weapon enclosure. The probe cable shield should be bonded to the weapon enclosure at the entry point to maintain the integrity of the enclosure shield. Voltage measurements shall be made at those frequencies at which the impedances in 4.6.3.2.1 were measured.

4.6.4 Calculating filter effectiveness. From the measured values of filter input voltage (V_{in}), load voltage (V_L), filter input impedance (Z_{in}), and load impedance (Z_L), the filter effectiveness at each frequency can be calculated using the following formula:

$$\text{Filter effectiveness (db)} = 20 \log |V_{in}/V_L| + 20 \log (|Z_L|/|Z_{in}|) + 10 \log (R_{in}/R_L)$$

where R_{in} and R_L are the real parts of Z_{in} and Z_L, respectively, and the brackets, | |, designate the magnitude of the impedances.

4.7 Effectiveness measurements below 300 MHz on filters for load not known.

4.7.1 Test apparatus. The test apparatus shall be arranged as shown in figure 11.

4.7.1.1 Measuring instruments. The voltmeter, signal generator, and impedance measuring device shall be as specified in 4.6.1.1 through 4.6.1.3.

4.7.1.2 Filter load. The load presented to the filter can be any arbitrary load; preferably, a standard 50-ohm termination should be used.

4.7.2 Preparation of the test filter. The filter shall be tested in a coaxial configuration to isolate the input from the output. If the filter does not have coaxial end connectors, it can be mounted in a metal cylinder, such as shown in figure 12. The filter shall be mounted on the barrier plate using the same techniques as is planned for actual use. The joints of the cylinder shall have a continuous electrical bond. The circuit between the filter and the signal source shall be shielded to avoid direct interference between the signal applied to the filter and the output voltage. The amount of interference can be determined by disconnecting the signal cable from the filter and, with the signal cable terminated in an arbitrary impedance, applying a signal voltage to the termination and observing the reading on the output voltage measuring device. The value of this reading shall be at least 10 db below the voltage value obtained when the signal voltage is applied directly to the filter.

4.7.3 Measurement technique. For the reasons given in 4.6.3, preliminary measurements of the filter shall be necessary to determine filter loss and whether subsequent measurements for the filter effectiveness are useful.

4.7.3.1 Determination of filter loss. Preliminary measurements shall be made and filter loss determined as in 4.6.3.1. If the filter loss is greater than 10, filter effectiveness shall be determined using the technique of 4.7.3.2.

4.7.3.2 Filter effectiveness measurement technique. The arrangement of the measurement apparatus shall be in accordance with figure 11.

4.7.3.2.1 Impedance measurements. The input impedance of the filter shall be measured at the input terminals of the filter with the filter load connected; the output impedance of the filter shall be measured at the output terminals of the filter looking toward the generator with the filter load disconnected. The load impedance shall be measured at the filter output terminals looking toward the load with the filter disconnected. The filter output and load impedance measurements shall be made at the same junction point in the circuit. All impedance measurements shall be made at a set of frequencies not more than 1 octave apart from 100 kHz to 300 MHz.

4.7.3.2.2 Voltage measurements. With the load connected to the filter, the output of the signal source shall be applied to the input terminals of the filter, and the input voltage shall be measured with the RF voltage measuring device. Simultaneously, the voltage developed across the load shall be measured. These voltages shall be measured at the same point in the filter input and output circuits at which the impedances were measured. The voltage measurements shall be made at the same frequencies at which the impedance measurements were made.

4.7.4 Calculating filter effectiveness. With the measured values of filter input impedance (Z_{in}), output impedance (Z_{out}), load impedance (Z_L), input voltage (V_{in}), and load voltage (V_L), filter effectiveness can be calculated using the following formula:

Filter effectiveness =

$$20 \log (V_{in}/V_L) + 10 \log |4 R_{in} R_{out}/Z_{in}^2| + 20 \log |Z_L/(Z_{out} + Z_L)|$$

where R_{in} and R_{out} are the real parts of Z_{in} and Z_{out}, respectively, and the brackets, | |, indicate the magnitudes of the impedances.

4.8 Effectiveness measurements above 300 MHz on filters for load not known.

4.8.1 Test apparatus. The test apparatus shall be arranged as shown in figure 13.

4.8.1.1 Signal generator. The signal source shall be as specified in 4.6.1.2.

4.8.1.2 Dual directional coupler. This can be any device capable of measuring the forward and reflected powers in a 50-ohm transmission line. The coupling of each coupler shall be greater than 15 db (see 4.4.1.3) and each shall have a directivity of greater than 35 db.

4.8.1.3 Isolator. The isolator shall be as specified in 4.4.1.4.

4.8.1.4 Power meters. The power meters shall be any devices which will measure the power dissipated in a 50-ohm load.

4.8.2 Preparation of test filter. The filter shall be tested in a coaxial configuration as specified in 4.7.2.

4.8.3 Measurement technique. The arrangement of the measurement equipment and test apparatus shall be in accordance with figure 13. The output terminals of the filter are those that will be toward the electroexplosive device in the application.

4.8.3.1 Insertion loss measurement. The forward input power (P_i) to the filter and the power (P_L) dissipated in a 50-ohm load terminating the filter shall be measured. The insertion loss (IL) of the filter shall be computed from the following formula:

$$\text{Insertion loss (db)} = 10 \log (P_1/P_L).$$

If the insert loss is less than 40 db, then the filter is not suitable for HERO applications and should be discarded. If the insertion loss is greater than 70 db, the filter is suitable for HERO application and need not be tested further. If the insertion loss is between 40 db and 70 db, filter effectiveness can be determined from the following paragraphs.

4.8.3.2 Input reflection coefficient magnitude measurement. The forward forward input power (P_1) to the filter and the power reflected (P_r) from the input of the filter shall be measured. The magnitude of the input reflection coefficient, $|\Gamma|$, of the filter in the 50-ohm measurement system shall be computed from the following formula:

$$|\Gamma| = (P_r/P_1)^{1/2}.$$

4.8.3.3 Output reflection coefficient magnitude measurement. The filter shall be turned around in the measurement system so that the former input terminals are now the output terminals. In this position, the filter (terminals away from the generator) shall be terminated in a 50-ohm load. The forward input power (P_1') to the filter and the power reflected (P_r') shall be measured. The magnitude of the output reflection coefficient, $|\Gamma'|$, of the filter shall be computed from the following formula:

$$|\Gamma'| = (P_r'/P_i')^{1/2}.$$

4.8.4 Calculation of filter effectiveness. Filter effectiveness shall be computed from the measured quantities with the following formula:

$$\text{Filter effectiveness} = IL - 10 \log \{1/[(1 - |\Gamma|^2)(1 - |\Gamma'|^2)]\}.$$

Review activities:
Navy - AS, EC

User activities.
Navy - MC

Preparing activity:
Navy - OS
(Project no. MISC-N668)

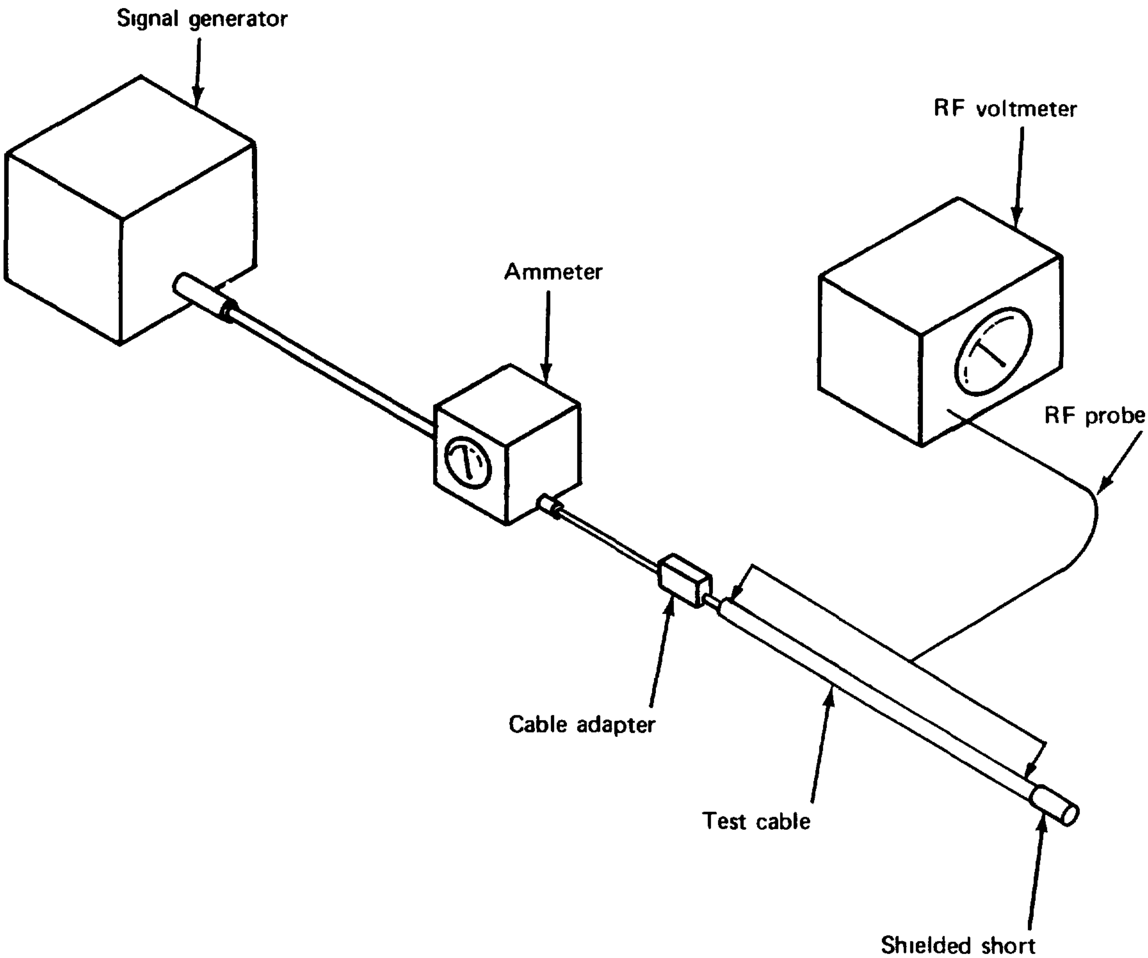


FIGURE 1. STI MEASUREMENT CONFIGURATION FOR CABLES

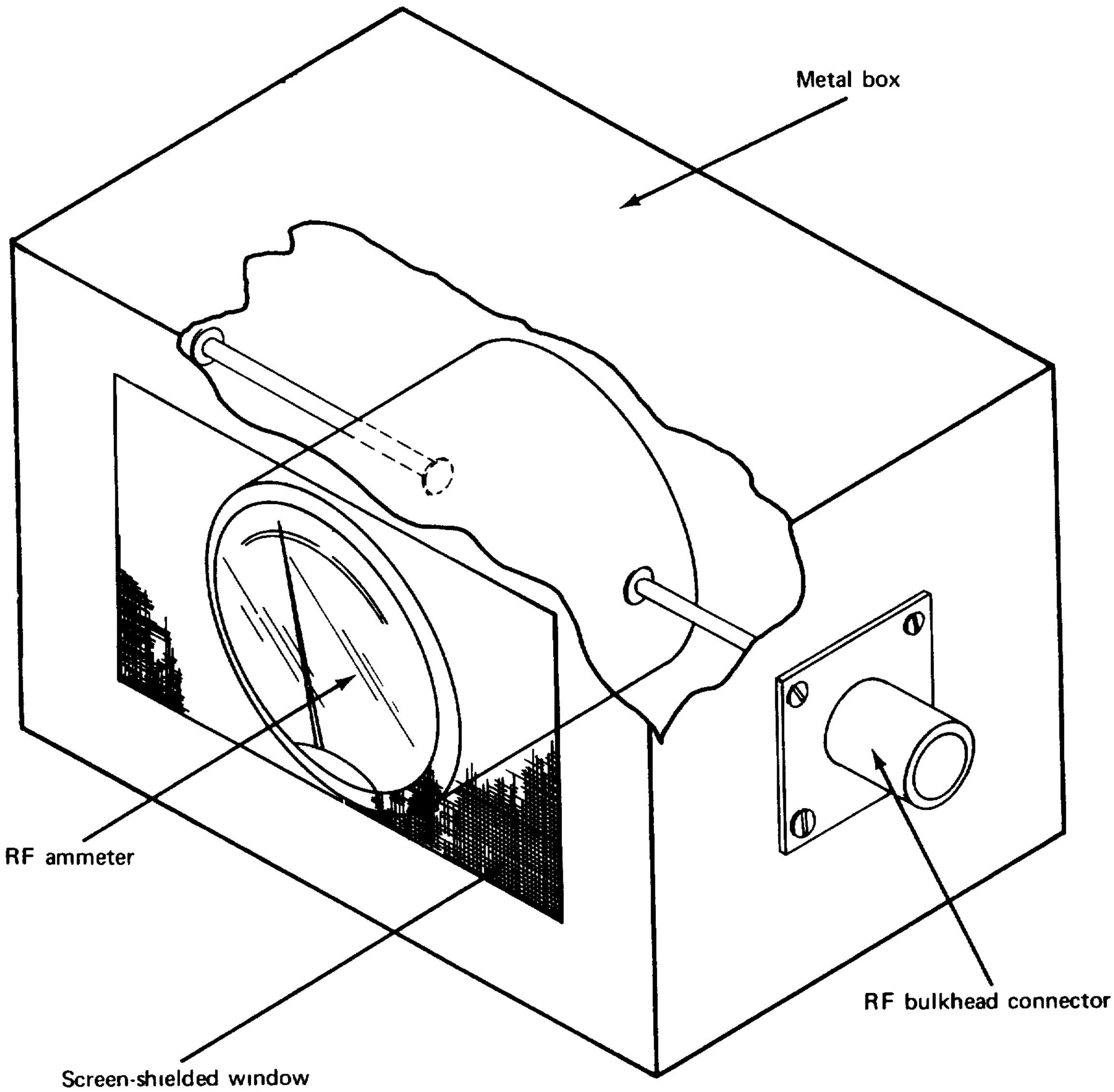


FIGURE 2. A POSSIBLE CENTER CONDUCTOR MEASURING DEVICE

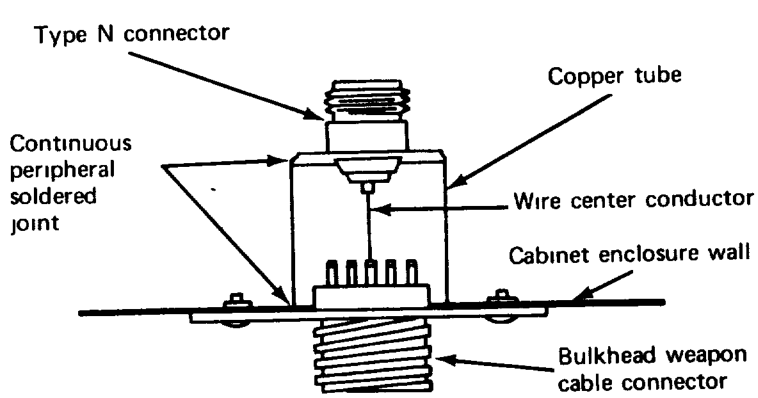


FIGURE 3. CONNECTOR ADAPTER

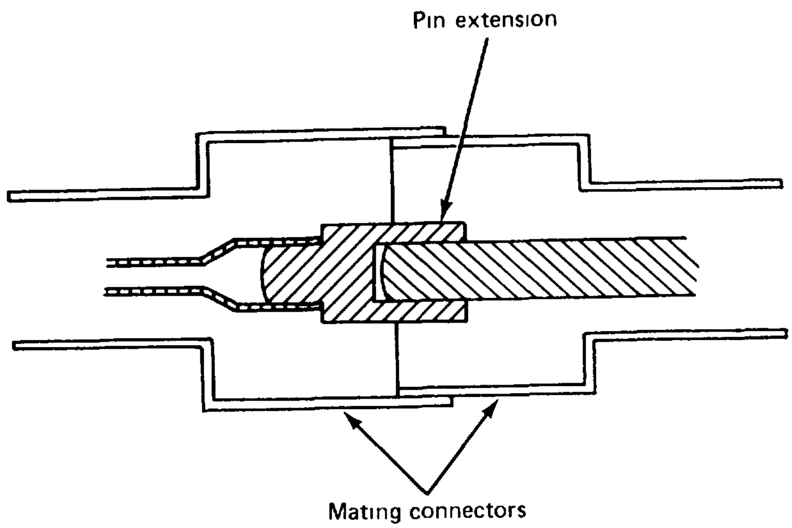


FIGURE 4. PIN EXTENSION INSERT

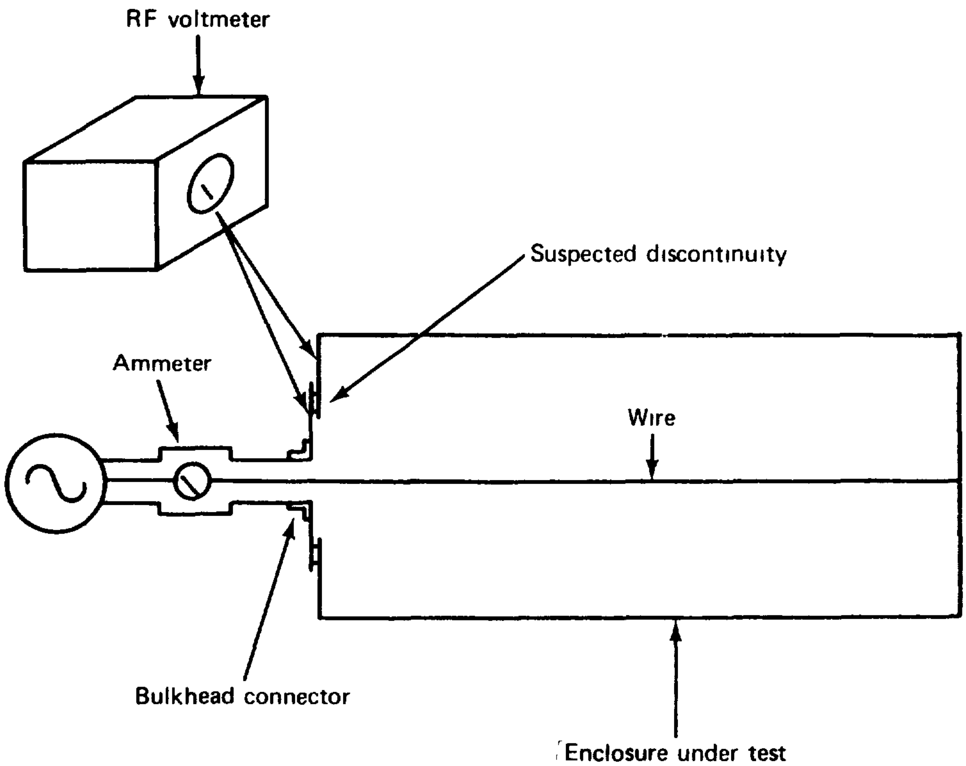


FIGURE 5. STI MEASUREMENT CONFIGURATION FOR ENCLOSURES

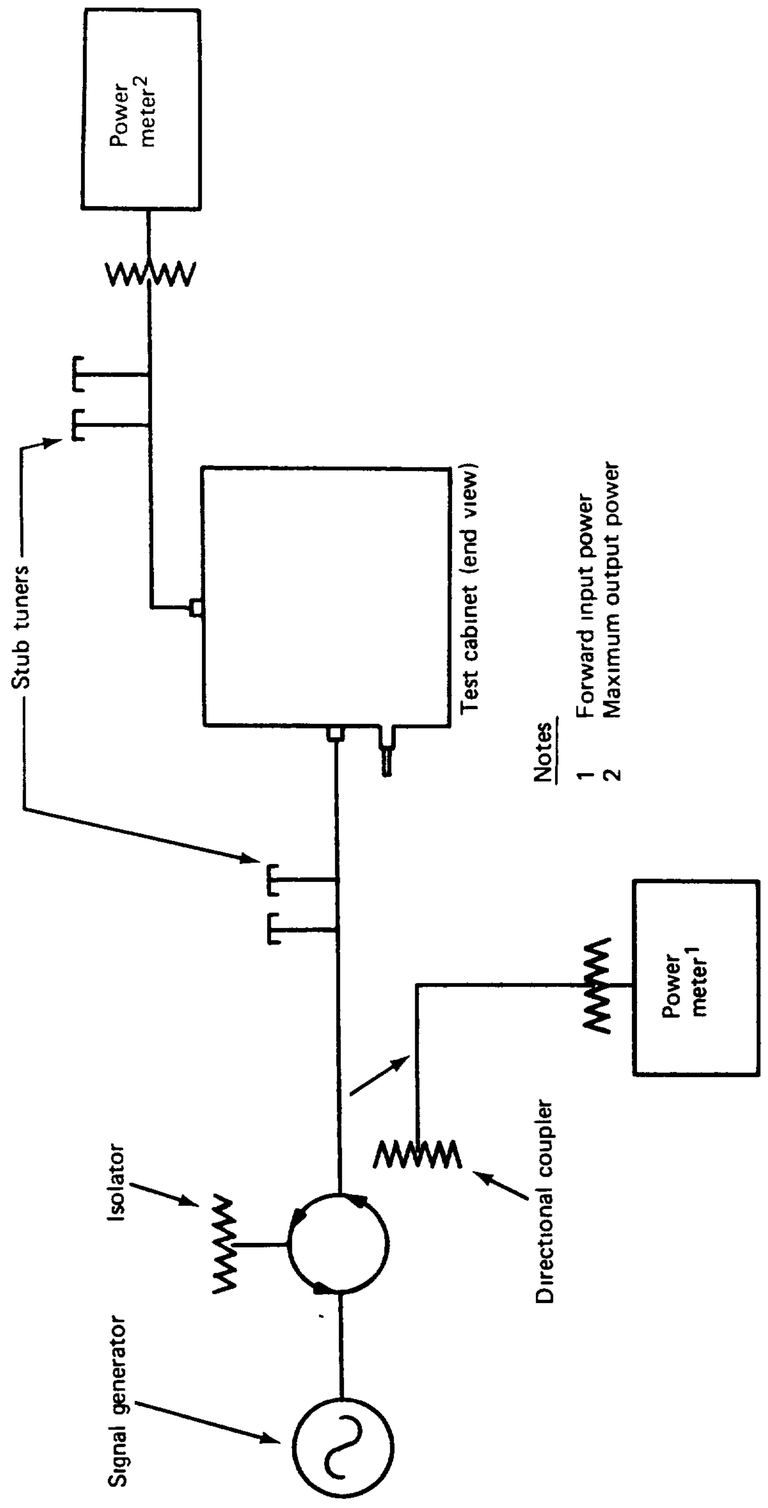
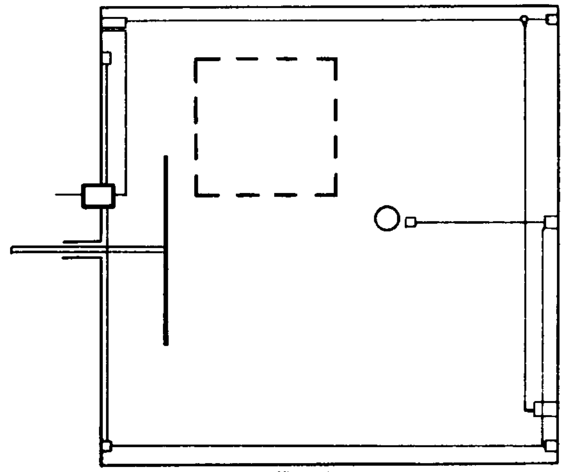


FIGURE 6. ARRANGEMENT OF TEST APPARATUS



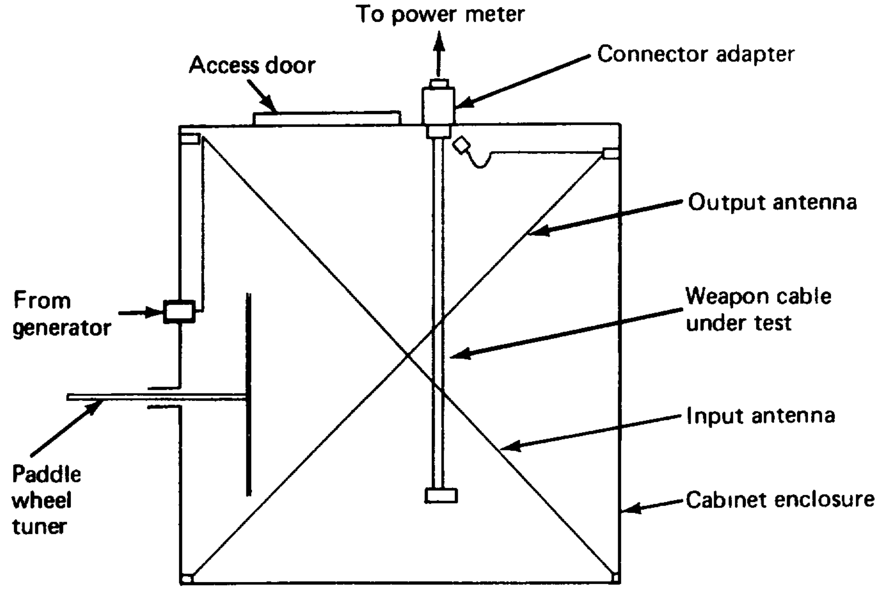


FIGURE 7. TEST CABINET (WITH WEAPON CABLE)

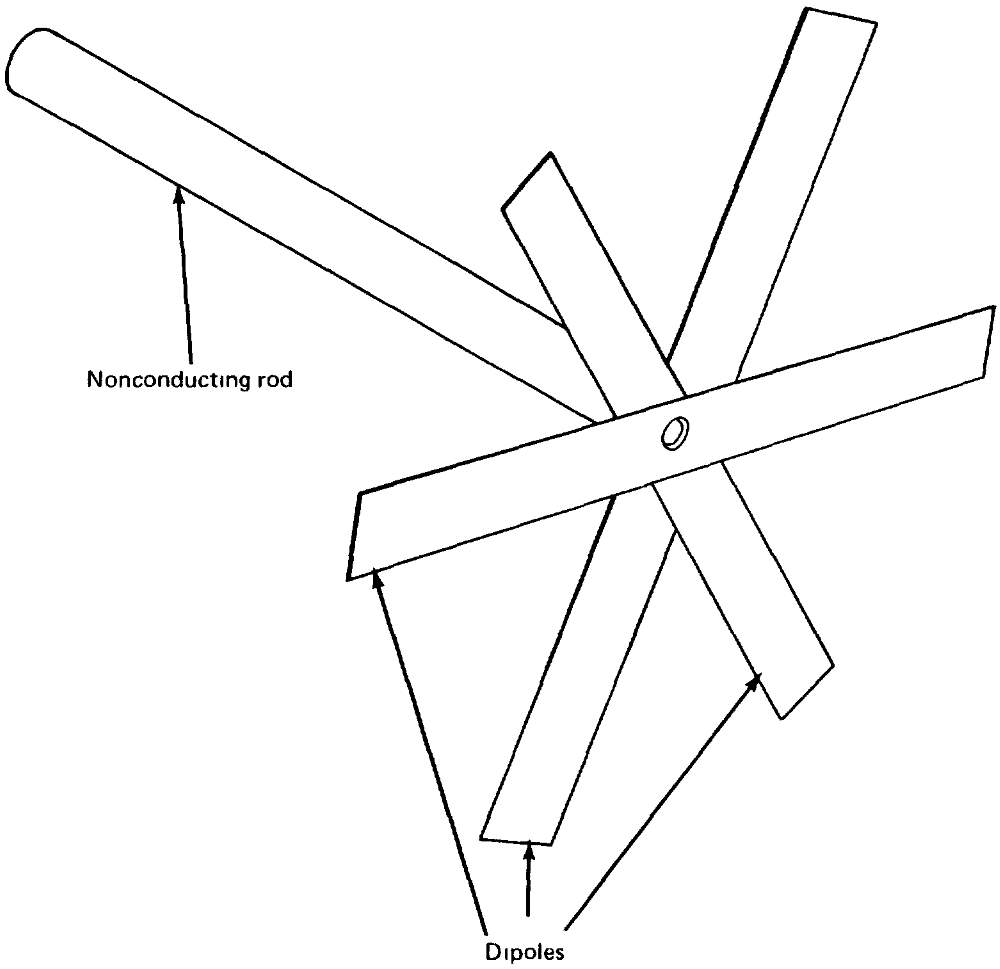


FIGURE 8. PADDLE WHEEL TUNER

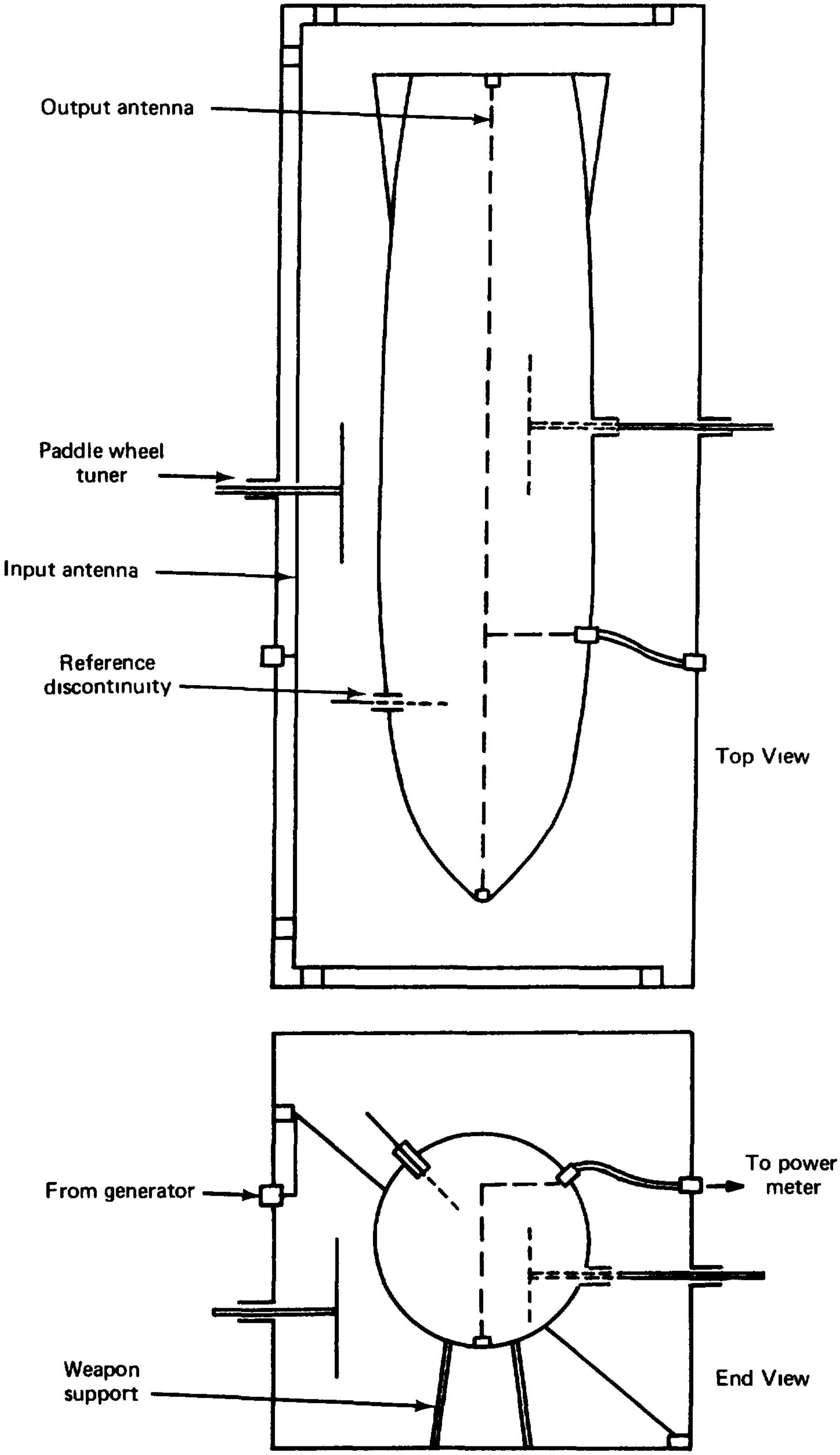


FIGURE 9. TEST CABINET (WITH WEAPON ENCLOSURE)

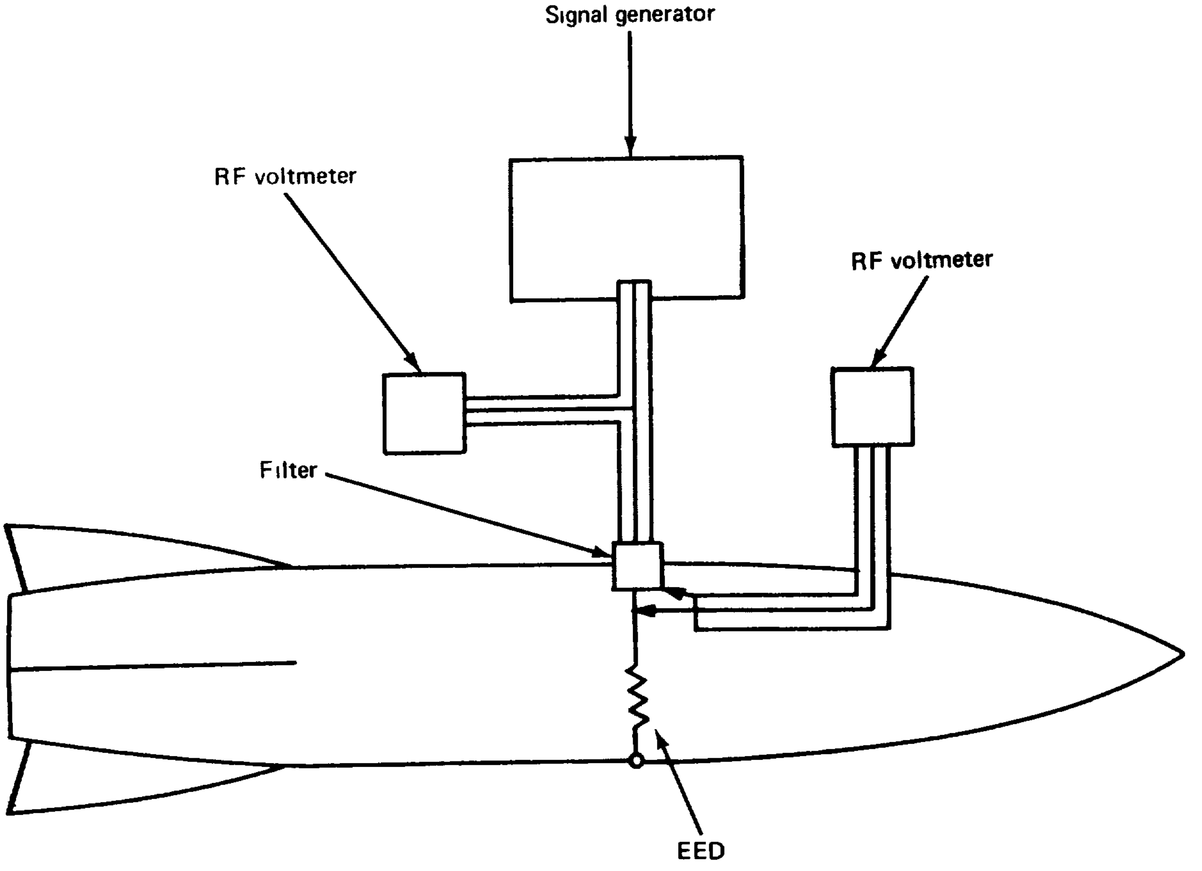


FIGURE 10. FILTER EFFECTIVENESS TEST CONFIGURATION
(BELOW 30 MHz; KNOWN LOAD)

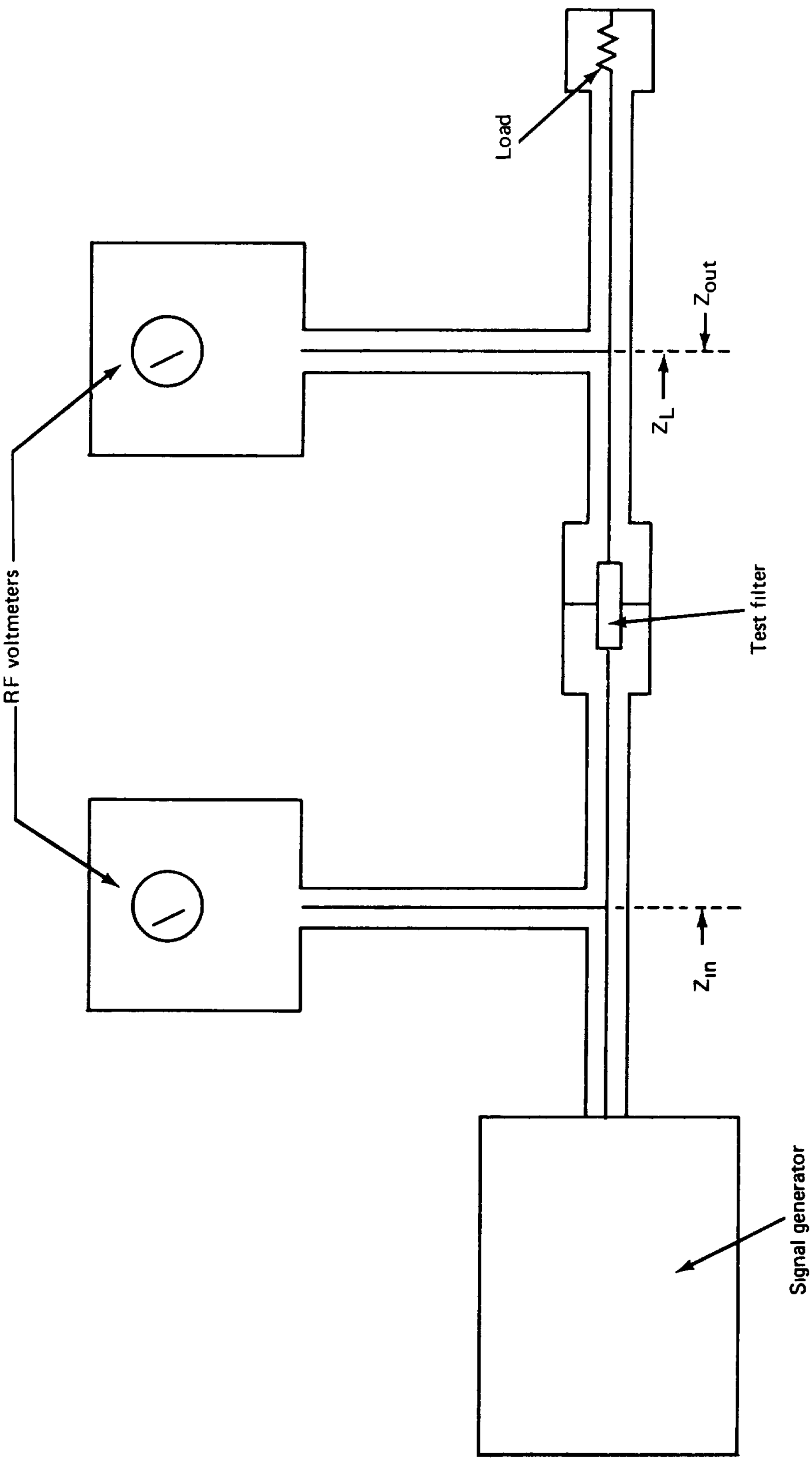


FIGURE 11. FILTER EFFECTIVENESS TEST CONFIGURATION
(BELOW 300 MHz; UNKNOWN LOAD)

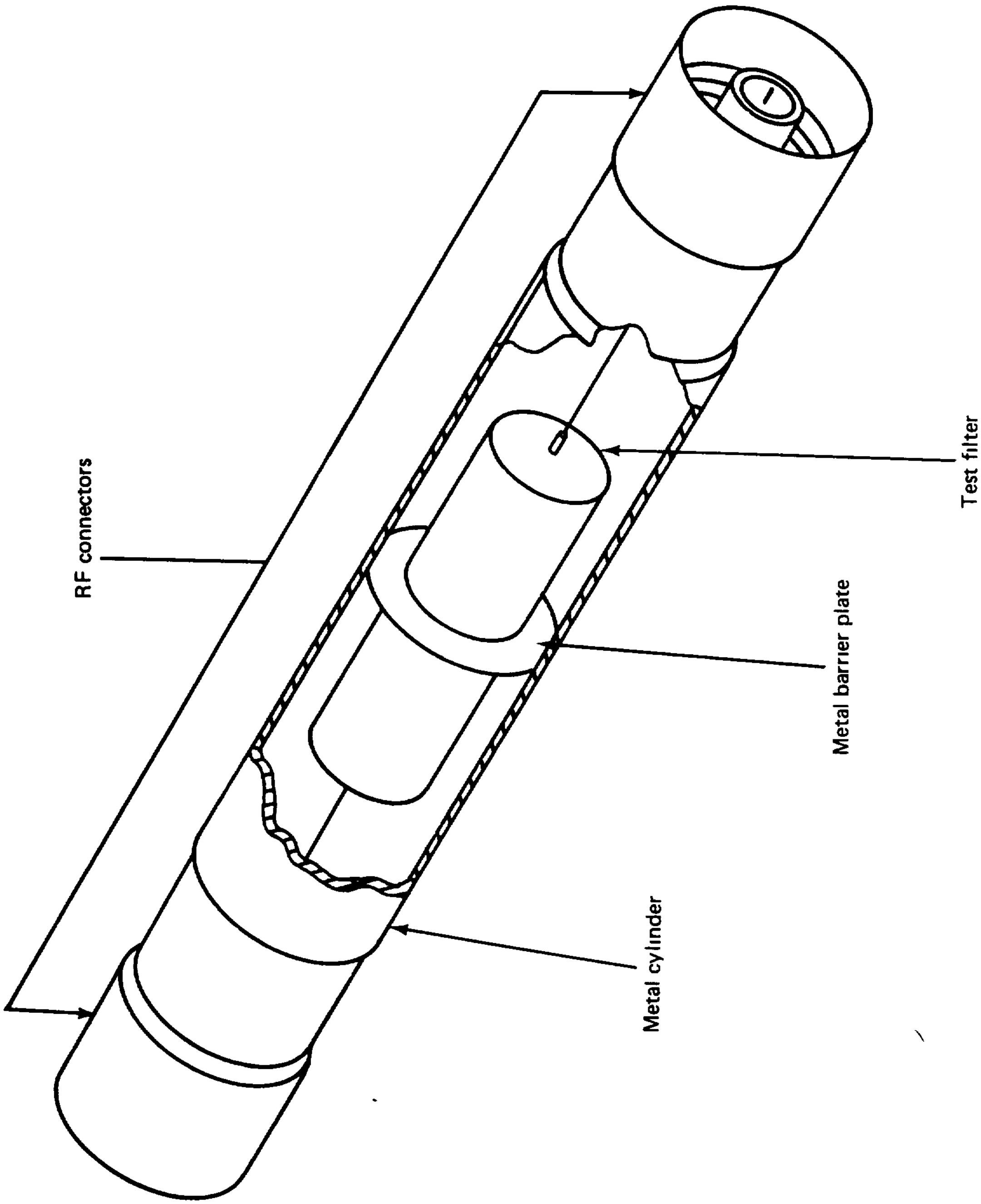


FIGURE 12. FILTER TEST FIXTURE

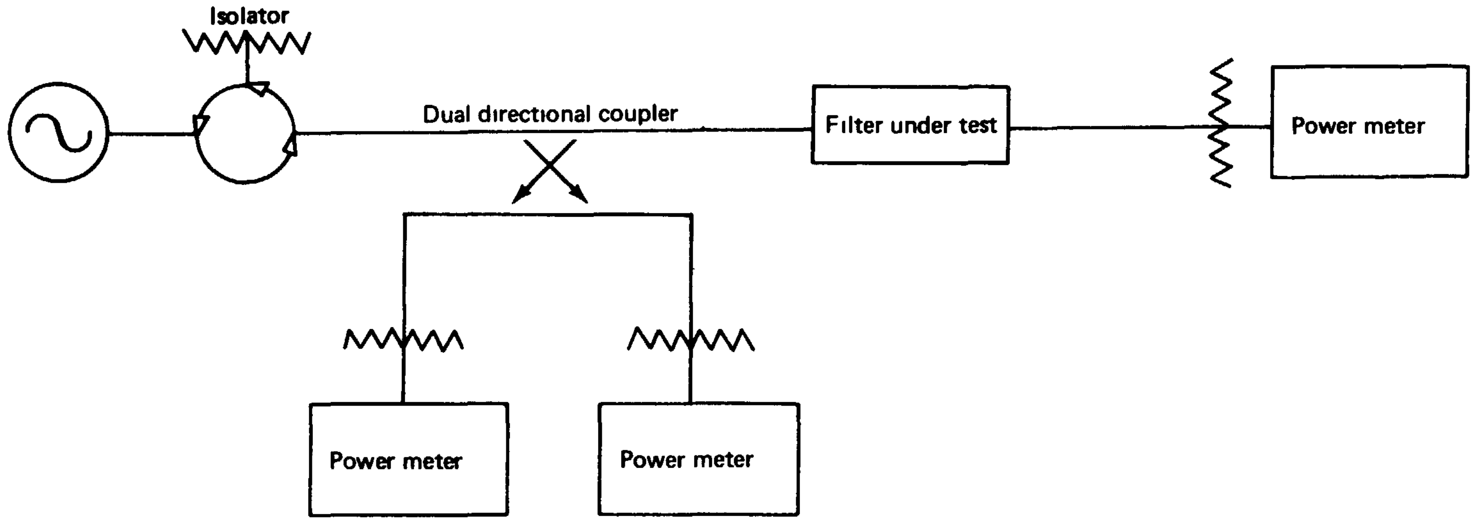


FIGURE 13. FILTER EFFECTIVENESS TEST CONFIGURATION (300 MHz to 10 GHz)

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