MILITARY STANDARD

TEST METHODS FOR ELECTRICAL CONNECTORS

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2	14 August 1981	2	10 September 1980
3	14 August 1981	3	10 September 1980
4	14 August 1981	4	10 September 1980
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(Project 5935-3261)

METHOD 3008

SHIELDING EFFECTIVENESS OF MULTICONTACT CONNECTORS

1. PURPOSE.

1.1 Purpose. This method measures the shielding effectiveness of multicontact connectors in the 1-10 GHz frequency range utilizing mode-stirred techniques.

1.2 Application. This method involves measuring the leakage at the connector pair interface of a multicontact connector placed in a shielded enclosure, as shown on figure A1. The connector under test is exposed to electromagnetic fields which are made statistically random by a rotating reflective surface (mode-stirrer). The leakage of the connector is expressed as shielding effectiveness measured in decibels (dB). The shielding effectiveness of the connector in decibels is defined as:

$$S.E. = 10 \log \left(\frac{\bar{P}_{REF}}{\bar{P}_{CUT}} \right)$$

Two sets of measurements are required: (1) a reference measurement and (2) a shield measurement. Both measurements shall be performed with the test item in the chamber and at the same frequency within 100 kHz. The reference measurement can be performed once at each frequency and can be utilized for subsequent connector tests provided the measurement system is linear.

2. DEFINITIONS.

2.1 Units. The International System of Units, as adopted by the United States Bureau of Standards is used. This system of units (designated "SI" for System Internationale d'Unites) was defined and given official status at the 11th General Conference on Weights and Measures in Paris at a 1960 meeting. MIL-STD-463 gives a description of the system of units used in this standard.

2.2 Terms. The meaning of terms contained in this test are in accordance with MIL-STD-463. In addition to those terms, the following terms are also defined:

2.2.1 Shielded conduit. Any conductor or conductors enclosed by a solid conducting sheath. The conductor or conductors may themselves serve as a sheath for other conductors.

2.2.2 Shielded enclosure. A housing, screen, or other object that is intended to substantially reduce the effect of electric or magnetic-fields upon devices or circuits on one side of the shield. Examples include cases, cabinets, airframes, etc.

2.2.3 Shielding effectiveness. For a given incident field, the ratio (usually expressed in decibels) of the power received by a load protected by an electromagnetic shield to that power which would be received by the load in the absence of the shield.

2.2.4 Test item. A general term used to refer either a shielded cable and/or connector.

2.3 Abbreviations and symbols.

AWG	American Wire Gauge
CUT	Connector under test
cm	Centimeters
d	Generalized dimension, in meters, for design of mode-stirrer
D	Distance of connector from chamber wall equal to one wavelength at the lowest test frequency
dB	Decibels
dBm	Power measured in dB referenced to one milliwatt
EM	Electromagnetic
f_{GHz}	Frequency in gigahertz
f_{opGHz}	Freqency in gigahertz of lowest operating frequency for which mode-stirred chamber is designed
FM	Frequency modulation
GHz	Gigahertz

$h(x)$	Height of the nearest edge of the connector forming the transmission line taper above test chamber wall at a distance "x" from the connector end of the taper (see figure B-2)
H	Height of the center of the long wire antenna above test chamber wall
kHz	Kilohertz
l	The length in centimeters measured along the conducting wire from which the transmission line taper is constructed (see figure B-2)
L	Length of extreme dimension associated with a test item
L/λ	Electrical length of test item
L_a	Total length of long wire antenna including the transmission line tapers attached to both ends
L_T	Length of one transmission line taper
λ	Wavelength associated with a given test frequency radiating in free space
m	Meters
MHz	Megahertz
MS	Mode-stirred ohms
$P_{in\ CUT}$	Input power to the mode-stirred chamber when P_{CUT} is being measured
$P_{in\ REF}$	Input power to the mode-stirred chamber when P_{REF} is being measured
P_{CUT}	Average power over one mode-stirrer rotation received by the connector under test
P_{REF}	Average power over one mode-stirrer rotation received by the reference antenna
R	Inside radius of type-N connector
RF	Radiofrequency
SE	Shielding effectiveness
VSWR	Voltage standing wave ratio
x	Distance, in centimeters, along transmission line taper as measured from the connector end of the taper (see figure B-2)

3. TEST EQUIPMENT.

3.1 General test equipment. The following equipment shall be used for these measurements. Characteristics are described in 3.1.1 through 3.1.5 for the items that have particular requirements.

a. Signal source
b. ISOLATOR
c. Frequency counter
d. Shielded cable
e. Directional couplers
f. Power meters
g. 50-ohm loads
h. Attenuators

3.1.1 Signal source. The signal source(s) shall be RF signal generator-power amplifier combination(s) or power oscillator(s) with a power output capability of one watt minimum. To assure measurement repeatability, the signal source shall have a residual FM stability of better than 100 kHz at any test frequency and the frequency shall be resetable within this tolerance when using a frequency counter.

3.1.2 Shielded conduit. A low-loss semirigid coaxial cable shall be utilized. This conduit, associated adaptors, and resulting joints shall have a shielding effectiveness at least 10 dB greater than that required of the connector under test to ensure that the leakage measured in paragraph 4 is due to the connector under test only.

3.1.3 Directional couplers. These shall be any devices capable of providing a signal proportional to the forward power from the signal source. They shall have a coupling of greater than 15 dB (i.e., the signal provided by the directional couplers shall be more than 15 dB below the forward power to be monitored) and directivity on the order of 20 dB or greater.

3.1.4 Power meters. These shall be devices that have input impedance of 50 ohms and that are capable of measuring conducted power from 1 to 10 GHz.

3.1.5 Receiver. This equipment must have the sensitivity to measure the small signals from the connector/conduit assembly. For a mode-stirred chamber with a lower usable frequency of 1 GHz, the receiver must have a sensitivity of -90 dBm to measure shielding effectiveness values of 90 dB from 1-10 GHz. For use of the "Continuous Sample Averaging" technique, described in paragraph 3.2.2.2, it is desirable that the receiver have a variable output time constant capability for signal averaging. A lock-in analyzer, or equivalent, has the specified sensitivity and the variable output time and constant capability.

3.1.6 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.

3.2 Special test equipment.

3.2.1 Mode-stirred chamber. This shall be a shielded metal enclosure that has a minimum shielding effectiveness above 1 GHz of 60 dB as measured by MIL-STD-285. Modifications to the chamber include installation of an input antenna, reference antenna, and mode-stirrer. Requirements for the shielded enclosure are contained in Appendix A, along with a description of the required modifications for converting it to a mode-stirred chamber.

3.2.1.1 Input antenna. An input antenna shall be provided by a long wire (>5λ at the lowest test frequency) installed along the sides of the mode-stirred chamber. An impedance matching taper can be utilized at both ends of this long wire antenna to effectively increase the dynamic range of the measurement system. These tapers are not necessary however, for proper mode-stirred chamber operation. Construction of the antenna along with its associated tapers is described in Appendix B. This installation of the antenna in the mode-stirred chamber shall be as described in Appendix A.

3.2.1.2 Reference antenna. A reference antenna, identical to the input antenna, shall be installed in the mode-stirred chamber. Installation and construction of the antenna is described in Appendices A and B.

3.2.1.3 Mode-stirrer. A mode-stirrer shall be installed in the mode-stirred chamber. This device may be constructed from sheet aluminum by using simple hand tools as described in Appendix C, with installation of the mode-stirrer described in Appendix A.

3.2.2 Data collection system. This system, which includes the receiver, must be capable of obtaining an average of the signals from the reference antenna and the connector/conduit assembly for one rotation of the mode-stirrer. A two-channel system will allow both measurements to be taken simultaneously. Measurements in the mode-stirred chamber are made by sampling the signals from the reference antenna and connector/conduit assembly as the mode-stirrer is moved through 360° in rotation. The signal averaging can be accomplished with the use of one of the following data collection systems: (1) Discrete Sample Averaging System, and (2) Continuous Sample Averaging System.

3.2.2.1 Discrete sample averaging system. This system, shown on figure 1, samples the signals at a discrete number (e.g., 200) of mode-stirrer positions. Each data value is then stored in a memory device and an average calculated after the measurement has been completed. This system must also control the stepper motor used for rotation of the mode-stirrer.

3.2.2.2 Continuous sample averaging system. This system, shown on figure 2, continuously rotates the mode-stirrer at a moderate speed with the signal averaged in real time by a device that has a time constant which is at least three (3) times longer than the time for one mode-stirrer rotation. The receiver and averaging device may be the same equipment or separate. This averaging system offers the advantage of reduced test time and a simpler data collection system.

3.2.3 Mode-stirrer motor. For the "Discrete Sample Averaging" system, a stepper motor with sufficient torque shall be used for rotation of the mode-stirrer. A variable speed, continuously rotating motor shall be used for the "Continuous Sample Averaging" system.

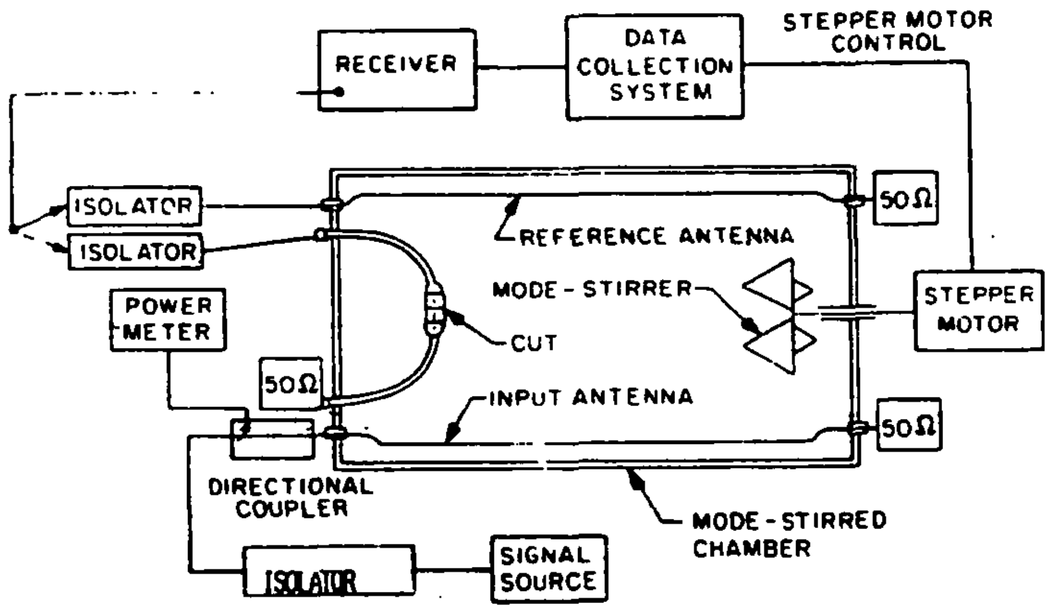


FIGURE 1. Discrete sample averaging system.

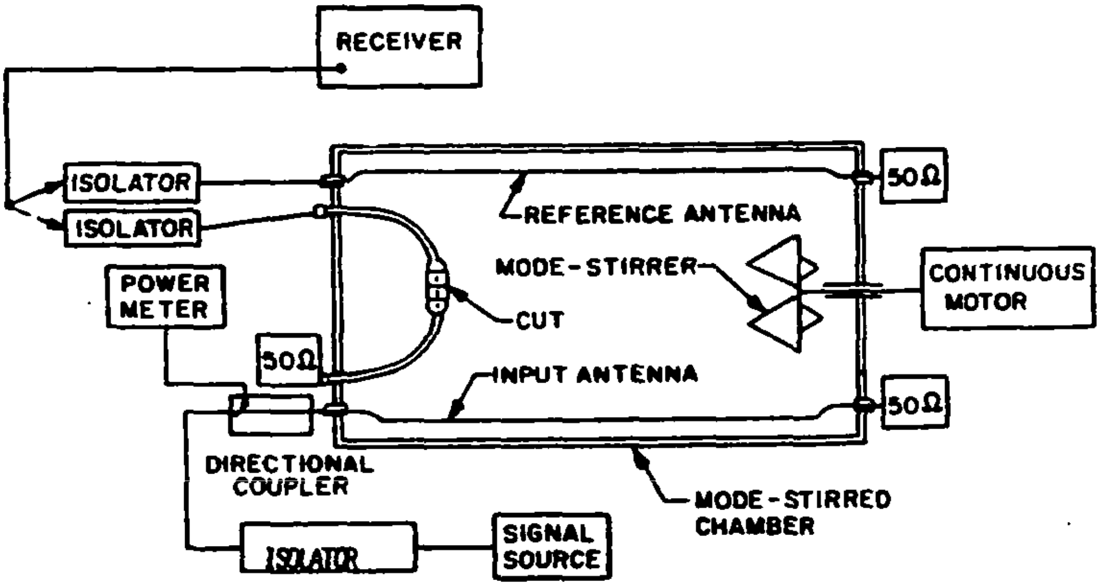


FIGURE 2. Continuous sample averaging system.

3.3 Measurement frequencies. Measurements shall be taken at ten (10) frequencies in the range from 1-10 GHz. The frequency intervals shall be such that no measurement frequency may lie within 80 percent of the next highest or 125 percent of the next lowest measurement frequency.

3.4 Preparation and installation of connector/shielded conduit assembly.

3.4.1 Preparation. The connector under test shall be connected to the shielded conduit and mounted on a chamber wall as shown on figure 3. The connector shall be located a distance, D, of one wavelength off the wall at the lowest test frequency. The length of the connector/conduit assembly shall be 4.0 ±0.1 wavelengths at the lowest test frequency. Adaptors may be used to fit the conduit to the connector under test. All resulting joints shall be peripherally sealed to obtain maximum shielding. The pickup wire inside the connector shall be a 5.0 ±0.5 centimeter length of the center conductor of the conduit obtained by removing the outer shield. The pickup wire shall be positioned in the center of the connector and held in place by dielectric retainers or the dielectric insert of the connector.

3.4.2 Installation. The connector/conduit assembly shall be securely fastened to the chamber wall with the conduit passing through the wall and terminated in type-N connectors as shown on figure 3. Care should be taken to ensure that the shielding integrity of the chamber is maintained at the points of attachment of the conduit to the chamber wall.

3.5 Swept frequency VSWR measurement on connector/conduit assembly. A swept frequency VSWR measurement shall be performed on the complete connector/conduit assembly shown on figure 3. The frequency range of the measurement shall be 1-10 GHz and a plot of the VSWR versus frequency shall be made on an X-Y recorder for every connector tested. This VSWR plot shall be included with the shielding effectiveness data obtained from the measurement described in paragraph 4.

4. TEST PROCEDURE.

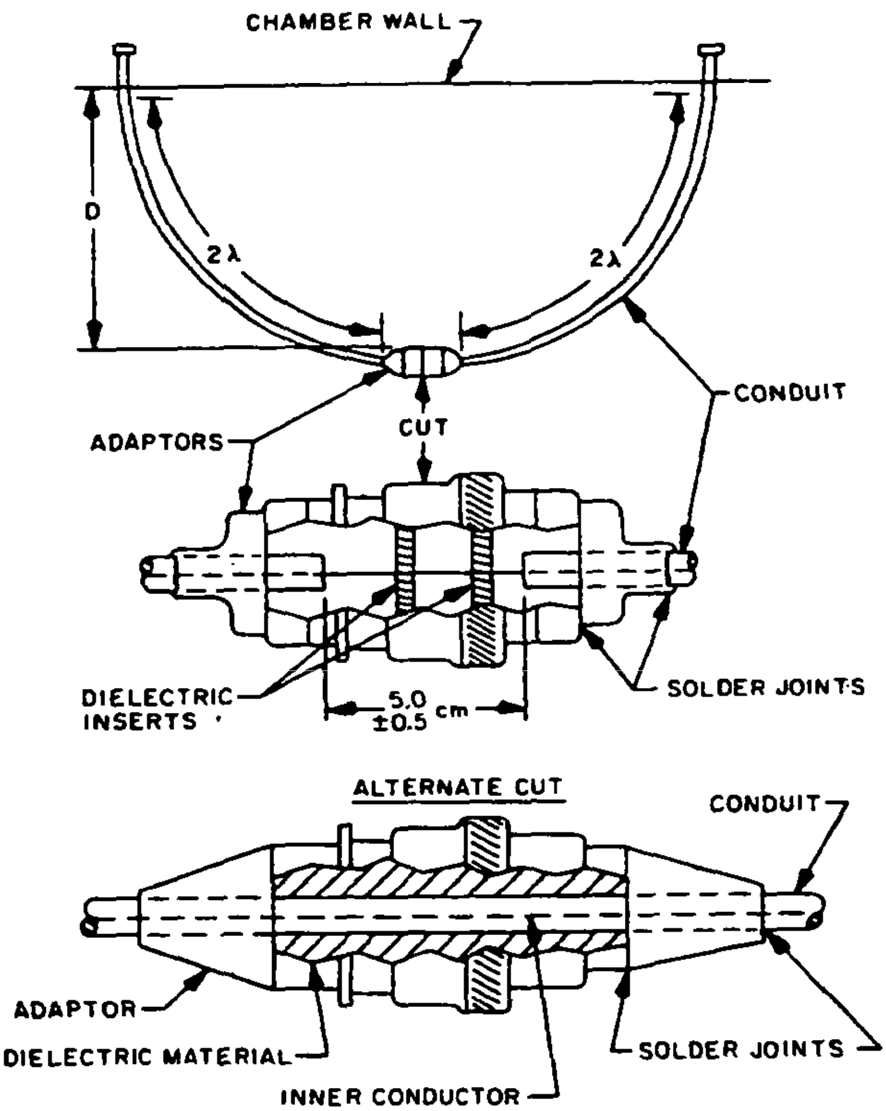
4.1 Test procedure. With the connector and conduit assembly prepared as described in paragraph 3.4 and the mode-stirred chamber configured as described in paragraph 3.2, the following procedures shall be performed at each frequency. These procedures utilize the test configurations shown on figures 1 and 2.

4.2 Reference measurements. Perform the following reference measurement:

a. Connect the equipment for measuring the average signal to the reference antenna.
b. Terminate both ends of the connector/cable assembly in 50-ohm loads.
c. Apply sufficient input power to the chamber to observe the signal on the reference antenna.
d. Obtain the average signal ($\overline{P}_{REF}$) on the reference antenna for mode-stirrer rotation.
e. Record this average value as well as the chamber input power ($P_{in\ REF}$).
f. Repeat at each frequency.

4.3 Shield measurements. At the same frequency (within 100 kHz) at which the reference measurement was performed, perform the following shield measurement:

a. Disconnect a 50-ohm load from one end of the connector/conduit assembly and connect the equipment for measuring the average signal.
b. Connect a 50-ohm load to the reference antenna input.
c. Apply sufficient input power to the chamber to observe the signal on the connector/conduit assembly.
d. Obtain the average signal ($\overline{P}_{CUT}$) on the connector/conduit assembly with the mode-stirrer rotation.
e. Record this average value as well as the chamber input power ($P_{in\ CUT}$).
f. Repeat at each frequency.



Alternate: The use of a test specimen having a 50 OHM ± 6 OHM cross-section through its length is permissible, see above.

FIGURE 3. Preparation and installation of connector/conduit assembly.

4.4 Calculated shielding effectiveness. For each test frequency, calculate the shielding effectiveness (S.E.) of the connector from the above data and the following formula:

$$S.E. = 10 \log_{10} \left[\left(\frac{P_{REF}}{P_{in\ REF}} \right) \Big/ \left(\frac{P_{CUT}}{P_{in\ CUT}} \right) \right]$$

5. DOCUMENTATION. Data sheets shall contain:

a. Title of test, date and name of operator.
b. Sample description - Include fixture, if applicable.
c. Test equipment used and date of latest calibration.
d. Values and observations.

6. SUMMARY. The following details shall be specified in the individual specification.

a. Frequencies to be tested if other than those listed in 1.1
b. Shielding effectiveness of the connector pair.