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CARDEROCK DIVISION

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IN REPLY REFER TO

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From: Commanding Officer, Naval Surface Warfare Center,
Carderock Division, Naval Ship Systems Engineering Station
To: Defense Logistics Agency,
Defense Supply Center Columbus (Code VQP)

Subj: ELECTROMAGNETIC EFFECTS TEST AND MEASUREMENT GUIDE, QUALIFIED PRODUCTS LIST, TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Encl: (1) Electromagnetic Effects, original release, dated 31 October 2005

1. Purpose.

This letter addresses the requirements for performing the electromagnetic effects test on Fiber Optic Cable Topology (FOCT) components. Proper documentation and performance are required for test laboratory suitability status audits from the Defense Supply Center Columbus (DSCC), proper test performance to FOCT military specifications (such as Qualified Products List or QPL inspections), and as part of a complete review of test procedures and test reports. The applicable FOCT military specifications, that are under DSCC cognizance and require QPL testing, are as follows: MIL-PRF-28876, MIL-PRF-29504, MIL-PRF-85045. An electromagnetic effects test and measurement guide, enclosure (1) of this letter, has been prepared to address military requirements and methods of performance.

2. Background.

Naval Surface Warfare Center, Carderock Division, Ship Systems Engineering Station (NSWCCD-SSES) is tasked by the Naval Sea Systems Command (NAVSEA) to provide technical support for qualification and test efforts regarding FOCT components. One subtask is to provide technical support/consultation to DSCC. As part of the subtask, NSWCCD-SSES has supported DSCC in the past efforts to qualify component vendors. These efforts include auditing of their in-house test facilities or an independent, commercial test laboratory, clarifications of requirements in military specifications, review of documentation (such as test procedures and reports) and other miscellaneous technical support. Development of this electromagnetic effects test and measurement guide is another type of support being provided.

3. Distribution statement

Distribution Statement A: Approved For Public Release, Distribution Is Unlimited.

4. Addressees.

This letter is intended for DSCC and other Government agencies/activities, parties in direct support of the Government agencies/activities, vendors, and out-of-house (outside the component's vendor facilities or independent) test laboratories.

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5. Point of contact.

DSCC-VQP is to be the initial point of contact for the qualification issues/inquiries that pertain to this matter. Principle point of contact is J. Casto. He can be contacted by telephone: (614) 692-7076 or E-mail: john.casto@dla.mil. Alternative point of contact is Richard Marbais. He can be contacted by telephone: (614) 692-0620 or E-mail: richard.marbais@dla.mil. NSWCCD-SSES point of contact for technical support to DSCC on this matter is E. Bluebond.

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Contents:
17 page document plus 13 Figures

Enclosure (1)

Electromagnetic effects.

1. Purpose.
   To ensure that the addition of fiber optic components (such as cables or connectors) and related fittings (connectorized or feedthrough) maintain the shielding effectiveness of the pre-existing structure or enclosure at a value that is greater than the minimum specified value.

2. Applicable documents
   IEEE 299-1997
   MIL-PRF-84045
   MIL-PRF- 28876

3. Requirement.

   a. Cable (M85045, 3.7.16). The propagated radio frequency (RF) attenuation of the modified enclosure, inclusive of the fiber optic cable and related fittings shall be not less than 100 dB attenuation for frequencies not greater than 1 GHz and 60 dB attenuation at 10 GHz.
   b. Connectors (M28876, 3.14.9). The propagated radio frequency (RF) attenuation of the modified enclosure, inclusive of the fiber optic connector and related fittings shall be not less than 60 dB attenuation for frequencies not greater than 10 GHz.

4. Frequency
   a. Required frequencies. The minimum number of test frequencies to be used is shown in Table 1.
   b. Frequency bands. The basic frequency bands for evaluation are from 9 kHz to 18 GHz.
   c. Below required test frequencies. Below 20 MHz both H & E fields shall be evaluated. Testing across this frequency band may be swept, or measured at discrete frequencies in sufficient number to ensure accurate results, as described in the approved Test Procedure.

TABLE I. Electromagnetic effects test frequencies.

Field propagation	Test frequency		
	1	2	3
Planewave	100 MHz	400 MHz	1 GHz
Microwave	10 GHz	---	---

5. Test Methodology.
   a. Intent. The test methodology employed in evaluating the effects of the fiber optic modification to the enclosure consists of distinct measurement phases. This test is performed to determine the propagation characteristics (either towards attenuation or towards conduction) of the cable through a waveguide or of a connector. In general, look at the test results for a relative increase in the signal strength. This increase relates to a decrease in the shielding effectiveness of the component under test.
   b. Dynamic range (Instrumentation): This step is intended to illustrate the instrumentation to be employed in the evaluation is working properly and has significant dynamic range (as defined in IEEE-STD-299) to adequately measure the full range of frequency and sensitivity relative to the noise floor to discriminate low levels signals and to establish the baseline signal relationship between the transmit and receiving systems without any attenuation present. This step will also define the repeatable transmit equipment settings to be used in follow on stages of the evaluation.
   c. Isolation measurement of enclosure shielding (Enclosure): This step will establish the baseline shielding effectiveness of the existing (unmodified) enclosure using the settings and procedures used in the previous step. Measurements made are to include those in the vicinity of utility entrances, doors and access panels.
   d. Isolation measurement of enclosure shielding with fitting installed (Enclosure with fitting): This step will determine the resultant shielding effectiveness of the enclosure with the penetrative fitting (feedthrough or connectorized). Measurements made are to include those in the vicinity of the access panel where the waveguide for testing of cable or receptacle for testing of a connector will later be installed.
   e. Resultant Shielding Effectiveness of the DUT (Enclosure with DUT installed in fitting): This step will determine the resultant shielding effectiveness of the enclosure with the complete fiber optic cable or connector installation, inclusive of any fittings or hardware.
   f. Analysis: A comparison of shielding effectiveness levels for pre-existing and modified enclosure configurations, and determination of acceptability of any degradation in shielding effectiveness observed.

6. Test Equipment.
   a. Transmitting equipment. The drive system is to include the following: signal/frequency source (generator), power amplifier (if required), optional pre-amplifier, transmit antenna, shielded cable. See Table II for antenna types. Matched antennas must be used (transmit & receive). See addendum A.
   b. Receiving equipment. The sensing system is to include the following: receiver (such as a spectrum analyzer), optional pre-amplifier, attenuator, receive antenna, shielded cable. See Table II for antenna types.
   c. Equipment verifications.

(1) Matched antennas. Provide documentation to verify matched antennas are used and for which frequency(s), generating and receiving equipment have sufficient capacity and sensitivity, respectively.
(2) Calibration. Provide NIST traceable calibration information. See addendum B.
(3) Interconnecting cabling. Verify that connecting cables have 50 Ohm impedance (to obtain maximum power transfer).
(4) Authorization to radiate. See addendum C.

d. Shielded enclosure. The minimum value for the shielding effectiveness of the shielded enclosure at each frequency shall be no less than the requirement for the propagated radio frequency at each frequency tested.
e. Other. Dielectric tripods, dielectric tie-offs.
f. Connector test specimen configuration. The connector plug shall be terminated with at least 5 meters of multiple fiber cable. The connector receptacle shall be terminated with at least 2 meters of OFCC (termini with single fiber cables to fill each cavity in the connector receptacle). Unless otherwise specified in the approved Test Procedure, MIL-PRF-85045 cable shall be used.

TABLE II. Antenna types.

Field propagation	Antenna type
Planewave	Log periodic or dipole
Microwave	Horn

7. Test Procedure.
   a. Dynamic range (Instrumentation).
      (1) Intent. Verify that the test equipment has the functionality to perform the measurements by determining if there is sufficient dynamic range (transmit and receive gain). Measure the amplitude of the transmitted signal via the receive system without an attentuative structure in place.
      (2) Setup.
         (a) Location. Verification should be performed in a low RF ambient environment, preferably anechoic. This may occur inside the shielded enclosure, provided the signal source equipment ambient does not affect the measurement. Care should be taken to electrically isolate the power sources for transmitting and receiving equipment.
         (b) Positioning. Each matched pair of antennas used for the test is placed in the horizontal plane (see figure 1). The transmit and receive antennas should be placed two meters apart and at least two meters from any reflective surface.
         Note: The 2 meter distance between the transmit antenna and the receive antenna is required (as shown in figure 1). The only exception to maintaining this 2 meter distance is if the positioning of the receive antenna within 5 cm from the access panel (for the subsequent isolation

and shielding effectiveness measurements) is blocked by a permanent, non-removable obstruction (which may include anechoic or other radiation absorbing/insulating materials). If this blockage is the case, a request for an allowance must be submitted to the Qualifying Activity. The additional distance, if allowed, is the one that permits the receive antenna to be the closest achievable without making contact with the obstruction. If the allowance is approved, then the distance between antennas are to be increased by the additional distance for the dynamic range measurement also. The dynamic range of the equipment must be above the signal level specified for the applicable component in 7.a(3)(b) at this increased distance.

Note: The 2 meter distance requirement, relative to the floor as a reflecting surface, is dependent upon the type of antenna used. Log periodic and horn antennas are directional (beam like that of a flashlight) and are not of concern since the radiation pattern will not illuminate the floor. The dipole antenna is multi directional with a radiation pattern that will reflect off the floor when in the horizontal position. This is of concern since an error up to 6 dB can occur. A dipole antenna must be positioned at least 2 meters from a reflective floor for this test.

(c) Measures to maximize coupling. In general, three measures taken to obtain maximum energy out of the receive antenna (maximum coupling) are no polarization mismatch, co-planar orientation and distancing for peak of the beam. For this document, antenna positioning shall ensure a co-planar orientation and no polarization mismatch (see 7a(3)(c) below). Antennas distancing is not required to be in the peak of the beam; however, the same angular alignment (shipboard "yaw" equivalent) must be maintained between the front faces of the transmit antenna and the receive antenna for all side view measurements. An attenuator may be used to reduce the radiated signal strength and avoid amplifier saturation. Radiated signal strength attenuation by deviation from the specified distance between antennas (of two meters) is not permitted.

(3) Procedure.

(a) Ambient verification measurement (transmitter-off measurement): With the transmit system off, verify the local ambient levels are adequate. For each frequency identified in the approved Test Procedure, tune the receiver to the specified test frequency using the designated antenna for that frequency. Maximize radiated signal strength as stated in 7a(3)(c) below. Record the measure ambient level for each frequency. Repeat for each required frequency.

Note: This measurement is designated as P_1 if a power level is measured, or E_1 if a voltage level is measured. All measurements are made at the receive antenna.

(b) Measurement of signal level induced in receive antenna (transmitter-on measurement): For each frequency used above, tune the transmitter and receiver to each specified test frequency using the designated antenna pair for that frequency. Attenuators may be used at the receiver to avoid

saturation. Maximize radiated signal strength as stated in 7a(3)(c) below. Record the measured levels via the receive system and record the signal source settings (and amplifier gain settings as applicable) required to produce the resultant field.

Note: This measurement is designated as P_2 if a power level is measured, or E_2 if a voltage level is measured. All measurements are made at the receive antenna.

i Cable. The dynamic range of the test equipment for planewave propagation shall be at least 6 dB above the specified signal attenuation of 100 dB for frequencies not greater than 1 GHz and at least 6 dB above the specified signal attenuation of 60 dB at 10 GHz.

ii Connector. The dynamic range of the test equipment for planewave propagation shall be at least 20 dB above the specified signal attenuation of 60 dB and for a microwave field propagation shall be at least 15 dB above the specified signal attenuation of 60 dB.

(c) Maximize signal strength.

i Maximize co-planar orientation. Receive antenna shall be moved in a translational manner (up-and-down, side to-side) to maximize the measurement for radiated signal strength.

ii Maximize for no polarization mismatch. Once maximized for the co-planar orientation, the receive antenna shall be moved in a rotational manner (counterclockwise or clockwise) to maximize the measurement for radiated signal strength. This rotation is also referred to as the rotation between the horizontal and vertical antenna positions (between horizontal and vertical polarization).

(d) Calculation of dynamic range.

i Approach. One approach to find the dynamic range is as follows: The Dynamic range is the range of amplitudes over which the receive system operates linearly and is calculated as DR_{RCVR} = P1(dB) – P2(dB). P1 is the largest possible input signal. This input signal measurement is taken with any internal or external attenuators to be used. P1 is taken at the 1 dB compression point (point at which output is 1 dB below input at amplifier saturation). P2 is the input signal at the noise floor or the minimum detectable signal.

Note: In general, the convention for a logarithmic unit will be the logarithmic power level with transmitter off minus the logarithmic power level with transmitter on.

ii Validity of data. Ensure that the scaled readings on the receive systems are commensurate with the transmitted signal, and that no saturation or gain compression is apparent.

(e) Transmit (input) signal level. The power level used during the isolation and shielding effectiveness portions of the test shall not be below the power level established for the dynamic range measurement. The same setting on the transmit equipment established during the dynamic range measurement shall be maintained for the remainder of the testing.

b. <u>Isolation measurements of the shielded enclosure (Enclosure only)</u>

(1) Intent. Verify shielding effectiveness prior to installation of waveguides/fittings and the fiber optic component under test (also referred to as the Device Under Test or DUT).

(2) Setup.

(a) Location. Place the transmit antenna outside the shielded enclosure 2 meters from the penetration port (location where the cable fitting/penetration will be made) and at least two meters from any reflective surface. The transmit antenna shall be pointed towards the shielded enclosure (pointed in the direction so that the radiated signal is propagated towards the shielded enclosure). Receiving equipment shall be located inside the shielded enclosure.

Note: An allowance may be made for a situation where transmitting the signal outside of an environmental chamber would interfere with the surrounding area. In this case, the transmitting equipment may be placed inside and the receiving equipment outside the shielded enclosure. If this test setup is used, the vendor assumes the risk that other stray electromagnetic interference may be measured resulting in a failure. The preferred test setup is when the transmitting equipment is outside and the receiving equipment is inside the shielded enclosure. Test performance in this document is written for using the preferred test setup.

(b) Positioning. Each matched pair of antennas used for the test is placed in the horizontal plane (see figure 1). The transmit antenna is positioned so that it will be co-planar with the receive antenna during the measurement.

(c) Other actions. Penetration ports in the access panel are to be capped. Power sources for instrumentation should be isolated.

(3) Procedure. Test is to be performed with the transmit antenna placed outside the shielded enclosure and orientated relative to the receive antenna as shown in figure 1. In the parallel direction, there is parallel transmission of the radiated signal.

(a) Placement of receive antenna. Place the receive antenna inside the shielded enclosure directly opposite the intended location of the fitting at a distance of 5 cm from the mounting plate. Orient the receive antenna, relative to the transmit antenna, as shown in figure 1.

(b) Travel of receive antenna during measurement. For each frequency identified in the approved Test Procedure and using the signal settings derived in step 7a(3), create and measure the resultant field inside the shielded enclosure. Maximize the signal strength as follows:

i Maximize co-planar orientation. Receive antenna shall be moved in a translational manner (up-and-down, side to-side) to maximize the measurement for radiated signal strength.

ii Maximize for no polarization mismatch. Once maximized for the co-planar orientation, the receive antenna shall be moved in a rotational manner (counterclockwise or clockwise) to maximize the measurement for radiated signal strength.

(c) Measurements to obtain.

i. Ambient measurement (Transmit-off). With the transmit system off, verify the local ambient levels are adequate. For each frequency identified in the approved Test Procedure, tune the receiver to the specified test frequency using the designated antenna for that frequency. Maximize radiated signal strength as stated in 7b(3)(b) above. Record the measure ambient level for each frequency. Repeat for each required frequency.

Note: This measurement is designated as P_3 if a power level is measured, or E_3 if a voltage level is measured. All measurements are made at the receive antenna.

ii. Induced signal level measurement (Transmit-on). For each frequency used above, tune the transmitter and receiver to each specified test frequency using the designated antenna pair for that frequency. Attenuators may be used at the receiver to avoid saturation. Maximize radiated signal strength as stated in 7b(3)(b) above. Record the measured levels via the receive system and record the signal source settings (and amplifier gain settings as applicable) required to produce the resultant field.

Note: This measurement is designated as P_4 if a power level is measured, or E_4 if a voltage level is measured. All measurements are made at the receive antenna.

(4) Calculation for shielding effectiveness. The shielding effectiveness of the shielded enclosure is determined from the power or voltage levels generated by the transmit antenna (propagated external field level) and those induced in the receive antenna with the shielded enclosure in the vicinity of the access panel, respectively, without changing the relative positions of transmit and receive antennas. Depending on the measurement parameter obtained (such as voltage or power level), one of the calculation methods listed below may apply.

(a) Measurement of voltage levels in linear units (Volts). The shielding effectiveness is $SE_{enclosure} = 20\log(E_{Ref}/E_4)$ where E_{Ref} and E_4 are the voltages from the propagated external field level by the transmit antenna (reference reading) and the measurement obtained from the receive antenna with the shielded enclosure in the vicinity of the access panel (transmit-on), respectively, without changing the relative positions of transmit and receive antennas.

Note: The propagated external field level by the transmit antenna (reference reading), P_{Ref}, is equal to the signal generator output plus the antenna gain minus the cable loss.

(b) Measurement of power levels in linear units (Watts). If the power levels rather than the voltage levels were measured, then the Shielding Effectiveness, $SE_{enclosure} = 10\log(P_{Ref}/P_4)$.

Note: In general, the convention for a logarithmic calculation will be the power generated by the transmit antenna (reference reading) over the power level measured with the receive antenna (transmit-on).

(c) Measurement in terms of non-linear, logarithmic units (such as dB, dB_{uV}, dB_{mW}). The Shielding Effectiveness, $SE_{enclosure} = P_{Ref} - P_4$.

c. Isolation measurement of the shielded enclosure with waveguide/blank mounting plate installed (Enclosure with fitting).

(1) Intent. Verify shielding effectiveness after the installation of waveguides/fittings, but prior to the installation of the DUT. For cable testing, this verifies that a waveguide at cut-off (WACO) is used. For connector testing, this verifies the effectiveness of the fitting/mounting plate and EMI gasket to prevent EMI conduction.

(2) Setup. Test is performed with the transmitting equipment outside the shielded enclosure and the receiving equipment on the inside.

(a) Cable test. Install the waveguide in the shielded enclosure access panel so that the waveguide protrudes inside the shielded enclosure for the wall. The waveguide shall be installed in the access panel and shall have an inside diameter to total length ratio of 1 to 72. For test purposes, a straight waveguide shall be used to simulate a worst-case condition. The waveguide shall protrude inside the shielded enclosure from the wall.

(b) Connector test. Install the fitting/mounting plate for the connector receptacle onto the access panel on the shielded enclosure. The fitting/mounting plate shall be positioned so that the connector plug or dust cover mates from the outside of the shielded enclosure. Place a blank cover plate onto the fitting/mounting plate with an EMI gasket between these two items. Use appropriate hardware to secure the blank cover plate. Note: The measurements for this test (section 7.c) are required for cable. The measurements for this test (section 7.c) are required for connectors only if a failure occurs with measurements once the DUT is installed (section 7.d).

(3) Procedure. Repeat 7b(3) above. Waveguide shall be lengthened, different EMI gasket used or other steps taken, if needed, so that there is no degradation of the shielding effectiveness of the shielded enclosure. Measurements are to be obtained for the following parameters:

(a) Ambient measurement (Transmit-off). With the transmit system off, verify the local ambient levels are adequate. For each frequency identified in the approved Test Procedure, tune the receiver to the specified test frequency using the designated antenna for that frequency. Maximize radiated signal strength as stated in 7a(3)(c) above. Record the measured ambient level for each frequency. Repeat for each required frequency. Note: This measurement is designated as P_5 if a power level is measured, or E_5 if a voltage level is measured. All measurements are made at the receive antenna.

(b) Induced signal level measurement (Transmit-on). For each frequency used above, tune the transmitter and receiver to each specified test frequency using the designated antenna pair for that frequency. Attenuators may be used at the receiver to avoid saturation. Maximize radiated signal strength as stated in 7a(3)(c) above. Record the measured levels via the receive system and record the signal source settings (and

amplifier gain settings as applicable) required to produce the resultant field.

Note: This measurement is designated as P_6 if a power level is measured, or E_6 if a voltage level is measured. All measurements are made at the receive antenna.

(4) Calculation for shielding effectiveness. The shielding effectiveness of the shielded enclosure with the fitting installed is determined from the power or voltage levels generated by the transmit antenna (propagated external field level) and those induced in the receive antenna with the shielded enclosure in the vicinity of the access panel, respectively, without changing the relative positions of transmit and receive antennas. Depending on the measurement parameter obtained (such as voltage or power level), one of the calculation methods listed below may apply.

(a) Measurement of voltage levels in linear units (Volts). The shielding effectiveness is $SE_{\text{enclosure with fitting}} = 20\log(E_{Ref}/E_6)$ where E_{Ref} and E_6 are the voltages from the propagated external field level by the transmit antenna (reference reading) and the measurement obtained from the receive antenna with the shielded enclosure in the vicinity of the access panel (transmit-on), respectively, without changing the relative positions of transmit and receive antennas.

Note: The propagated external field level by the transmit antenna (reference reading), P_{Ref}, is equal to the signal generator output plus the antenna gain minus the cable loss.

(b) Measurement of power levels in linear units (Watts). If the power levels rather than the voltage levels were measured, then the Shielding Effectiveness, $SE_{\text{enclosure with fitting}} = 10\log(P_{Ref}/P_6)$.

Note: In general, the convention for a logarithmic calculation will be the power generated by the transmit antenna (reference reading) over the power level measured with the receive antenna (transmit-on).

(c) Measurement in terms of non-linear, logarithmic units (such as dB, dB_{uV}, dB_{mW}). The Shielding Effectiveness, $SE_{\text{enclosure with fitting}} = P_{Ref} - P_6$.

d. <u>Resultant shielding effectiveness of the DUT (Enclosure with DUT installed in fitting)</u>.

(1) Intent. Verify shielding effectiveness after the installation of waveguides/fittings and the installation of the DUT by measuring for the propagated radio frequency attenuation.

(2) Setup. Test is performed with the transmitting equipment outside the shielded enclosure and the receiving equipment on the inside.

(a) Cable test. Install the cable (with a minimum length of 6 meters) into the waveguide fitting so that 0.3 meters of the cable extends beyond the waveguide inside the shielded enclosure as shown in figure 2. See Table III for additional placement distance information. Verify that the cable is extended perpendicular to the enclosure wall and is suspended dielectrically at least 1 meter above the floor of the shielded enclosure on both sides of the enclosure wall. Dielectric tie-off may be used to secure

to a structure. Dielectric tripods may be used to suspend the cable above the floor.

(b) Connector test. Install the connector receptacle onto the outside surface of the access panel on the shielded enclosure (see figure 3 or figure 4, as applicable). The same EMI gasket (used in step 7c) shall be used between the connector receptacle and the fitting/mounting plate. Test sample configurations shall consist of connector receptacles mated to connector plugs with backshells and connector receptacles mated to dust covers. Connector plugs and receptacles are to be terminated, including the cable. Mate the connector plug or the dust cover with the connector receptacle, as applicable. Verify that the connector plug or the dust cover when mated is outside the shielded enclosure (see note below for exception). The connector plug with cable or connector end cap must be with (on the same side of the access panel as) the transmit antenna. The multiple fiber cable from the connector plug shall be extended parallel (to the connector longitudinal axis) for the minimum distance specified (different distances for testing in the perpendicular and parallel directions). The single fiber cable from the connector receptacle shall be extended parallel (to the connector longitudinal axis) for a minimum of 2 meters on the other side of the shielded enclosure wall as shown in figure 3 or figure 4, as applicble. Unless otherwise specified in the approved Test Procedure, MIL-PRF-85045 cable shall be used. Dielectric tie-off may be used to secure to a structure. Dielectric tripods may be used to suspend the cable above the floor.

Note: Connector installation. Connector plug with cable must be with the transmit antenna. MIL-PRF-28876 states that "the test specimen receptacle (connector receptacle) shall be mounted into the wall (panel) of the enclosure such that the plug or dust cover mates from the inside of the shielded enclosure". The intent was to allow for a situation where transmitting the signal outside of an environmental chamber would interfere with the surrounding area. If this test setup is used, the vendor assumes the risk that other stray electromagnetic interference may be measured resulting in a failure. The preferred test setup is when the test specimen receptacle is mounted on the access panel so that the plug or dust cover mates from the outside of the shielded enclosure. The transmit antenna is placed outside the shielded enclosure. Test performance in this document is written for using the preferred test setup. As stated previously, in either setup, the connector plug with cable must be with the transmit antenna.

i Connector plug cable routing for testing in the parallel direction. The multiple fiber cable exiting the backshell on the connector plug shall be suspended and extended parallel (to the connector longitudinal axis) to the floor and perpendicular to the access panel for a minimum distance of 5 meters on one side of the shielded enclosure wall as

shown in figure 3. At the end of this distance of 5 meters, the cable shall be secured dielectrically.

ii Connector plug cable routing for testing in the perpendicular direction. The multiple fiber cable exiting the backshell on the from the connector plug shall be suspended and extended parallel (to the connector longitudinal axis) to the floor and perpendicular to the access panel for a distance of 1 meter on one side of the shielded enclosure wall as shown in figure 4. At 1 meter, the cable shall be placed/tied to a dielectric stand such that the cable is perpendicular to the floor. Between this transitioning from parallel to perpendicular cable directions, the cable shall be placed in a bend at the cable's minimum long-term bend diameter. Upon reaching the floor, the remaining cable length shall have a straight run in a direction 45 degrees to the right (facing access panel) from the suspended portion of the cable. Between this transition from perpendicular to parallel cable directions, the cable shall be placed in a bend at the cable's minimum long-term bend diameter.

TABLE III. Antenna placement distances.

Location	Placement 1/
Receiving antenna to cable	5 cm
Transmitting antenna to cable	1 m
Transmitting antenna to shielded enclosure	2 m

1/ Extended dipole antenna distance measurements shall be made from the center of the antenna elements.

(3) Procedure. Test is to be performed with the transmit antenna in both the parallel and perpendicular directions. In the parallel direction, the radiating elements of the transmit antenna are parallel to the cable length. In the perpendicular direction, the radiating elements of the transmit antenna are perpendicular to the cable length or parallel to the cable circumference. Waveguide shall be lengthened, different EMI gasket used or other steps taken, if needed, so that there is no degradation of the shielding effectiveness of the shielded enclosure.

(a) Parallel direction for placement of transmit antenna. Place transmit antenna at outside the shielded enclosure 2 meters from the location where the cable fitting/penetration will be made. The transmit antenna should be

one meter from the cable and oriented in the parallel direction, as shown in figures 5 through 7.

i Cable as DUT. The transmit antenna shall be placed 1 meter from the DUT and co-planar to the receive antenna (place on same horizontal plane as the cable).

ii Connector as DUT (receptacle with dust cover configuration). Measurements in the parallel direction are not performed for this connector configuration.

iii Connector as DUT (receptacle with mating plug configuration). Measurements in the parallel direction are required for this connector configuration only if a failure occurs with measurements obtained in the perpendicular direction. The transmit antenna shall be placed 1 meter from the connector plug cable and co-planar to the receive antenna.

(b) Placement and travel of receive antenna. Place the receive antenna inside the enclosure at a distance of 5 cm from the cable (cable as DUT) or from the cable with connector receptacle (connector as DUT).

Note: Refer to the first note in 7.a(2)(b) for conditions if there is an allowed deviation from the 5 cm distance.

i Cable as DUT. Measurements are to be made on the 0.3 meter minimum length of the cable that extends beyond the waveguide. First position the receive antenna 5 cm from the cable in the side view (receive antenna radiating elements are perpendicular to the length of the cable, i.e. perpendicular transmission). The receive antenna shall be offset from the transmit antenna, as specified. The receive antenna shall be moved along the 0.3 meter length of the cable while measuring the radiated signal strength. Maximize the measurement of the receive antenna for radiated signal, using method employed for co-planar orientation and for no polarization mismatch, as stated in 7a(3)(c). Second, position the receive antenna in the end view (measure around cable circumference). Move receive antenna around the circumference of the cable at one point long the cable length. Next, move the receive antenna to the next position to be measured along the 0.3 meter section of the cable length. Repeat the movement of the receive antenna around the circumference of the cable at this position. Repeat for each position along the 0.3 meter section of cable to be measured. Obtain the maximum measurement in the end view. Maximize the measurement of the receive antenna for radiated signal strength, for both co-planar orientation and no polarization mismatch, as stated in 7a(3)(c). Repeat for each frequency identified in the approved Test Procedure.

ii Connector as DUT, receptacle with mating dust cover. Measurements in the parallel direction are not performed for this connector configuration.

iii Connector as DUT, receptacle with mating plug. Measurements in the parallel direction are required for this connector configuration only if a

failure occurs with measurements obtained in the perpendicular direction. Orientate the receive antenna 5 cm from the cable in the side view (antenna radiating elements are perpendicular to the cable and the longitudinal axis of the connector plug). The receive antenna shall be co-planar with the transmit antenna. The receive antenna shall be moved along the 2 meter length of the cable while measuring the radiated signal strength. Maximize the measurement of the receive antenna for radiated signal strength, for both co-planar orientation and for no polarization mismatch, as stated in 7a(3)(c). Repeat for each frequency identified in the approved Test Procedure.

(c) Perpendicular direction for placement of transmit antenna. Place transmit antenna outside the shielded enclosure 2 meters from the location where the connector receptacle is located in the access panel. The transmit antenna should be one meter from the cable and pointed in the perpendicular direction, as shown in figures 8 through 10 for testing with the cable as the DUT, figures 11 through 13 with the connector as the DUT.

i Cable as DUT. For measurements within the Planewave field propagation, the transmit antenna shall be placed 1 meter above the DUT and to the receive antenna. For measurements in other field propagations (frequency ranges), the transmit antenna shall be placed 1 meter from the DUT and co-planar to the receive antenna.

ii Connector as DUT (receptacle with dust cover configuration). Measurement in the perpendicular direction is performed for this configuration. The transmit antenna shall be placed in line with the connector receptacle end cap and co-planar to the receive antenna. There is no 1 meter offset from the radial center of the end cap.

iii Connector as DUT (receptacle with mating plug configuration). The transmit antenna shall be placed in line with the connector receptacle mated to the connector plug and co-planar to the receive antenna. There is no 1 meter offset from the radial center of the connector receptacle/plug.

(d) Placement and travel of and measurement with the receive antenna shall be the same as for the orientation in the parallel direction.

(e) Measurements to obtain.

i. Ambient measurement (Transmit-off). With the transmit system off, verify the local ambient levels are adequate. For each frequency identified in the approved Test Procedure, tune the receiver to the specified test frequency using the designated antenna for that frequency. Maximize radiated signal strength as stated in 7a(3)(c) above. Record the measure ambient level for each frequency. Repeat for each required frequency.

Note: This measurement is designated as P_7 if a power level is measured, or E_7 if a voltage level is measured. All measurements are made at the receive antenna.

ii. Induced signal level measurement (Transmit-on). For each frequency used above, tune the transmitter and receiver to each specified test frequency using the designated antenna pair for that frequency. Attenuators may be used at the receiver to avoid saturation. Maximize radiated signal strength as stated in 7a(3)(c) below. Record the measured levels via the receive system and record the signal source settings (and amplifier gain settings as applicable) required to produce the resultant field.

Note: This measurement is designated as P_8 if a power level is measured, or E_8 if a voltage level is measured. All measurements are made at the receive antenna.

(4) Calculation for shielding effectiveness. The shielding effectiveness of the fiber optic component under test (DUT) when placed in the shielded enclosure (as described in the setup) is determined from the power or voltage levels generated by the transmit antenna (propagated external field level) and those induced in the receive antenna with the DUT inserted into the shielded enclosure, respectively, without changing the relative positions of transmit and receive antennas. Depending on the measurement parameter obtained (such as voltage or power level), one of the calculation methods listed below may apply.

(a) Measurement of voltage levels in linear units (Volts). The shielding effectiveness is $SE_{DUT} = 20\log(E_{Ref}/E_8)$ where E_{Ref} and E_8 are the voltages from the propagated external field level by the transmit antenna (reference reading) and the measurement obtained from the receive antenna with the DUT inserted into the shielded enclosure (transmit-on), respectively, without changing the relative positions of transmit and receive antennas.

Note: The propagated external field level by the transmit antenna (reference reading), P_{Ref}, is equal to the signal generator output plus the antenna gain minus the cable loss.

(b) Measurement of power levels in linear units (Watts). If the power levels rather than the voltage levels were measured, then the Shielding Effectiveness, $SE_{DUT} = 10\log(P_{Ref}/P_8)$.

Note: In general, the convention for a logarithmic calculation will be the power generated by the transmit antenna (reference reading) over the power level measured with the receive antenna (transmit-on).

(c) Measurement in terms of non-linear, logarithmic units (such as dB, dB_{uV}, dB_{mW}). The Shielding Effectiveness, $SE_{DUT} = P_{Ref} - P_8$.

(5) Calculation for propagated radio frequency (RF) attenuation. The propagated RF attenuation is the shielding effectiveness of the DUT, SE_{DUT}.

8. Analysis & Documentation.

a. Data sheet. In addition to the information listed in Section IX of the Optical Test Measurement Guide, the following items are to be included on the data sheet. Data sheet shall include the following: company performing the test name and address, frequency column, field propagation/orientation column, enclosure shielding effectiveness column, reference level column, dynamic range column, measured level column, propagated RF attenuation column, required RF

attenuation column, pass/fail column. The reference level shall include the source output, receiver sensitivity and antenna gain. The propagated RF attenuation is the measured level subtracted from the dynamic range.

b. Test report. The test report shall be submitted after the test and include the exact procedure followed (procedure number if an existing, DSCC approved procedure was used or a marked-up procedure if there were deviations/revisions to the DSCC approved procedure), equipment used for each test, equipment calibration dates, test results in graphical and tabular format, photographs/sketches of the test setups, results, conclusions and recommendations.

Addendum A – Matched Antennas

1. Definition. Two antennas are considered matched antennas or like antennas when both are of the same model, same bandwidth (usable frequency range) and same cross pole rejection (i.e., linearly polarized).
2. Concern with use of unmatched antennas. Larger measurement error is unnecessarily introduced with the use of unmatched antennas. This is due to greater variation within the electrical parameters.
3. Allowance for use of unmatched antennas. Unmatched antennas will be allowed if care is taken in the antenna setup and the dynamic range verification in the manner stated below.
   a. Antenna setup. Radiated signal strength is maximized during placement and travel (movement along the DUT in both end view and side view) of the receive antenna. Maximization for co-planar orientation and for no polarization mismatch shall be performed during this travel. This process is repeated and two measurements for each position of travel, co-planar orientation and polarization do not deviate by 2 dB.
   b. Dynamic range verification. Ensure antenna gain is maintained at each test frequency (drops as low as the noise floor may be seen at some frequencies).

Addendum B – Equipment Requiring Calibration

In general, test equipment is to be calibrated and be within the manufacturer's published limits of error. The calibration shall be traceable the National Institute of Standards and Technology (NIST) and conform to ANSI/NSCL Z540-1. At a minimum, the following test equipment must be calibrated:

1. Antennas.
   a. Antenna factor. Antenna factor versus frequency calibration at stepped frequencies through the frequency range shall be in the form of charts or tabulated values and shall be traceable to NIST. The antenna factors shall be included in the test report.
   b. Gain. Peak antenna gain versus frequency calibration at stepped frequencies through the frequency range shall be in the form of charts or tabulated values and shall be traceable to NIST. Peak antenna gain shall be within $\pm$ 0.5 dB. The table/chart for gain shall be included in the test report.

c. Voltage Standing Wave Ratio (VSWR) or return loss. The energy of the reflected signal to the incident energy shall be a maximum of 2:1 as defined in a linear ratio (VSWR). As an alternative, the return loss is this same parameter expressed in a logarithmic scale and shall be a maximum of 9.54 dB.
d. Electrical characterization of parameters. At a minimum, the electrical characterization of cross pole rejection shall be verified. The cross pole rejection for each antenna shall be a minimum of 20 dB. This electrical characterization can be obtained from the antenna manufacturer and does not need to have a calibration that is traceable to NIST. The delta or difference in cross pole rejection between the two antennas is of interest. The delta for this parameter shall be within 3 dB.

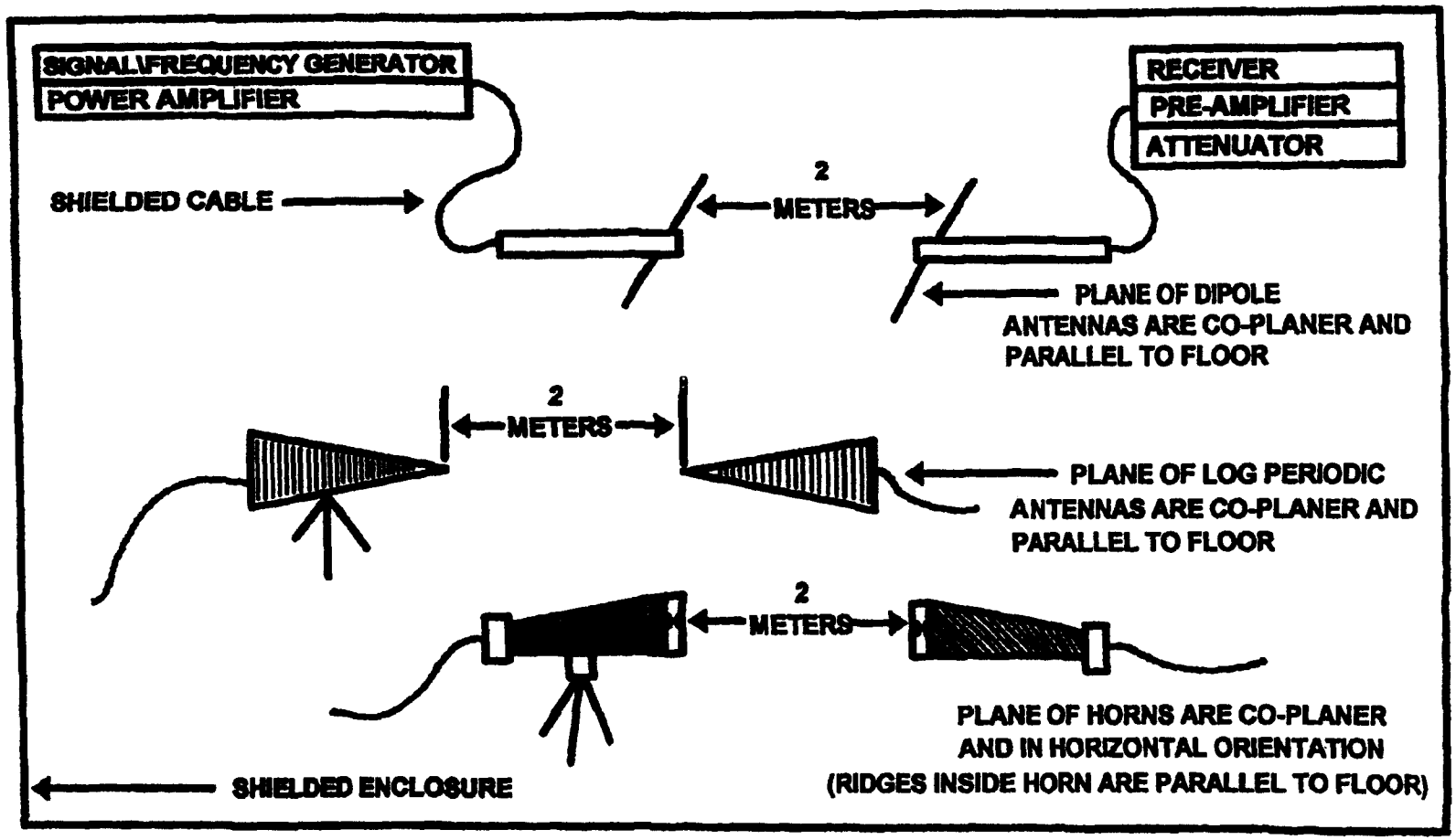
2. Receiver. The calibration of the spectrum analyzer or other receiver used shall be traceable to NIST. The power level at each frequency shall be within $\pm$ 1 dB.
3. Transmitting (Source) Signal Generator. The signal generator used shall be calibrated and traceable to NIST. Parameters of significance include the frequency, wave shape (spectral purity of the electromagnetic wave) and power output (linearity with respect to frequency, power level with respect to repeatable output at each frequency and to personnel hazard considerations of electromagnetic radiation).
4. Other correction factors. Test equipment (for both transmission and measurement) used during testing (such as cable loss and preamplifier gain) for which correction factors are applied shall be calibrated and traceable to NIST. These correction factors are to be included in the test report.

Addendum C – Test Laboratory Authorization to Radiate

1. Applicability. The test laboratory is responsible for obtaining authorization to radiate when testing includes radiating in an unshielded environment.
2. Alternative of testing in a shielded environment. Authorization is not required when the entire test can be conducted within an RF shielded environment. This testing must be done with the assurance that no radiation will be transmitted outside of this shielded environment. Two adjacent shielded enclosures or a shielded enclosure with anteroom setup with an access panel in between satisfies this requirement. The area in each enclosure must be of sufficient size to conduct the test properly.
3. Mechanism to obtain authorization.
   a. Commercial test laboratory. Application for permission to radiate must be submitted to the federal Communications Commission (FCC). If there is an interfering station at one or more test frequencies at that location, then the FCC will provide an alternate frequency at which the radiation is performed. If the alternate frequency deviates by more than 1 percent, then acceptance by the Qualifying Activity is required.
   b. Test laboratory on a military base. Application for permission to radiate must be submitted to the Office of frequency Management at the National

telecommunications Information Agency (NTIA). The NTIA will stipulate any test restrictions.

4. Equipment information required for determining the Effected Radiated Power (ERP). The ERP is a function of the power level and the frequency. For each frequency, the maximum output of the transmitting signal generator, the loss in transporting energy through the cable and the gain in the transmitting antenna is required.
5. Safety considerations.
    1. Regulations. It is recommended that the test laboratory follow safety practices for measurements of electromagnetic fields. Commercial standards include IEEE C95.1 (Standard for Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields) and IEEE C95.3 (Standard Recommended Practices for Measurement of Potentially Hazardous Electromagnetic Fields, RF and Microwave). Also, the military must be in compliance with applicable documentation such as NAVSEA OP 3565/NAVAIR 16-1-529/NAVELEX 0967-LP-624-6010, Volume 1, Technical Manual, Electromagnetic Radiation Hazards (Hazards to Personnel, Fuels and Other Flammable Material) and Volume II, Technical Manual, Electromagnetic Radiation hazards (Hazards to Ordinance).
    2. Considerations in obtaining the dynamic range. A more sensitive receiver (one with a lower noise floor) can be used rather then increasing the output power of the transmitting signal generator.



NOTES: 1. POSITION ANTENNAS TO BE CO-PLANAR BY PLACING BOTH IN SAME HORIZONTAL PLANE.
2. FRONT FACE OR APEX OF ANTENNAS ARE 2 METERS APART AND POINTED TOWARDS EACH OTHER.
3. MATCHED ANTENNAS SHALL BE USED.

FIGURE 1. DYNAMIC RANGE AND ISOLATION MEASUREMENTS. 08/23/05

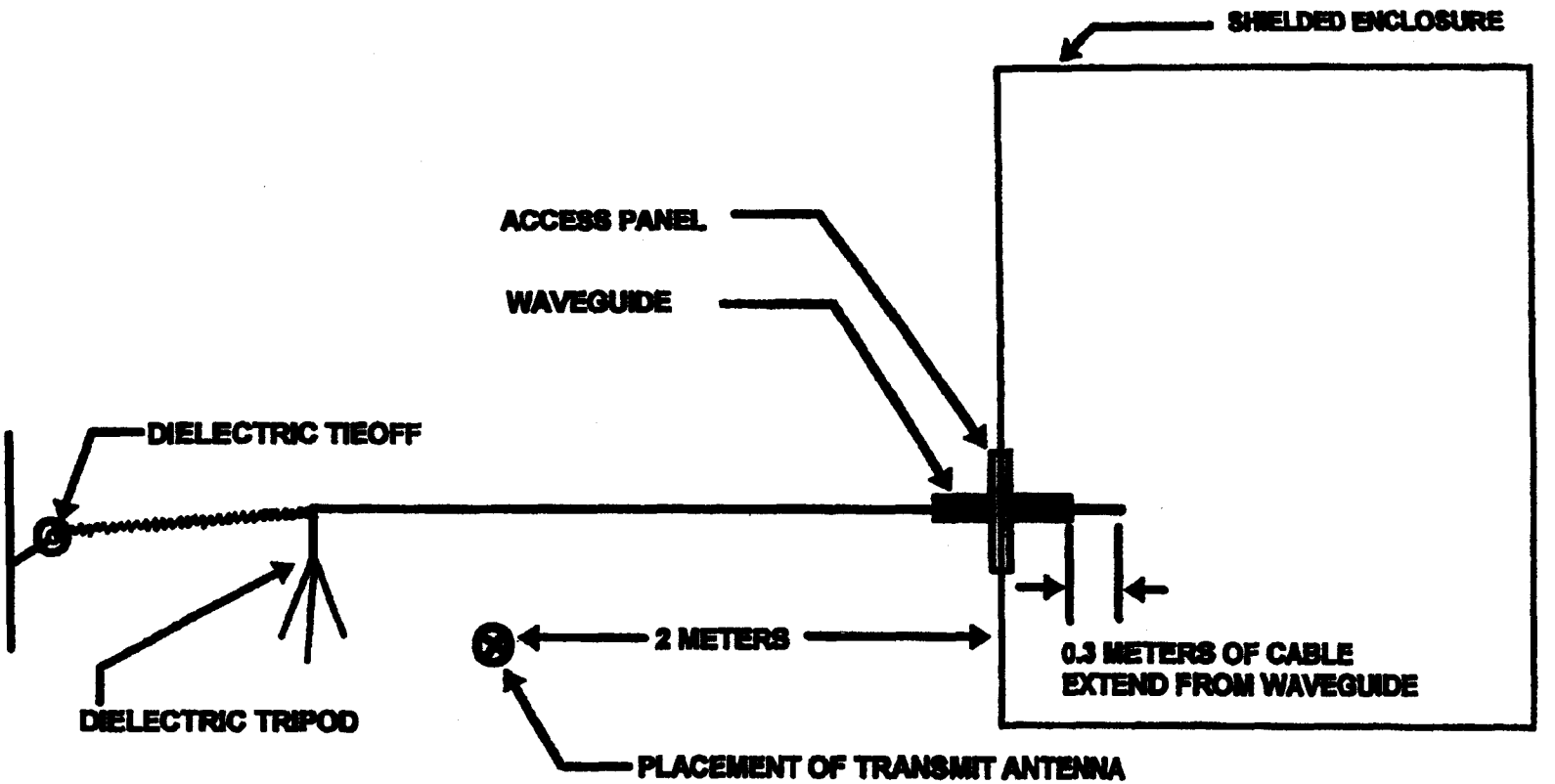


FIGURE 2. CABLE SETUP FOR SHIELDING EFFECTIVENESS OF A DUT.

08/23/05

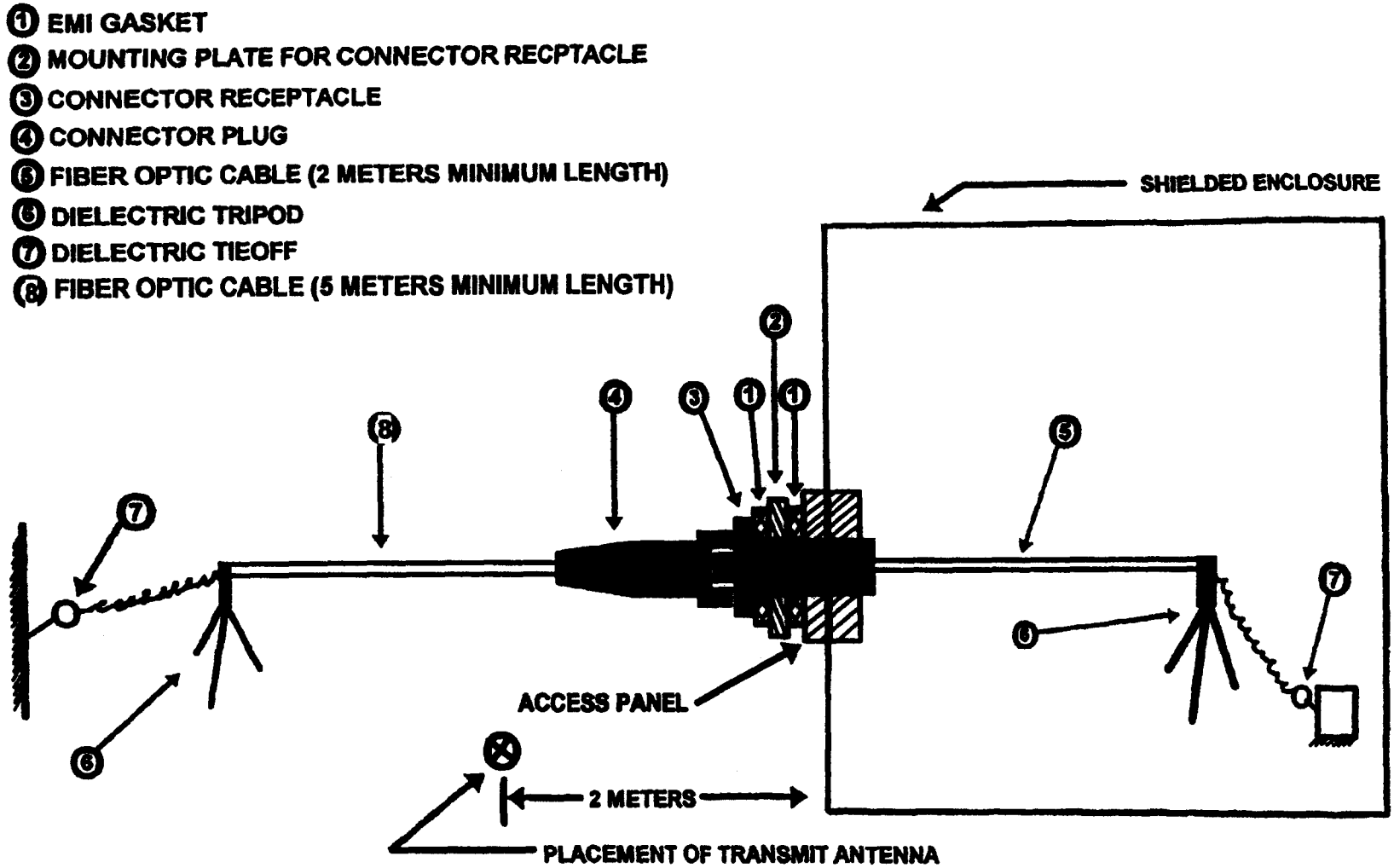


FIGURE 3.

CONNECTOR SETUP FOR SHIELDING EFFECTIVENESS OF A DUT USING PARALLEL DIRECTION OF TRANSMIT ANTENNA .

08/23/05

1. EMI GASKET
2. MOUNTING PLATE FOR CONNECTOR RECPTACLE
3. CONNECTOR RECEPTACLE
4. CONNECTOR PLUG
5. FIBER OPTIC CABLE (2 METERS MINIMUM LENGTH)
6. DIELECTRIC TRIPOD
7. DIELECTRIC TIEOFF
8. FIBER OPTIC CABLE (5 METERS MINIMUM LENGTH)
9. NON CONDUCTIVE FLOOR / NON CONDUCTIVE MAT ON FLOOR

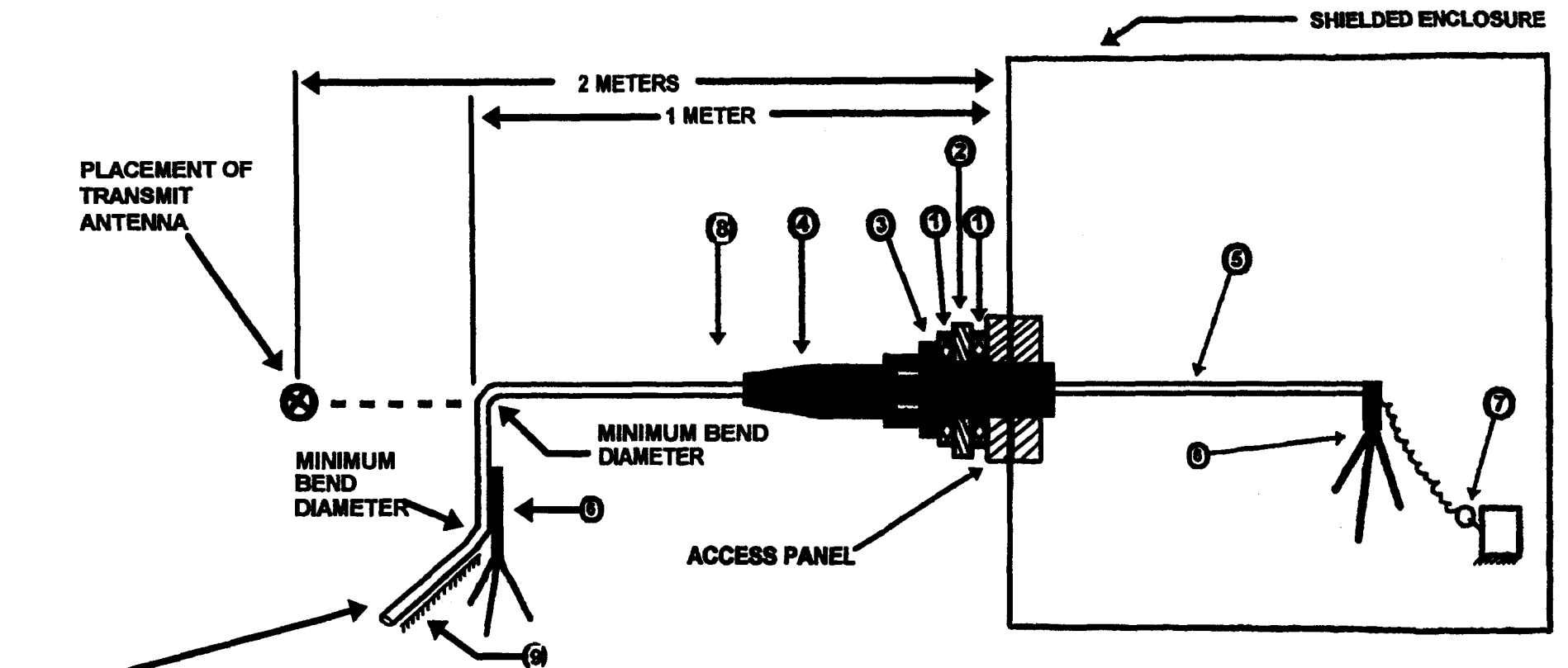
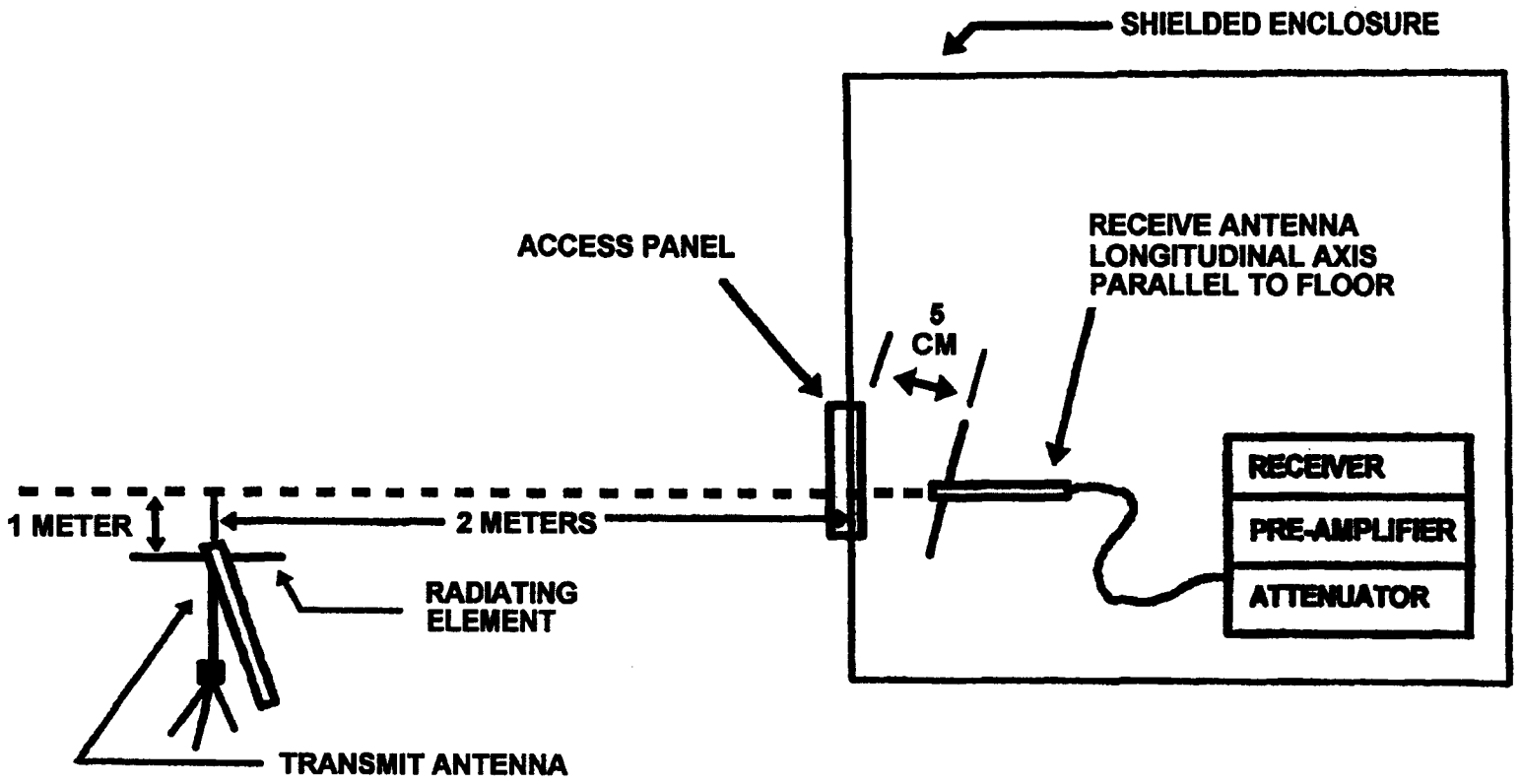


FIGURE 4. CONNECTOR SETUP FOR SHIELDING EFFECTIVENESS OF A DUT USING PERPENDICULAR DIRECTION OF TRANSMIT ANTENNA.

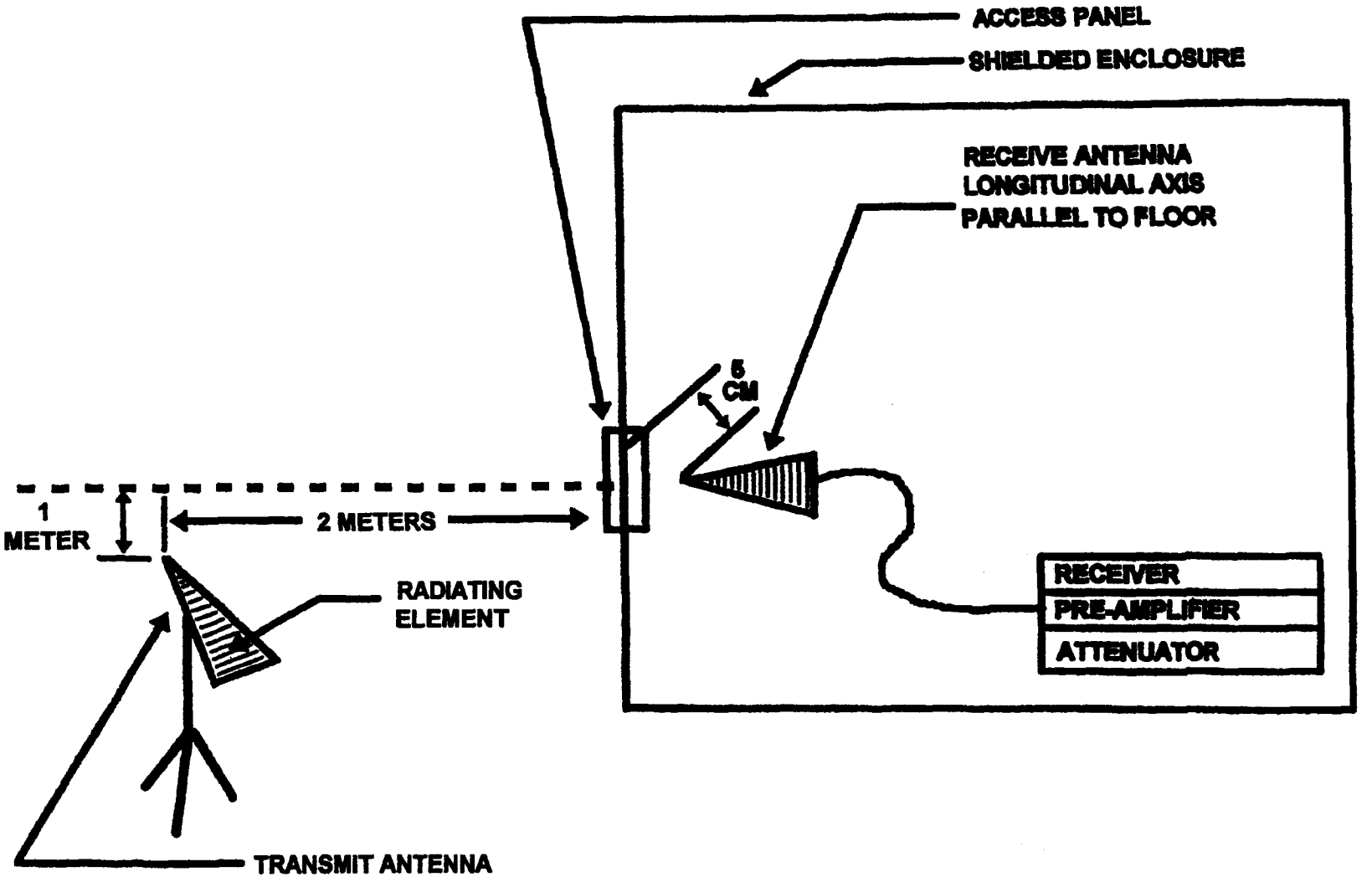
08/23/05



NOTES: 1. FOR PARALLEL DIRECTION, THE TRANSMIT ANTENNA RADIATING ELEMENTS ARE PARALLEL TO THE CABLE LENGTH.
2. TRANSMIT AND RECEIVE ANTENNAS SHALL BE PLACED IN SAME HORIZONTAL PLANE AS THE CABLE.
3. MATCHED ANTENNAS SHALL BE USED.

FIGURE 5. ORIENTATION FOR PARALLEL DIRECTION OF TRANSMIT ANTENNA AND DIPOLE ANTENNA PLACEMENT FOR SHIELDING EFFECTIVENESS MEASUREMENTS.

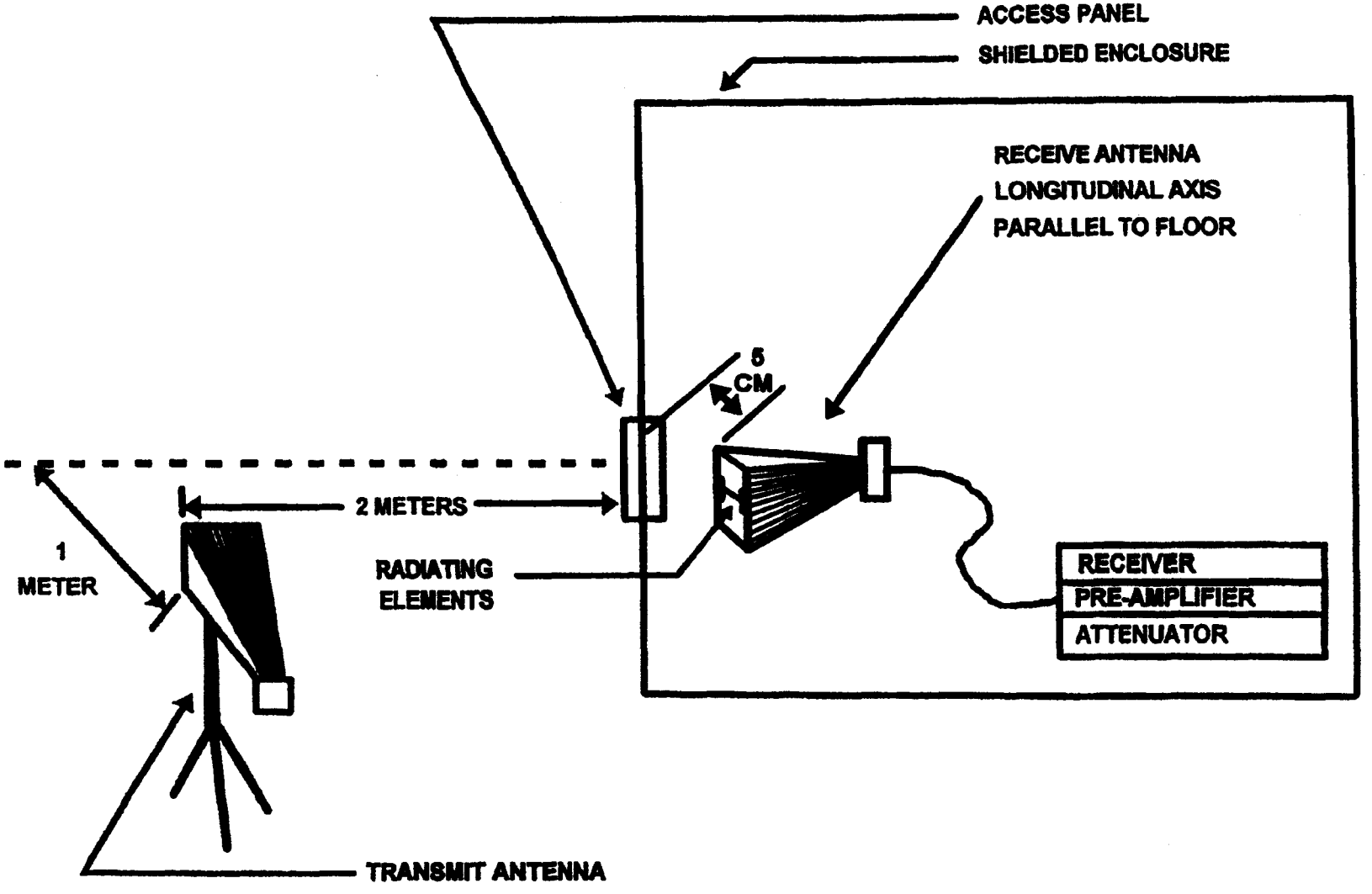
08/23/05



NOTES: 1. FOR PARALLEL DIRECTION, THE TRANSMIT ANTENNA RADIATING ELEMENTS ARE PARALLEL TO THE CABLE LENGTH.
2. TRANSMIT AND RECEIVE ANTENNAS SHALL BE PLACED IN SAME HORIZONTAL PLANE AS THE CABLE.
3. MATCHED ANTENNAS SHALL BE USED.

FIGURE 6. ORIENTATION FOR PARALLEL DIRECTION OF TRANSMIT ANTENNA AND LOG PERIODIC ANTENNA PLACEMENT FOR SHIELDING EFFECTIVENESS MEASUREMENTS .

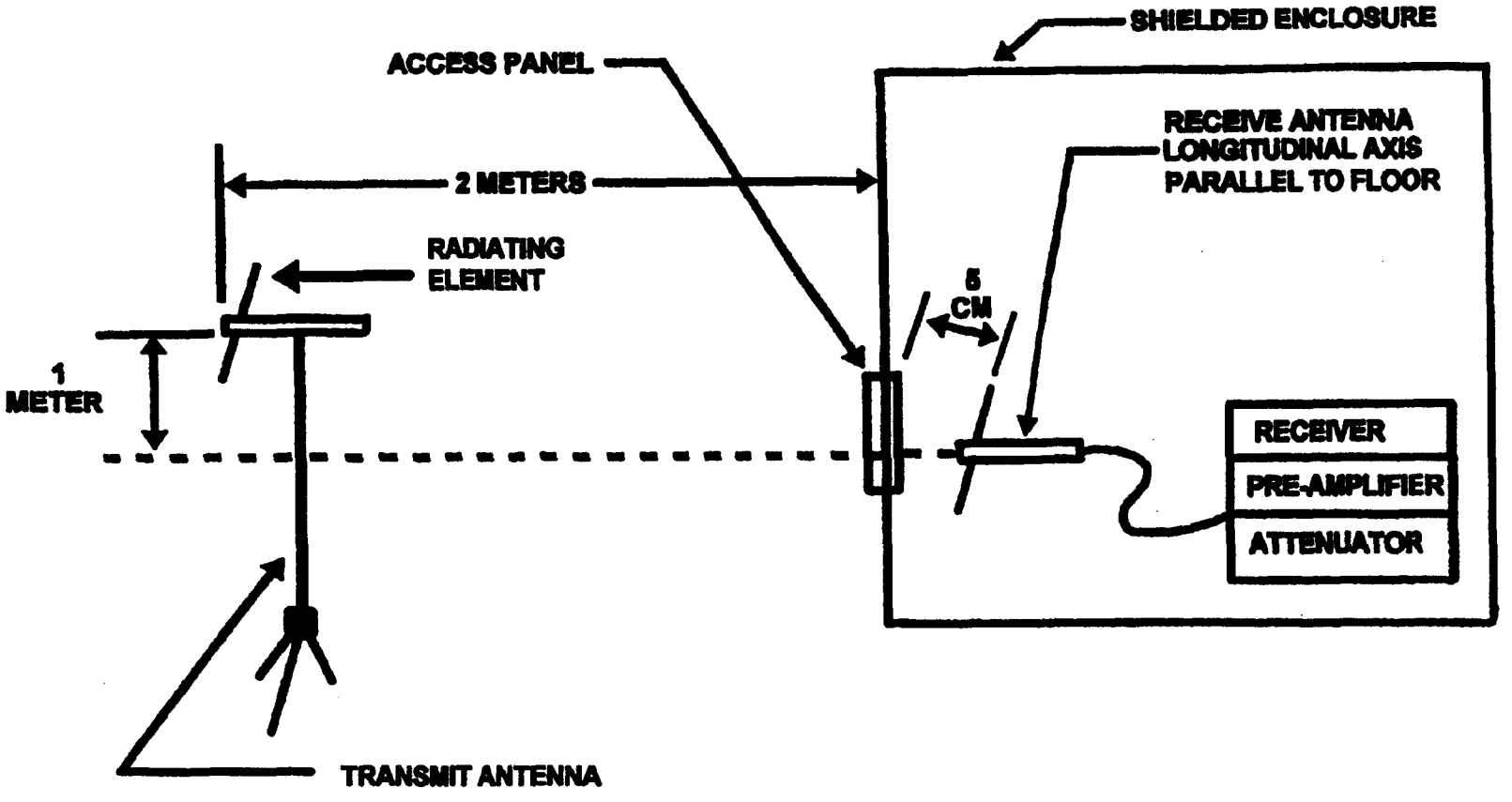
08/23/05



NOTES: 1. FOR PARALLEL DIRECTION, THE TRANSMIT ANTENNA RADIATING ELEMENTS ARE PARALLEL TO THE CABLE LENGTH.
2. TRANSMIT AND RECEIVE ANTENNAS SHALL BE PLACED IN SAME HORIZONTAL PLANE AS THE CABLE.
3. MATCHED ANTENNAS SHALL BE USED.

FIGURE 7. ORIENTATION FOR PARALLEL DIRECTION OF TRANSMIT ANTENNA AND HORN ANTENNA PLACEMENT FOR SHIELDING EFFECTIVENESS MEASUREMENTS .

08/23/05



NOTES: 1. FOR PERPENDICULAR DIRECTION, ANTENNA RADIATING ELEMENTS ARE PERPENDICULAR TO THE CABLE LENGTH.
2. TRANSMIT ANTENNA SHALL BE PLACED ONE METER ABOVE AND FRONT FACE POINTED IN OPPOSITE DIRECTION FROM ENCLOSURE AND RECEIVE ANTENNA.
3. MATCHED ANTENNAS SHALL BE USED.

FIGURE 8. ORIENTATION FOR PERPENDICULAR DIRECTION OF TRANSMIT ANTENNA AND DIPOLE ANTENNA PLACEMENT FOR CABLE SHIELDING EFFECTIVENESS MEASUREMENTS.

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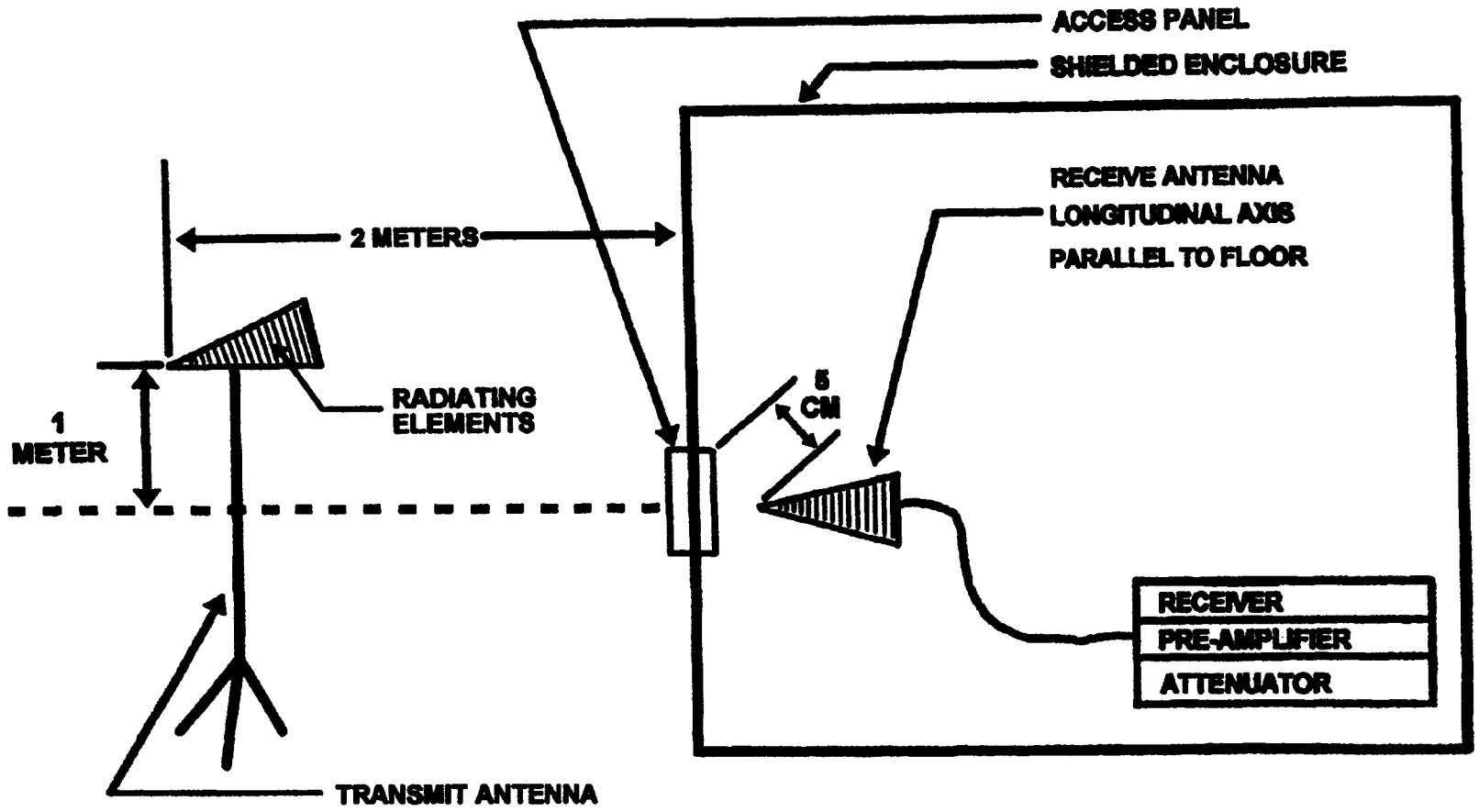

NOTES: 1. FOR PERPENDICULAR DIRECTION, ANTENNA RADIATING ELEMENTS ARE PERPENDICULAR TO THE CABLE LENGTH.
2. TRANSMIT ANTENNA SHALL BE PLACED ONE METER ABOVE AND FRONT FACE (APEX) POINTED IN OPPOSITE DIRECTION FROM CABLE AND RECEIVE ANTENNA.
3. MATCHED ANTENNAS SHALL BE USED.

FIGURE 9. ORIENTATION FOR PERPENDICULAR DIRECTION OF TRANSMIT ANTENNA AND LOG PERIODIC ANTENNA PLACEMENT FOR CABLE SHIELDING EFFECTIVENESS MEASURMENTS .

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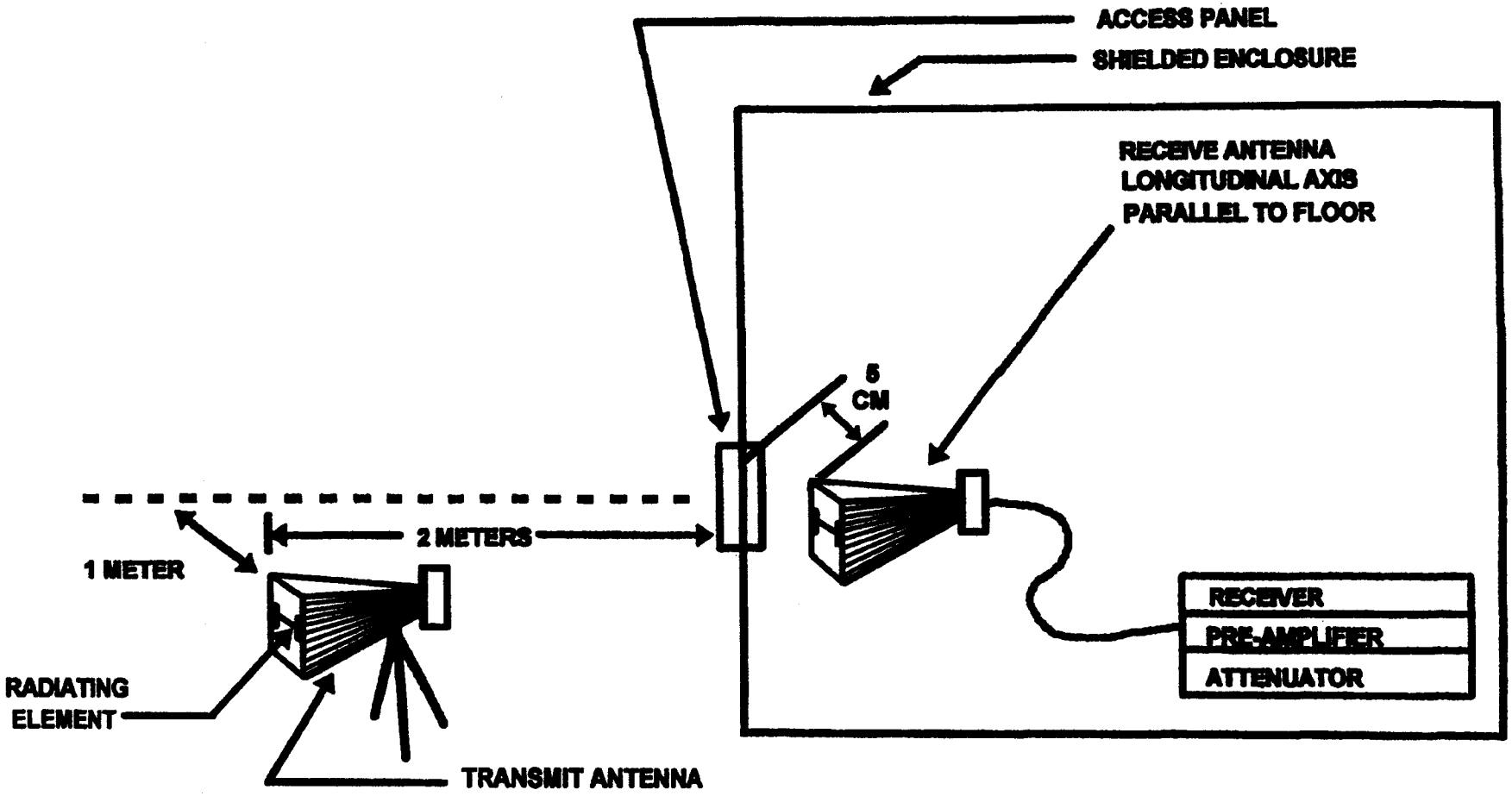

NOTES: 1. FOR PERPENDICULAR DIRECTION, ANTENNA RADIATING ELEMENTS ARE PERPENDICULAR TO THE CABLE LENGTH.
2. TRANSMIT AND RECEIVE ANTENNAS SHALL BE PLACED IN SAME HORIZONTAL PLANE AS THE CABLE.
3. TRANSMIT ANTENNA FRONT FACE SHALL BE POINTED IN OPPOSITE DIRECTION FROM ENCLOSURE AND RECEIVE ANTENNA.
4. MATCHED ANTENNAS SHALL BE USED.

FIGURE 10. ORIENTATION FOR PERPENDICULAR DIRECTION OF TRANSMIT ANTENNA AND HORN ANTENNA PLACEMENT FOR CABLE SHIELDING EFFECTIVENESS MEASURMENTS .

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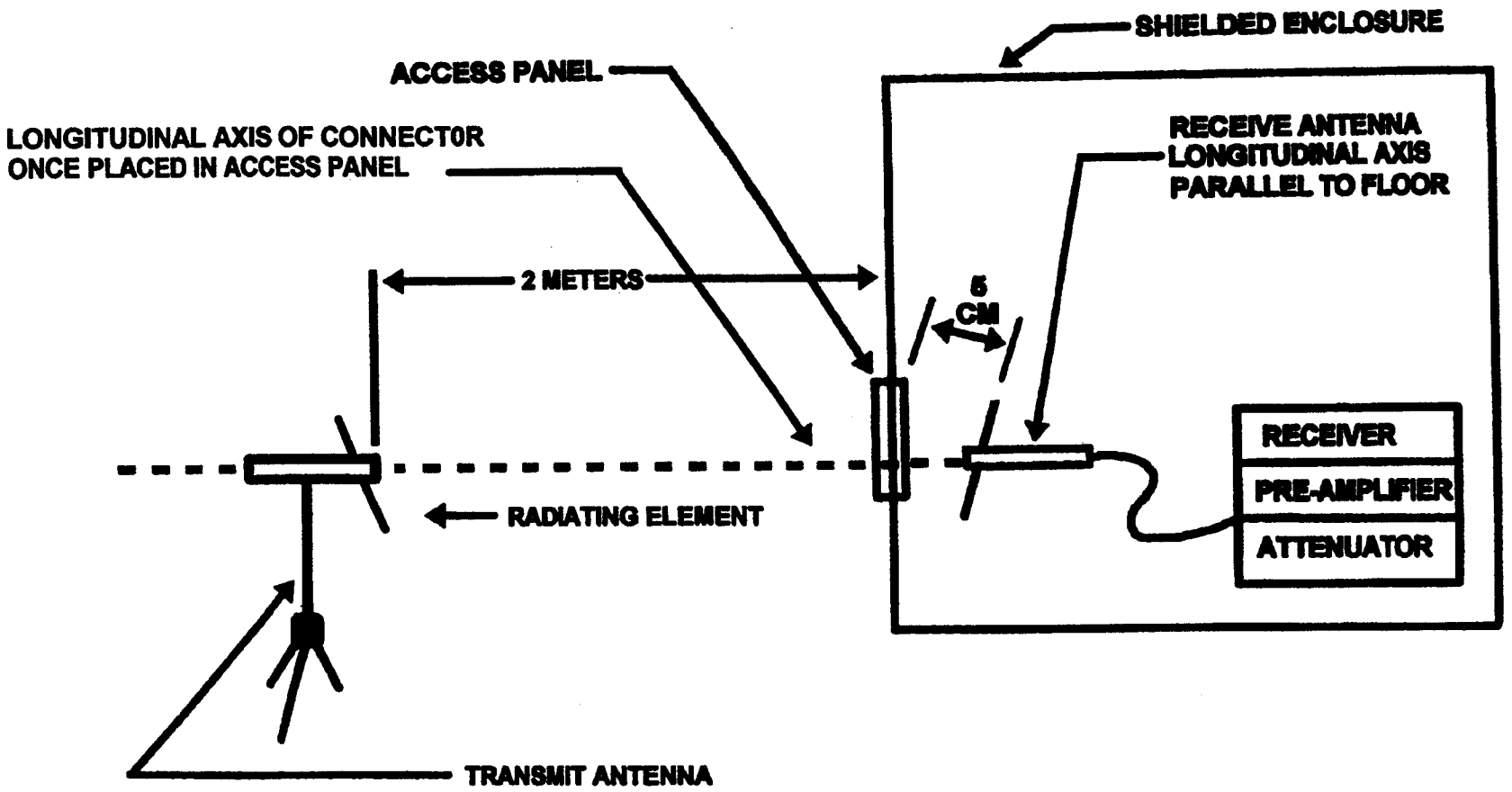


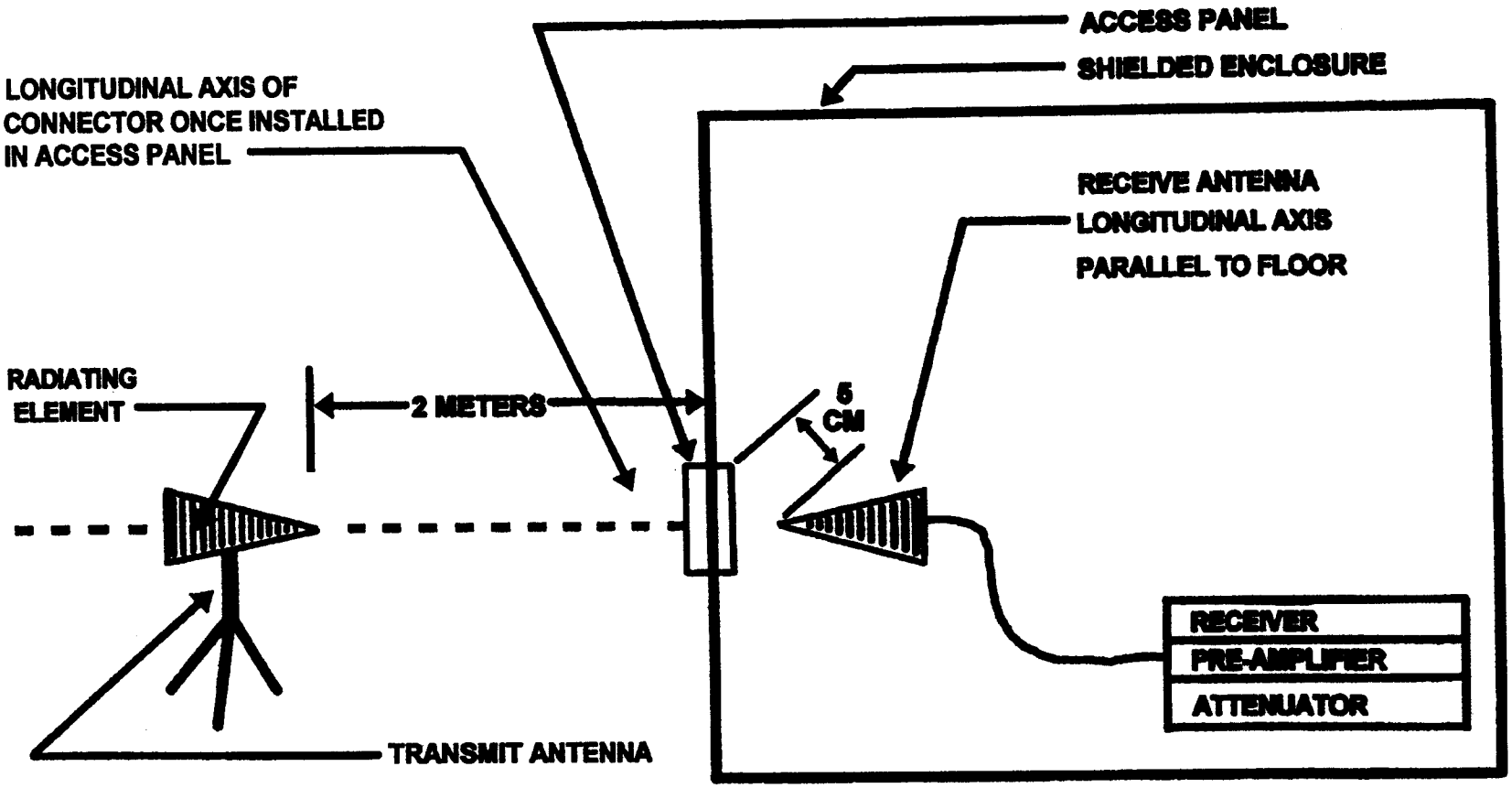
NOTES: 1. FOR PERDENDICULAR DIRECTION, ANTENNA RADIATING ELEMENTS ARE PERPENDICULAR TO THE LONGITUDINAL AXIS OF THE CONNECTOR.

2. TRANSMIT AND RECEIVE ANTENNAS SHALL BE PLACED IN SAME HORIZONTAL PLANE AS THE LONGITUDINAL AXIS OF THE CONNECTOR.

3. TRANSMIT ANTENNA FRONT FACE SHALL BE POINTED IN DIRECTION OF ENCLOSURE AND RECEIVE ANTENNA.

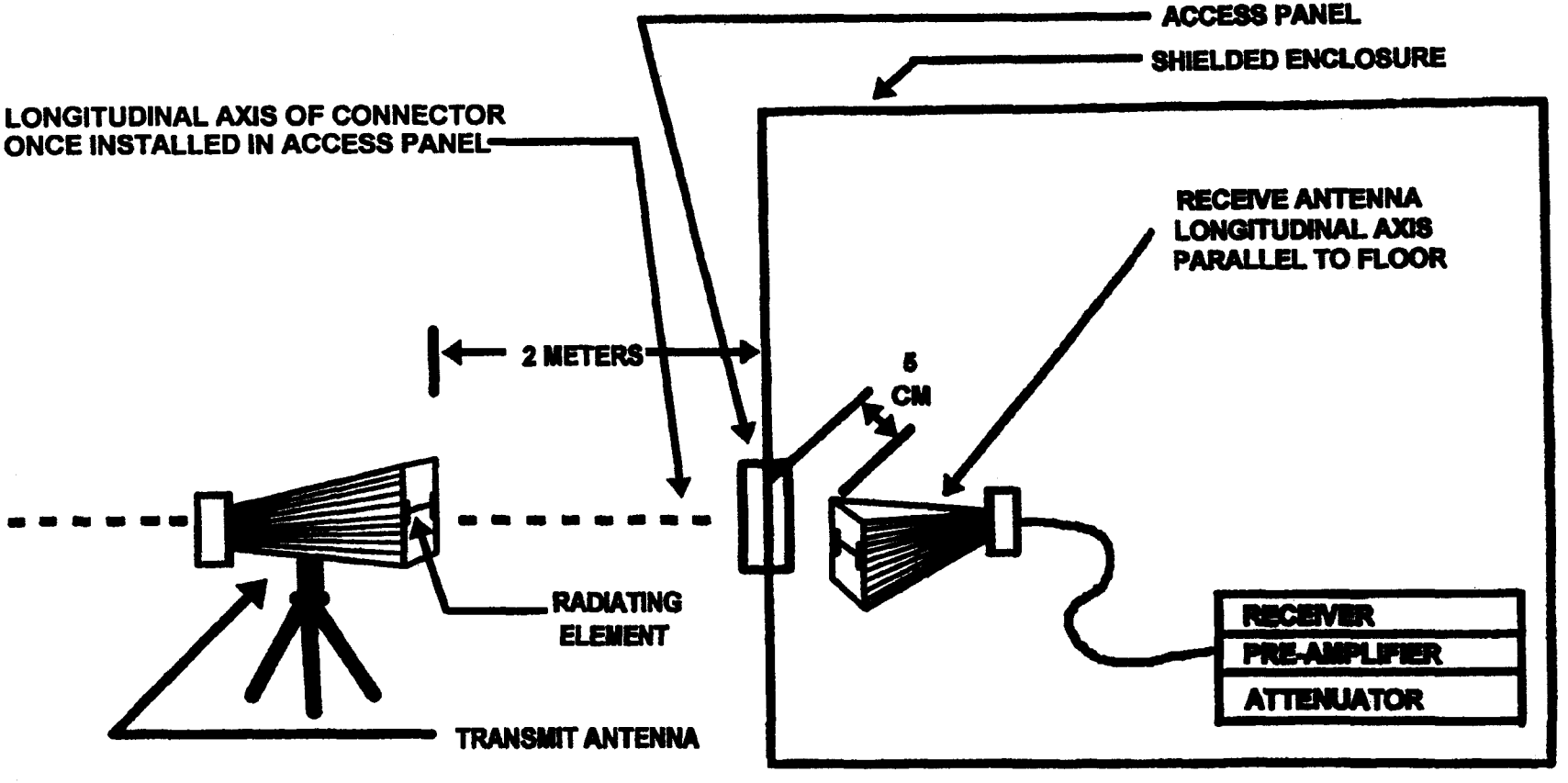
4. MATCHED ANTENNAS SHALL BE USED.

FIGURE 11. ORIENTATION FOR PERPENDICULAR DIRECTION OF TRANSMIT ANTENNA AND DIPOLE ANTENNA PLACEMENT FOR CONNECTOR SHIELDING EFFECTIVENESS MEASUREMENTS .



NOTES:
1. FOR PERPENDICULAR DIRECTION, ANTENNA RADIATING ELEMENTS ARE PERPENDICULAR TO THE LONGITUDINAL AXIS OF THE CONNECTOR.
2. TRANSMIT AND RECEIVE ANTENNAS SHALL BE PLACED IN SAME HORIZONTAL PLANE AS THE LONGITUDINAL AXIS OF THE CONNECTOR.
3. TRANSMIT ANTENNA FRONT FACE SHALL BE POINTED IN DIRECTION OF ENCLOSURE AND RECEIVE ANTENNA.
4. MATCHED ANTENNAS SHALL BE USED.

FIGURE 12. ORIENTATION FOR PERPENDICULAR DIRECTION OF TRANSMIT ANTENNA AND LOG PERIODIC ANTENNA PLACEMENT FOR CONNECTOR SHIELDING EFFECTIVENESS MEASUREMENTS.



NOTES: 1. FOR PERPENDICULAR DIRECTION, ANTENNA RADIATING ELEMENTS ARE PERPENDICULAR TO THE LONGITUDINAL AXIS OF THE CONNECTOR.

2. TRANSMIT AND RECEIVE ANTENNAS SHALL BE PLACED IN SAME HORIZONTAL PLANE AS THE LONGITUDINAL AXIS OF THE CONNECTOR.
3. TRANSMIT ANTENNA FRONT FACE SHALL BE POINTED IN DIRECTION OF ENCLOSURE AND RECEIVE ANTENNA.
4. MATCHED ANTENNAS SHALL BE USED.

FIGURE 13. ORIENTATION FOR PERPENDICULAR DIRECTION OF TRANSMIT ANTENNA AND HORN ANTENNA PLACEMENT FOR CONNECTOR SHIELDING EFFECTIVENESS MEASURMENTS .

08/23/05