Designation: E 1851 – 02

An American National Standard

Standard Test Method for Electromagnetic Shielding Effectiveness of Durable Rigid Wall Relocatable Structures[1]

This standard is issued under the fixed designation E 1851; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The test method described in this standard can be used to determine the electromagnetic shielding effectiveness of durable relocatable shielded enclosures.

1.1.1 The intended application of this test method is for virgin shielded enclosures that do not have any equipment or equipment racks. It is recommended that tests be conducted before the interior finish work begins. However, the shield assembly including all enclosure penetrations shall be completed and required penetration protection devices shall be installed in accordance with the design specification. The test method can also be used on existing shielded enclosures after repair work is done to verify workmanship, but it may be necessary to remove equipment or equipment racks to gain access to a test area.

1.1.2 The test procedures delineated in this document are comprehensive and may require several days to complete for a room-size shielded enclosure. A user can apply this test method for a first article test that requires proof of concept and validation of design and fabrication technique. Appendix X2 provides guidance on choosing test points so shielding effectiveness tests on a room-size shielded enclosure may be completed in about one-half day for which it applies to shielded enclosures coming off an assembly line.

1.2 This test method is for use in the following frequency ranges: 140 to 160 kHz, 14 to 16 MHz, 300 to 500 MHz, 900 to 1000 MHz, and 8.5 to 10.5 GHz. Specific test frequencies within these ranges are required (see 10.1.1 and 10.2.1). Additional measurements in the range of 10 kHz to 10.1.5.1 GHz may be performed. For specific applications, the frequency range may be extended from 50 Hz to 40 GHz. Appendix X1 provides guidance on selecting measurement frequencies.

1.3 This test method is not applicable to individual components such as separate walls, floors, ceilings, or shielded racks.

1.4 This standard may involve hazardous materials, operations, equipment, or any combination.

1.5 The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *IEEE Standards:*

IEEE Std 299-1997, IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures

IEEE Std C95.1-1991, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

2.2 *Military Standard:*

MIL-STD-188-125, High Altitude Electromagnetic Pulse (HEMP) Protection for Ground Based C^4I Facilities Performing Critical, Time-Urgent Missions

2.3 *OSHA Standard:*

OSHA Regulation, 29 CFR 1910, Department of Labor, July 1992

3. Summary of Test Method

3.1 *Test Configuration*—A transmitting antenna is connected to an electromagnetic source set to a specific frequency and amplitude. A receiving antenna is placed a specified distance from the transmitting antenna, and the received electromagnetic field level is recorded as a reference or calibration measurement. The transmitting antenna and electromagnetic source are placed outside the shielded enclosure. The receiving antenna and associated test equipment are placed inside the shielded enclosure. The transmitting and receiving antenna's separation, frequency, and amplitude are the reference measurements. The transmitting and receiving antennas are at the same height for a given test point. The received electromagnetic field level is recorded as the test measurement. The ratio of the test measurement to the reference measurement is the electromagnetic shielding effectiveness of the shielded structure at the measurement location and frequency. The

[1] This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.53 on Materials and Processes for Durable Rigidwall Relocatable Structures.

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logarithm of this ratio is typically used in expressing the shielding effectiveness in decibels.

3.2 *Test Frequencies*—A summary of nominal test frequencies and corresponding test configurations is shown in Table 1.

4. Significance and Use

4.1 This standard provides measurement procedures for determining the electromagnetic shielding effectiveness of durable rigid wall relocatable shielded enclosures. This standard specifies a method for comparing the shielded enclosure performance of structures provided by different suppliers. In addition, this standard is written to minimize variations in measured shielding effectiveness at a given frequency and test point regardless of test personnel, equipment, and test site. Therefore, the shielding effectiveness of a durable rigid wall relocatable shielded enclosure of any size from any supplier can be determined. This standard specifies a minimum set of measurements at a given frequency and a minimum set of frequencies to determine shielding effectiveness.

4.2 *Source Fields*—Performance of a shielded enclosure is to be assessed for two source fields: magnetic and plane wave.

4.2.1 *Magnetic Field Measurements*—The attenuation provided by a shielded enclosure is assessed by using a local source to generate the near field. The magnetic field measurements are specified for two narrow frequency bands: 140 to 160 kHz and 14 to 16 MHz.

4.2.2 *Plane Wave Measurements*—The attenuation provided by a shielded enclosure is assessed by using a locally generated distant source or plane wave field. The plane wave measurements are specified for three narrow frequency bands: 300 to 500 MHz, 900 to 1000 MHz, and 8.5 to 10.5 GHz.

5. Interferences

5.1 *Interference with Electronic Equipment*—Care shall be taken to avoid interference with other electronic equipment operating in the vicinity.

5.2 *Operational Impact Analysis and Risk*—The electromagnetic barrier must remain intact during the shielding effectiveness measurement sequence, and use of electrically noisy equipment must be restricted. Therefore, construction activity or unusual operations (facility modification or maintenance) may be affected. Radiated signal levels should present no hazard to equipment, but frequency adjustments may be required to avoid self interference or interference with nearby facilities. Record the actual test frequencies. Normal electrical safety precautions apply.

6. Apparatus

6.1 The required apparatus is identified in Table 2. Choose test equipment that provides a dynamic range of at least 10 dB in excess of the shielding effectiveness requirement at the test frequency.

TABLE 1 Test Frequencies and Test Configurations

Nominal Test Frequency	Corresponding Test Configuration
150 kHz and 14 MHz	Fig. 1
400 MHz, 1000 MHz, and 10 GHz	Fig. 2

TABLE 2 Test Apparatus

Equipment	Characteristics
Oscillator(s)	140 to 160 kHz, 14 to 16 MHz, 300 to 500 MHz, 900 to 1000 MHz, 8.5 to 10.5 GHz
Power Amplifier(s)	140 to 160 kHz, 14 to 16 MHz, 300 to 500 MHz,[A] 900 to 1000 MHz,[A] 8.5 to 10.5 GHz, amplification and noise figures as required for dynamic range
Preamplifier(s)	140 to 160 kHz, 14 to 16 MHz, 300 to 500 MHz, 900 to 1000 MHz, 8.5 to 10.5 GHz, amplification and noise figures as required for dynamic range
Receiver(s)/Spectrum Analyzer(s)	140 to 160 kHz, 14 to 16 MHz, 300 to 500 MHz, 900 to 1000 MHz, 8.5 to 10.5 GHz
Antenna Kit	140 to 160 kHz,[B] 14 to 16 MHz,[B] 300 to 500 MHz,[C] 900 to 1000 MHz,[C] 8.5 to 10.5 GHz[D]
Miscellaneous Cables and Attenuators as Required[E]	

[A] The power amplifier output is usually matched to an unbalanced to balanced (balun) transformer; the balanced output is matched to a balanced dipole.

[B] Circular loop antenna whose diameter is 30 cm (1 ft) shall be used. The shielded circular receiving antenna can have multiple turns, but the total length of wire forming the loop shall be less than ⅛ wavelength.

[C] Any antenna that radiates at the prescribed frequencies may be used. However, antennas that require a large clear space in the direction of wave propagation shall not be used where clear space is limited for testing. Examples of such antennas are linearly polarized log periodic dipole and circularly polarized conical spiral antennas. Procedures are written assuming use of dipole antennas for plane wave measurements. If a dipole antenna is used as a receiving antenna, its length shall be less than ⅛ of wavelength. The receiving antenna is usually connected to a balun then to an attenuator.

[D] Any antenna that radiates at the prescribed frequencies may be used except a linearly polarized log periodic dipole antenna or circularly polarized conical spiral antenna. Procedures are written assuming use of aperture antennas for high frequency plane wave measurements. An isolator is usually used between the source and its antenna to minimize variation of power between reference and test measurements.

[E] Well shielded coaxial cable such as flexible semi-rigid coaxial cable, RG-214 or RG-223, shall be used.

7. Hazards

7.1 For human exposure to electromagnetic energy in controlled environments, the maximum permissible exposure to electric and magnetic field strengths shall be minimized to the maximum extent possible. Acceptable levels can be found in IEEE C95.1-1991 and OSHA Regulation 29 CFR.

8. Preparation of Apparatus

8.1 *New and Existing Durable Relocatable Enclosure Testing*—Testing of new durable rigid wall relocatable shielded enclosures can be conducted at the manufacturing site. Manufacturing site testing can locate structural defects or weaknesses or both and corrections may be easily implemented. For existing structures, weaknesses can be determined and corrected during maintenance or periodic retesting.

8.2 *Movable Equipment*—Moveable equipment containing metal, not normally housed in the enclosure or attached outside the enclosure, shall be removed from the enclosure prior to making measurements.

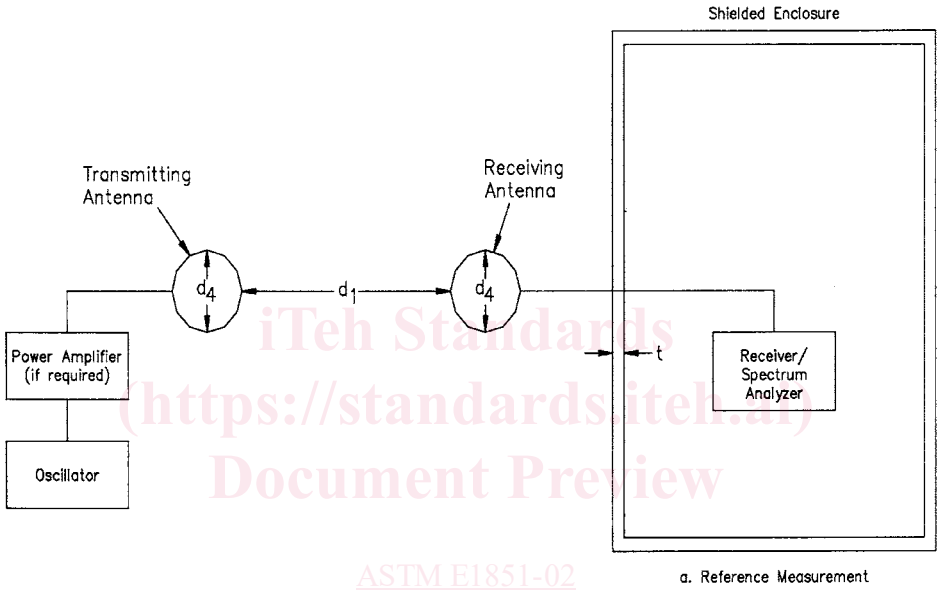
8.3 *Preliminary Procedures*—Perform the following preliminary test on all accessible shielding faces to detect weak points and to permit remedy of shielding defects caused by faulty assembly and poor workmanship prior to actual measurement.

8.3.1 With the transmitting antenna turned off, perform a continuous wave (cw) measurement at each frequency to be used for testing to ensure that no emitters are nearby that may cause interference. Frequency adjustments may be necessary to

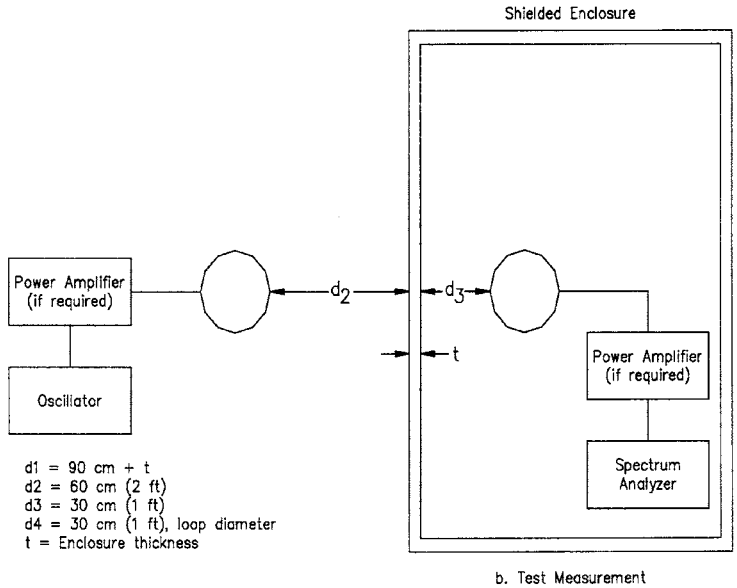
avoid interference. Setup for this measurement is the reference measurement (see Section 9 and Fig. 1a and Fig. 2a).

8.3.2 Additionally, perform a receiving equipment coupling measurement. The setup for this measurement is the reference measurement (Section 9) with the following exceptions. Disconnect the receiving antenna from the nearest cable and replace the receiving antenna with a dummy load (resistive load matched to the characteristic impedance of the receiving system) as shown in Fig. 3. Measured levels shall be negligible so the required dynamic ranges are maintained. If the measured levels are larger than expected, determine the penetration points and correct the identified leakage points. Repeat the receiving equipment coupling measurements until negligible levels are maintained.

8.3.3 Perform a noise measurement with the following equipment setup. Place the receiving antenna and equipment inside the enclosure and turn off the transmitting antenna placed outside the enclosure (see Fig. 4). The receiving antenna can be placed outside the enclosure. When this is done an attenuator shall be inserted between the receiving antenna and



a. Reference Measurement



b. Test Measurement

FIG. 1 Magnetic Field Test Procedures

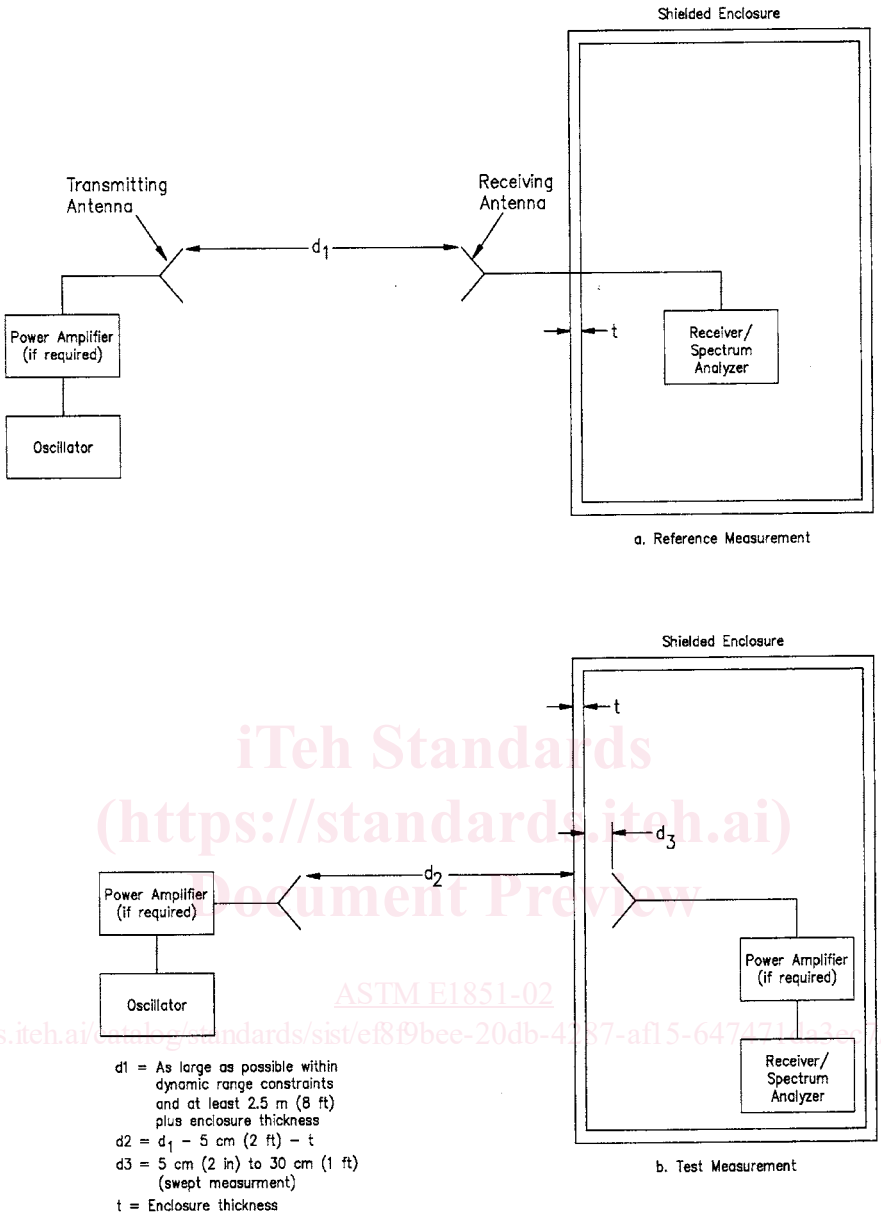


FIG. 2 Plane Wave Field Test Procedures

receiving equipment, and it shall be set to a shielding effectiveness level of the enclosure being tested. Measure the noise level at each frequency to be used for testing.

8.3.4 After noise levels have been found negligible (or the test equipment has been modified to make the penetration negligible), position the transmitting and receiving antennas in accordance with the procedures detailed in Section 10. For each location, use the receiving antenna as a probe to locate areas of maximum penetration. Alternatively, a commercial leak detector may be used. Check all penetrations such as doors, power line filters, air vents, seams, and coaxial cable fittings. If the performance of the enclosure appears to be inadequate for its design, remedial measures are suggested prior to complete testing. Identify regions of significantly greater field penetration for later measurements.

9. Calibration Procedures

9.1 *Magnetic Field Calibration Procedure*—Conduct the calibration for magnetic field measurements for each magnetic field test frequency as shown in Fig. 1a. Choose test equipment that provides a dynamic range of at least 10 dB in excess of the shielding effectiveness requirement at the test frequency. Place the loops of the transmitting and receiving antennas in a coplanar configuration. Place the transmitting and receiving antennas so the distance between them is 90 cm (3 ft) plus the thickness of the enclosure (see Fig. 1a). If an attenuator is used

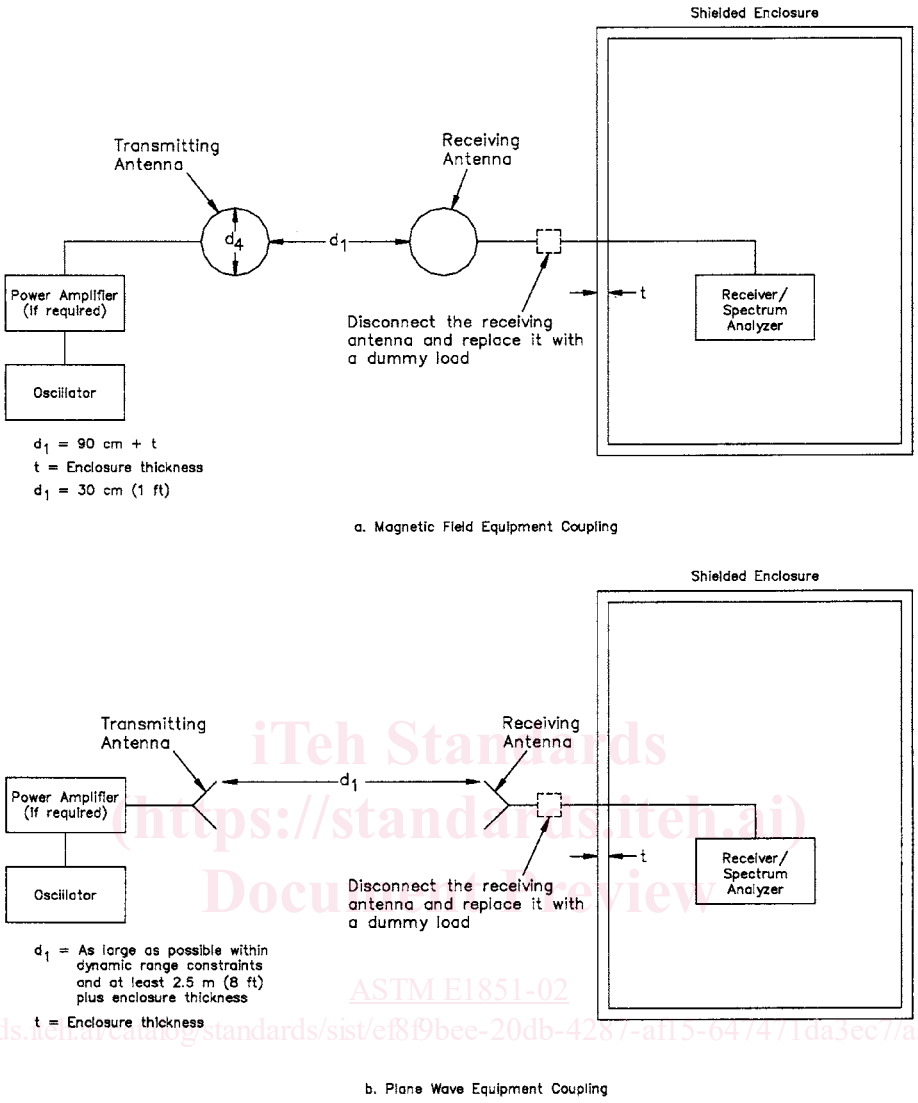


FIG. 3 Equipment Coupling Measurement

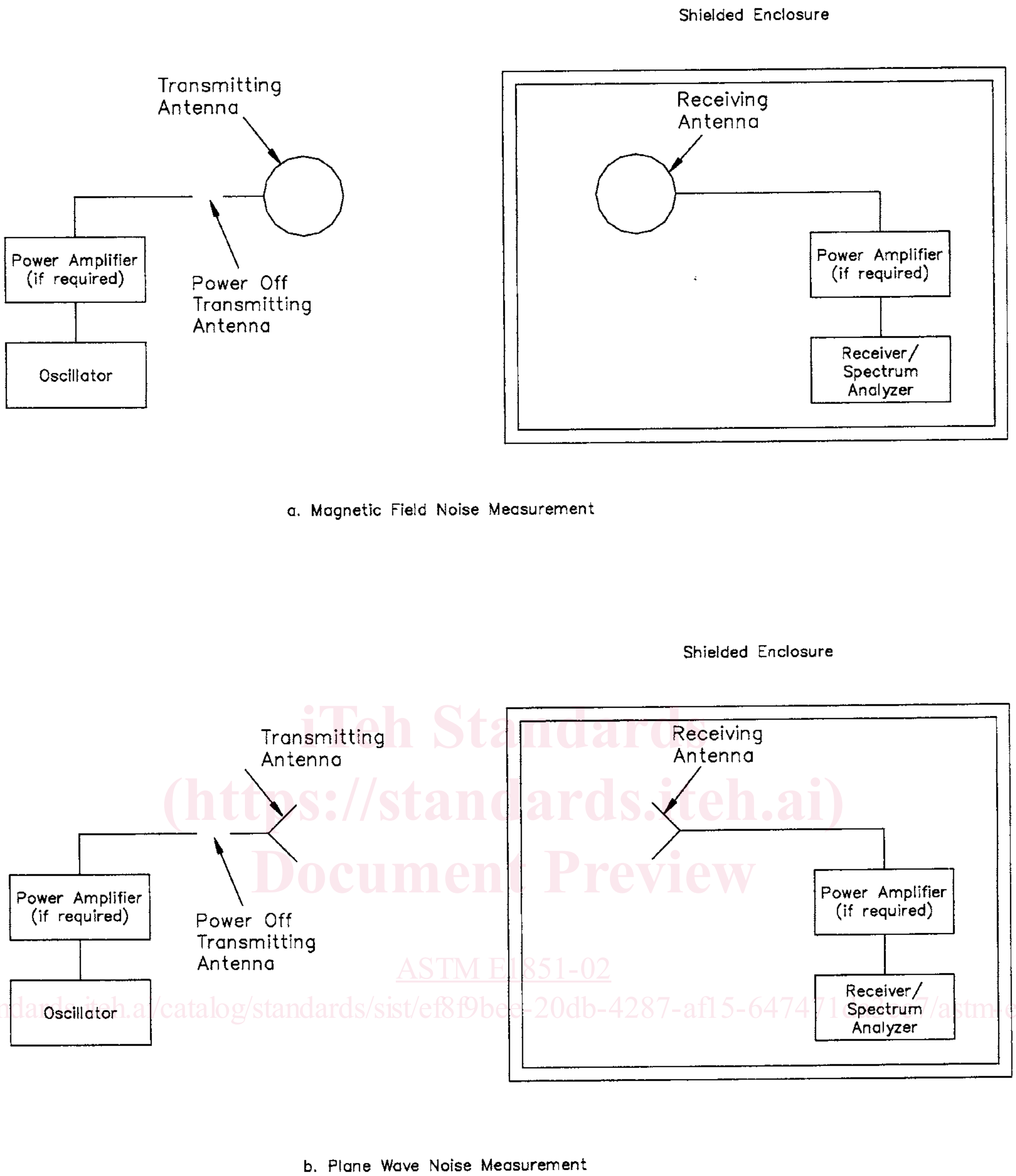
as the basis for the desired measurement, the attenuator shall be calibrated and the results shall be documented. The attenuator impedance shall match the system transmission line impedance. Place the receiving system, but not the receiving antenna, inside the enclosure.

9.1.1 During calibration no other equipment or electromagnetic reflectors (except ground) shall be closer than three times the antenna separation. The antennas shall be at least 1 m (3.3 ft) above the ground.

9.1.2 Record the received signal strength for each frequency and transmitting antenna polarization as the calibration signal (V_c) for that configuration. Record all equipment settings, including generator loop current or transmit power.

9.2 *Plane Wave Calibration Procedure*—Conduct the calibration for plane wave measurements for each plane wave test frequency and antenna polarization as shown in Fig. 2a. Choose test equipment that provides a dynamic range of at least 10 dB in excess of the shielding effectiveness requirement at the test frequency. For dipole antennas, place the transmitting and receiving antennas so both antennas lie in the same plane (coplanar) and their elements are parallel. For aperture antennas, place the transmitting and receiving antennas so their apertures are parallel. Separation distance between the antennas shall be as large as possible within dynamic range constraints, but at least 2.5 m (8.2 ft) plus enclosure thickness. Place the receiving system, but not the receiving antenna, inside the enclosure. Vary the receiving antenna position ± 0.3 m (1 ft) from its nominal location toward and away from the transmitting antenna to measure the local maximum, but do not vary the antenna alignment or polarization.

9.2.1 During calibration, no other equipment or electromagnetic reflectors (except ground) shall be closer than three times the antenna separation. The antennas shall be at least 1 m (3.3 ft) above the ground.



a. Magnetic Field Noise Measurement

b. Plane Wave Noise Measurement

FIG. 4 Noise Measurement Procedures

9.2.2 Record the highest received signal strength for each frequency and both antenna polarizations as the calibration signal (V_c) for that configuration. Record all equipment settings, including generator output.

9.3 *Antenna Coverage*—Measure the maximum test area during the calibration. Place the vertically polarized transmitting antenna at least 2.5 m (8.2 ft) away from the vertically polarized receiving antenna, move the receiving antenna horizontally from left to right from its center, and measure the distance X (m) between the −3 dB points (below the peak amplitude). Repeat the above procedure by moving the receiving antenna up and down from its center position without changing either antenna polarizations and measure the distance Y (m) between the −3 dB points.

10. Test Measurement Procedures

10.1 *Magnetic Field Test Measurement Procedure*—Conduct the magnetic field test measurement as shown in Fig. 1b. Use the same equipment, antennas, cables, loop current or transmit power, and equipment settings (except attenuator settings) that were used in the calibration sequences.

10.1.1 *General Test Procedures*:

10.1.1.1 Place the transmitting antenna outside the test structure and center it on the test point. Place the antennas in