

IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures

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Abstract: Uniform measurement procedures and techniques are provided for determining the effectiveness of room-sized, high-performance electromagnetic shielding enclosures at frequencies from 14 kHz to 18 GHz (extendable to 50 Hz and 100 GHz, respectively). The types of enclosure covered include single-shield or double-shield structures of various constructions such as bolted demountable, welded, or integral with building and made of materials such as steel plate, copper or aluminum sheet, screening hardware cloth or metal foil. The intent is to reflect current practice and to provide a common reference for suppliers and users on the performance of shielding enclosures.

Keywords: double-shield enclosures, electromagnetic shielding enclosures, room-sized enclosures, screened rooms, shielded rooms, shielding effectiveness, single-shield enclosures

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Foreword

(This Foreword is not a part of IEEE Std 299-1991, IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures.)

This document provides a standard set of methods and procedures for determining the shielding effectiveness of large shielding enclosures. The enclosures of concern include those used for testing groups of equipment, vehicles, computing equipment formed into systems, and smaller units whose electromagnetic emission and susceptibility require determination, absent disturbance from other sources. MIL-STD 285 has been the common reference for many years, but the applicability of that document lessened with the advent of smaller, more sensitive equipment and devices. These advances, coupled with more powerful emitters in the same environment, required more advanced methods of determining the effectiveness of the enclosures in which equipments and systems were tested. More and more frequently, MIL-STD 285 was used as a reference, with greater dependence on the Test Plan. The basic premise of MIL-STD 285 is still in position—the shield effect is to provide an insertion loss to outside influence.

Richard B. Schulz's detailed analyses, composition, research and tutorial concepts must be recognized and acknowledged. His initial concepts, based on fundamentals, provided the backbone of the standard. Dr. Ralph Showers also provided valuable insight. The working group that developed this standard had the following membership:

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IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures

1. General

1.1 Scope. This standard provides uniform measurement procedures and estimation techniques for determining the effectiveness of room-size, high-performance electromagnetic (EM) shielding enclosures at frequencies from 14 kHz to 18 GHz (extendable to 50 Hz and 100 GHz, respectively). These procedures may be used throughout this range (except for some excluded frequencies), although certain frequencies are required.

1.2 Application. The measurement procedures herein determine the EM shielding performance of various types of enclosures, including the following characteristics:

- (1) *Configurations:* single shield or double (isolated and cell-type) shield.
- (2) *Construction:* demountable (bolted), fixed-seam (welded, brazed, or soldered), integral with building, etc.
- (3) *Materials:* steel plate, copper, or aluminum sheets; screening; hardware cloth; metal foil; etc.

1.3 Objectives. The objectives of this standard are to provide the following:

- (1) Standard procedures for the measurement of the effectiveness of shielding enclosures.
- (2) The minimum essential measurement requirements for a uniform basis of comparison between shielding enclosures, including a minimum set of standard measurement frequencies.
- (3) Identical measurement procedures applicable to frequencies other than the standard set.
- (4) A measurement technique to detect the nonlinear behavior of high-permeability ferromagnetic enclosures (see Appendix C).

2. References

- [1] ANSI C63.2-1987, American National Standard for Instrumentation—Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz—Specifications.¹
- [2] ANSI C95.1-1982, American National Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz.
- [3] IEEE Std 100-1988, IEEE Standard Dictionary of Electrical and Electronics Terms—4th ed. (ANSI).²
- [4] IEEE Std 291-1969 (Reaff 1981), IEEE Standards Report on Measuring Field Strength in Radio Wave Propagation.
- [5] IEEE Std 473-1985, IEEE Recommended Practice for an Electromagnetic Site Survey (10 kHz to 10 GHz) (ANSI).

3. Definitions

Unless defined below, all technical terms are defined in accordance with IEEE Std 100-1988 [3].³

distant source. A distant source is an emitter located far enough away from a shielding enclosure for its energy to illuminate uniformly an entire shielding face.

¹ANSI publications are available from the American National Standards Institute, Sales Department, 11 West 42nd St., 13th Floor, New York, NY 10036, (212) 642-4900.

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, 1-800-678-4333.

³The numbers in parentheses correspond to those of the references in Section 2.

local source. A local source is an emitter located close enough to a shielding enclosure for its EM energy to illuminate only a localized portion of a shielding face. The effect is assessed by choosing the poorest performance in the set of measured locations.

shielding enclosure. A structure that protects its interior from the effect of an exterior electric or magnetic field, or conversely, protects the surrounding environment from the effect of an interior electric or magnetic field. A high-performance shielding enclosure is generally capable of reducing the effects of both electric and magnetic field strengths by one to seven orders of magnitude depending upon frequency. An enclosure is normally constructed of metal with provisions for continuous electrical contact between adjoining panels, including doors.

shielding effectiveness. The ratio of the signal received (from a transmitter) without the shield, to the signal received inside the shield; the insertion loss when the shield is placed between the transmitting antenna and the receiving antenna (IEEE Std 100-1988 [3]).

4. General Procedures

4.1 Background. Prior to measuring shielding-enclosure performance, locations of poor performance shall be determined for later use in the measurement procedure and also for possible improvement in shielding performance prior to measurement. For these purposes, a preliminary procedure is provided for each frequency range, any one of which may be employed.

For the low range of frequencies (14 kHz to 20 MHz), small magnetic loops are utilized as sensor and source antennas; in the midrange (300 to 1000 MHz), electric dipoles are employed; and, in the high range of frequencies (1.7 to 18 GHz), microwave horns or the equivalent are used. The measurements specified are utilized to determine the shielding performance for both local and distant sources.

WARNING

Care shall be taken to protect personnel from RF hazards (ANSI C95.1-1982 [2]).

Care should also be taken to avoid interference with other electronic equipment operating in the vicinity.

4.2 Preliminary Procedures. Movable equipment containing metal not normally housed in the room should be removed from the enclosure prior to making measurements.

A preliminary scan shall be made along all accessible shielding faces to detect weak points and to permit remedy of shielding defects prior to actual measurement. While especially useful for newly installed enclosures, the scan should be done in all cases.

Prior to making any measurement, a test of the field-strength meter for case penetration shall be made at all measurement frequencies at its closest usable proximity to the source antenna.

After case penetration has been found negligible (or the case has been modified to make the penetration negligible), the transmitting and receiving antennas shall be positioned in accordance with the preliminary procedure detailed in 5.4.3, 5.5.3, or 5.6.3, and Figs 1 and 2. For each location, the receiving antenna is used as a probe to locate areas of maximum penetration. Alternatively, a commercial leak detector may be used. Items that should be checked are doors, power-line filters, air vents, seams, and coaxial-cable fittings. If the performance of the enclosure appears to be inadequate for its design (see Table C3 in Appendix C for comparison), remedial measures are suggested prior to tests. Regions of significantly greater field penetration than most others shall be identified for later measurement.

4.3 Basic Measurement Procedure. The method of measurement is to place an electromagnetic field source (transmitter) outside the shielding enclosure to be evaluated, to place a detector inside the enclosure, and to make provision for simulating removal of the enclosure. Details of the method differ somewhat according to frequency range. However, each

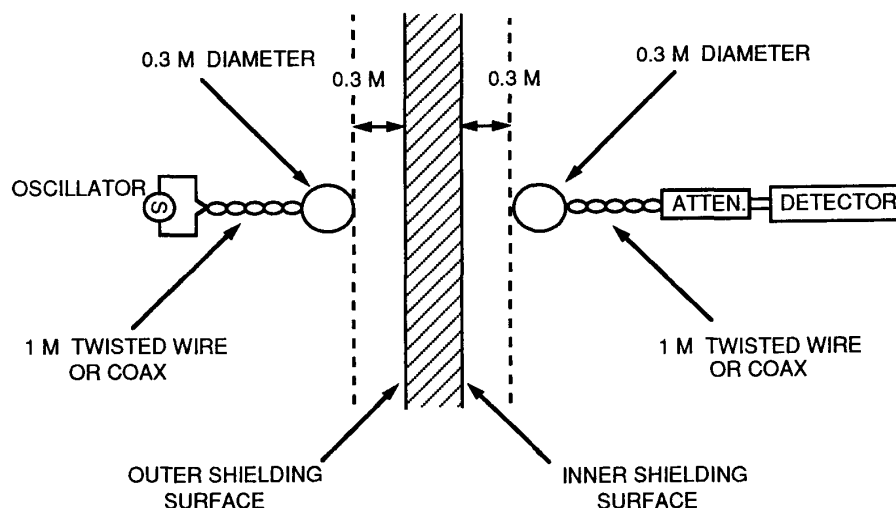


Fig 1
Small-Loop Test Setup

procedure requires measurements to be made over all walls containing doors and around room penetrations (including those of other walls), such as air vents, power-line filter panels, coaxial-connector panels, compressed-air lines, water pipes, telephone filter panels, etc. (see Fig 2). These measurement procedures shall be used for standard locations and standard frequencies within ranges for which the procedures are valid. Additional locations and frequencies may be needed to adequately test a unique enclosure situation.

To provide a means for comparing the relative performance of enclosures, single-frequency measurements shall be made in each of seven fairly narrow bands: 14 to 16 kHz, 140 to 160 kHz, 14 to 16 MHz, 300 to 400 MHz, 850 to 1000 MHz, 8.5 to 10.5 GHz, and 16 to 18 GHz. (Test frequencies unique to the specific installation should also be considered.) These *standard frequencies* are selected from *standard frequency ranges* over which the procedures are valid and are described in detail: 14 kHz to 20 MHz, 300 MHz to 1 GHz, and 1.7 to 18 GHz. These detailed procedures may, with minor modification, be applied to the *extended-range* frequencies: 14 kHz down to 100 or 50 Hz, and 18 GHz up to 40 GHz.

The low-range small-loop method presented is extendable downward several octaves, but a larger loop is convenient for power frequency region measurements. Spatial resolution is therefore reduced in that frequency region.

Microwave hardware for extension of the microwave measurements up to 40 GHz is available, and the procedure remains the same.

5. Detailed Procedures

5.1 Standard Measurement Frequencies. Measurements shall be made at one or more frequencies in each of seven bands as summarized in Table 1.

5.2 Extended-Range Measurement Frequencies. When shielding measurements are desired outside the standard frequency ranges, those in Table 2 should be used.

5.3 Shielding Relationships. Data obtained by the measurement techniques of the following subsections are converted to shielding effectiveness results by the relationships of Table 3. See Appendix B for explanation.

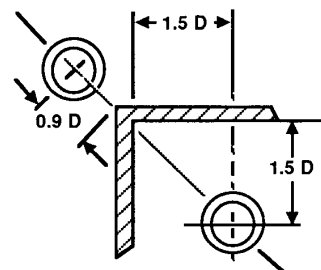
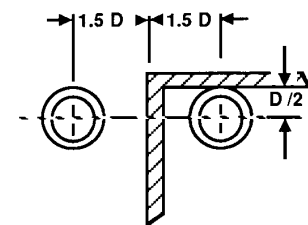
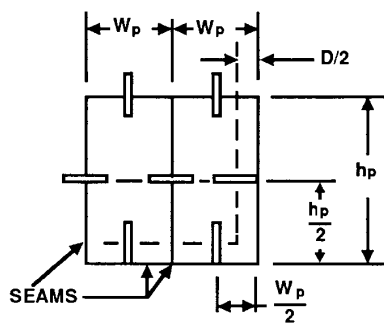
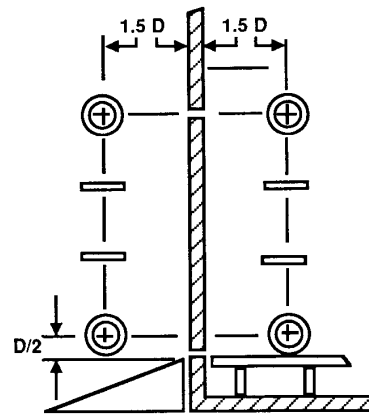
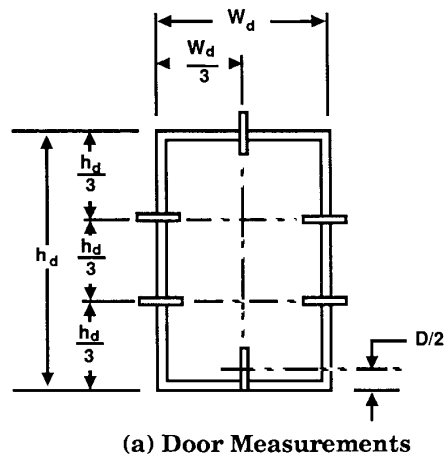


Fig 2
Standardized Positions for Small-Loop Test