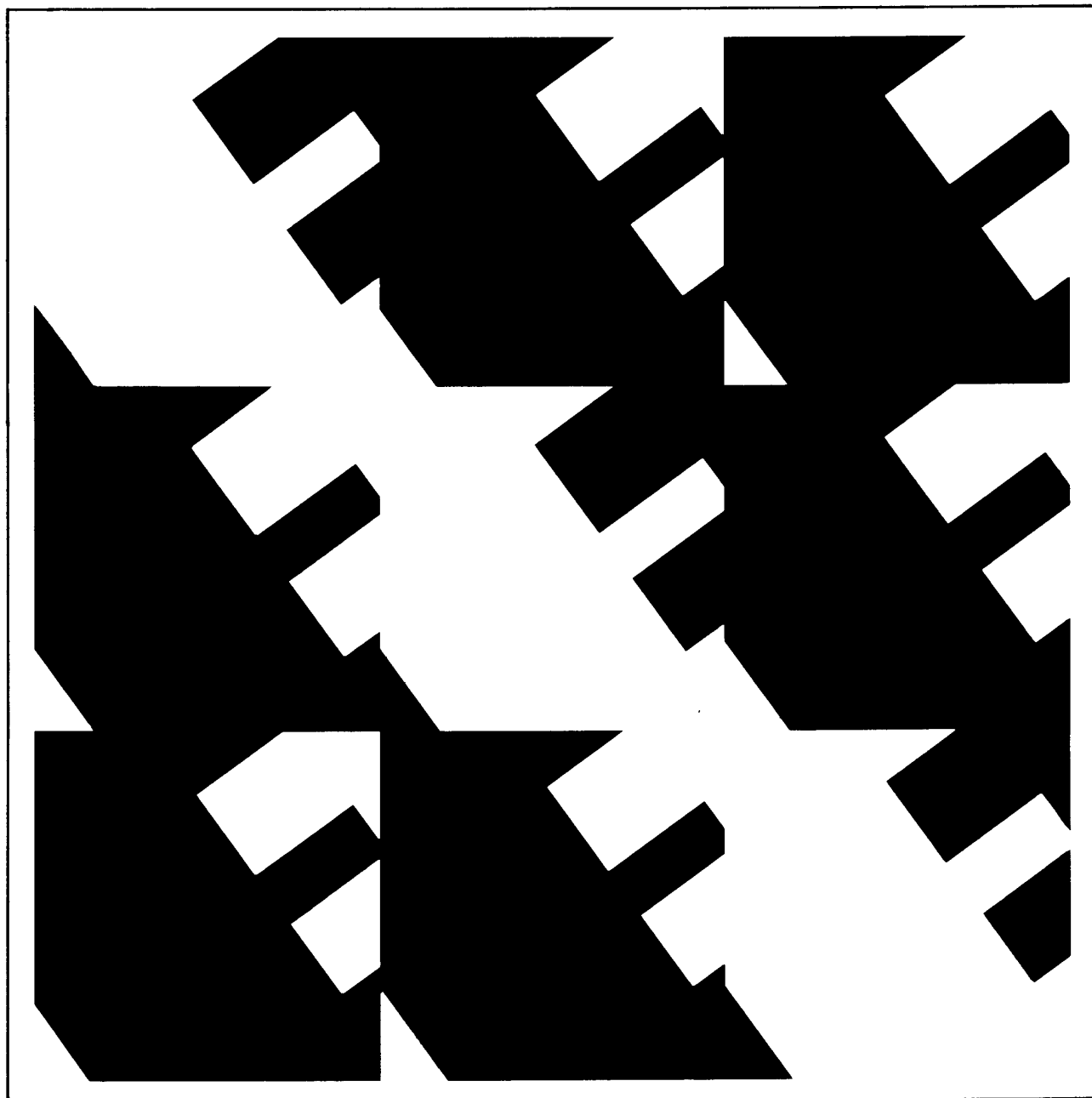


IEEE Recommended Practice for Measurement of Shielding Effectiveness of High-Performance Shielding Enclosures



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MEASUREMENT OF SHIELDING EFFECTIVENESS OF HIGH-PERFORMANCE SHIELDING ENCLOSURES

1. OBJECT AND SCOPE

The object of this Recommended Practice is to provide uniform test procedures and estimation techniques to determine the relative effectiveness of room-size high-performance shielding enclosures. Specifically, uniform practices are designated to determine the effectiveness of an enclosure in the usual shape of a rectangular parallelepiped with edge dimensions ranging from 1.5 to 15 meters. Test procedures are formulated to enable use of commercially available equipment for conducting tests under nonideal conditions, such as within typical facilities used to house the shielding enclosure.

A shield is defined in the IEEE Standards on Industrial Electronics as "material used to suppress the effect of an electric or magnetic field within or beyond definite regions."* A shielding enclosure is a structure composed of such a material. A high-performance shielding enclosure is generally considered to be capable of suppressing by orders of magnitude both the electric and magnetic fields.

It is constructed of panels of metallic conducting sheets with provisions for continuous electric contacts between the panels or doors. Its function may be to provide an interference-free location for the conducting of electromagnetic tests or for the operation of sensitive radio or electronic equipment where large-amplitude unwanted electromagnetic fields would otherwise be present; or it may be to confine generally high-level unwanted radiation produced by electric or electronic equipment to a limited space and thereby reduce the possibility of interference with other equipment.

Tests herein are not intended for obtaining quantitative data for the design of shielding enclosures or for evaluating the shielding effectiveness of materials, though this may be a useful by-product. This Recommended Practice does not specify construction details for shielding enclosures, nor does it suggest methods for calculating the effectiveness of such enclosures.

Uniform practices are provided to determine the effectiveness over the frequency ranges from 100 hertz to 20 megahertz, from 300 to 1000 megahertz, and from 1.7 to 12.4 gigahertz. Where it is desirable only to obtain a general estimate of the effectiveness by employing limited measurements, single-frequency tests are recommended within three standard frequency ranges: a) 14–16 kilohertz, b) 850–950 megahertz, and c) 8.5–10.5 gigahertz.

Measurement results for these three standard frequency ranges form a uniform basis for comparing the performance of various shielding enclosures.

Theoretical, practical, and instrumentation considerations have determined the nature of the test procedures, particularly the form of the signal source and sensor design. For the lowest frequency range (100 hertz–20 megahertz), magnetic loops are employed; in the ultrahigh frequency range (300–1000 megahertz), dipoles are employed; and in the microwave region (1.7–12.4 gigahertz), microwave horns or the equivalent are used.

In the lowest frequency range, tests using both small and large loops are employed. The small-loop test simulates, in some degree, the fields from sources near the enclosure walls. It also provides a measure of the effectiveness of certain constructional features such as bonds between adjacent panels or gaskets between doors and walls. The small-loop test procedure covers the frequency range from 100 hertz to 20 megahertz.

The large-loop test procedure simulates, in some degree, a magnetic field encompassing the entire enclosure. As such, it provides a measure of the overall performance in the low-frequency region from 100 hertz to 200 kilohertz. Provision for two large-loop tests are made, but the one involving the entire enclosure is recommended, where access to all walls of the enclosure is possible. Where limited access exists, an alternate test is delineated that requires access to only one wall.

For the ultrahigh frequency range (300–1000 megahertz), dipole-to-dipole tests are delineated. The effect of a nearby source on all portions of accessible wall areas is determined by one test procedure. In the microwave region (1.7–12.4 gigahertz), one specific measurement procedure is also set forth to simulate the effect of a nearby source on all portions of accessible wall areas. The effect of distant sources, either ultrahigh frequency or microwave, is assessed by combining measurement results on all accessible portions of the enclosure.

While single-frequency measurements in the three recommended frequency ranges (14–16 kilohertz, 850–950 megahertz, and 8.5–10.5 gigahertz) should provide a good guide to the relative performance of enclosures in all ranges, tests using other frequencies pertinent to the specific installation should be considered. No recommended practices are noted for frequencies between 20 and 300 megahertz owing to the sensitiveness of the test results to small variations in measurement procedure. Large antenna sizes and enclosure cavity resonances in this

* See 55 IRE 10.S1 published in *Proc. IRE*, vol. 43, September 1955, p. 1072.

region often give rise to uncorrelatable results. Where tests in this region are desired, the practices noted for the small-loop tests or the ultrahigh frequency tests may be used as a guide.

2. DEFINITION OF SHIELDING EFFECTIVENESS

In general, fields penetrating a shielding enclosure arise from both the electric and magnetic components of the electromagnetic energy impinging upon the enclosure. If the penetrating magnetic or electric fields are measured separately, each can be demonstrated to be a function of both the electric and magnetic components of the impinging waveform. In addition, the applied fields are radically altered in penetrating a high-performance enclosure, and the measured penetrating waveforms are affected by the position of the sensor. As a consequence, measurement results are highly sensitive to the test procedures employed, and simple amplitude ratios between any external and internal electric field vectors (or the magnetic field vectors) alone do not correctly characterize the shielding phenomenon. For similar considerations, simple measurements of power-flow ratios in the conventional sense cannot be employed without reference to a standardized test procedure. As a result a definition of a measure of enclosure performance is set forth and must be associated with a specific test and procedure. This measure is termed "shielding effectiveness."

In the low-frequency region (200 hertz–20 megahertz), shielding effectiveness* is expressed by

$$S_H = 20 \log_{10} \left(\frac{H_1}{H_2} \right) \quad (1)$$

where

H_1 = magnetic field in absence of enclosure
 H_2 = magnetic field within the enclosure.

For the ultrahigh frequency range (300–1000 megahertz), the shielding effectiveness* is expressed by

$$S_E = 20 \log_{10} \left(\frac{E_1}{E_2} \right) \quad (2)$$

where

E_1 = electric field in absence of enclosure
 E_2 = electric field within the enclosure.

For the microwave region (1.7–12.4 gigahertz), the effectiveness* is defined in terms appropriate to the detector indication and is expressed by one of the following equations:

$$S_P = 10 \log_{10} \left(\frac{P_1}{P_2} \right) \quad (3)$$

* This definition applies only to a specific measurement procedure described in subsequent sections.

where

P_1 = power detected in the absence of the enclosure
 P_2 = power detected within the enclosure;

$$S_E = 20 \log_{10} \left(\frac{E_1}{E_2} \right) \quad (4)$$

where E_1 and E_2 are defined as in Equation (2); or

$$S_P = A_1 - A_2 \quad (5)$$

where

A_1 = attenuator setting in decibels for a specified detector output in the absence of the enclosure
 A_2 = attenuator setting for the same detector output within the enclosure.

3. METHOD

The method of measurement described here is based on the placement of a source of electromagnetic field (transmitter) outside the shielding enclosure to be tested and a detector inside the enclosure together with provision for removal or simulation of removal of the enclosure. Test procedures according to the general method differ somewhat depending on the frequency to which the test is made. For any given test only one of the ratios S_H , S_E , or S_P will apply.

Some test procedures require multiple measurements of a similar performance feature at different locations or polarizations. For a given procedure, the minimum and average shielding effectiveness will be reported. The average shielding effectiveness shall be based on an average amplitude and computed for K measurements as follows:

$$(H_2)_{\text{ave}} = \frac{1}{K} \left\{ \sum_{n=1}^{n=K} (H_2)_n \right\} \quad (6)$$

$$(E_2)_{\text{ave}} = \frac{1}{K} \left\{ \sum_{n=1}^{n=K} (E_2)_n \right\} \quad (7)$$

$$(P_2)_{\text{ave}} = \left\{ \frac{1}{K} \sum_{n=1}^{n=K} [(P_2)_n]^{1/2} \right\}^2 \quad (8)$$

$$(A_2)_{\text{ave}} = 20 \log_{10} \left\{ \frac{1}{K} \sum_{n=1}^{n=K} [\log_{10}^{-1} (0.1 A_2)_n]^{1/2} \right\} \quad (9)$$

where the subscript n denotes the n th measurement of K measurements. In addition, the number of accessible walls, the number of walls tested, and the number and location of local area tests shall be reported.

All radio-frequency cables, power lines, and other utilities normally entering the shielding enclosure shall be in place when tests are conducted. Special care should be taken to make measurements in the vicinity of utility entrances, doors, access panels, and panel-to-panel seams. Experience indicates that the ultrahigh frequency preliminary procedure (Section 5.4) is best for locating imperfections near these constructional features.

Special precautions should be observed to insure that biological hazards do not occur, especially for the micro