Shielding Effectiveness Testing of RF Shielded Enclosures

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INTRODUCTION

Over the years, numerous articles have been written about RF shielded rooms and enclosures. These articles have dealt with topics such as the purchase, construction and installation of enclosures, and with grounding or electrical concerns. Although these articles have been highly informative, none has comprehensively addressed the issue of shielding effectiveness testing of the enclosure or room. This article explains and describes the test procedures used within the industry to determine shielding effectiveness levels of enclosures.

SHIELDING EFFECTIVENESS TESTING

While shielding effectiveness testing or performance testing of a shielded enclosure or room is typically the last phase of installation, it is possibly the most important phase. Unfortunately, the test process is viewed as a nuisance or some type of magic. In reality, the shielding effectiveness test is very simple and is identical to MIL-STD-220, which is an insertion loss (type) test. The major difference is the equipment used to perform the test.

Essentially, the shielding effectiveness test is equivalent to calibrating electronic test equipment. Like test equipment, a shielded enclosure should be calibrated to determine if its effectiveness has decreased or has been degraded.

Radiated test techniques are used when calibrating an enclosure or when determining the

Shielding effectiveness testing is possibly the most important phase of shielded enclosure development.

shielding effectiveness level of a shielded enclosure. Fortunately, standards have been established by U.S. military and security agencies. These standards describe the test methodology, equipment and performance at specific frequencies and fields of test. With minor modifications, these test procedures can be applied to any shielded enclosure installation or user requirement.

Two of the most commonly used standards or test procedures for shielding effectiveness testing are MIL-STD-285 and NSA 65-6. These documents describe the proper equipment arrangements and fields of test. Each procedure also specifies the frequencies of test and the level of attenuation.

DESCRIPTION OF TEST STANDARDS

MIL-STD-285

Over the years, MIL-STD-285 has become the workhorse of the industry. This standard is by far the most popular. The procedures of MIL-STD-285 are often referenced in enclosure specifications but the frequencies are modified to the user's requirements.

MIL-STD-285 was one of the first standards issued for testing radio frequency (RF) shielded enclosures. Released in June 1956, it was a replacement for MIL-A-18123 (SHIPS) which was released in August 1954.

The primary purpose of MIL-STD-285 was to establish a standard or method for measuring the attenuation characteristics of RF shielded enclosures which were used for electronic testing in the frequency range of 100 kHz to 10 GHz. The standard includes frequencies and fields of test as well as the levels of attenuation (or shielding effectiveness) that are required of the shield. MIL-STD-285 also provides a description of the equipment types that are required to perform the test.

Though MIL-STD-285 was established to cover the frequency range of 100 kHz to 10 GHz, it only requires measuring the attenuation characteristics of an enclosure at five frequencies (Table 1).

For its time, MIL-STD-285 was very specific for evaluating a shielded enclosure. It went so far as to suggest test point locations, indicating that tests should be performed in the vicinity of utility entrances, doors and access panels. MIL-STD-285 also requires that a reading be taken on all four sides of the enclosure, and that the antenna be oriented horizontally and vertically to the section seams and panel seams.

NSA 65-6

NSA 65-6 is possibly the most important standard published regarding the evaluation of RF

*See Advertisement on Page 13.

shielded enclosures. NSA 65-6 was released in October 1964. In addition to specifying shield performance, NSA 65-6 also includes specifications for the assembly of an enclosure, design objectives, reliability of the enclosure and electrical filter requirements.

Even though it was not intended to replace MIL-STD-285, NSA 65-6 has become a standard in its own right. Where MIL-STD-285 is a suggested procedure for testing between 150 kHz and 400 MHz (suggested to 10 GHz), NSA 65-6 is very specific in its test frequency range of 1 kHz through 10 GHz. As with MIL-STD-285, NSA 65-6 also includes a list of frequencies and fields (Table 1).

NSA 65-6 drastically increased the required frequencies over those required by MIL-STD-285. NSA 65-6 also clarified the test point locations. NSA 65-6 specifies test areas as the door frame (or perimeter), accessible joints, filters and air ducts. It also indicates that the maximum signal emanating from the enclosure should be found by moving the antennas to at least four different locations.

TEST PLAN

Regardless of which test standard or procedure is used, a test plan is required so the end user will fully understand the test process. The test plan will also ensure that the user's requirements are met. The user may opt for two tests if interior finishes are scheduled to be installed. Frequency and attenuation levels can also be modified.

Other than the number of frequencies and test point locations, a major difference between MIL-STD-285 and NSA 65-6 is the magnetic field antenna orientation during the test process. MIL-STD-285 specifies that the loop antennas be placed perpendicular to the shielding surface (planar) and NSA 65-6 requires that the loop antennas be placed parallel (coaxial) to the shield surface.

To help understand the test process, a generic test plan is given here.

TEST PROCEDURE

SHIELD PERFORMANCE REQUIREMENTS

Attenuation or shielding effectiveness is the performance criteria of the shielded enclosure. Shielding effectiveness is defined as the level of electromagnetic reduction provided by a shield.

Shielding effectiveness for electric fields is defined as:

$$SE_{dB} = 20 \log_{10} \frac{E_b}{E_a}$$

Where E_b is the electric field strength with no shield and E_a is the electric field strength with a shield installed.

Shielding effectiveness for magnetic fields is defined as:

$$SE_{dB} = 20 \log_{10} \frac{H_b}{H_a}$$

Where H_b is the magnetic field strength with no shield and H_a is the magnetic field strength with a shield installed.

MAGNETIC AND ELECTRIC FIELDS

Prior to performing shielding effectiveness measurements for magnetic and electric fields, the reference level and dynamic range are established. To establish the reference level and dynamic range,

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	MIL-STD-285	NSA 65-6
Magnetic Field	1 Frequency between 150 kHz-200 kHz Required attenuation or shielding effectiveness: 70 dB	4 Frequencies between 1 kHz and 1 MHz: 1 kHz Required shielding effectiveness: 20 dB 10 kHz Required shielding effectiveness: 56 dB 100 kHz Required shielding effectiveness: 96 dB 1 MHz Required shielding effectiveness: 100 dB
Electric Field	3 Frequencies, 200 kHz, 1 MHz, 18 MHz Required attenuation or shielding effectiveness: 100 dB	5 Frequencies between 1 kHz and 10 MHz: 1 kHz Required shielding effectiveness: 70 dB 10 kHz Required shielding effectiveness: 100 dB 100 kHz Required shielding effectiveness: 100 dB 1 MHz Required shielding effectiveness: 100 dB 10 MHz Required shielding effectiveness: 100 dB
Plane Wave	1 Frequency, 400 MHz Required attenuation or shielding effectiveness: 100 dB	4 Frequencies between 100 MHz and 10 GHz: 100 MHz Required shielding effectiveness: 100 dB 400 MHz Required shielding effectiveness: 100 dB 1 GHz Required shielding effectiveness: 100 dB 10 GHz Required shielding effectiveness: 100 dB

Table 1. *Attenuation Requirements of MIL-STD-285 and NSA 65-6.*

the transmit antennas (tunable loop for magnetic fields and rod style for electric fields) are placed outside the enclosure to ensure there is no case leakage of the receiver or spectrum analyzer. The antennas are placed 24 inches apart plus the thickness of the shielding media, which is approximately 1 inch thick, for a total separation of 25 inches (Figure 1). The antennas are oriented coaxially during the reference level and dynamic range establishment procedure.

The received signal level value is recorded in the "Reference Level" column of a shielding effectiveness test results form (Figure 2). The reference level value is determined by combining the value of any external attenuation and the received signal level which is displayed on the spectrum analyzer (or receiver).

With the reference level established and recorded, the receiver sensitivity/noise floor can be determined. This is accomplished by placing the receive antenna inside the enclosure and removing any fixed attenuation and/or any spectrum analyzer/receiver internal attenuation. If pre-amplification of the received signal is required, the pre-amplifier remains on during this measurement. The receiver sensitivity level, which is in dBm, is recorded in the "Receiver Sensitivity" column of the test results form (Figure 2). During this measurement, the transmitter or source is turned off.

The system or measurement dynamic range can now be established. The dynamic range is the numerical difference between the reference level value and the receiver sensitivity value.

With the reference level, receiver sensitivity and dynamic range established and recorded, the receive antenna is placed at a predetermined test point location within the enclosure. The distance of the antenna to the shield surface (panel) is 12 inches and in the same orientation as was used during the reference establishment. The source antenna is placed at the same test point but on the outside of the enclosure. The antenna is placed 12 inches from the shield surface (panel) and in the same orientation as the receive antenna (Figure 3). Any fixed attenuators that were used during the reference establishment are removed from the receive or transmit lines and the enclosure door(s) are closed.

The received signal level at this point is recorded in the "Receiver Level" column of the test results form. The numeric difference between the reference level and the receiver level is the attenuation or shielding effectiveness of this test point. This value is recorded in the "Attenuation (S/E)" column of the test results form. The transmit and receive antennas are placed at any remaining test point locations and the received signal levels are recorded. Upon completion of all test points, a second reference level is taken to ensure that the source gain or receiver sensitivity does not change.

The lowest recorded value will be the attenuation or shielding effectiveness at this frequency.

PLANE WAVE

Test frequencies for plane wave measurements are given in Table 1. The testing procedure for plane wave conditions is similar to that for magnetic and electric fields.

Prior to performing the shielding effectiveness measurements, the reference level and dynamic range are established. To establish the reference level and dynamic range, the transmit (dipole or log periodic) antenna and the receive (dipole or log periodic) antenna are placed outside the enclosure to ensure there is no case leakage of the receiver or spectrum analyzer. The antennas are placed 74 inches

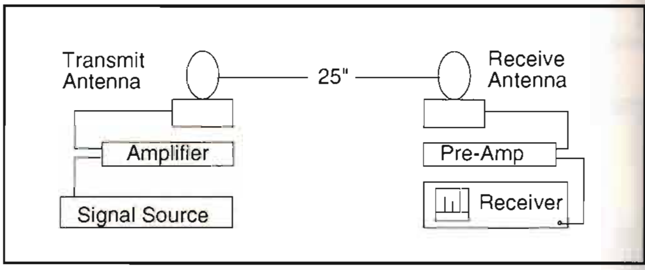

Figure 1. *Test Setup to Measure Reference Level and Dynamic Range.*

Shielding Effectiveness Test Results

Job Number:________________
Project:________________
Location:________________

Qualification Test ____ Acceptance Test ____ Other ____

Field	Center Freq.	Test Position	Ref. Level (dBm)	Rcv. Sen. (dBm)	Dynamic Range (dBm)	Rcv. Level (dBm)	Attenuation (S/E) (dB)	Spec (dB)

H = Magnetic E = Electric P = Plane Wave MW = Microwave

Witness:________________ Test Technician:________________
Date:________________ Date:________________

Figure 2. *Sample Shielding Effectiveness Test Results Form.*

apart plus the thickness of the shielding media which is approximately 1 inch, for a total separation of 75 inches (Figure 4). The antennas are co-polarized (either horizontally or vertically) during the reference level and dynamic range establishment procedure.

The received signal level value is recorded on the shielding effectiveness test results form (Figure 2). The reference level value is determined by combining the value of any external attenuation and the received signal level which is displayed on the spectrum analyzer (or receiver).

Essentially, the shielding effectiveness test is equivalent to calibrating electronic test equipment.

With the reference level established and recorded, the receiver sensitivity/noise floor can be determined. This is accomplished by placing the receive antenna inside the enclosure and removing any fixed attenuation and/or any spectrum analyzer/receiver internal attenuation. If pre-amplification of the received signal is required, the pre-amplifier remains on during this measurement. The receiver sensitivity level, which is in dBm, will be recorded in the "Receiver Sensitivity" column of the test results form. During this measurement the transmitter or source is turned off.

The system or measurement dynamic range can now be established. The dynamic range, which is recorded in the "Dynamic Range" column of the test results form is the numerical difference between the reference level value and the receiver sensitivity value.

With the reference level, receiver sensitivity and dynamic range established and recorded, the receive antenna is placed at a predetermined test point location within the enclosure. The distance of the antenna to the shield surface (panel) is no less than 2 inches and in the same orientation as was used during the reference establishment. The source antenna is placed at the same test point but on the outside of the enclosure. The antenna is placed 72 inches from the shield surface (panel) and in the same orientation as the receive antenna (Figure 5). Any fixed attenuators that were used during the reference establishment are removed from the receive or transmit lines and the enclosure door(s) are closed.

The received signal level at this point is recorded in the "Receiver Level" column of the test results form. The numeric difference between the reference level and the receiver level is the attenuation or shielding effectiveness of this test point. This value is recorded in the "Attenuation (S/E)" column of the test results form. The transmit and receive antennas are placed at any remaining test point locations and the received signal levels are recorded. Upon completion of all test points, a second reference level is taken to ensure that the source gain or receiver sensitivity does not change.

The lowest recorded value is the attenuation or shielding effectiveness at this frequency.

TEST POINT LOCATIONS

Test point locations include the following areas:

- Perimeter of the door(s)
- Waveguide plumbing penetrations
- Waveguide HVAC vents (full scan)

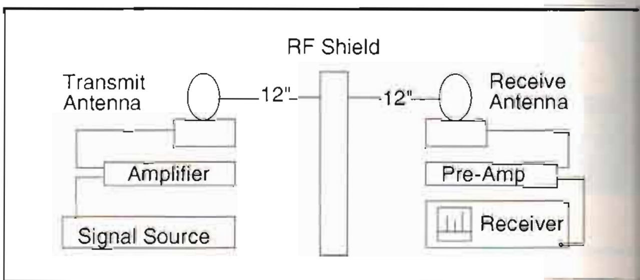

***Figure 3**. Receive Antenna Placed at a Predetermined Test Point.*

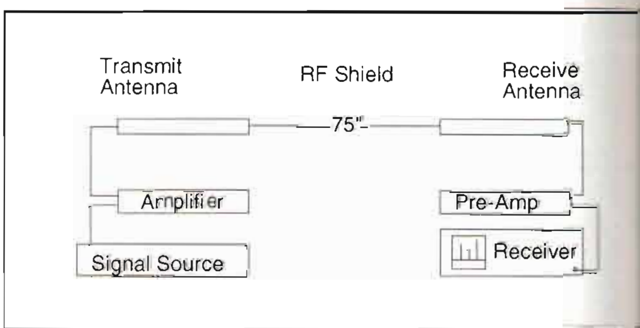

***Figure 4**. Test Setup for Plane Wave Measurements.*

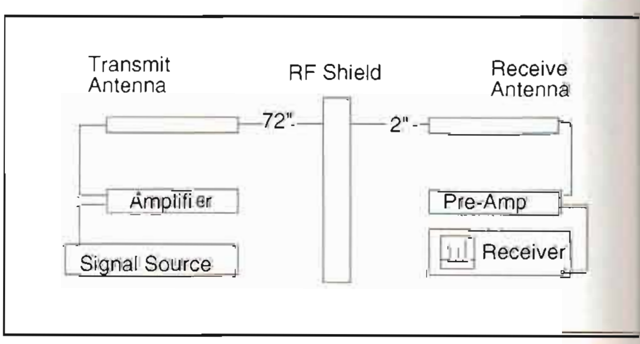

***Figure 5**. Test Setup for Plane Wave Shielding.*

- Electrical and communication filter areas (full scan)

- Wall seams (number of seams is dependent on enclosure size and accessibility)

As a minimum, the door will be tested at six (6) points and a minimum of one wall seam, per wall, will be tested if accessible on both sides of the shield. Actual test point locations are determined at the time of test.

CONCLUSIONS

Regardless of which test standard or procedure is used, it is important that a test plan is submitted and utilized. With submission of a test plan, the actual test process will be performed in a timely manner. When recalibrating a shielded enclosure, the same or original test plan can be used, if modified slightly.

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