Radio Frequency Interference (RFI) Shielding Principles

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1.0 Introduction

The purpose of this document is to provide Krieger Specialty Products clients and personnel information pertaining to shielding effectiveness requirements for Radio Frequency (RF) doors, and their application into a shielded enclosure. Also, to provide important criteria that must be consider when selecting an appropriate door commensurate with customers requirements and needs.

1.1 Reference Material

IEEE -299	IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielded Enclosures
Mil Std 285	Military Standard Attenuation Measurements for Enclosures, Electromagnetic Shielding, for Electronic Test Purposes, Method of
Mil Std 188-125-1	DoD Interface Standard High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions
NSA 94-106	National Security Agency Specification for Shielded Enclosures
NSA 73-2A	Specification for Foil RF Shielded Enclosure (Tempest Protection for Facilities)
ASTM D4935	Standard Test Methods for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials
MIL-HDBK-1195	Military Handbook, Radio Frequency Shielded Enclosures

2.0 Shielding Overview

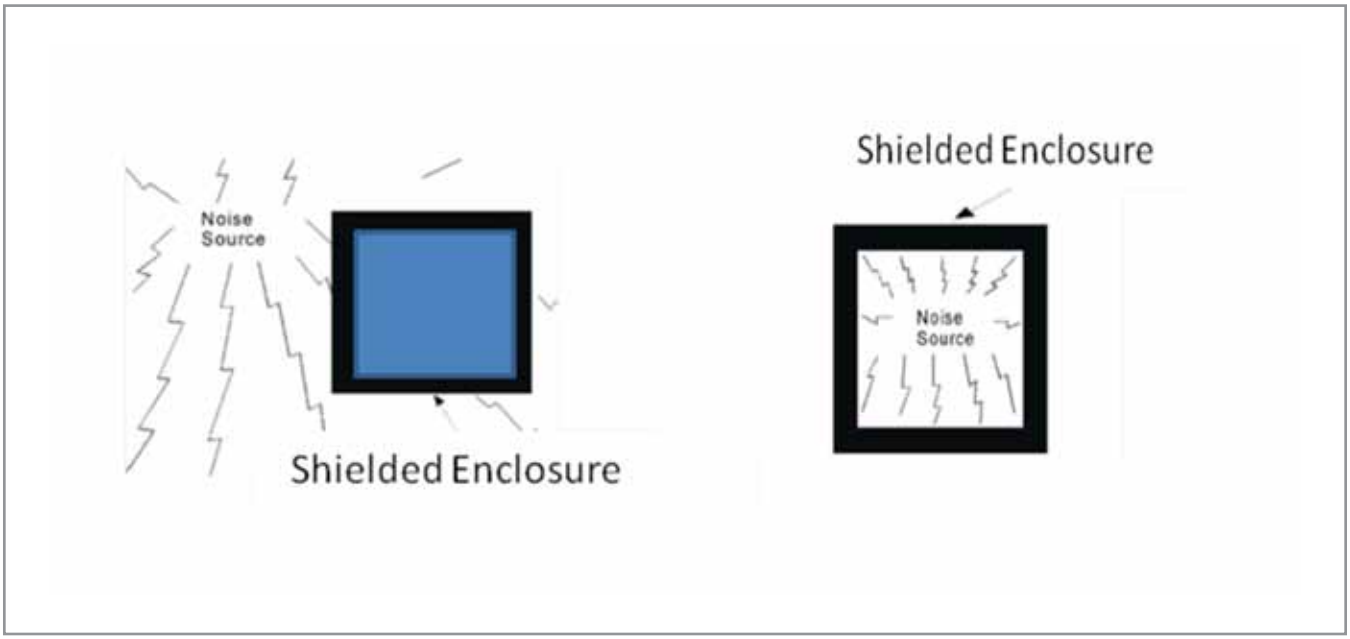
An RF shielded enclosure is a “system” comprised of interacting components (e.g., doors , windows, electrical RF filters for power and signal lines, and mechanical penetrations for water, honeycomb air vents for HVAC, sprinklers for fire protection) that when integrated provides a functional shield barrier that reduces an RF noise source to an acceptable level. An essential part of a shielded system is that it be designed with the appropriate conductive materials, that when bonded together achieve a six-sided-box (i.e., walls, ceiling, floor), referred to as a “Faraday Cage”.

An RF shield is only as good as the weakest component in the system. Section 5, “Krieger RF Door Installation Considerations”, will provide insight into what to evaluate when considering an RF Door for a specific shielding application.

The purpose of RF shielding is to reduce levels of electromagnetic emissions. One reason is to contain the RF energy within a shielded enclosure; such as, sensitive information from being transmitted outside of the

shielded facility. Another reason is to exclude external RF noise from getting into the shielded enclosure to protect sensitive equipment or test environments from being adversely affected by external RF noise sources. Figure 1 illustrates the two conditions where a shielded enclosure contains or excludes an RF noise source.

Figure 1 Purpose of a Shield



The reduction of the noise source provided by the shield is expressed in dB (decibels), and is referred to as Shielding Effectiveness (SEdB), or attenuation (dB). Shielding effectiveness can be calculated using the following equations.

$SE_{dB} = 20\log H_1/H_2$ (dB)

Where:
H_1 is the Magnetic Field (μA/m or μT) detected without a shield
H_2 is the Magnetic Field (μA/m or μT) detected with a shield between the noise source and sensitive environment

$SE_{dB} = 20\log E_1/E_2$ (dB)

Where:
E_1 is the Electric Field (μV/m) detected without a shield
E_2 is the Electric Field (μV/m) detected with a shield between the noise source and sensitive environment

$SE_{dB} = 10\log P_1/P_2$ (dB)

Where:
P_1 is the Power (watts) detected without a shield
P_2 is the Power (watts) detected with a shield between the noise source and sensitive environment

3.0 Shielding Specifications and Standards

Many Specifications and Standards are used within industry to convey requirements required for specific user shielding needs. Key criteria defined in these documents are frequencies of interest, RF Fields (i.e., Magnetic (or H-Field), Electric (or E-Field), Plane Wave (PW), and Microwave (MW), the SEdB, and the test methodology to be used to verify the SEdB. The most commonly used are MIL-STD-285 and IEEE-299. Table 1 provides an overview of some of these specifications and standards that are used.

Table 1 - Specifications and Standards

Standards	Frequency Range	Field	SE Requirement	Comments
IEEE Std 299-1997*	9 kHz - 16 MHz	H Field	Owner specified SEdB, and frequencies, fields, and SEdB (Test Plan required to define them)	Referred to as "**low frequency range**". Prescriptive perimeter test around the door in vertical and horizontal polarization
	20 MHz - 300 MHz	E-Field/PW		Referred to as "**resonant frequency range**". No prescribed test location around door but requires each test location be swept in all antenna orientations at specified distances and intervals and the worst case measurement recorded. Applicable to enclosures with a 2 meter minimum dimension
	300 MHz - 18 GHz	PW/MW		Referred to as "**high range**". No prescribed test location around door but requires each test location be swept in all antenna orientations at specified distances and intervals and the worst case measurement recorded
NSA 73-2A	1 kHz - 1 MHz	H Field	Specific frequencies and attenuation detailed in the spec.	10 dB @ 1 kHz, 20 dB @ 10 kHz, 30 dB @ 100 kHz, 40 dB @ 1MHz, 50 dB @ 10 MHz, Foil or Textile Shield Enclosure are typical
	10 kHz - 10 MHz	E Field		50dB @ 10kHz, 100kHz, 1 MHz, and 10 MHz. Foil or Textile Shield Enclosure are typical
	100 MHz - 1 GHz	Plane Wave		50 dB @ 100 MHz, 400 MHz, 1 GHz. Foil or Textile Shield Enclosures are typical

Standards	Frequency Range	Field	SE Requirement	Comments
NSA 94-106 (was NSA 95-6)	1 kHz - 1 MHz	H Field	Specific frequencies and attenuation detailed in the spec.	20 dB @ 1KHz, 56 dB @ 10 kHz 90 dB @ 100 kHz, 100 dB @ 1 MHz. Modular or Welded Rooms are typical
	1 kHz - 10 MHz	E-Field		70 dB @ 1kHz, 100 dB at 10 kHz, 100 kHz, 1 MHz, 10 MHz, Modular or Welded Rooms are typical
	100 MHz - 10 GHz	PW/MW		100 dB @ 100 MHz, 400 MHz, 1 GHz, 10 GHz
Mil Std - 285	150 - 200 kHz	H Field	70 dB	No explicit requirement to do a perimeter test around the door. Typically a center test performed at the door.
	200 kHz 1 MHz 18 MHz	E Field	100 dB	
	400 MHz	PW	100 dB	
ASTM D4935	30 MHz - 1.5 GHz	H Field	Not specified	There are cases where shielded enclosure specifications will use test result using ASTM D4935 test methodology. The SEdB is not provided and must be calculated. The appropriate formula provided in Section 2 “Shielding Overview” must be applied. Results are typically 60 dB or less. These tests are of small test samples of the material (e.g. ~3 inch diameter). Application of these results are questionable for shielded enclosure applications as the test results do not evaluate seams and overlap requirements of the material which may reduce SEdB performance.
	30 MHz - 1.5 GHz	E Field		

Standards	Frequency Range	Field	SE Requirement	Comments
Mil Std 188-125-1	10 kHz - 20 MHz	H Field	10 kHz @ 20 dB, 20 MHz @ 70 dB (Test Plan required)	Specifically states “geometric center of shielded doors” for test location. Test method is to step through the frequencies as opposed to selection of discrete frequencies.
	20 MHz - 1 GHz	Plane Wave	80 dB (Test Plan required)	Referred to as “**resonant/plane wave range**”. Specifically states “geometric center of shielded doors” for test location. Test method is to step through the frequencies as opposed to selection of discrete frequencies.

*Extended range: low frequency H field 50 Hz - 1.1 kHz; high range 35 - 100 GHz

Often specification frequencies and SEdB are tailored for specific shielded enclosure applications. As can be seen from in Table 1, some specifications and standards are explicit in defining the required frequencies, fields, and SEdB; while others, leave it to the customer or end user to define (typically in a Test Plan). If the specification sited is silent on specific frequencies, fields, and SEdB it is important to document what is expected to ensure the requirements are understood. Section 6 of this document provides questions that should be consider when assessing shielding requirements.

3.1 MRI Shielding Specifications and Standards

Not included in Table 1 is a specification or standard for Magnetic Resonance Imaging (MRI) applications. Typically, the MRI equipment manufacture provides the SEdB, frequencies, and fields required specific to their scanning electronics sensitivity to Electromagnetic Interference (EMI). MRI electronics are sensitive to EMI produced by high-amperage power lines, electrical equipment, and transformers in the frequency range of 5 MHz to 128 MHz.

Acoustic design considerations are also important as contemporary MRI scanners can produce sound in excess of 110 decibels (dB). Therefore, it is important to understand if both RF and Acoustic requirements are needed for the door application, and the required Sound Transmission Class (STC).

4.0 Krieger RF Door Shielding Performance

Krieger Specialty Product Doors provides RF SEdB greater than 60 dB from 1 kHz to 18 GHz for Electric Field, Plane Wave, and Microwave when tested per IEEE-299. For Magnetic Field SEdB of greater than 30 dB at 1 kHz increasing to 94 dB at 14 MHz, when tested per MIL-STD 285 test methodology. Figure 2 provides frequency versus SEdB performance levels of worst case measurements recorded by independent test laboratories. Lower

level performance doors for 20 – 40 dB applications from 1 kHz to 18 GHz are also available. Krieger's in-house R&D test results are provided in Figure 3 for magnetic field (1 kHz to 1 MHz), and plane wave/microwave from 400 MHz to 18 GHz (triangles indicate measured level recorded at the discrete frequencies selected).

Figure 2 Krieger RF Door SE 60 – 100 dB Capability

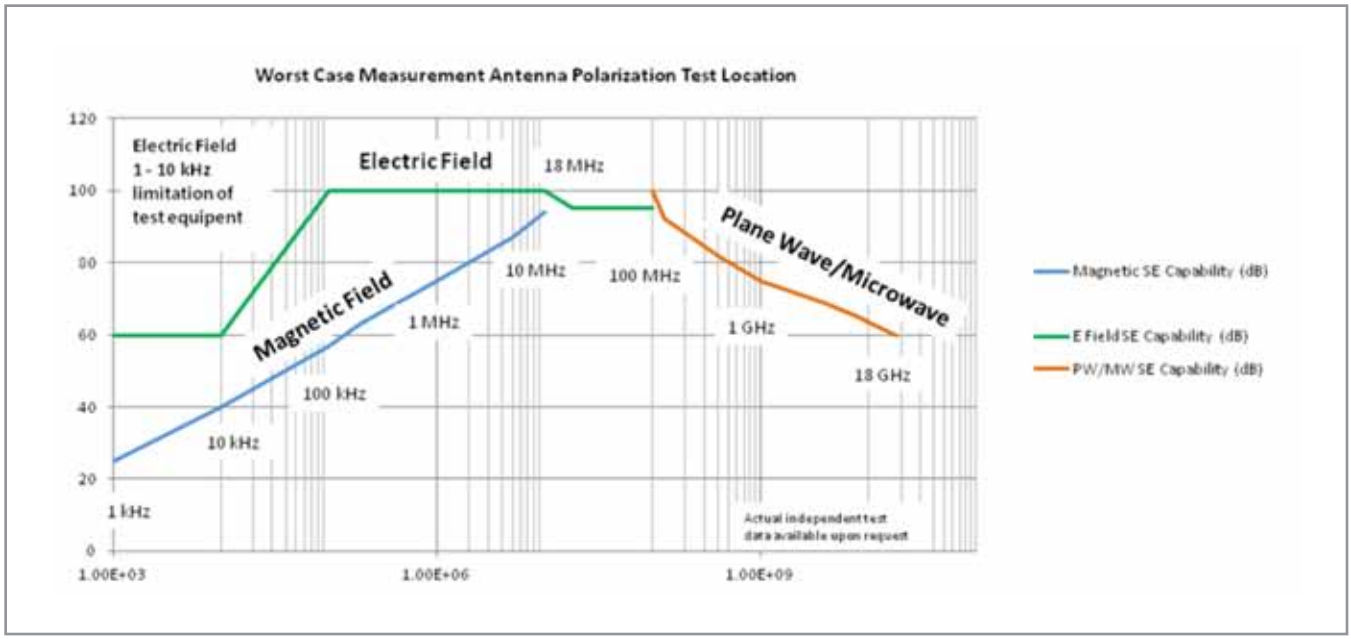
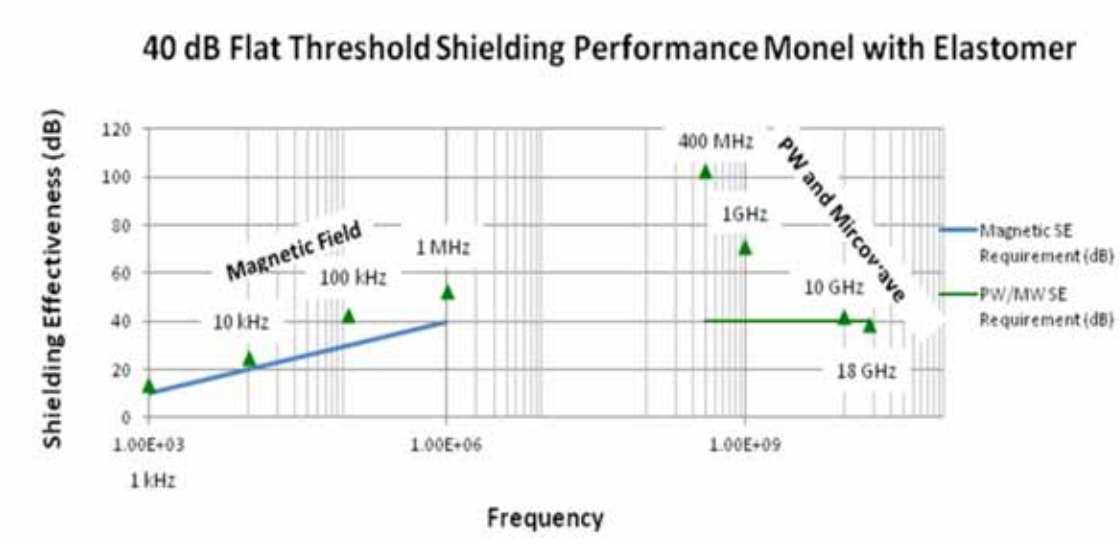


Figure 3 Krieger RF Door SE 20 – 40 dB Capability



5.0 Krieger RF Door Installation Considerations

As stated in Section 2, an RF shield is a system, and an RF door is a component within that system that when integrated maintains the shielding integrity of the enclosure to the SEdB required. Doing the appropriate evaluation of a shielded enclosure whether it is a new build or existing is crucial. Military Handbook-1195 is an excellent resource for understanding architectural designs and consideration for different types of shielding construction methods.

For new shielded enclosure designs, typically the specifications and/or standards are part of the procurement negotiations with regard to frequency, fields, and SEdB to include the construction type that the RF door will interface with. New construction will typically require that the shielding effectiveness verification test be performed prior to the installation of interior wall coverings, raised computer floors, drop ceilings, and other interior or exterior features that would impede installation of the RF Doors(s). It is recommended that the shielding effectiveness verification test be performed prior to installation of interior finishes to allow for repairs, if required.

For existing designs, specifications and standards specified may not apply, because the construction is not capable of meeting the standard being called out. For example, a foil shielded enclosure is able to perform at >50dB when first installed, a modular shielded enclosure >100dB, and a welded shielded enclosure >120dB. However, over time they degrade as an overall system. Also, modifications to existing enclosures can void the effectiveness of the shielded enclosures performance. The best way to determine the current condition is to perform a test of the existing shielded enclosure prior to installation of new components. If testing cannot be performed, ask when the room was last tested to determine the shielding performance. As a last resort, a visual inspection is advised to ensure the shielded enclosure does not have any obvious deficiencies.

With existing facilities interior and exterior wall ceiling and floor treatments (i.e., drywall, raised flooring, etc.) must be evaluated, and a plan developed to address how the installation will be accomplished, to include any demolition necessary to access where the RF door frame interfaces with the shield floor, walls, and ceiling. The checklist in Section 6 is intended to assist in the evaluation of installation and performance requirements of shielded enclosures and facilities.

6.0 Shielding Requirements Assessment Form

Construction type: ☐ Welded ☐ Modular ☐ Foil ☐ Copper Screen ☐ Other _____

New or existing shield enclosure: _____

If existing, how old: _____ When was it last tested for shielding SEdB: _____

If yes, what was the performance level achieved: _____

Will demolition be required to install the door: ☐ Yes ☐ No

Internal walls (drywall or other): _____

External walls (drywall or other): _____

Internal ceilings (drop ceiling or other): _____

External ceilings (drop ceiling or other): _____

Internal flooring (raised computer floor or other): _____

External flooring (raised computer floor or other): _____

Other considerations: _____

Specification or Standard Specified: ☐ Yes ☐ No

If yes, what Specification or Standard: _____

Is there a Test Plan required: ☐ Yes ☐ No

Does the test plan modify/tailor the Specification or Standard: ☐ Yes ☐ No

Required Fields

Magnetic Field (low frequency): ☐ Yes ☐ No

Electric Field (resonant frequency): ☐ Yes ☐ No

Plane Wave/Microwave (high frequency): ☐ Yes ☐ No

Required Frequencies

Magnetic Field (low frequency): _____

Electric Field (resonant frequency): _____

Plane Wave/Microwave (high frequency): _____

Required SEdB

Magnetic Field (low frequency): _____

Electric Field (resonant frequency): _____

Plane Wave/Microwave (high frequency): _____