JOINT CAPABILITIES GROUP

JOINT LOGISTICS COMMAND

RF Shielding Effectiveness of Metal Ammo Boxes

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Introduction

"…HERO UNSAFE Ordnance can be protected by completely enclosing the item in a sealed, all-metal container."

NAVSEA OP 3565 Vol 2 Rev 19 page 7-2

Fundamental Questions

"…HERO UNSAFE Ordnance can be protected by completely enclosing the item in a sealed, all-metal container."

- What are the underlying assumptions concerning a sealed, all-metal container?
- Does the sealed, all-metal container imply that it is a Faraday cage?
- What are the characteristics of a (non)ideal Faraday cage?
- Does 'protected' imply that the packaged EO is now HERO SAFE?

Key Concepts

The following concepts will be explained hereafter:

- Faraday cage, ideal vs non-ideal
- Radio Frequency (RF) Shielding Effectiveness (SE)
- HERO SAFE & UNSAFE Ordnance
- Cavity Resonant Behaviour of Boxes Ammunition Metal (BAM)

Faraday Cage Concept – (Near) Ideal

- Continuous, highly conductive enclosure with no gaps, seams or penetrations.
- Incident RF energy is reflected/attenuated, producing negligible internal E-fields.
- Shielding effectiveness is predictable and broadband.
- Electro-explosive Devices inside are effectively isolated from the external HERO environment.

Faraday Cage Concept – Non-Ideal

- Seams, lid joints, imperfect electrical contacts and penetrations allow RF energy to couple into the enclosure.
- The conductive box behaves as a resonant cavity at frequencies determined primarily by its internal dimensions.
- At resonance, internal fields can exhibit localised E-field maxima, rather than simple uniform attenuation.
- Internal field strength can therefore be strongly frequency - and position-dependent.
- HERO implication: proper shielding effectiveness should not be assumed solely because an EED is inside a metal container.

RF Shielding Effectiveness

- **RF Shielding Effectiveness (SE):** *"The reduction in electromagnetic field strength provided by a shielded enclosure, such as a metal ammunition box, between the outside and inside environments, usually expressed in dB."*
- RF SE is made up of different loss factors that depend with different weightings on frequency, material type, thickness etc.
- SE equations provides a gut feel for SE behaviour of a metal sheet. Cannot be used directly for SE analysis of a BAM.
- SE testing will best inform the SE response of a BAM.

Examples of HERO UNSAFE Ordnance





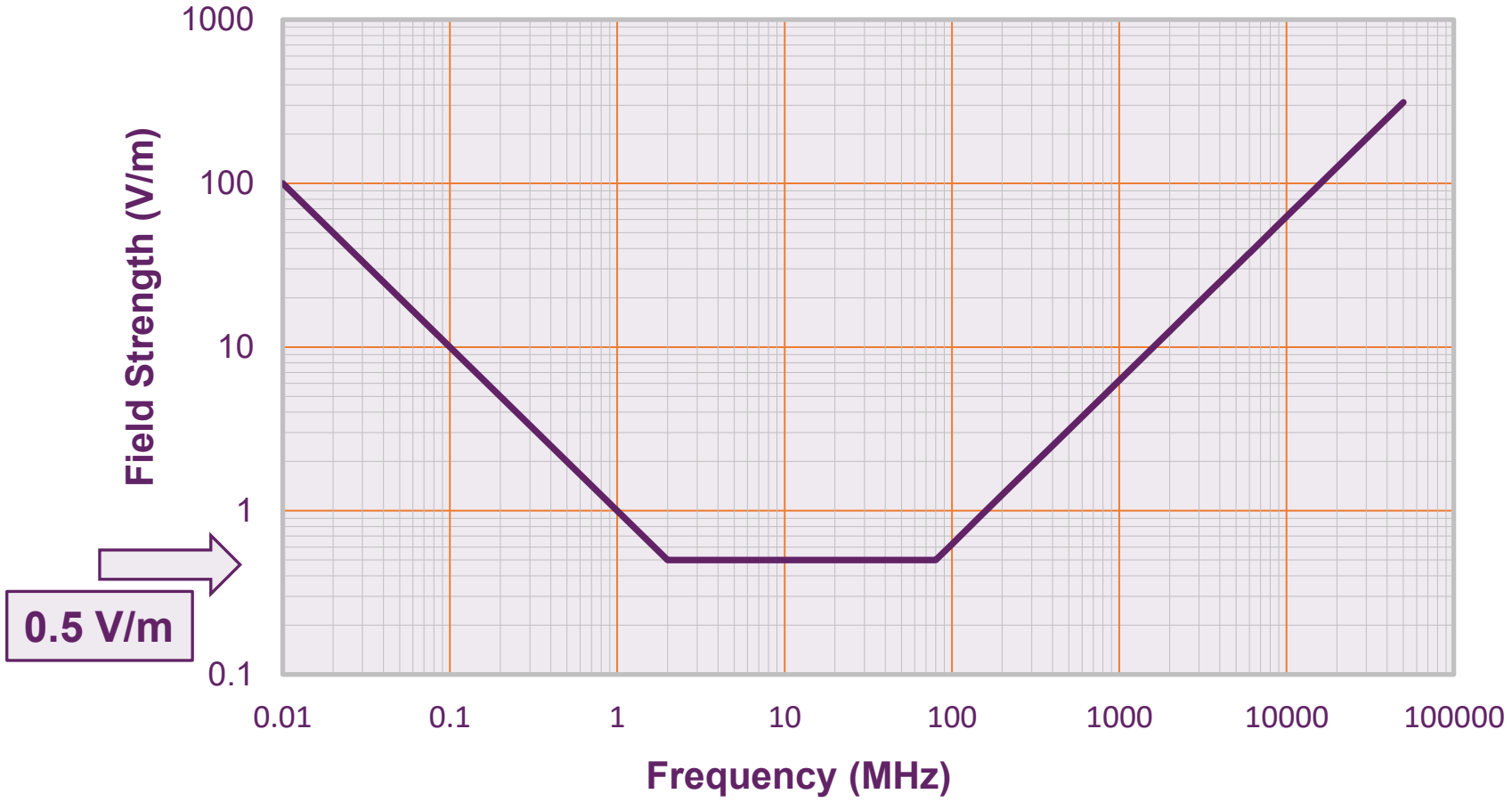






Susceptibility Trace for HERO UNSAFE Ordnance

- Default trace use for EO considered as HERO UNSAFE.



HERO SAFE Ordnance

ADF Baseline EM Environment

Frequency Range (MHz)	Unrestricted Average (V/m)	Restricted Average (V/m)
0.01-2	200	80
2-30	200	100
30-150	200	80
150-225	200	70
225-400	200	100
400-700	410	100
700-790	410	270
790-1000	490	270
1000-2000	600	160
2000-2700	500	160
2700-3600	2620*	220
3600-4000	280	200
4000-5400	660	200
5400-5900	660	240
5900-6000	270	240
6000-7900	400	240
7900-8000	400	200
8000-8400	400	200
8400-8500	400	200
8500-11000	910	300
11000-14000	680	220
14000-18000	680	250
18000-50000	580	200

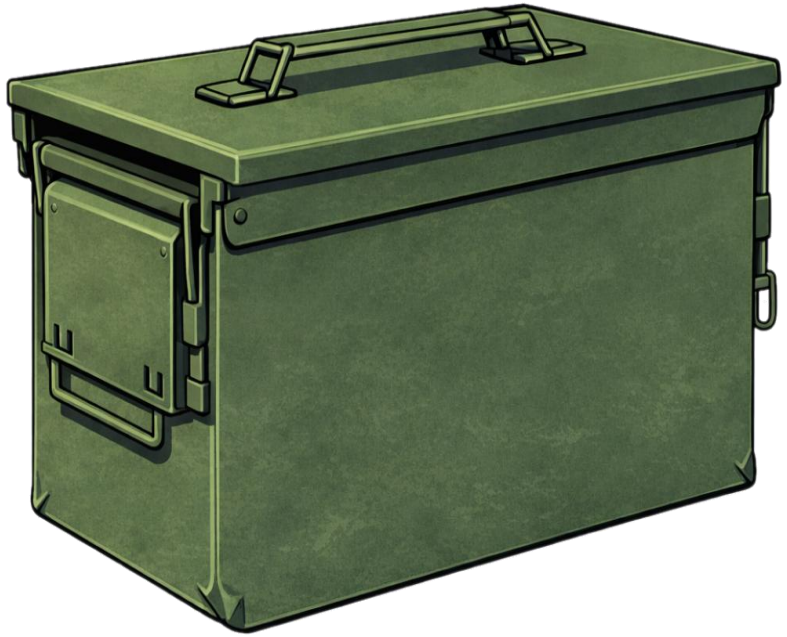
HERO SAFE: EO can operate safely in its specified RF environment (ADF Baseline), with acceptably low risk to safety and reliability, requiring only general HERO controls.

Uses of BAMs

- Used to store and transport EO items with any HERO classification i.e. HERO SAFE, SUSCEPTIBLE or UNSAFE.
- May provide the necessary RF shielding to render a packaged EO item HERO SAFE.
- Also provides physical protection to EO.
- Provides protection to EO against different forms of EEH e.g. personnel-borne Electrostatic Discharge (ESD).
- Impacts Insensitive Munitions (IM) considerations.

RF Shielding Effectiveness of Boxes Ammunition Metal (BAMs)

- BAMs are not ideal Faraday cages.
- Factors affecting SE, include:
  - Dimensions
  - Gaps/slots
  - Distance between latches
  - Paint-to-paint contact.
  - Wear & tear
  - Damage



SE Testing of BAMs

- Probe choice is quite different from a normal open-area RF survey probe.
- Inside the BAMs, the combination of very limited space, conductive walls, cavity resonances, and the need to get the probe signal out without compromising the enclosure makes a physically small, optically linked E-field probe highly desirable.

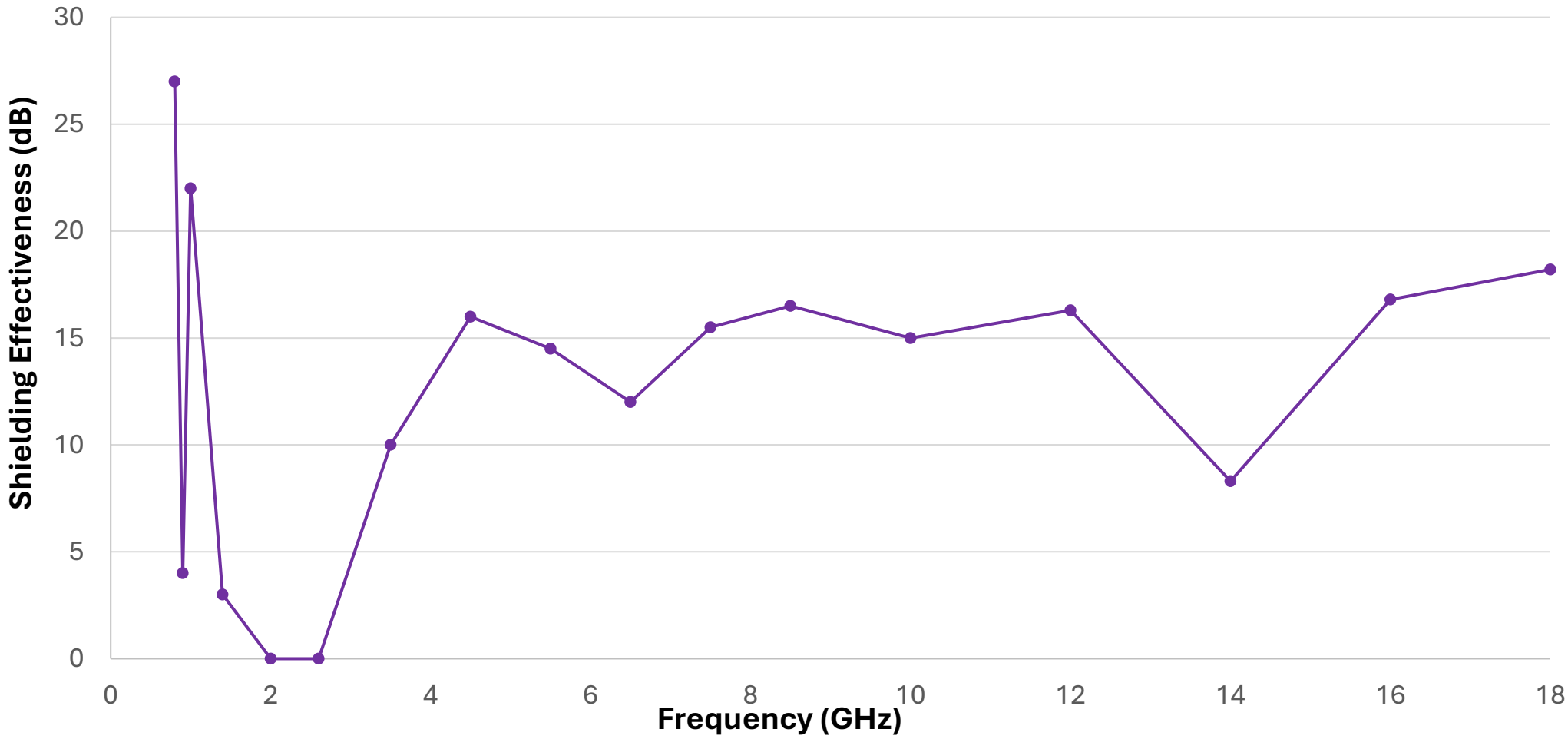
L × W × H = 32 mm × 32 mm × 32 mm



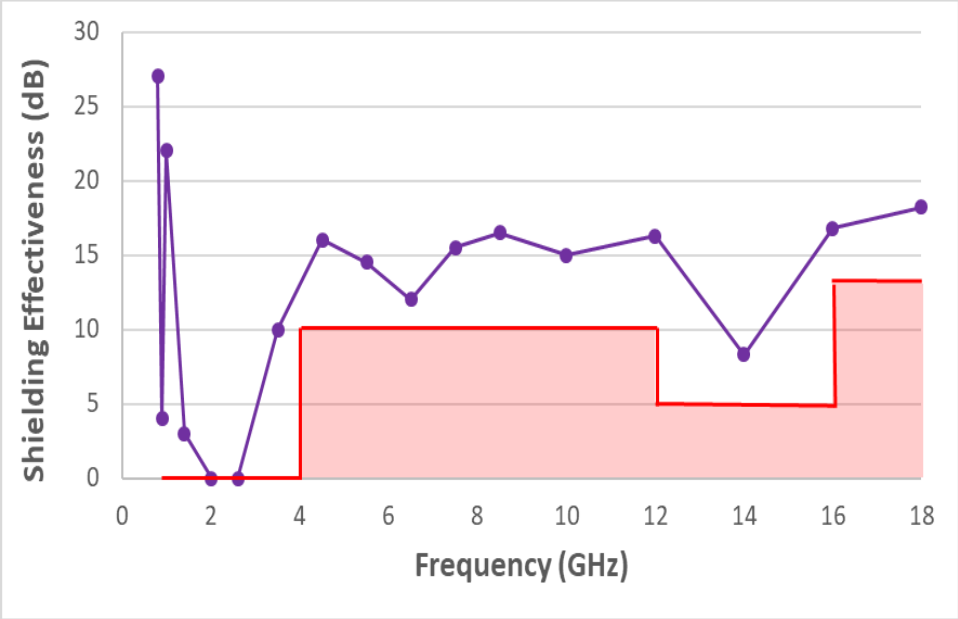
HI-6105 Electric Field Probe 100 kHz to 6 GHz | ETS-Lindgren

Reference: https://apctech.com/hi-6105.html?srsltid=AU7gw4XC65qqRcjQ3g2mmtV5p92RteI9weZrSYJIYsKaURzTJKrWEOuS

SE Trace of a Particular BAM



SE Trace of a Particular BAM



- Note the resonant behaviour especially at f ≤ 3.5 GHz.
- Across 2 - 2.6 GHz the BAM offers no RF shielding!

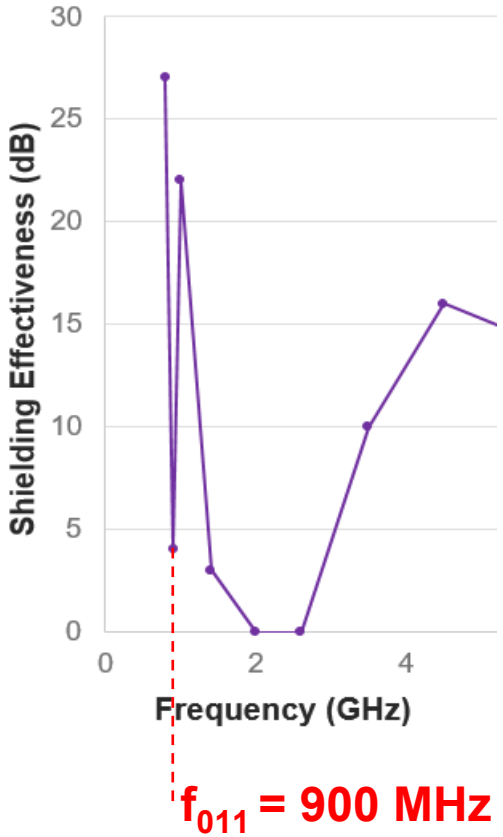
- A low fidelity trace is shown i.e. test frequencies are not closely spaced. Resonant behaviour between frequencies could be missed.
- Red ‘envelope trace’ is deemed conservative to specify SE – especially when a single test sample was used.

Cavity Resonant Behaviour of BAMs

- Internal BAM dimensions establish predictable cavity resonant modes.
- Coupling through seams and apertures can produce sharp SE degradation at specific frequencies.
- Average SE may overstate protection available to enclosed EEDs.
- HERO assessment should focus on worst-case SE minima, particularly where measured SE ‘dips’ align with predicted cavity modes.
- HERO compliance should therefore consider the minimum measured SE across the applicable RF environment, particularly where a cavity resonance coincides with a significant external RF threat.

Cavity Resonant Behaviour of Rectangular Enclosures

- Resonant modes can be predicted.



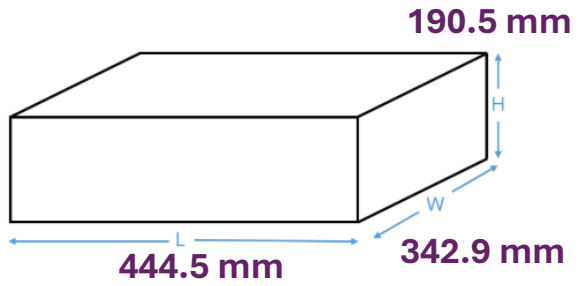
f_{011} = 900 MHz

Resonant Frequencies of a Rectangular Enclosure

Parameters	Input
Length (L)	m
Width (W)	m
Height (H)	m
Relative permittivity: ε_r =	1

Resonances (Hz)

f_{110} =	f_{101} =	f_{011} =
f_{111} =	f_{201} =	f_{120} =
f_{211} =	f_{210} =	f_{021} =
f_{220} =	f_{221} =	f_{121} =



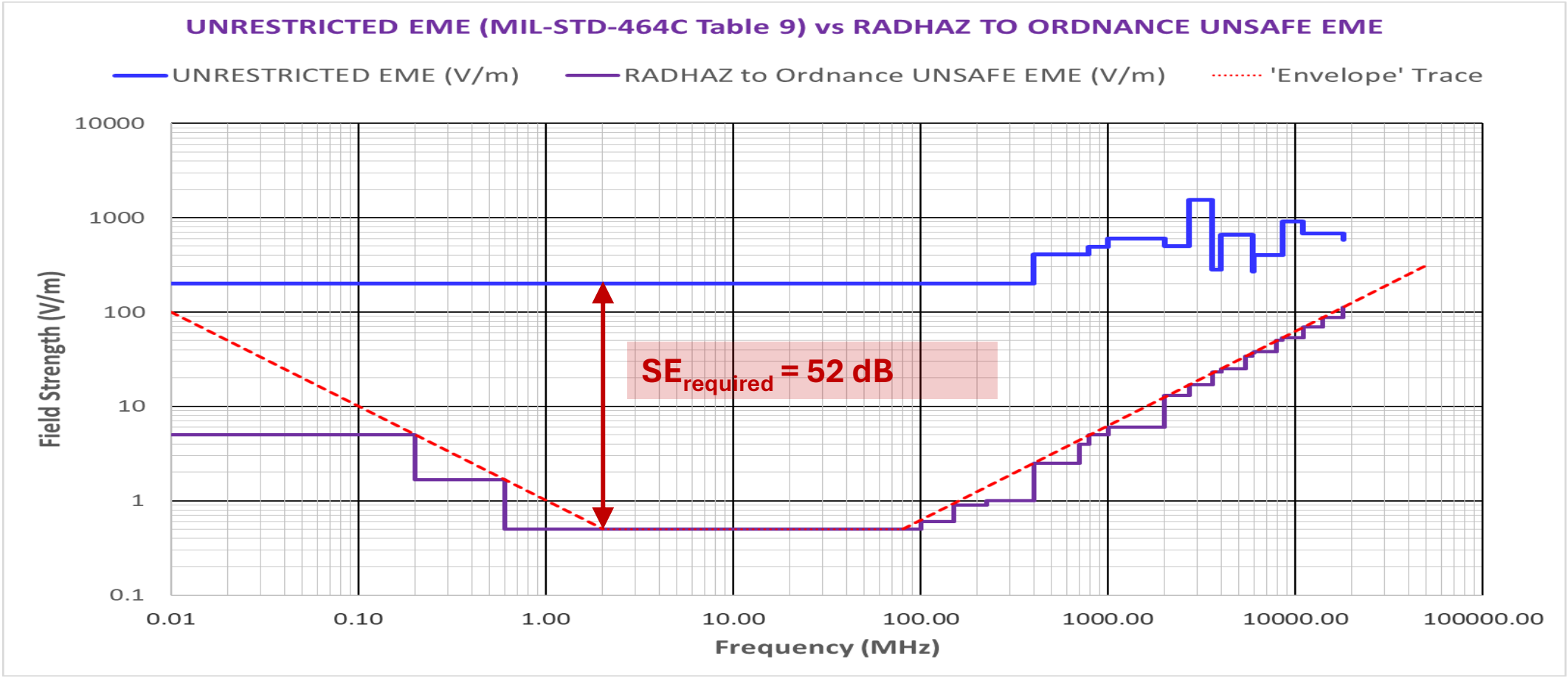
$$f_{mnp} = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2 + \left(\frac{p}{H}\right)^2}$$

$$f_{mnp} = f_{011} \approx 900\ MHz$$

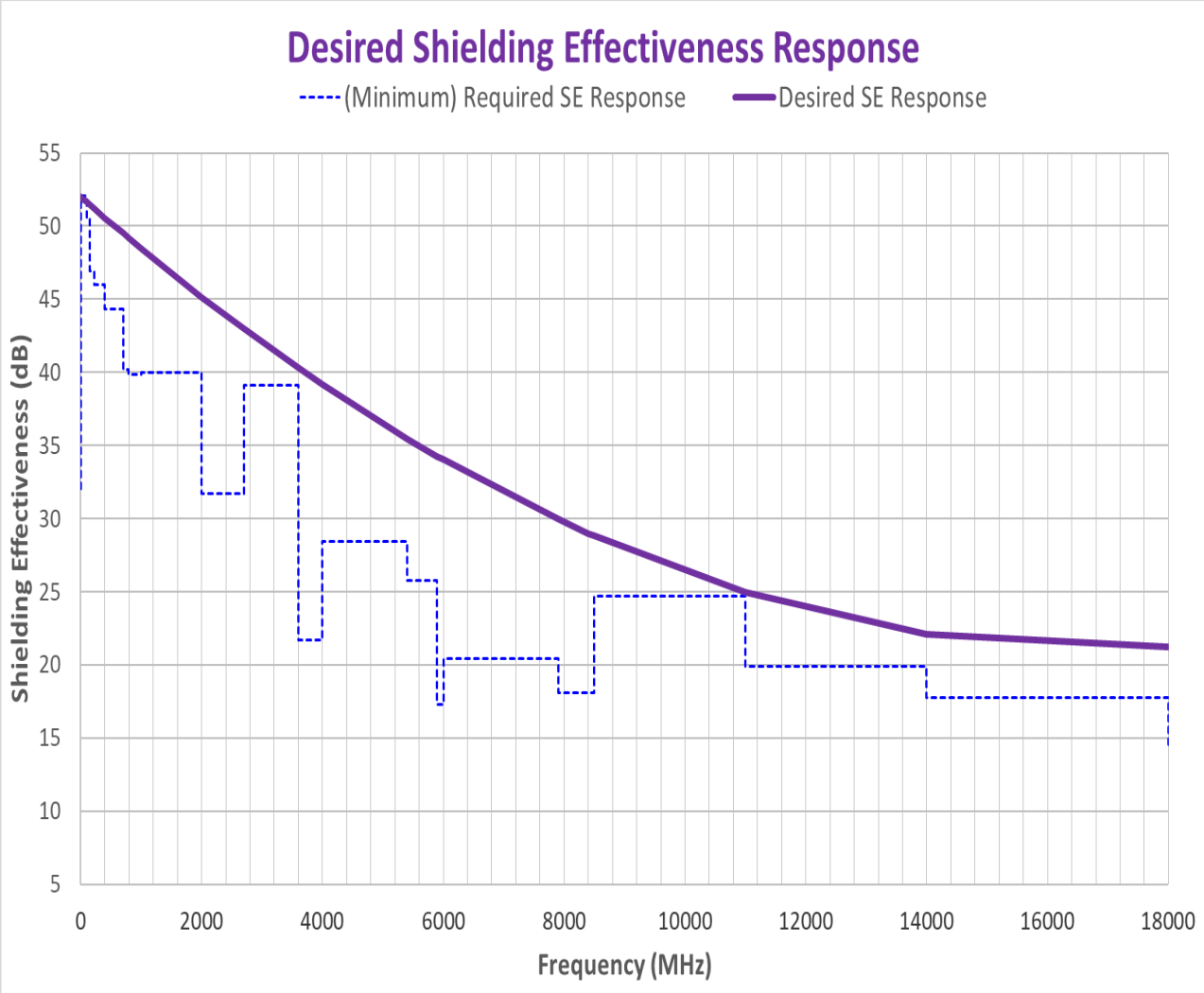
Reference: https://learnemc.com/ext/calculators/cavity_resonance/rect-res.html

Design Criterion of ‘an ideal’ BAM for ADF Service

HERO UNSAFE EO ⇨ **HERO SAFE (WHEN PACKAGED)**



Desired SE of ‘an ideal’ BAM for ADF Service



- Target SE response shown.
- Conservative polynomial response.
- Caters for Unrestricted EME of MIL-STD-464C Table 9.
- Costly redesign.
- Insensitive Munitions (IM) Considerations.

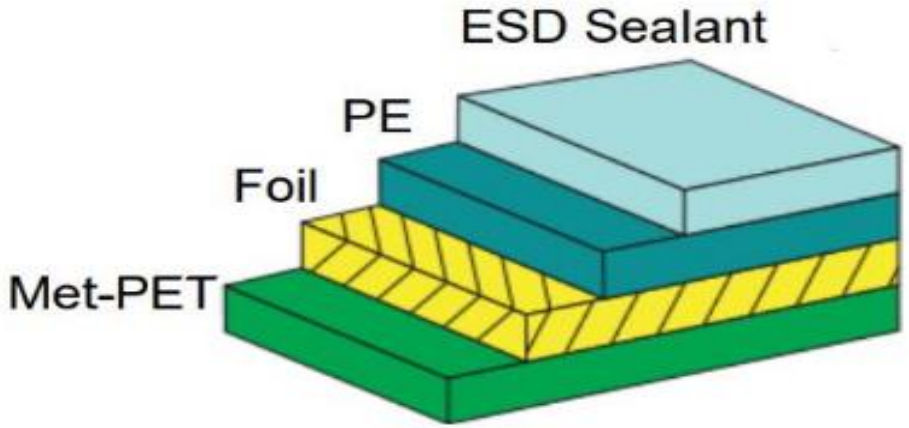
Insensitive Munitions Considerations

- The trade-off here is that good SE of a BAM might have poor IM response and vice versa.
- Confinement can increase pressure during burning or decomposition and potentially produce a more violent reaction than would occur with an unconfined article.
- Lid design, catches, seals, hinges, pressure-relief features and structural strength can all influence whether pressure is released or retained.

Use of Barrier Materials as Inner Packaging



MIL-PRF-81705F Type I bags for reliable protection against ESD, Electromagnetic Interference (EMI), and moisture.



Reference: https://staticcontrol.descoindustries.com/SCSCatalog/ESD-Bags/MIL-PRF-81705E-Type-I/817I0812/

MIL-PRF-81705F Type 1 as Inner Packaging



- MIL-PRF-81705F of 27 Apr 23
- Type 1, Class 1 or 2
- SE = 25 dB (min), 1-10 GHz
- SE substantially greater than 25 dB, below 1 GHz.

Factors Affecting SE of Barrier Materials

- seams, folds, penetrations and the package geometry
- sealing mechanisms & integrity
- damage
- normal wear e.g. flexing & bending

Conclusions

"…HERO UNSAFE Ordnance can be protected by completely enclosing the item in a sealed, all-metal container."

- Appropriately packaged EO can indeed be rendered HERO SAFE.
- BUT, a sealed, all-metal container is not necessarily a near-perfect broadband Faraday cage.
- BAMs in ADF service likely have deficient broadband SE responses.
- Formal SE characterisation of all conductive EO containers is recommended, to make better informed decisions.
- Redesigns may not be possible. Use of proper RF/ESD barrier materials as 'another layer' is deemed essential.

Questions

Contact

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