Shielding Effectiveness of Expanded Metal Foils (EMFs)

1 Introduction

Under normal operation, all electronic equipment radiates some amount of electromagnetic energy. At the same time, all electronic equipment is (to some degree) susceptible to interference from outside sources of electromagnetic energy.

Electromagnetic compatibility (EMC) is the branch of electrical engineering concerned with the unintentional generation, propagation and reception of electromagnetic energy which may cause unwanted effects such as electromagnetic interference (EMI) or even physical damage in operational equipment. The goal of EMC is the correct operation of different equipment in a common electromagnetic environment.[1]

2 EMI Shielding

Careful circuit design and component layout can minimize EMC issues, but additional shielding measures are often necessary to ensure proper operation of electronic equipment, and to ensure conformance with mandated interference standards.

On the circuit board level, this might entail the addition of shielding enclosures ("board-level shielding") to isolate and protect individual circuit elements. On the equipment level, the conductivity of enclosures may need to be enhanced, and the use of shielding gaskets at feedthroughs, cable ports, doors, openings, etc. may be necessary to ensure that a seamless "Faraday cage" surrounds susceptible electronics.

3 Expanded Metal Foils (EMFs)

Expanded metal foils (EMFs) are versatile and effective EMI shielding materials. EMFs are formed from thin metal foils in a "slit-and-stretch" process, resulting in products that are strong, light and flexible.

Unlike knit or woven meshes, EMFs exhibit consistent and predictable conductivity. EMFs will not fray or unravel, and they conform readily to complex surfaces, making them compatible with manufacturing processes for composite materials (eg. for enhancing the conductivity of lightweight composite enclosures).

[1] https://en.wikipedia.org/wiki/Electromagnetic_compatibility

Copper is a commonly-used EMI shielding material, but aluminum, nickel, Monel™ and stainless steel have also been used where corrosion resistance, galvanic compatibility, or other concerns are present.

4 Shielding Effectiveness (SE)

The key measure of merit of an EMI shielding product is its *shielding effectiveness* (SE). SE is a measure of how well a material reduces (attenuates) electromagnetic field strength.

SE is defined as the ratio of power received *with* and *without* a material present for the same incident power (expressed in dB):

$$SE = 10\, log \frac{P1}{P2}\ (dB)$$

5 Measurement of shielding effectiveness

Shielding effectiveness can be measured via a number of methods. ASTM D4935-10 (*Standard Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials*)[2] is a well-established and widely-accepted method for measuring the SE of thin, planar materials like expanded foils.

ASTM D4935-10 defines a specimen holder that is an enlarged, tapered coaxial transmission line, designed to hold planar test samples between its two halves, and to maintain 50Ω impedance throughout its length. (Fig 1.)

Shielding effectiveness for most materials varies as a function of frequency. The ASTM test fixture is designed for SE measurements from f= 30 MHz to 1.5 GHz.

To extend SE measurements to higher frequencies, specimen holders based on the same principal, but designed to maintain 50Ω impedance from 1.5 GHz to 10 GHz, are commercially available. (Fig 2.)

Fig 1. ASTM D4935-10 test fixture for SE measurements at f= 30 MHz - 1.5 GHz.

Dexmet has in-house test capabilities to measure the SE of its expanded metal foils at frequencies from 30 MHz to 8 GHz.[3]

In addition to the specimen holders, the Dexmet SE test station incorporates a spectrum analyzer/tracking generator combination rated from 100 kHz to 12.4 GHz, and RF amplifiers with flat gain over the measurement range of interest.

The dynamic range of the test station is ≈100 dB, and measurement comparisons against certified reference samples indicates an accuracy of ±1 dB.

Fig 2. Test fixture for SE measurements at f= 1.5 - 10 GHz.

6 SE measurement results

Fig 3 shows the result of SE measurements made on 25 expanded metal foil types. Copper, aluminum, nickel, stainless steel and Monel™ types are represented on this chart.

[2] https://www.astm.org/Standards/D4935.htm

[3] The upper frequency limit for SE measurements at Dexmet is currently 8 GHz due to amplifier bandwidth limitations.

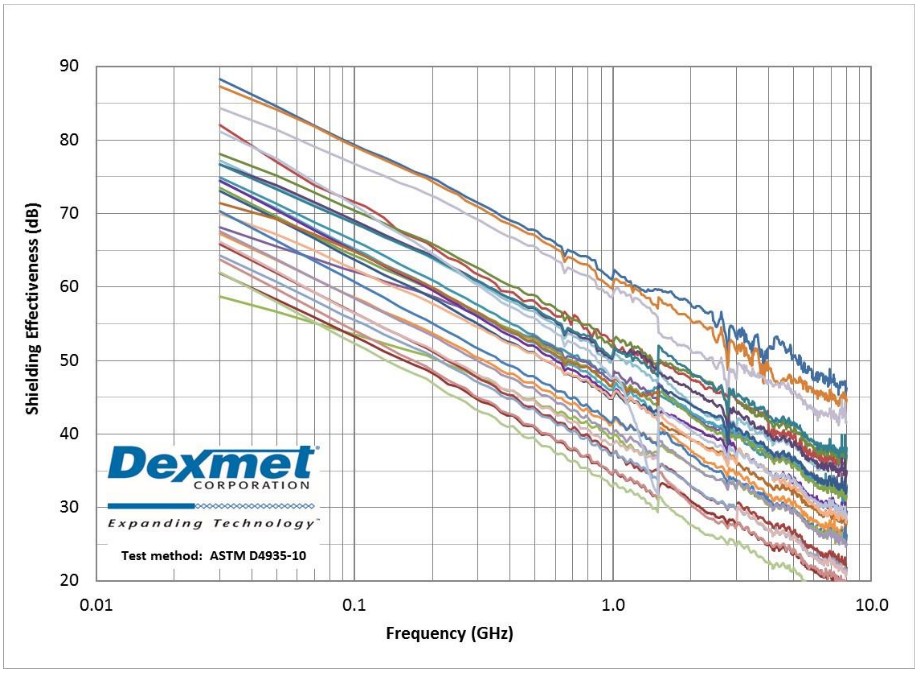

Fig 3. Measured shielding effectiveness (SE) of 25 expanded metal foil types.

7 Analysis

The results in Fig 3 correlate well with theory, with customer-reported results, and with measurements by independent laboratories.

Ott[4] describes the behavior of shielding materials with apertures.

EMFs are planar shielding materials with multiple apertures. The maximum linear dimension of the apertures is the "Long Way of the Opening" (LWO) of the mesh. (Fig 4.)

Such shielding materials exhibit an SE reduction of 20 dB/decade with frequency, and exhibit minimum shielding (SE= 0 dB) when the maximum linear dimension of the apertures equals ½ wavelength.

Furthermore, for linear arrays of closely-spaced apertures, SE is reduced by a factor proportional to the square root of the number of openings.

An "aperture coefficient" can therefore be defined that is proportional to the product of the LWO and the square root of the openings per unit area.

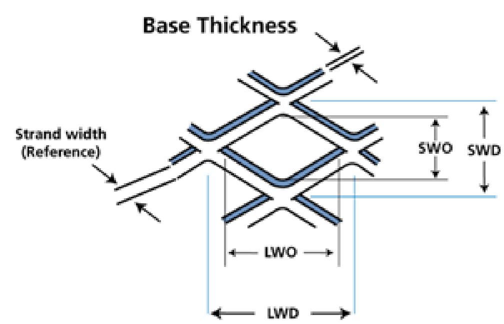

Fig 4. Dimensions of expanded metal foils (EMFs).

In Fig 5, SE data for four (4) copper EMFs with various aperture coefficients is extrapolated to the theoretical 0 dB crossing frequency. The predicted 20 dB/decade reduction of SE with frequency is experimentally confirmed.

[4] H.W. Ott. *Electromagnetic Compatibility Engineering*. Hoboken, NJ: John Wiley & Sons, 2009, pp. 267-73.

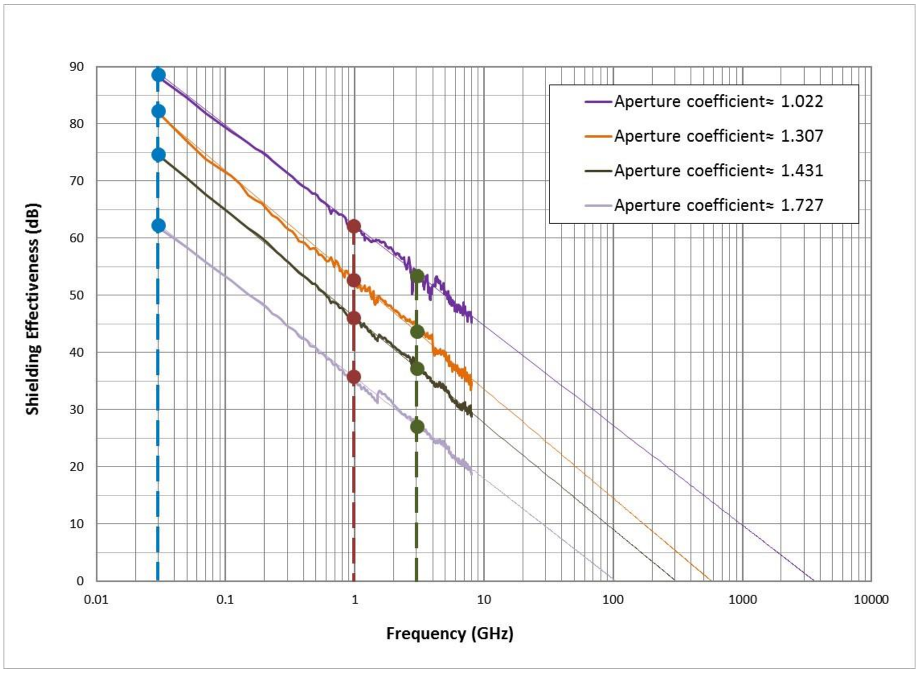

Fig 5. Extrapolation of measured SE values for four (4) copper EMFs to 0 dB crossing frequency.

The traces in Fig 5 all have the same slope, which means the SE varies linearly with aperture coefficient at all frequencies. Fig 6 shows this relationship at three (3) frequencies: f= 30 MHz, 1 GHz and 3 GHz.

EMFs with desired minimum shielding levels can therefore be designed by controlling the LWO and the number of openings per unit area during manufacture such that the needed aperture coefficient is met.

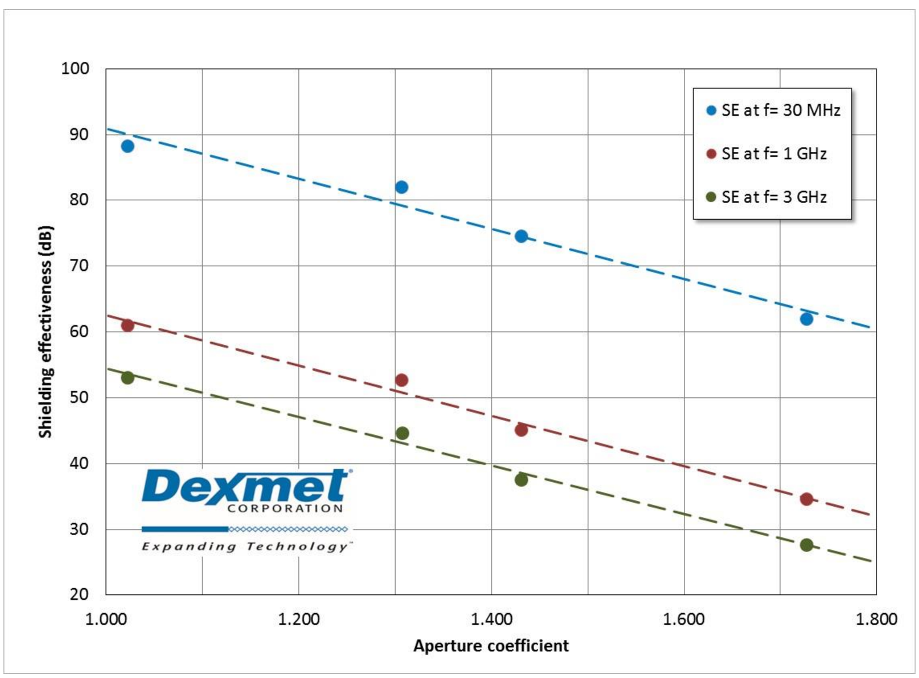

Fig 6. Linear dependence of SE on aperture coefficient for four (4) copper EMFs from Fig 5.

8 Conclusions

- Dexmet's ASTM D4935-10 test station yields verifiably accurate SE values that agree well with theory, with customer-reported results, and with measurements by independent laboratories.
- By defining an "aperture coefficient", process parameters can be adjusted to design EMFs that meet minimum levels of shielding effectiveness.
- Dexmet continues to build its database of the SE performance of expanded foils suitable for shielding applications.
- In-house SE measurement capability enables Dexmet to offer value-added verification services and enhanced customer support for users of expanded metal foils in EMI shielding applications.

9 Abbreviations

- dB decibel
- EMC Electromagnetic compatibility
- EMF Expanded metal foil (aka. "expanded mesh", "expanded metal mesh", or simply "mesh")
- EMI Electromagnetic interference
- GHz gigahertz (=10^9 s^{-1})
- kHz kilohertz (=10^3 s^{-1})
- LWO Long Way of the Opening
- MHz megahertz (=10^6 s^{-1})
- SE Shielding effectiveness

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