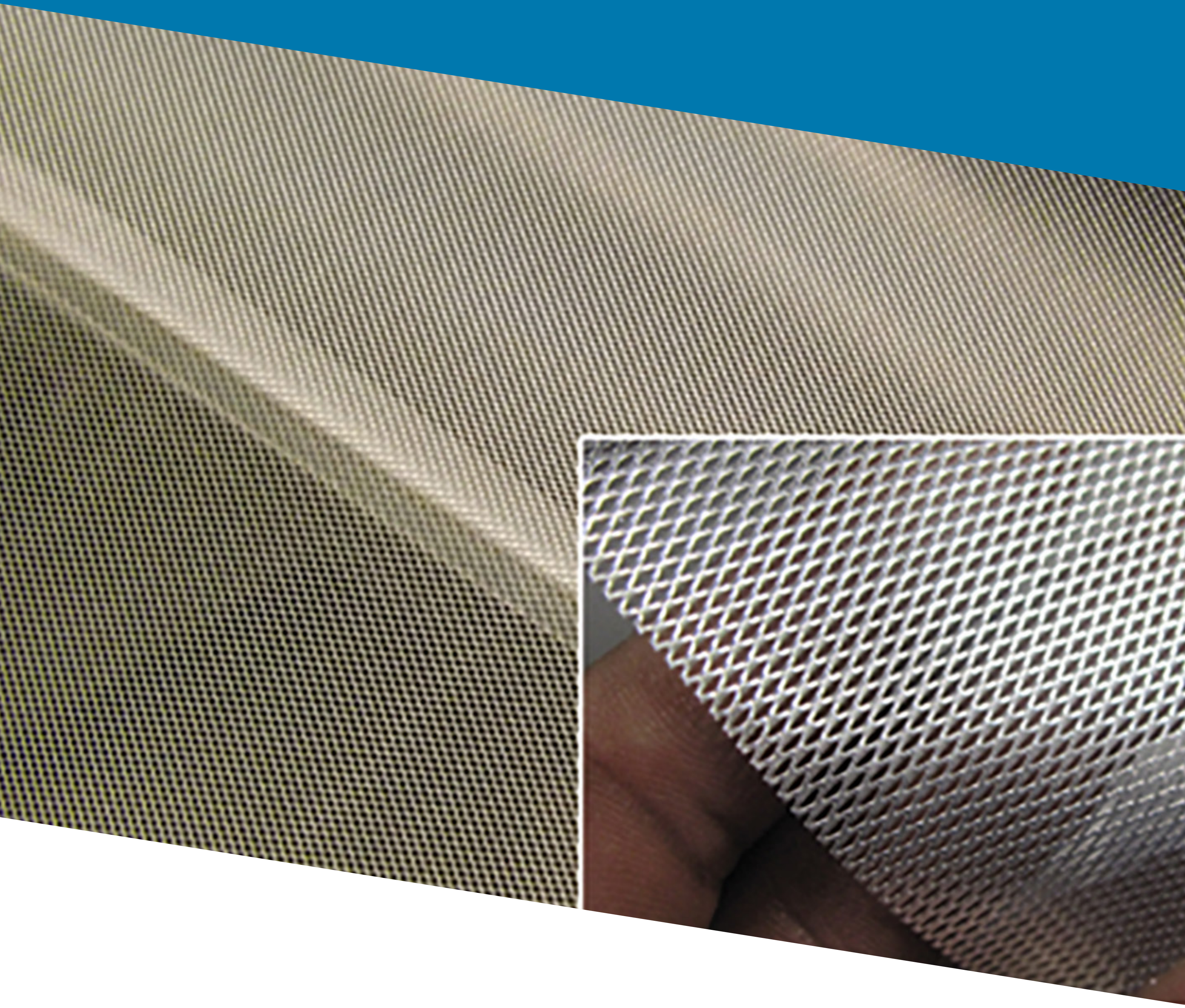
Technical Bulletin

Engineered Materials

Shielding effectiveness of expanded metal foils (EMFs)



Shielding effectiveness of expanded metal foils (EMFs)

Contents

1. Introduction

Under normal operation, all electronic equipment emits 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.

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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 conformance with mandated interference standards.

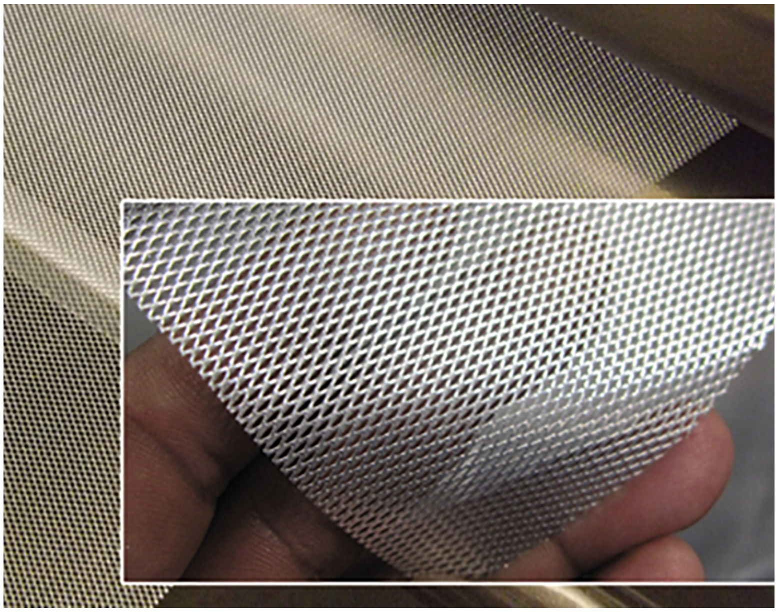
Typically, this entails forming a Faraday cage around susceptible equipment. On the circuit board level, conductive enclosures are used to isolate and protect individual circuit elements. On the equipment level, shielding gaskets may be added to block leakage paths at feedthroughs, cable ports, doors, openings, etc., or the conductivity of enclosures may be enhanced with the addition of thin, conductive elements like expanded metal foil.

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 a lightweight sheet material that is strong and flexible.

Unlike knit or woven meshes, EMFs exhibit consistent and predictable conductivity. They will not fray or unravel, and they conform readily to complex surfaces, making them well-suited to manufacturing processes for composite materials.

Expanded copper foil is commonly used for EMI shielding, but aluminum, nickel, Monel™ and stainless steel foils can also be used where weight, corrosion resistance, galvanic compatibility, or other concerns are present.



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

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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 to 10 GHz, are commercially available. (Fig 2.)

PPG 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 PPG 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 1. ASTM D4935-10 test fixture for SE measurements at f=30 Mhz - 1.5 Ghz.

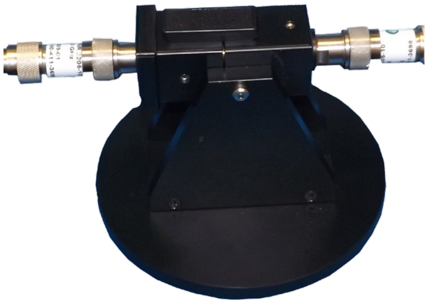
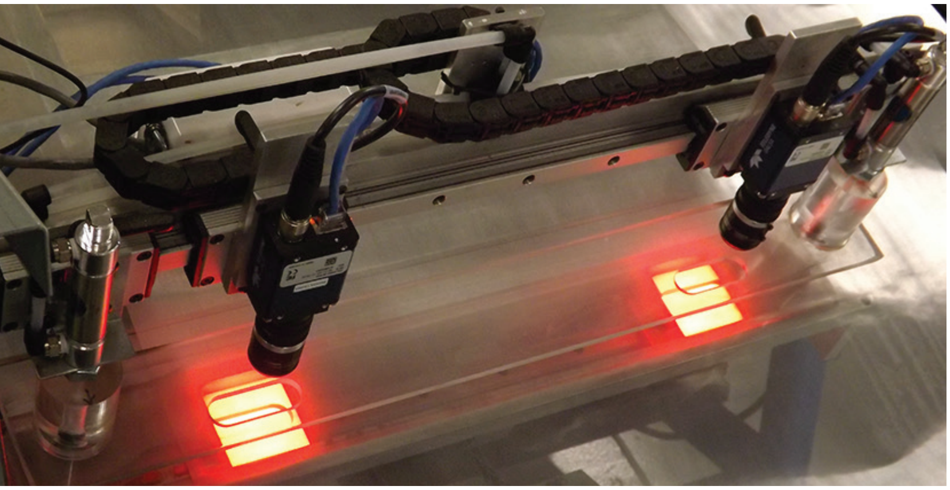


Fig 2. Test fixture for SE measurements at f=1.5 - 10 Ghz.



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

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

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6. SE measurements 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.

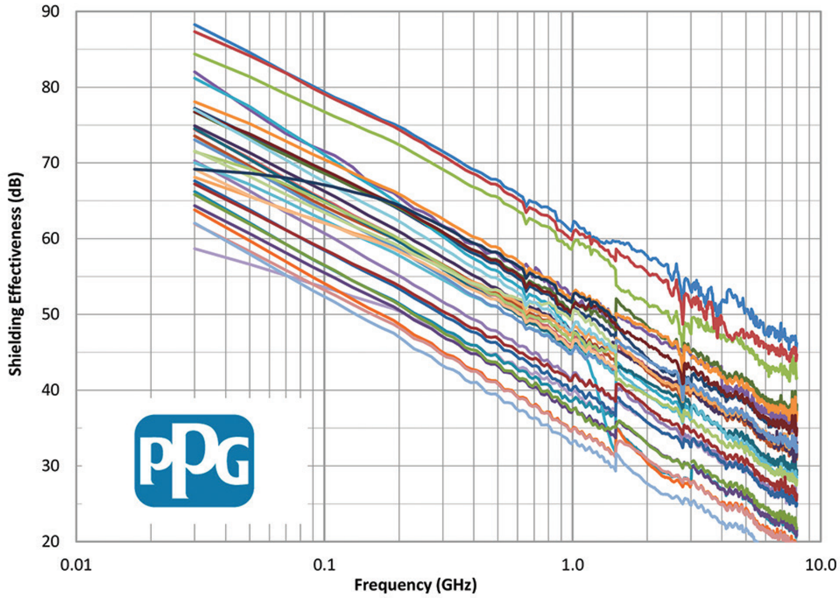

Fig 3. Measured shielding effectiveness (SE) of 25 expanded metal foil types.

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 linear arrays of closely-spaced apertures. The "maximum linear dimension" of the apertures is the "Long Way of the Opening" (LWO) of the mesh. (Fig 4.)

The SE of such shielding materials declines with frequency at 20 dB/decade, and reaches a minimum (SE= 0 dB) when LWO= $\lambda/2$.

SE is furthermore 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.

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.

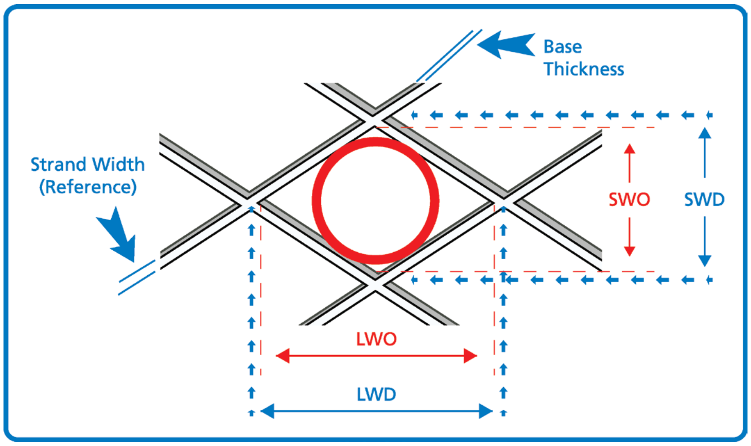

Fig 4. Dimensions of expanded metal foils

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

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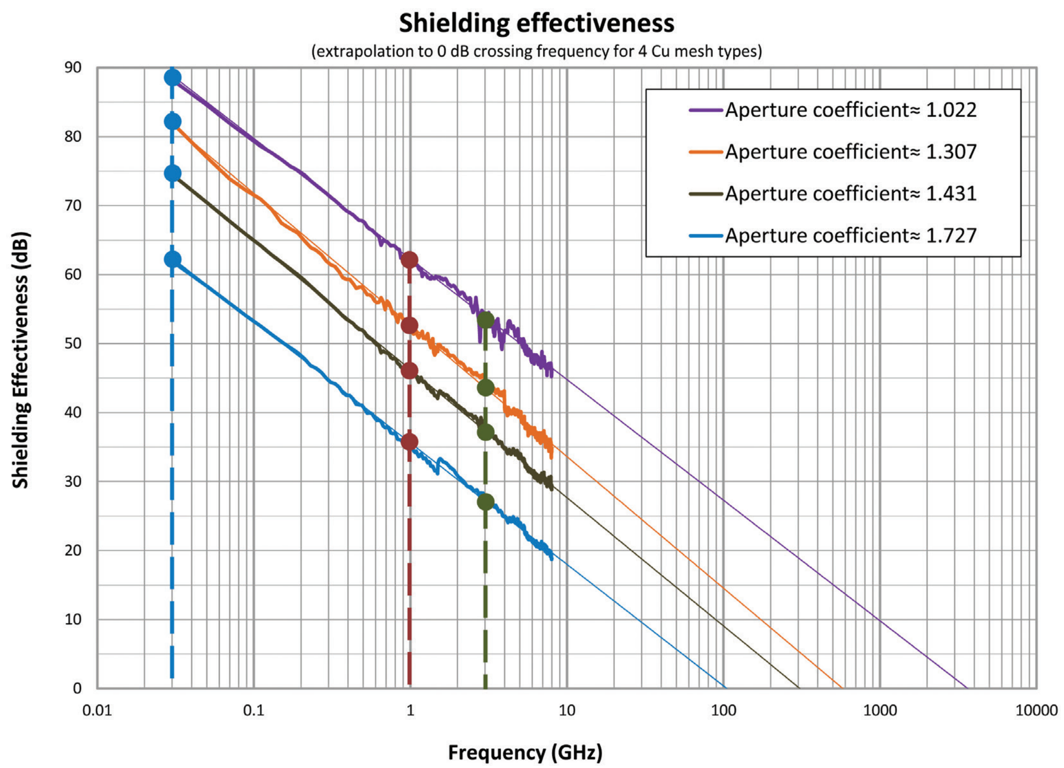

Fig 5.

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 be designed by controlling the LWO and the number of openings per unit area during manufacture such that the needed aperture coefficient is met.

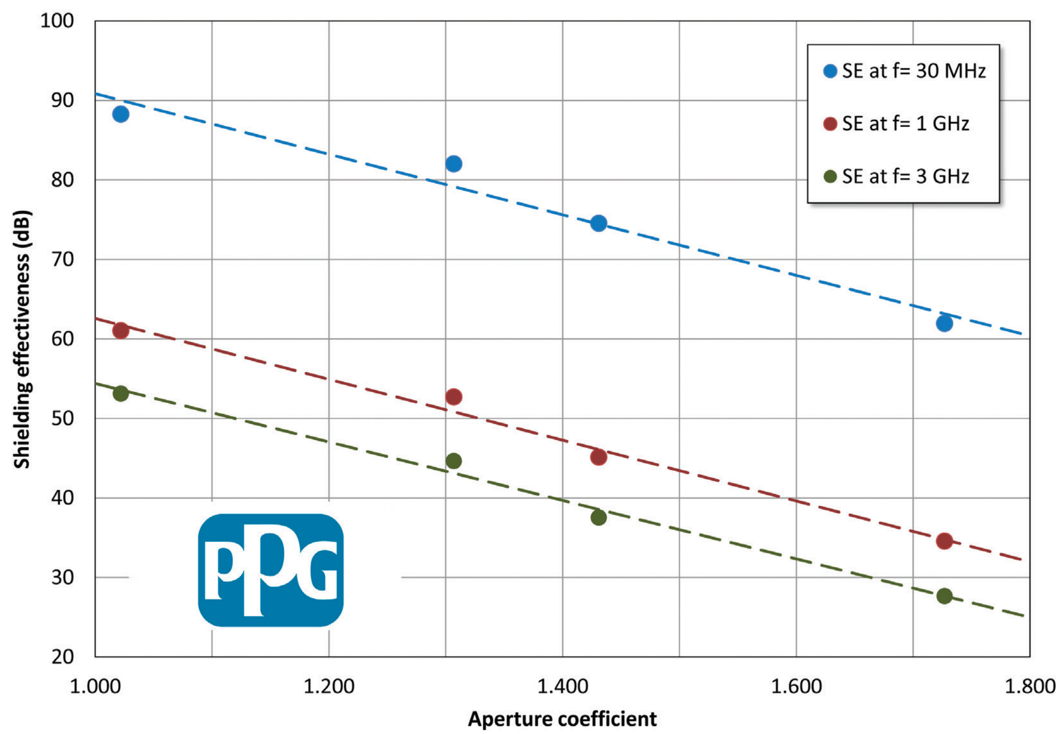

Fig 6.

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

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8. *MicroGrid* EM standard products

PPG offers a standard line of expanded metal foils for EMI shielding. Available in four metals and a total of eight configurations, *MicroGrid* EM foils are suitable for most shielding applications.

As with all these products, standard types can be customized to meet user requirements for weight, resistivity, formability, and shielding effectiveness.

			Weight[2]			Shielding Effectiveness[1] (dB)		
Type	***Material***	***Thickness***	$g \cdot in^{-2}$	$g \cdot m^{-2}$	***Open Area***	***100 MHz***	***1 GHz***	***10 Ghz***
EM2Cu	Cu	.002" (50 µm)	.139	215	53%	72	53	33
EM3Cu	Cu	.003" (75 µm)	.158	245	64%	60	42	25
EM2Al	Al	.002" (50 µm)	.042	65	53%	70	51	32
EM3Al	Al	.003" (75 µm)	.048	74	64%	58	41	23
EM2Ni	Ni	.002" (50 µm)	.138	214	53%	60	46	28
EM3Ni	Ni	.003" (75 µm)	.157	243	64%	54	40	24
EM2ML	*Monel*	.002" (50 µm)	.175	271	39%	67	53	36
EM3ML	*Monel*	.003" (75 µm)	.255	395	41%	63	46	30

1 Test Method: ASTM D4935-10

2 ±10%

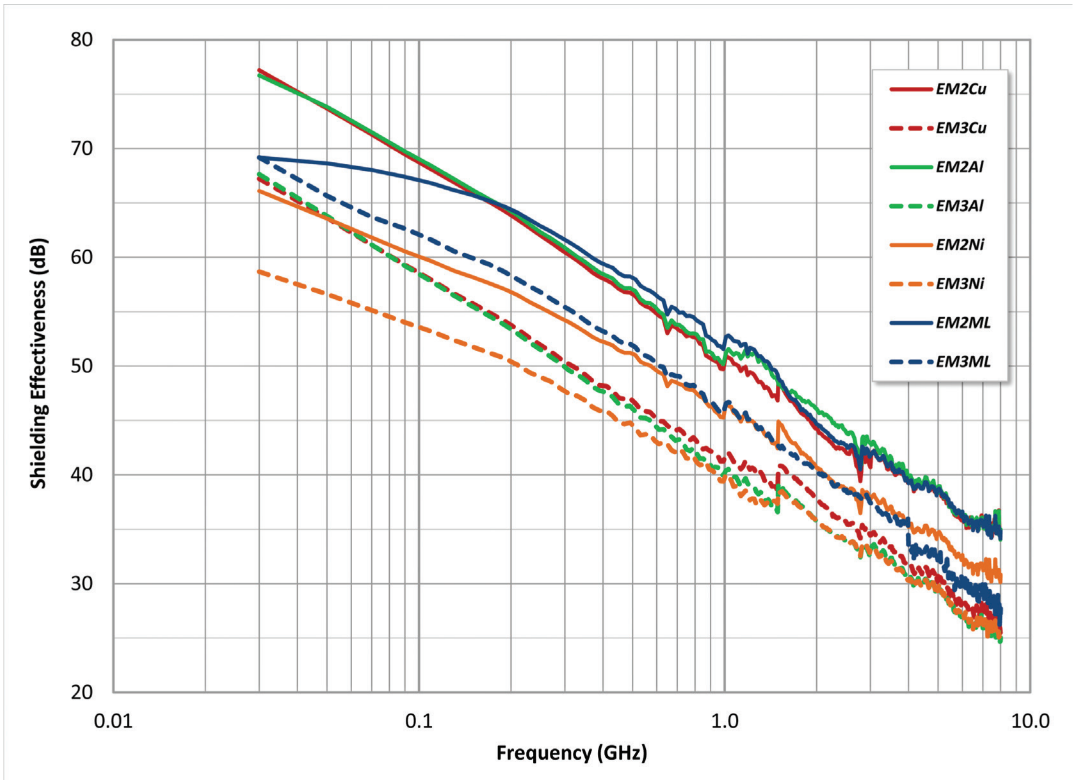

Fig 7. Measured shielding effectiveness (SE) of *MicroGrid* EM standard foils for EMI shielding.

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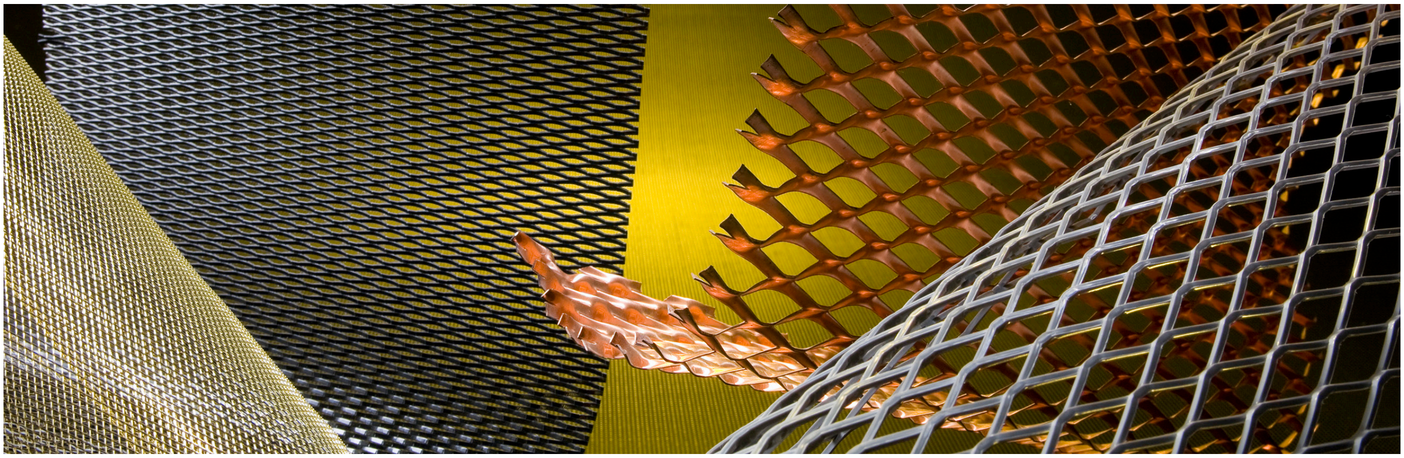
9. Conclusions

- PPG'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.
- PPG continues to build its database of the SE performance of expanded foils used in shielding applications.
- In-house SE measurement capability enables PPG to offer value-added verification services and enhanced customer support for users of expanded metal foils in EMI shielding applications.
- PPG's *MicroGrid* EM series of standard expanded foils for EMI shielding are designed to cover most shielding applications, and serve as a "starting point" for custom designs tailored to user requirements.

10. Abbreviations

- Al — aluminum
- ASTM — American Society for Testing and Materials
- Cu — copper
- 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
- SWO — short way of the opening
- MHz — megahertz (=10^6 s^{-1})
- Ni — nickel
- SE — shielding effectiveness



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