Correlating DC resistance to the shielding effectiveness of an EMI gasket

Gaskets display a frequency dependence that is not necessarily a function of DC resistance.

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Traditionally, engineers predict how an EMI gasket will perform based on the DC resistance through the gasket. DC resistance is a reasonable indicator of how a gasket shields low frequency signals, but can be misleading about how the gasket performs at higher frequencies. Without getting into electromagnetic shielding theory, the purpose of a gasket is to create a continuous conductive path across a break or seam in a metal enclosure. If an electronic device could be entirely enclosed in a continuous metal box, it would not radiate outward or be susceptible to external radiation. However, breaks or seams in metal enclosures are necessary in order to access electronic devices for assembly or repair.

When the material within the gap, the EMI gasket, is not perfectly conductive, radiation from the enclosure can occur. This happens because the currents flowing on the inside of the enclosure create voltages across the gap, which can then be "transferred" to the outside of the enclosure and potentially radiate. Therefore, one would think that if the resistance across the gap is made as low as possible, the best shielding effectiveness (SE) possible could be achieved. This is only true if low resistance is achieved by placing a continuous, homogeneous gasket around the perimeter of the seam. If low resistance is achieved by placing periodic grounding points, or screws, along the perimeter of the gap, the shielding effectiveness of the enclosure may change dramatically with frequency.

This frequency dependence comes from basic antenna theory that says when the dimensions of gaps or apertures approach the wavelength of the frequency of operation, radiation can occur. Therefore, if periodic conductive paths are used as the EMI gasket, the spacing between the contact points must be very small compared to the wavelength at the highest frequency. The following formula shows the relationship between frequency and wavelength:

$$\frac{c}{\sqrt{\varepsilon'_r}} = \lambda \cdot f$$

where
λ = wavelength
f = frequency
c = speed of light
ε'_r = dielectric constant

Given this information, one could wonder: How does the DC resistance of a gasket correlate to shielding effectiveness? The answer is that it truly depends on the form of the EMI gasket and the environment, or enclosure, surrounding the gasket. A case study in which a coaxial test fixture is used to simulate the shielding environment of an enclosure sealed with an EMI gasket is used to illustrate this fact.

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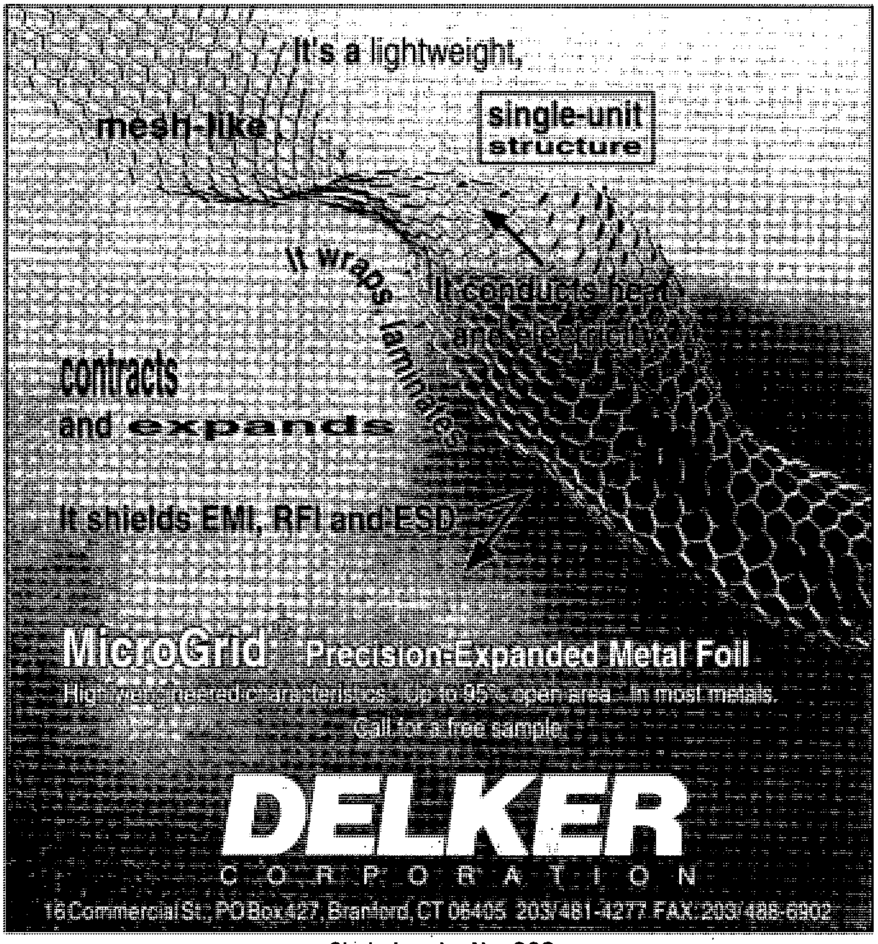

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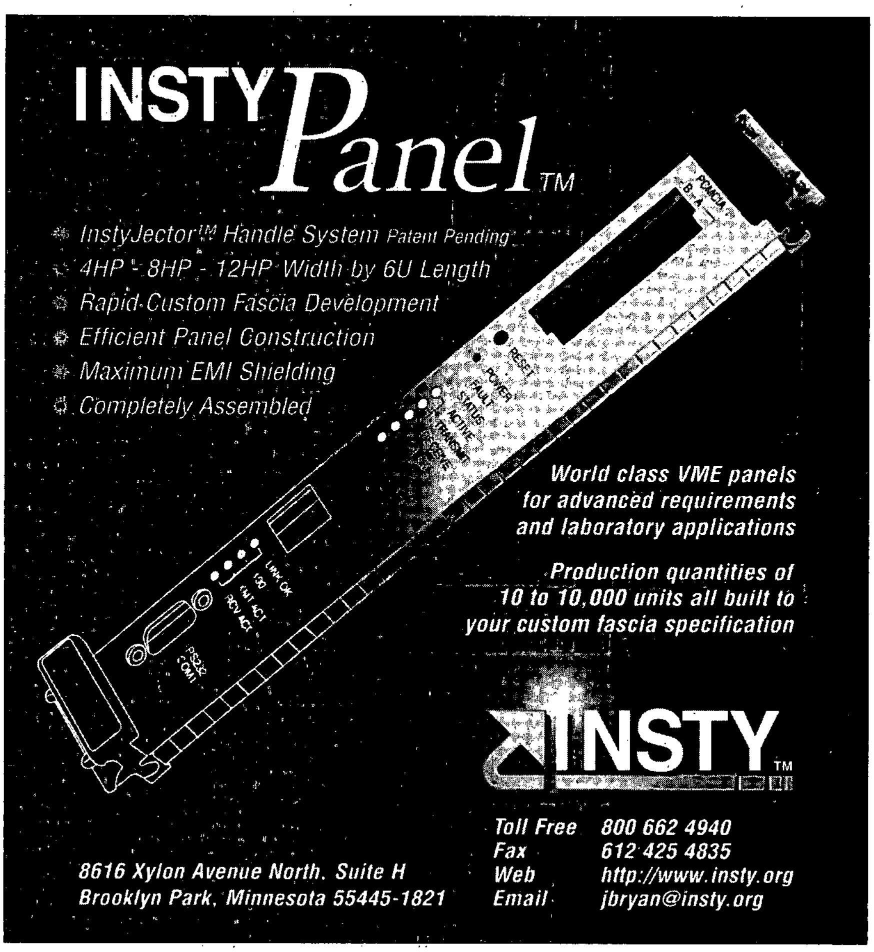

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CASE STUDY

Using the case where an EMI gasket is used in the far field of an incident electromagnetic signal, its ability to shield the signal can be defined by comparing the transmitted signal to the incident. This transmission coefficient (τ) can be expressed as shielding effectiveness, in decibels, if 20 log (τ) is computed. A way of actually measuring this phenomenon is to use coaxial transmission lines to simulate the TEM, plane wave propagation. This technique has been used for many years as a method of determining the relative shielding effectiveness of EMI gasket materials. The conductive gasket, shaped as an annular ring, creates a short circuit between the inner conductor and outer conductor (Figure 1).

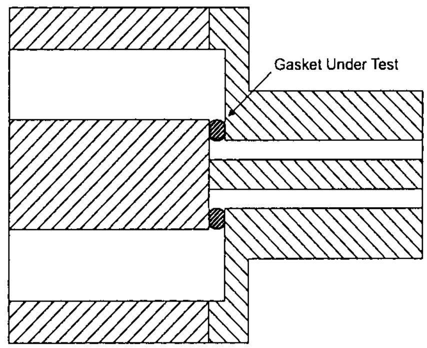


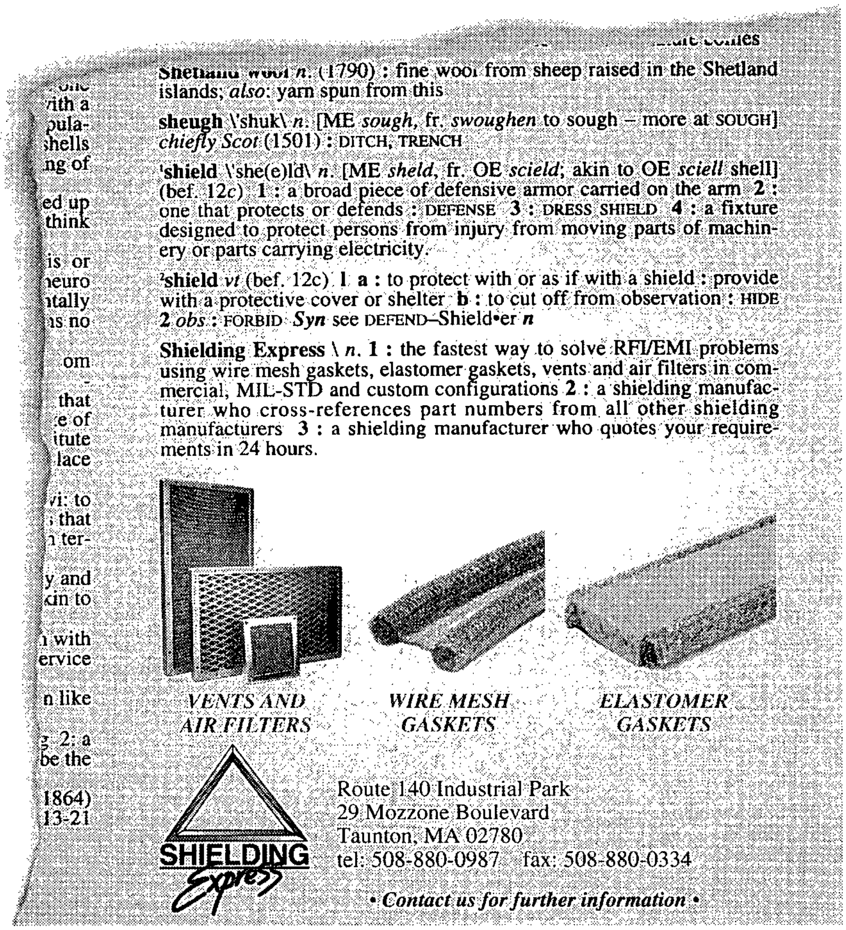
Figure 1. Diagram of test fixture.

At sufficiently low frequencies, the size of the gasket is much smaller than the wavelength. This means that the effect of the gasket can be represented as a "lumped" equivalent circuit at the junction of the gasket, as shown in Figure 2.

The transmission coefficient for the above model would be as follows:

$$\tau = \frac{2Z}{Z_o + 2Z}$$

where
Z_o = characteristic impedance
Z = gasket impedance
and the shielding effectiveness (SE) would be expressed as
SE = 20 log (τ).
If the impedance of the gasket is as-



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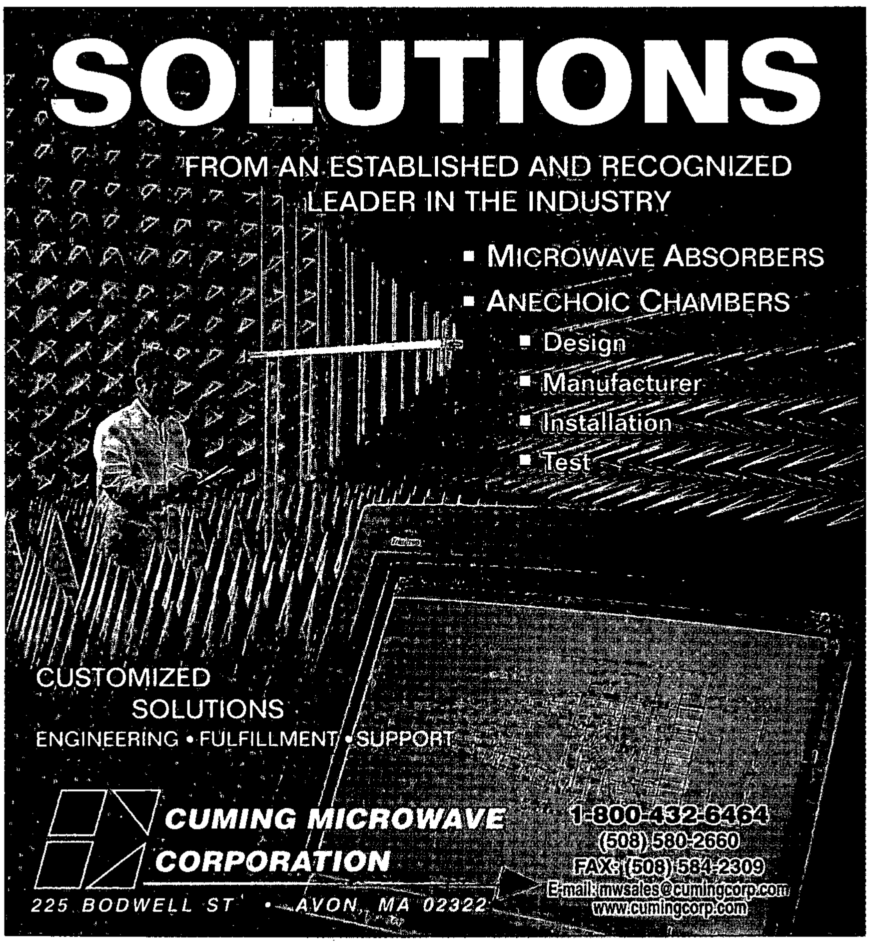

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sumed to be equal to the DC resistance, R, across the gap, then for a typical 50-ohm line the expression becomes:

$$\tau = \frac{R}{25 + R}$$

If this expression is plotted in terms of shielding effectiveness as a function of DC resistance, Figure 3 results.

TEST PROCEDURE

In order to collect actual data based on the above model, an EMI gasket test fixture, similar to the one in the case study, was used. For the gasket under test, two different materials were selected, Gasket A and Gasket B. Both were about 0.015 inches thick and 0.040 inches wide. First, the SE data was collected with the fixture connected to a network analyzer. Then the actual DC resistance of the gap was measured with the gasket still in place, using a special probe and a micro-ohm meter. Using Figure 3, one would expect the measured DC resistance to correlate well to the low frequency shielding effectiveness.

RESULTS

Figure 4 shows the measured shielding effectiveness of the two gasket materials. Gasket A performed better than Gasket B, but Gasket B displays significant improvement in shielding performance with frequency. When the DC resistance was measured across the gasket while still in the fixture, the results were approximately 1 ohm for Gasket B, and 10 milliohms for Gasket A.

Referring to Figure 3, 1 ohm correlates to 28 dB of shielding effec-

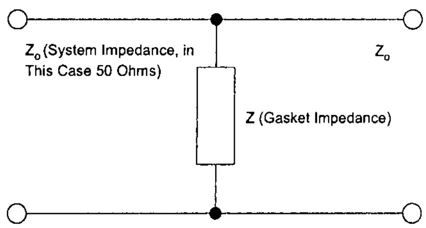

Figure 2. Lumped equivalent circuit of gasket junction.

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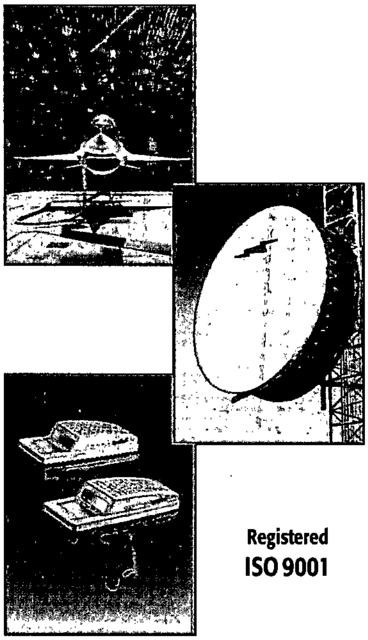

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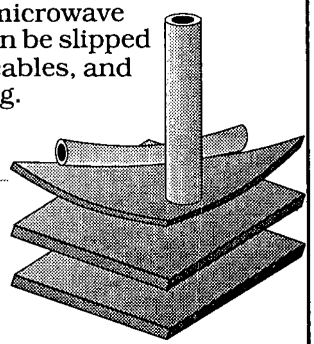

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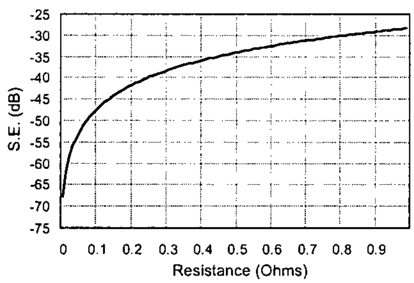

Figure 3. Predicted low-frequency shielding effectiveness based on DC resistance.

tiveness, and 10 milliohms correlates to 68 dB of shielding effectiveness. Comparing these predicted results to the actual results shown in Figure 4, we see that the low frequency shielding correlates to our simple model. However, it is apparent that this model does not predict what happens at higher frequencies. It is a complex task to accurately model all of the higher frequency effects of the EMI gasket junction. Even skin effect losses and transmission line effects do not explain the high frequency behavior of typical gasket materials.

To illustrate this point further, three 0.33-ohm, 1210-SMT chip resistors were placed around the perimeter where the gasket would normally go, to act as a three-point grounding EMI solution. These resistors were placed at 120° increments around the annulus, and used as contacts between the center conductor and the outer conductor.

Figure 5 indicates that the actual low frequency shielding effectiveness is about 46.7 dB. The actual DC resistance across this gap was measured to be 0.121 ohms. If this number is plugged into the formula, a

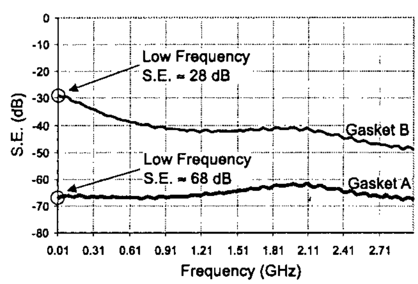

Figure 4. Measured shielding effectiveness of gaskets.

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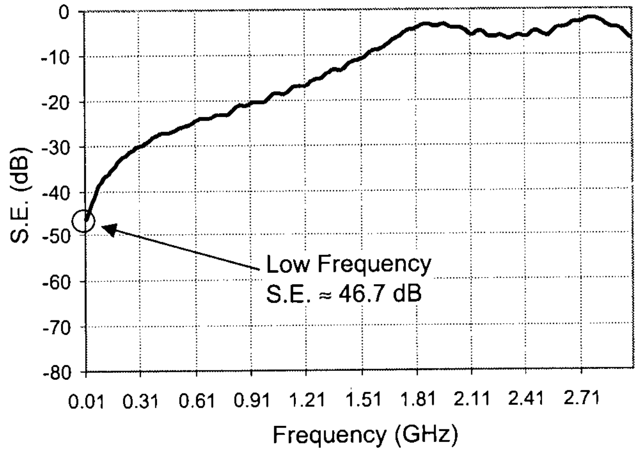


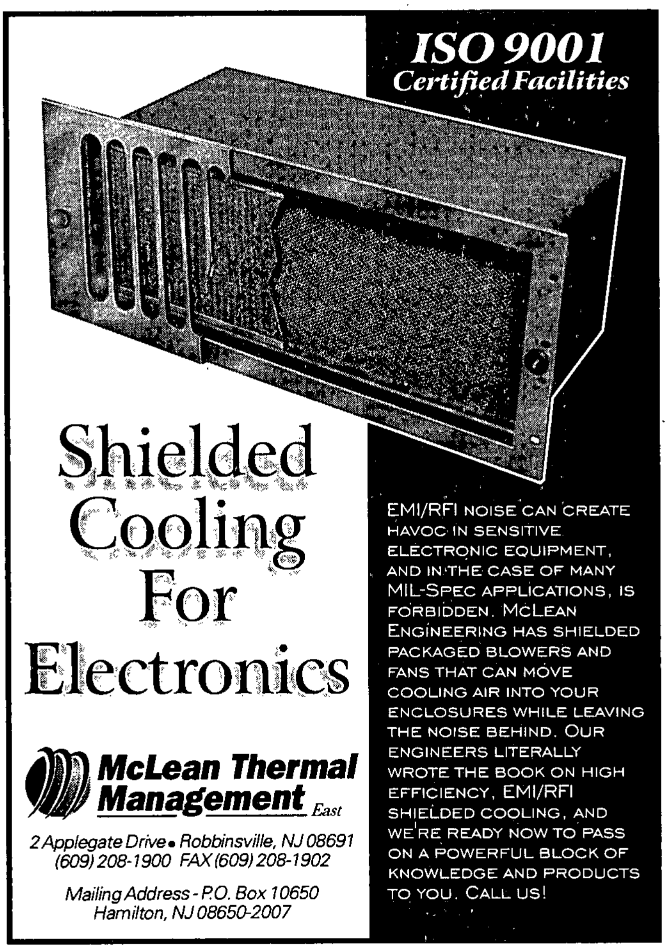
Figure 5. Measured shielding effectiveness of three resistors.

predicted SE of 46.3 dB results. Therefore, the low frequency values correlate very well, but the high frequency shielding does not, becoming almost zero above 1.81 GHz. The reason for this is that at the point where the signal ¼ wavelength approaches the separation distance, or chord, between the grounding points (approximately 1.6 inches), the slot would be expected to radiate (approximately 1.85 GHz).

SUMMARY

In theory, if one could create an EMI gasket from perfectly homogeneous materials, then a model could be produced that would predict the higher frequency effects of shielding performance. The model would include factors like the DC resistance of the gasket, skin effect losses, absorption, and transmission line effects, and would only be accurate for this kind of test fixture. However, in real life enclosures, practical EMI gaskets made from metal springs, metal spring fingers, conductive particle-filled elastomers, etc., display a frequency dependence that is not necessarily a function of the DC resistance of the gasket.

***THOMAS CLUPPER** has been with Gore for 14 years and is currently the RF/microwave technologist for the GORE-SHIELD® family of EMI solutions. GORE-SHIELD® is a registered trademark of W. L. Gore & Assoc., Inc. Tom was instrumental in developing gasket material advances through proprietary modeling software and characterization using internally-designed coaxial fixtures and mode-stirred chambers. (410) 392-3800.*



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