Chapter 24: Additional Shielding Concepts

24.1E Determine an expression for the near-field magnetic SE in dB for a flat thin shield. Compare the equation with that provided for near-field electric fields. Clearly indicate the limitations of your expression.

24.2 A multilayer flat shield consists of two different metals (a two-layer laminate), in direct contact with each other, that are parallel with another single-layer metal. The two-layer metal laminate is insulated from the single layer metal by an excellent dielectric of thickness *d* and relative permittivity ε_r. Determine the equations for the far-field absorption loss and the reflection loss (but not multiple-reflection loss) for this multilayer flat shield. Assume that the thicknesses and electrical properties of the metals are different.

24.3C The equation for the difference in dB between a double and single shield constructed of good, electrically thick metal is

$$\Delta_{dB} = 20\log\left|1 + j\frac{\pi\dfrac{s}{\lambda_o}}{\dfrac{\eta}{\eta_o}}\right|$$

where $s << \lambda_o$, s is the spacing between the layers of metal for the double shield, and η is the intrinsic impedance of the metals. Derive this expression. Therefore, for frequencies such that

$$\pi\frac{s}{\lambda_o} << \left|\frac{\eta}{\eta_o}\right|$$

the difference in shielding is negligible. Assume that the thickness of metal used for the double shield is equal to that for the single shield. Plot this difference over the same frequency range and with the same parameters as in the chapter's discussion. Compare with the more exact results in this chapter. Is the inequality given satisfied?

24.4EC A shield consists of three different metals of three different thickness (a three-layer laminate), in direct contact. Assuming that the two outer layers are copper and the sandwich layer is steel, numerically investigate the shielding effectiveness of this shield versus frequency for various electrically thin and electrically thick situations. Then, compare these results to a solid single-layer copper shield of the same overall thickness. Clearly indicate the far-field absorption loss and reflection loss (but not multiple-reflection loss) for this multilayer flat shield.

24.5 Explain why at high frequencies for the double cylindrical magnetic shield, the exponential portion of the expression

$$\frac{H_e}{H_i} = \frac{e^{\gamma_1 d_1 + \gamma_2 d_2}}{4}\left(\frac{j\omega\mu_o\sigma_1 r_1}{2\gamma_1} + \frac{j\omega\mu_o\sigma_2 r_1}{2\gamma_2}\right)$$

is sometimes referred to as the absorption loss while the remaining terms are referred to as the reflection loss. What is the relationship between skin effect and Eddy current losses? (Hint: examine the appropriately modified expressions for R_{dB} and MR_{dB} given for plane wave shields.)

24.6C Numerically show for at least three unique cases that at high frequencies the magnetic shielding effectiveness of a double cylindrical shell increases with spacing between the shells (assuming the spacing is much less than a wavelength).

24.7 Qualitatively study the effect of varying the spacing and thickness of a two-shell shield on its electric field shielding ability. Assume that the electric field is transverse to the shield's surface.

24.8C Determine the frequency range that the expression

$$R_s = \frac{1}{\delta\sigma} \ \ \Omega/\text{sq}$$

for the surface resistance can be used to determine the ac resistance of a #20 AWG copper wire.

24.9C Derive the expression for the shielding effectiveness in dB of a very thin (film), flat copper shield starting with the expressions provided for R_{dB}, A_{dB}, and MR_{dB} for a good-conducting flat shield. Can this thin shield expression be written entirely as a function of the surface resistance? Plot the SE_{dB} for a copper film 30 Å thick over a wide a frequency range as possible.

24.10C Plot both the magnitude and phase of the current density versus distance (from zero to 10 skin depths) in a thick, copper flat shield assuming that the tangential electric field at the air-metal boundary is 1 μV/m. At what distance into the shield is the current 180° out of phase with the current along the surface? For a transient signal, does this imply that the current at and somewhat beyond this point is traveling in the opposite direction in this shield? Explain.

24.11EC The general expression given in this chapter for the surface resistance for a flat conductor of thickness *t* is

$$R_s = \frac{1}{\delta\sigma}\left[\frac{\sinh\left(\frac{2t}{\delta}\right) + \sin\left(\frac{2t}{\delta}\right)}{\cosh\left(\frac{2t}{\delta}\right) - \cos\left(\frac{2t}{\delta}\right)}\right] \ \Omega$$

and the much simpler approximate expression is

$$R_s = \frac{1}{\delta\sigma}\frac{1}{1-e^{-\frac{t}{\delta}}} \ \ \Omega$$

It was stated that there is less than 1% difference between these two expressions for $t/\delta > 4.63$ and $t/\delta < 0.02$. Show that this statement is true by plotting the percent difference between the general expression and its approximation versus t/δ. Then, plot each of these functions (without the $1/(\delta\sigma)$ multiplier) on a log-log scale versus t/δ and determine the break point. From this information, determine another approximation for the surface impedance expression that has less error over a wider t/δ range.

24.12EC A 10 GHz plane wave with a field strength of 300 V/m is normally incident upon a 0.1 mm thick, flat chassis constructed of aluminum. What are the expected maximum amplitudes of the current and voltage along this chassis due to this plane wave? Assume that the characteristic impedance of the chassis relative to a nearby large ground is 10 Ω, the chassis is grounded at one end, and the chassis is over 10 cm in length. Can the surface resistance be ignored in the calculations? (See the *Radiated Emissions and Susceptibility* chapter.)

24.13 Determine the smallest possible size of a long square pipe if visible light is to pass through it. The wavelength of visible light is roughly 400 nm to 700 nm.

24.14 Derive the wave equation

$$\nabla^2\vec{H}_s + \omega^2\mu_o\varepsilon_o\vec{H}_s = 0$$

starting from Maxwell's equations. State all assumptions.

24.15 Starting from the wave equation, derive the expression for the electric field in the frequency domain inside a lossless rectangular waveguide of dimensions *a* (in the *x* direction) by *b* (in the *y* direction) if the field is *x* polarized and only varying in the *y* direction. (The signal in the guide is traveling in the positive *z* direction.) Then, determine the magnetic field in the time domain.

24.16 Show that a seam of dimensions l_{th} by *b* has greater leakage than a circular aperture of radius *a* ($l_{th} >> a$) if the areas of the two apertures are the same.

24.17 Instead of using a heavy shielded door for a shielded room, it is proposed that a long hallway (with a few turns to save space) of width 0.75 m and height 3 m be used to cut off undesirable signal interference in either direction. Discuss the advantages and disadvantages of such an approach.

24.18 Compare the minimum attenuation of a circular waveguide of diameter *d* with a square waveguide of side dimension *a* by assuming that the cross-sectional areas are identical. Specific numerical values may only be used as a check.

24.19S Determine the cutoff frequency of a typical, residential, metallic hot-air duct. Identify three potential sources that can pass unattenuated through this duct.

24.20 By using the concept of electrical length, determine a rough approximation for the lowest frequency for a coaxial cable (with an inner radius of the outer conductor equal to *a* and an outer radius of the inner conductor equal to *b*) where non-TEM modes just begin to propagate. Then, compare this approximation to the results given in the *Test Chambers* chapter.

24.21 A poor shield around a transmitter allows RF current to pass through to the shield's outer surface. Will grounding the shield reduce the emission level? Explain. It is common practice to ground shields designed to reduce external radiation. Is this really necessary? What are two benefits of this grounding?

24.22 Name one major disadvantage and one major advantage in shielding the source rather than the victim.

24.23 Why are magnetic fields usually only measured in the near field? Why is it sometimes preferable to measure magnetic fields rather than electric fields in the near field?

24.24 A piece of copper foil is placed over a cable. If the noise passing to the conductors in the cable increases, then the noise is most likely near-field____________(electric or magnetic) and if the noise level decreases then the noise is most likely near-field _______ (electric or magnetic).

24.25 Emissions from an automobile are measured in a "shed" constructed mainly of dried wood and fiberglass. Discuss the effect of these materials on the tests.