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Microwave Absorbers: Reducing Cavity Resonances

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Microwave materials offer a proven method for reducing or eliminating resonance. Both magnetically and dielectrically loaded materials can be used.

After rigorous and costly design, circuit-board engineers often find that their well-devised circuit board does not operate properly when it is integrated with the shielded cavity or chassis. The resonance in shielded microwave cavities is increasingly the cause of the problem. Such resonance can hinder the performance of the circuit board or the overall performance of the system.

Microwave cavities have certain resonant frequencies that oscillate. Microwave-absorbing materials are a demonstrated, viable method for eliminating both simple and complex cavity resonances. The energy can be attenuated when lossy magnetic or dielectric materials are introduced into the cavity.

To address resonance problems during testing, engineers often use either microwave-absorbing elastomers or foam products. Magnetically loaded elastomers are the most commonly used. These thin elastomers are nonconductive, so they will not short the microwave circuit. However, less-expensive dielectrically loaded foam materials despite their thickness and conductivity, can also help safeguard circuit boards. Either approach can eliminate cavity resonances.

Reducing Reflections

Historically, the U.S. military used microwave-absorbing materials to reduce reflections of high-frequency energy. However, with the increase in clock speeds, there has been a trend toward the use of microwave-absorbing materials in commercial applications. Consumer electronics, notebook computers, wireless LAN devices, network servers and switches, wireless antenna systems, cellular phone base stations are just a few of the high-frequency device applications that have adopted this technology. Many manufacturers now commonly design extra room into their products for absorber materials, knowing that these materials can dampen the cavity resonances.

As clock and processor speeds increase, the frequency that is emitted also climbs. Standard shielding materials such as finger stock, fabric-over-foam, and board-level shields become less effective at the increased speeds. For example, the proliferation of wireless technology into electronics drives more high-frequency energy through communication boards creating greater interference. Microwave absorbers can address frequencies from 500 MHz to as high as 77 GHz. Microwave-absorbing materials act as coatings whose electrical or magnetic properties have been modified to allow absorption of microwave energy at discrete or broadband frequencies.

Because of time constraints, circuit-board designers generally do not go through the complex resonance modeling exercise necessary to select a material for their cavity. Alternatively, and more commonly, engineers use microwave-absorber samples and evaluate them by cutting and pasting different materials into the circuit board cover and then testing the board.

Often, traditional shielding solutions such as finger stock or conductive elastomers actually contribute to the resonance problem. Although such shielding is necessary, finger stock or conductive elastomer materials provide a conductive path for energy, which in turn contains the energy inside the cavity. This contained energy may adversely affect other components on the board and may keep the board from functioning properly.

Material Selection

Microwave-absorber materials must optimize electrical performance. The electrical or magnetic properties of these materials are altered to allow absorption of microwave energy.

Common dielectric materials—such as foams, plastics, and elastomers—have no magnetic properties, which gives them a permeability of 1. High-dielectric loss materials, such as carbon, graphite, and metal flakes, are used to modify the dielectric properties of these base materials. By contrast, in magnetically loaded materials, fillers such as ferrites, iron, and cobalt-nickel alloys, increase the permeability of the base materials.

Microwave absorbers generally are either resonant or graded dielectric. Resonant materials can be manufactured to absorb at multiple frequencies. By controlling the critical magnetic and dielectric loading and thickness of each layer, two discrete frequencies can be tuned.

The most straightforward type of resonant absorber is the Salisbury screen, which is made up of a thin, resistive sheet spaced λ wavelength from the conductive ground plane. A thin resistive sheet has a resistance of 377 Ω per square matching that of free space. The incoming wave incident upon the screen surface is partially reflected and partially transmitted. The transmitted portion undergoes multiple internal reflections to give rise to a series of emergent waves. At the design frequency, the sum of the emergent waves is equal in amplitude to (by 180° out of phase with) the initial reflected portion. In theory, zero reflection takes place at the design frequency. In practice, absorption of >30 dB may be achieved. Still, problems exist with the Salisbury screen. Poor flexibility, weak environmental resistance, and increased thickness occur at lower frequencies.

Distributing dielectric or magnetic fillers into a flexible medium (e.g., an elastomer) can create a more-practical absorber. Increasing the permeability and permittivity of the layer increases the refractive index and allows for decreased thickness. For example, a Salisbury screen that is designed for 10 GHz is nominally 0.25 in. (6.4 mm) thick, whereas an elastomer loaded with carbonyl iron filler, which also is designed for 10 GHz, is only 0.068 in. (1.7 mm) thick. Equivalent electrical performance can be achieved in a material that is 25% as thick. Microwave-absorbing elastomers are typically supplied in thicknesses as thin as 0.008 in. (0.2 mm) and as thick as 0.175 in. (4.5 mm). Most commonly, engineers choose a material that is between 0.02 (0.5) and 0.125 in. (3.0 mm).

By contrast, graded-dielectric absorbers achieve absorption through a gradual tapering of impedance from that of free space to a lossy state. Little reflection results if the transition goes smoothly. The absorbing medium is a conductive carbon coating on polyurethane foam. Good levels of reflectivity reduction (>20 dB) can be achieved in materials < ⅓ wavelength thick. Dielectric absorbers are commonly offered in thicknesses of 0.125–4.0 in. (3–102.5 mm).

Additionally, designers must consider electrical, physical, and application parameters when determining whether to use a different absorbing material for reducing electromagnetic interference (EMI). Engineers must account for coverage area, frequency bands, order of coverage importance, and absorption specifications.

Compared with broadband foams, elastomeric-type absorbers generally generate better environmental resistance. Elastomeric-type absorbers have been used successfully for more than 40 years. A variety of elastomers are available for designing into a specific environment. For example, thin, flexible absorbers work well outdoors. These absorbers are applied with an adhesive bonding to a metal substrate, which lowers the chance of surface waves and reflections. The use of silicone elastomers is most common in circuit-board applications. Silicone offers a temperature range of –60° to 350°F.

By comparison, broadband, or open-cell, absorbers are usually used in a protected environment. The adhesive bonding-application process becomes less critical in this environment. Often, cohesive failure of the material occurs before adhesive failure.

Both the elastomeric-type absorbers and the broadband foam materials are commonly sold as die-cut parts with a pressure-sensitive adhesive (PSA) backing. Inexpensive steel-ruled dies enable manufacturers to cut the sheet material down into specific geometries. Parts can either be die-cut, where the part is cut free from the sheet of material, or kiss-cut where the part may be supplied in a pad. Kiss cutting typically allows for a simpler removal of the PSA liner paper. The die-cut parts are most commonly applied into cavities by hand; alternatively, automated in-line installations are also used. Automated installation fixtures use either a vacuum chuck or a magnetic chuck, which holds the part in place while the PSA liner is removed. An actuator is then used to press the die-cut part into the chassis.

Comparing Magnetically and Dielectrically Loaded Materials

To properly eliminate cavity resonances in circuit-board applications, companies frequently rely on magnetically loaded materials because these materials offer thin, nonconductive characteristics. These silicone-based products reduce cavity resonance without the risk of shorting the circuit board. Magnetically loaded elastomers are filled with an iron-based product and are electrically nonconductive.

Magnetically loaded elastomers are being integrated into electronics during the design phase of more and more frequently. However, there are still cases in which engineers believe that they have incorporated adequate shielding to pass regulatory tests, yet the products still fail.

Dielectrically loaded materials offer users a cost advantage over magnetically loaded materials. The dielectrically loaded materials use an inexpensive foam medium coated with latex carbon. A drawback of these materials is that the foam-type substance is thicker than that used for magnetically loaded materials. For dielectrically loaded materials, the thinnest matter, at ⅛ in., is too thick to design into many small of packages. However, if environmental conditions allow and the thickness can be tolerated, this foam can be a viable option. Both dielectrically and magnetically loaded materials are effective for reducing cavity resonance.

Looking to the Future

The future of microwave absorbers is moving toward thinner and more electrically effective materials. As packages shrink, customers' designs get smaller. Some of the traditional foam-type options that have thicknesses of up to 4–in. thick are too bulky to be useful in such small designs. It will become more important than ever to consider the thickness of the material.

Harmonics, which are multiples of the fundamental frequency, occur within shielded electronics. In many high-speed electronics, harmonics are becoming an increasingly critical issue. As frequencies within electronics rise, so do the levels of their harmonics. Some large server equipment is tested for EMI up to 40 GHz, and many of the higher frequency issues are actually harmonics of the fundamental frequencies. Standard shielding materials becomes less effective at these frequencies, because any aperture that may be inherent of the design materials might leak energy. Absorbers can dampen energy in these applications.

Conclusion

The need for microwave absorbers or absorbing shields is increasing as devices such as computers, cell phones, and other electronics move to higher frequencies and speeds. To avoid compromising the shielded cavity, it is crucial to alter designs to allow room for microwave-absorbing materials. This is a viable, cost-effective method to ensure proper functioning of the circuit board.

To generate consistency with the electrical performance, thickness, weight, mechanical properties, and cost, designers use magnetically or dielectrically loaded materials to enhance performance. Although each type has slightly different performance parameters, they both provide valuable options for reducing cavity resonance.

In addition, absorbers help products function more effectively or to allow it to pass EMI tests. These methods are the best means of addressing cavity resonance while taking into consideration the thickness, weight, mechanical properties, and cost.