Microwave absorbers manage military electronics RF interference

Various types of microwave absorbing materials use either dielectric or magnetic loss to limit RF interference in military electronics equipment.

By Jack T. Gear

The increased use of microwave electronics by today's military carries with it the increased potential for RF interference. The impact of RF interference on military microwave electronics creates major problems, causing errors in targeting, reducing system efficiencies and limiting operating capabilities. Microwave absorbing materials help eliminate or reduce to manageable levels most problems involving RF interference.

The military's use of microwave absorbing materials dates back to the 1940s, spawned by the introduction of radar. The military community describes microwave absorbing materials with the acronym 'RAM' for radar absorbing materials. Microwave absorbers are materials specifically designed to attenuate or absorb microwave energy. The increased use of military electronics, more specifically, microwaves electronics, including EW systems, radar systems, IFF systems and RF communications systems all bring to bear increased RF interference.

Selection of a RAM for a particular application can be simple or complex depending on how well the RF interference can be characterized. For many applications, the tried and true method of trying different types of RAMs is the best approach.

Microwave absorber types

RAMs are designed to attenuate or absorb microwave energy with the absorbed energy converted to heat. Microwave absorbers fall into two general categories: those that absorb propagated microwave energy (electromagnetic waves capable of propagating in empty space or a vacuum) termed free space absorbers and those that absorb standing waves that exist inside waveguides, coaxial lines and other closed volumes where microwave radiation exists. These absorbers are called load absorbers, cavity damping absorbers and bulk loss absorbers.

Attenuation of microwave energy occurs due to the dielectric loss and/or magnetic loss of a microwave absorber. Dielectric loss is found in the imaginary component of the complex permittivity and acts on the electric (E) field. Magnetic loss is found in the imaginary component of the permeability and acts on the magnetic (H) field. Microwave absorbers using dielectric loss to absorb the electric field portion of an electromagnetic wave use carbon particles in many cases as a loading to create the proper complex permittivity. Microwave absorbers using dielectric loss are electrically conductive in most cases. This property has the potential to cause short circuits in some applications where the absorber is located near RF circuits.

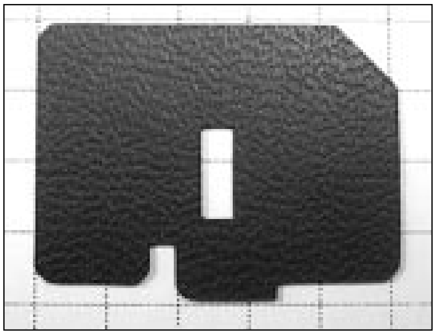

Figure 1. Custom-shaped cavity resonance microwave absorbers can be formed into different shapes to suit a particular application.

Microwave absorbers employing magnetic loss are filled with magnetic fillers, including special irons and ferrites. Dielectric-loss microwave absorbers are generally thicker physically than the magnetic-loss microwave absorbers due to their smaller real and imaginary parts of the permittivity. Magnetic-loss microwave absorbers are thinner physically due to their higher real parts of both the permittivity and permeability. A favorable property of the magnetic microwave absorbers is that they are insulators at DC with volume resistivities of $>10^8\ \Omega$-cm. This property allows their use inside microwave circuit modules near or in contact with circuits.

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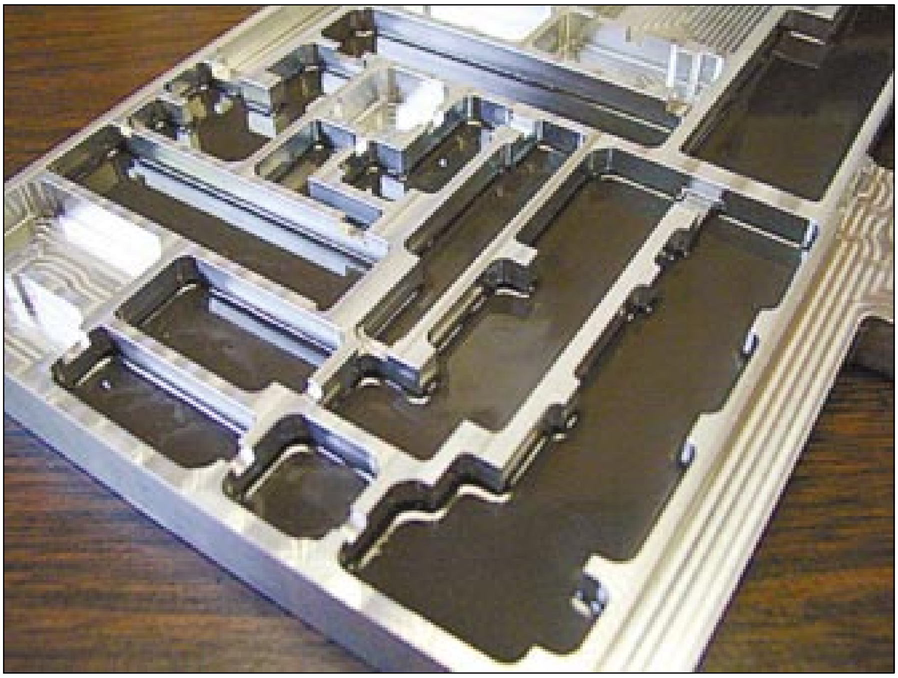

Figure 2. An example of a multiple-cavity Eccosorb MIP application shows how the cavities are filled with the cavity damping material.

are designed to operate at a specific frequency and provide absorption of -20 dB (99% absorbed) of the incident microwave energy at the design frequency ±5%. These tuned microwave absorbers usually exhibit high magnetic loss (permeability) or high dielectric loss (permittivity) and are designed to be ¼-wavelength in electrical thickness at the design frequency. The tuned or resonant absorbers require mounting on a ground plane or electrically conductive surface to achieve cancellation of the reflected RF energy occurring at the front with the reflection occurring at the rear surface of the tuned or resonant absorber. The phase of these two reflections are 180° apart due to the electrical thickness of ¼-wavelength resulting in cancellation of the two reflections. Thickness of the more popular high permeability silicone-tuned absorbers ranges from 0.160 inch (4.06 mm) at 1.0 GHz to 0.030 inch (0.76 mm) at 30.0 GHz.

The elastomer-tuned or resonant absorbers offer many properties of interest to the military user: minimal thickness, flexibility, service temperature of -54°C to +163°C and good weather ability. These microwave absorbers are easily formed into custom shapes using steel-ruled dies. They are available with high-performance peel-and-stick adhesive (SS-6M) for ease of mounting as well as with metal backing. Applications include the reduction of narrow-frequency interfering RF reflections from metal surfaces around antennas, inside radar nacelles and, in some cases, the damping of resonance occurring inside microwave modules. The tuned or resonant absorber family is effective at attenuating surface currents. Tuned or resonant microwave absorbers are also effective in damping cavity resonance, although the less expensive and thinner cavity damping absorbers are recommended.

Cavity damping absorbers

Microwave absorbers designed for damping cavity resonance are, in most cases, high-permeability, thin elastomer sheets with broad frequency magnetic loss (permeability) properties. Cavity resonance interference is also described as high Q or ringing and occurs when a cavity generates a standing wave due to stray radiation and the physical properties of the cavity. Other microwave absorbers such as resonant or tuned absorbers may also correct cavity damping problems and may not be the best selection based on cost and weight. The high-permeability cavity damping absorbers range in thickness from 0.010 inch (0.25 mm) to 0.040 inch (1.02 mm) and are easily formed into custom shapes using razor blade, steel rule dies, water jet or laser cutting (Figure 1). The binder material of choice is silicone due to its flexibility, service temperature of -54°C to +163°C, power handling of 0.2 W/cm^2, low outgassing and availability with a high-performance peel-and-stick adhesive (PSA) SS-6M.

Cavity resonance problems occur more frequently due in part to increased circuit function, reduction in the physical size of microwave modules, and the need to enclose these microwave circuit boards in metallic housings to provide shielding. Cavity resonance, in some cases, shows up late in the design process when the module cover is installed. In these situations, thickness, cost and ease of applying the cavity damping absorber become paramount. Most cavity damping absorber materials are applied to the cover of the microwave module.

A recent application involved RF interfer-

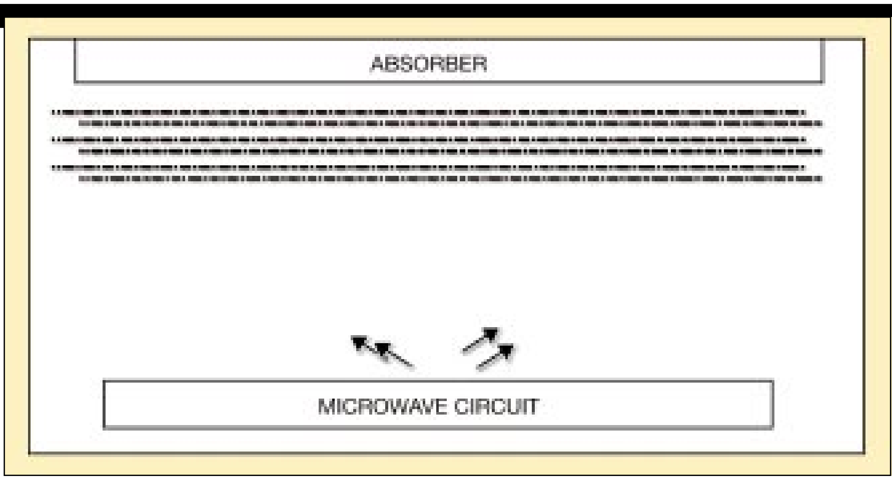

Figure 3. A cavity-resonance absorber can be attached to a module cover to reduce the number of absorbers required in a multiple-cavity application.

ence inside an X-band T/R module of a phased array. The interference was corrected by the application of a cavity-damping microwave absorber (Figure 2). The cavity damping absorber selected was silicone, 0.030 inch (0.76 mm) thick, attenuation of 36 dB/cm and supplied with the SS-6M high-performance PSA. In multiple-cavity modules, from 20 to 50 cavities can be in a module. Some cavities have no microwave circuitry, while others house microwave circuitry and require cavity-damping absorbers. A mold-in-place (MIP) Eccosorb cavity-damping absorber from Emerson & Cuming Microwave Products Inc. is used in these applications. The MIP material is applied to the resonant cavities of a multiple-cavity housing by the microwave absorber manufacturer.

The Eccosorb MIP approach offers customers a cost-effective solution of cavity resonance issues in multiple-cavity modules. Selecting the most cost-effective solution can be difficult due to the complex nature of resonant cavities. Therefore, most absorber manufacturers make available, at no cost, a sample kit of absorbing materials. These absorber sample kits are supplied with PSA absorber samples, allowing engineers to experiment and determine the most cost-effective cavity damping absorber. An example of a cavity resonance absorber attached to a module cover is shown in Figure 3.

Graded-impedance free space absorbers

Free space or specular microwave absorbers are designed to operate in a free space condition—that is, the microwave-absorbing material is illuminated by a propagating wave. A propagating wave exhibits a uniform phase front across the front surface of the microwave absorber and is achieved in what is termed, *free space*. Graded-impedance microwave absorbers are, in most cases, carbon doped or impregnated urethane foams. The impedance taper or gradient is achieved using geometric shaping such as pyramids, wedges or convolutions or is electrically tapered or graded by varying the carbon loading or doping of flat layers, decreasing in impedance from front to back.

Physically graded microwave absorbers are classified as high-performance materials providing RF absorption levels of -40 dB (99.99% absorbed) to -50 dB (99.999% absorbed). These absorbers have an impedance at the front plane (tips of the pyramids) close to free space (near 377 Ω/square), which decreases uniformly to the back surface. They are used in test facilities such as anechoic chambers and other types of microwave measurement enclosures.

Types of measurements conducted in these anechoic facilities include antenna pattern measurements, radar cross-section, EMI emissions, susceptibility and compatibility, and target simulation. These anechoic high-performance absorbing materials are fire-retardant, meeting NRL 8093 tests 1, 2 and 3. The multilayer or flat-sheet layer specular microwave absorber series provides excellent absorption of -20 dB (99% absorbed) over a frequency range of 600 MHz to 40 GHz. They are thin, typically ¼-wavelength at the lowest operating frequency, lightweight, flexible and meet the UL 94 HBF Fire Retardancy Standard. Multilayer microwave absorbers are available with weatherproof jackets for outdoor use, with PSA adhesive and with metal backing to improve shielding effectiveness. The multilayer microwave absorber can be easily formed into custom shapes with conventional tools or water jet (Figure 4).

Sheets and more complex custom shapes can be treated with a moisture sealing coating allowing their use in high humidity or moderately wet environments. Applications for the multilayer absorber include the in-nose section of radar-guided missiles to reduce reflections around the seeker antenna, inside military aircraft nose sections to reduce reflections around radar systems, lining of antenna caps used to terminate aircraft antennas allowing on-the-ground testing of radar systems, and on-surface ships to reduce reflections around antennas.

Load absorbers

The most common load absorber products are epoxies filled with a special iron. They are rigid, easy to machine to tight tolerances, have a service temperature of 177°C and are low outgassing in a vacuum. Load absorbers are available in eight types with attenuations at 10.0 GHz ranging from 2.2 dB/ cm to 190 dB/cm. Changing the filler ratio of the high-permeability special iron filler controls the attenuation. The load absorbers are useful over the frequency range of 1.0 GHz to 18.0 GHz, with the higher-attenuation load absorbers being more effective at the lower frequencies and the lower-attenuation load absorbers more effective at the higher frequencies. The most effective (providing the lowest VSWR) are machined loads for use in X-band (8.2 GHz to 12.4 GHz), for example, made using the load absorber type

Figure 4. An antenna housing using a custom multilayer RAM can be formed into custom shapes with conventional tools or water jet.

with attenuation between 32 dB/cm and 56 dB/cm at 10.0 GHz.

Also available are castable load absorbers. These are two-part epoxy systems that cure at elevated temperatures between 74°C and 149°C. Castable load absorber systems are useful in situations where load volumes are high and the shape of the load is moldable. In addition, there are silicone castable load absorbers providing similar attenuations and more flexibility. The castable silicone load absorbers are more difficult to mold due to higher viscosities.

Practical RAM solutions

For applications where the RF interference is caused by a propagating wave, selecting a free space or specular microwave absorber is appropriate based on the lowest frequency of the RF interference, amount of absorption required, space available and environmental conditions. In cases where a reflection in free space at 7.5 GHz is causing RF interference in a dry environment, application of Eccosorb AN-73 a 3/8-inch (9.5 mm)-thick RAM will reduce the offending free space reflection by -20 dB (99%). The AN-73 is near ¼-wavelength in thickness at 7.5 GHz, lightweight, moderate cost and can be custom-shaped to fit a particular application. In applications where moisture is present, Eccosorb ANW-73, the weatherproof version of AN-73 is available. Another microwave absorber choice for this particular application is Eccosorb SF-7.5, a tuned or resonant microwave absorber that will also reduce the offending RF interference by -20 dB (99%). The SF-7.5 requires mounting on a metal surface and has a thickness of 0.074 inch (1.88 mm). This RAM can be exposed to moisture and is easily formed to special shapes using steel rule dies, water jet or laser cutting. It is heavier and a little more expensive than the AN-73. Both RAM products are available with PSA.

RF interference applications involving cavity resonance or ringing occur once the cover of a module is installed. The resulting resonance causes serious problems with the operation of RF circuits inside the RF module. The RF modules housing RF circuits are usually aluminum or some other metal to provide EMI shielding, to reduce emissions and to reduce susceptibility. Stray RF inside modules can set off a standing wave or resonance that will adversely affect the performance of the microwave circuitry. In applications where the resonance occurs at frequencies between 1.0 GHz and 8.0 GHz, the recommended cavity damping RAM is Eccosorb MCS, a 0.040 inch (1.01 mm) thick high-permeability silicone rubber sheet material. For cavity resonance occurring between 6.0 GHz and 35.0 GHz, the recommended cavity damping RAM is Eccosorb GDS, a 0.030 inch (0.76 mm) thick, moderately high-permeability silicone rubber material. Both of these products are available with a high-performance PSA (SS-6M) adhesive, easily formed to special shapes using steel rule dies, water jet and laser cutting. Microwave absorbing materials are continually being developed to keep pace with today's microwave electronics, both military and commercial. DE

ABOUT THE AUTHOR

Jack T. Gear is a former sales marketing manager for Emerson & Cuming Microwave Products Inc. (1996-2000). He retired in 2000 and is currently consulting for ECMP. Gear's work at ECMP includes quality control, application engineering and field sales (1982-1996).