RF Shielding Gaskets

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INTRODUCTION

Electronic equipment is shielded to attenuate radiation from emitters, to attenuate radiation that may interfere with circuits that act as receptors of RF energy, and to control parasitic coupling capacitance which results in crosstalk. Shielding is the only suppression technique that does not result in limiting the high frequency operation of the equipment. Depending upon the application, shielding is provided by small metal cans mounted on PC boards, by equipment enclosures, or by large-scale building structures.

Of the various factors that limit the overall shielding effectiveness of an electronic enclosure, it is the many discontinuities that have the greatest effect on shielding. These discontinuities exist at all temporary and semipermanent seams, and because of the length/frequency relationship, the attenuation decreases as the opening widens. If seams could be eliminated by welding, brazing, or soldering, the enclosure shielding would be protected. Even though fastening techniques such as welding provide continuous contact and eliminate discontinuities, they do not permit the mating surfaces to be easily separated.

Since it is virtually impossible to maintain continuous contact between movable mating surfaces through tooling or milling methods alone, RF gaskets were developed. These electrical components provide a continuous electrical bond across temporary and semipermanent seams of an enclosure, permit separation of the mating surfaces, and conform to surface irregularities. Spring finger gaskets were the first RF gaskets to be produced. They were introduced in 1944 and are still of prime importance in the electronics market today. Although the earliest spring finger gaskets were made from beryllium copper (BeCu), they have been made from various metals, and new configurations have been developed. In parallel developments, other forms of RF gaskets have been created to solve unique problems that could not be solved by spring fingers alone.

Designers choose from alternative gasket configurations on the basis of conductivity, compression force and environmental factors.

RF GASKET CONFIGURATIONS

There are a number of different forms of RF gaskets: spring fingers, coiled spring, knitted wire mesh, braided wire mesh, embedded woven wire screen, oriented wire, metal foil over elastomer, and elastomers filled with powdered metal. These gasket forms have additional variations which result from the use of alternative materials. Each offers advantages to the designer in specific applications so the designer must be knowledgeable about the gasket and the situation in which it is used. From the many variations, the four major types of gasket configurations used in today's systems and enclosures are beryllium copper spring fingers, beryllium copper hollow tubular wire mesh, Monel/tin-copper-iron (SnCuFe) solid wire mesh, and silver-filled conductive elastomers. Several varieties of these gaskets are shown in Figure 1.

Important factors to be considered when choosing a gasket are conductivity, shielding effectiveness, corrosion control, compression forces, compressibility, compression range, compression set, and environmental sealing.

CONDUCTIVITY AND INDUCTANCE

When used for dc or low frequency grounding/bonding, the conductivity is the most important parameter. At the higher RF frequencies, the gasket inductance becomes the most important parameter. Beryllium copper has the highest conductivity of any material that can be converted into a spring. Its conductivity is 150-percent greater than the next best material. When configured into a conductor, the conductivity, which is important at lower frequencies, is proportional to the cross-sectional area. Solid fingers have greater cross-sectional area, hence higher conductivity. In addition, the finger shape during use (width is much greater than length) has the characteristics of an interconnecting ground plane with large contact surface area rather than that of a wire. The inductance of a ground plane is three to four orders of magnitude less than that of a wire.

At frequencies over approximately 100 MHz, thin silver-filled elastomer gaskets (where contact area is much greater than the largest cross-sectional area) subjected to high compression forces provide low impedance bonds between mating surfaces. This results in RF shielding effectiveness equal to that of the beryllium copper spring finger.

The conductivity/inductance relationships are both material and shape dependent. For low frequencies (from 50 kHz to 10 MHz), BeCu spring fingers and BeCu wire mesh are the best choices. At high frequencies (over 100 MHz) BeCu spring fingers and silver-filled elastomers are the best choices.

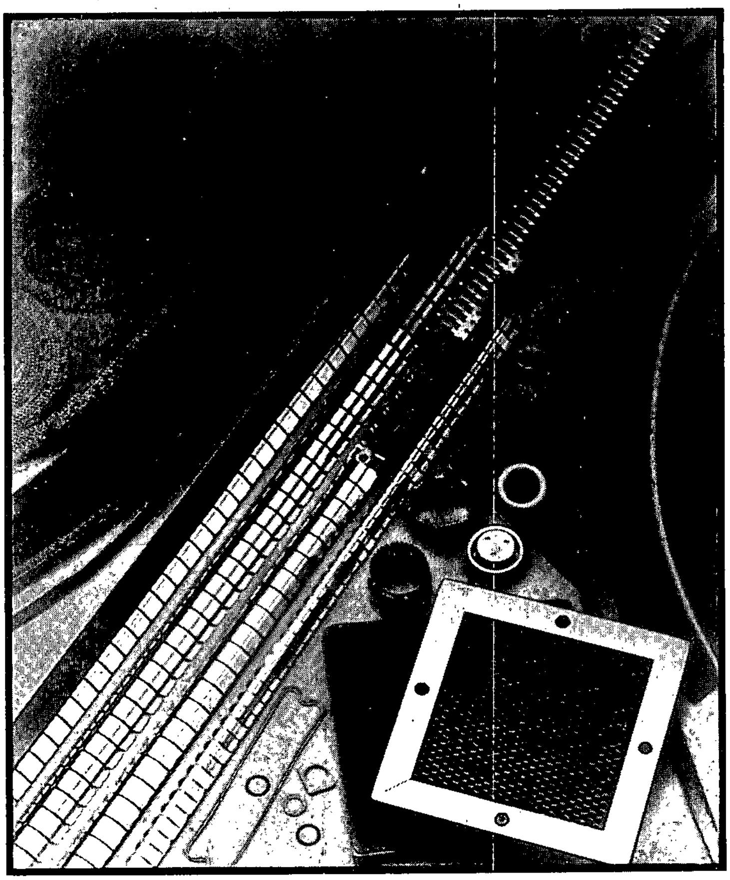

FIGURE 1. *Gasket Configurations.*

SHIELDING EFFECTIVENESS

For electric field and plane wave shielding, RF gaskets made from beryllium copper provide the highest shielding effectiveness of any gasket made from metal spring materials. This is due to the high conductivity and low inductance levels. As a result of its high conductivity and low inductance, beryllium copper also provides better magnetic field shielding at frequencies over approximately 1 MHz. However, for magnetic fields below about 50 kHz, beryllium copper, like other nonmagnetic materials, suffers because of its unity permeability. As a result, the magnetic field shielding is not normally provided by gasket materials regardless of their composition. Low frequency magnetic field attenuation is provided by high permeable enclosure materials and not by the gasket. This is accomplished by designing the enclosure mating surfaces to be in contact with one another to create minimum air gaps in the path of the magnetic flux. At RF frequencies, shape becomes important because inductance is shape related.

Beryllium copper finger gaskets are more effective than BeCu and Monel/SnCuFe wire mesh materials because the BeCu fingers have larger contact surface area, greater cross-sectional area, and lower inductive reactance than the mesh materials. If constructed in the same way, BeCu wire mesh gaskets are more effective than Monel/SnCuFe wire mesh gaskets because beryllium copper has about ten times higher conductivity than Monel/SnCuFe and has unity permeability. Unity permeability reduces the deterioration with frequency which results from skin effect.

Flat spring finger configurations contribute to improved shielding effectiveness because of the greater contact surface area and because each finger acts as two parallel bond straps having a length-to-width ratio of much less than one. The lower the length-to-width ratio, the lower the inductance of the material configuration and the better the shielding becomes. When the length is equal to or less than the width, the bond behaves as a ground plane and the inductance becomes very small. At extremely high frequencies (20-30 GHz), the slots between the fingers begin to permit RF energy transmission through the projected bounded slot configuration. This bounded slot area (A) is extremely small and is determined by the separation distance (D) of the mating surfaces and by the finger slot width (W); i.e., A = D · W. The lowest frequency of transmission is determined by the larger of D and W, and the overall attenuation of the transmitted wave is determined by the overlapping width of the mating surfaces. Regardless of whether D or W is greater, the pitch of the part is many times greater than the slot width, which reduces in-phase RF coupling effects between adjacent slots.

At frequencies over approximately 100 MHz, thin silver-filled elastomer gaskets with a contact area much greater than their largest cross-sectional area and which are subjected to high compression forces provide low impedance bonds between mating surfaces. The resultant RF shielding effectiveness is equal to that of the BeCu spring finger. At extremely high frequencies (20-30 GHz) and above, the spacing between the silver conductive particles begins to permit RF energy transmission through the gasket material. The lowest frequency of transmission is determined by the particle distribution matrix, and the overall attenuation of the transmitted wave is determined by the overlapping width of the mating surfaces.

The relationship between compression forces and shielding effectiveness for the four most popular forms of gaskets is illustrated in Figure 2. Each band represents the shielding variation from the lowest to the highest compression force for a gasket type. In this figure, the Monel and the BeCu wire mesh gaskets have similar construction in order to illustrate the effects of the material. The deterioration at the higher frequencies is a result of the density of the weave. The permeability of the wire mesh material determines the break points that occur at approximately 1 MHz and 10 MHz. The lower attenuation values for the silver-filled elastomer at the lower frequency is a result of the particles being partially insulated by the silicon carrier. The maximum values are determined by the level of silver concentration in the elastomer.

CORROSIVE ENVIRONMENTS

Corrosion is a major problem in electronic systems because the corrosion salts that are produced during electrochemical reactions can be either insulators, which degrade the shielding, or semiconductors, which create unwanted RF signals through nonlinear mixing. This is known as the *"rusty bolt problem."* The three major contributors to the problem are exposed surface area, dissimilarity of materials, and the presence of an electrolyte, usually moisture. Stamped or formed solid metal gaskets have minimum surface area. The surface is non-permeable, and thus does not permit the infusion of moisture. Also, metal is generally not hygroscopic. These characteristics act to reduce but not eliminate corrosion. Solid metal gaskets and wire mesh gaskets can be easily plated with other metals to minimize galvanic corrosion couples. Elastomer gaskets tend to be self-sealing, which reduces moisture infiltration through the edges. This characteristic frequently limits the corrosion to the outer edges of the gasket contact region. Unfortunately, the porosity is a big variable among the different elastomers that are used, and many elastomers permit the infusion of moisture, especially after long-term exposure.

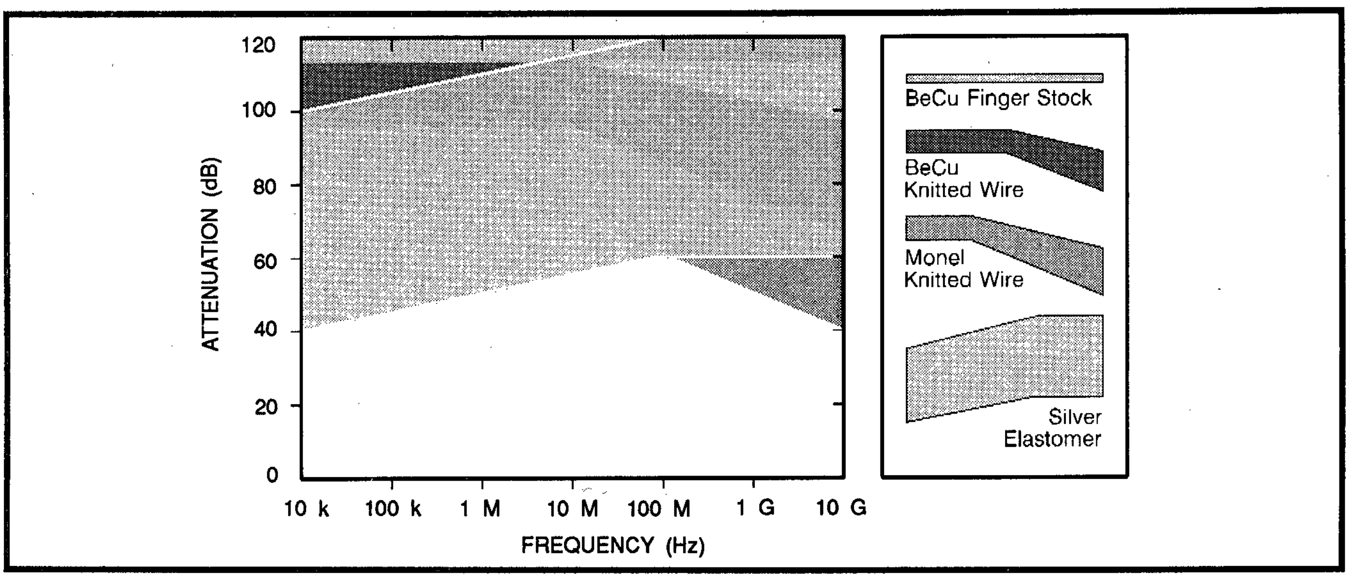

FIGURE 2. *Qualitative Shielding Effectiveness.*

The generally accepted criteria for galvanic compatibility is MIL-STD-1250. Very briefly, this standard does not permit galvanic couples that exceed 0.25 volts. Most commercial applications in a controlled environment will allow up to 0.5 volts. One of the worst possible galvanic couples is that of silver against aluminum, which can range to 0.85 volts. For applications where large contact voltages occur, the more reactive material will be destroyed. To prevent this problem, the gasket material and/or the mating surfaces will need to be plated with a material that is compatible.

SLIDING CONTACT SURFACES

Solid metal flat spring type products can be used in either a shear application or under direct compression. The capability of being used in shear permits the design of a seam at which the solid metal gasket compression forces will be aligned parallel with the mating surfaces of an enclosure. The knife-edge arrangement is an example of such a seam. Direct compression forces are normal to the mating surfaces. There is a distinct advantage to parallel force alignment because it eliminates the requirement for multiple evenly spaced fasteners to maintain the gasket compression. In either case, with a spring finger configuration, shear forces will develop because the shield and gasket surfaces will slide across each other. Since the BeCu surface is very hard compared with the oxidation and/or corrosion films, the gasket and mating surfaces form a self-cleaning contact.

COMPRESSION RANGE

Solid metal BeCu gaskets have a maximum deflection range of approximately 90 percent of their free height, with a usable range of approximately 60 percent. This compares with a 75 percent range for hollow core BeCu wire mesh, a 10 percent range for solid wire mesh, and a 15 percent usable range for solid elastomers. Geometry is not such an important issue for BeCu finger gaskets, but is very important for wire mesh and conductive elastomers. For example, depending upon their shape, conductive elastomer gaskets have deflection ranges from 15 percent up to about 60 percent, with the usable range being approximately half of this value. The elastomer shape considered to be the best trade-off between compression force and compression height is a hollow tube with either a circular or "D" cross-section. With this configuration, 30-40 percent usable deflection can be obtained.

COMPRESSION FORCE/ COMPRESSION SET

Depending upon the configuration, BeCu solid metal and BeCu hollow core wire mesh gaskets typically require compression forces between 3 and 20 pounds per linear foot to establish surface contact and to provide adequate shielding. Monel or SnCuFe wire mesh and elastomer gaskets require compression forces of 15 to 800 pounds per linear foot to achieve shielding effectiveness. The combination of compression force and gasket material characteristics determines compression set.

Compression set forces the user to apply higher compression forces to the gasket after each opening of the enclosure in order to maintain a constant shielding effectiveness value. This results in increased additional compression set during each opening/closing cycle. This compression set cycle continues until the gasket resiliency is lost and the gasket must be replaced.

Depending upon the manufacturing method used, BeCu spring finger and wire mesh gaskets have essentially no compression set. This is a characteristic of beryllium copper and is a function of how the BeCu material was processed and not of its configuration. Conductive elastomer gaskets, particularly the taller configurations, have compression set values in excess of 25 to 35 percent. Monel and SnCuFe wire mesh compression set is about half of the conductive elastomer and ranges from about 10 to 15 percent. Solid metal gaskets made from cold-worked spring materials such as stainless steel, phosphor bronze, etc., have compression set values about half of the corresponding wire mesh value. These range from about 4 to 6 percent.

GASKET WEIGHT/SYSTEM WEIGHT

Unless the design is a spacecraft, the weight of the gasket material used in the design is generally not considered. Most ground based applications would not be concerned with a one to two pound weight savings brought about by selecting a different gasket design. Comparing the different gasket designs, the BeCu solid metal or hollow-core wire mesh gaskets tend to be lighter and weigh only 10 to 17 percent of either Monel/ SnCuFe wire mesh or conductive elastomers. However, the use of BeCu gaskets allows the designer to save more weight overall in the system configuration because the lower mechanical forces of the BeCu gasket permits the use of lighter weight structural materials. That is generally more important than the actual gasket weight savings, especially in airborne and spacecraft applications and applications such as lightweight metal or plastic computer cabinets where fastener withdrawal forces are low.

GASKET BREAKAGE

RF gaskets are electronic components. All electronic components can suffer damage and/or breakage which can limit their useful life. Since RF gasket materials are generally used on movable surfaces where they become exposed to direct physical contact, designers should consider some form of inherent protection for the materials.

Solid metal BeCu RF finger gaskets are very rugged, with a yield/breakage strength of approximately 190,000 pounds/inch^2. Unfortunately, the cross-sectional area is between 0.001 and 0.002 inch^2, which reduces the tensile breakage force to about 190 to 380 pounds for a typical finger. Flexure life is in excess of 50,000 cycles, and any premature breakage of the material is generally the result of a deficient installation design. During use, solid metal BeCu gaskets do not stretch or tear, which prevents misalignment that might otherwise result in breakage. Even if the material breaks, the pieces are large compared with BeCu or Monel/SnCuFe wire mesh and conductive elastomer fragments. Also, the pieces do not splinter.

Wire mesh gaskets made from beryllium copper retain the breaking strength and flexure life of the solid metal gaskets, but the wire strand cross-sectional area is on the order of 0.00001 to 0.00002 inch^2. This reduces the tensile breakage strength per strand to one to two pounds. The lower breakage strength results in increased wire strand breakage which is partially offset by the limited compression range of the mesh gaskets.

Although elastomer gaskets give the appearance of a breakage-free configuration, the application of tensile and compression forces results in the release of the gasket's conductive particles located at the surface. The number of released particles increases over time as a result of the material aging process. During this process the surface of the material, which contains conductive particles, is sloughed.

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Gasket materials for a given application must be selected and positioned after considering what damage can result from broken fingers, broken wire strands, conductive flakes and particles that can be distributed throughout the electronics through natural and/or forced air cooling systems.

CONCLUSION

Shielding is the only suppression technique that does not affect the high speed operation of today's electronic devices. In new equipment designs, shielding should be used in conjunction with or after circuit suppression, isolation, and desensitization measures have been implemented. For existing off-the-shelf items, shielding can frequently be used as a solution to the interference problem. In any case, the shielding effectiveness primarily depends upon the number and configuration of discontinuities in the shield.

RF gaskets are used as seals for removable discontinuities. The four major types of gasket configurations used in today's systems and enclosures are beryllium copper (BeCu) spring fingers, beryllium copper (BeCu) hollow tubular wire mesh, Monel/SnCuFe solid wire mesh, and silver-filled conductive elastomers. Each offers advantages to the designer in specific applications but requires that the designer be knowledgeable about the gasket and its position and environment in the end product.

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