Shielding the Case

Design for Compliance

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Shielding may be used as the primary method of emissions control or combined with board-level measures. A command of shielding techniques requires knowledge of how shields function and of the characteristics of the different materials available.

How Shielding Works

A shield's performance is due to reflection and absorption. At the shield's surfaces, there is an impedance discontinuity, which reflects impinging electrical fields back to the shield's interior. Inside the shield, the field is attenuated by the same mechanism that causes the skin-depth effect. Finally, additional reflections occur at the shield's boundary.

The relative strengths of these effects depend on the material used, the shield geometry, and the characteristics of the internal radiating source. The shield material's primary variables are conductivity, permeability, and thickness. The source variables include the frequency of operation and the source composition.

The source composition affects the details of how a shield works because the shield is electrically close to the source — that is, in its near field, where the detailed source structure determines whether the fields impinging on the shield are primarily electrical or magnetic. In the far field (say, more than a meter away at 30 MHz), the details of the source are unimportant; the radiated fields are electromagnetic and nearly planar, consisting of coupled electrical and magnetic fields. Closer to the circuitry, however, electrical fields will predominate for the di-polar elements, and magnetic fields for the current loops. The actual shielding provided by a metal barrier will depend on which type of field predominates. Reflection does not affect predominantly magnetic fields, although it is highly effective against plane waves and electric fields. Absorption is the mechanism required for magnetic-field attenuation.

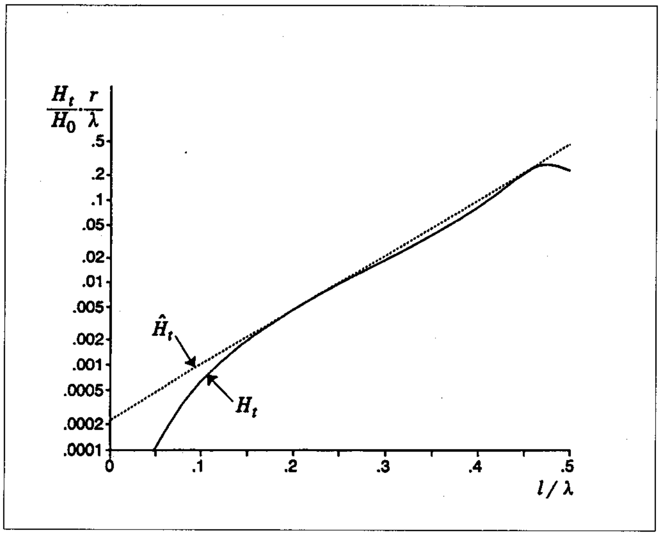

FIGURE 1: The field radiated from an otherwise shielded box is a function of the slot's electrical length and the distance away from the slot. This figure shows the ratio of the transmitted field outside to the field incident on the slot. Shielding effectiveness deteriorates rapidly as slot size approaches one-half wavelength.

Shielding with Metal

If a metal shield is used, the details of the source and the shield material are relatively unimportant in most commercial applications, because the ultimate shielding capability of a seamless metal enclosure is far greater than required. However, it is vital to pay attention to the details of the shield's construction. Digital hardware is not enclosed in seamless enclosures; rather, it is placed in boxes that have seams, cracks, and openings for access or ventilation. These apertures act like radiating antennas, limiting shielding effectiveness.

The nature of aperture radiation can be modeled as an antenna of the same shape and size as the aperture, driven by the energy incident on the aperture. Because longer antennas produce lower resonance, longer cracks and seams are resonant at lower frequencies. Breaking up a seam into smaller apertures makes it an array of smaller antennas and cuts its ability to radiate at low frequencies. The resonant frequency of such a slot antenna is inversely proportional to its size, and emitted signals are polarized along the dimension of the slot or seam.

Fortunately, most emissions from computing equipment are concentrated at frequencies below 300 MHz. At these frequencies, the wavelength is relatively long, 1 meter or more. Apertures shorter than 10% of the wavelength, 10 cm or so, are simply too small to be effective antennas. As a general rule, keeping the size of slots or apertures shorter than a few inches will yield satisfactory performance. Larger vents can be covered with screens made of any metal that will break up the aperture to sizes smaller than one-quarter square inch. Doors can be broken up with contact points every few inches along their length. For computers using clock frequencies exceeding 100 MHz, harmonics approaching one gigahertz are still quite strong, and more extensive gasketing and shielding will be needed.

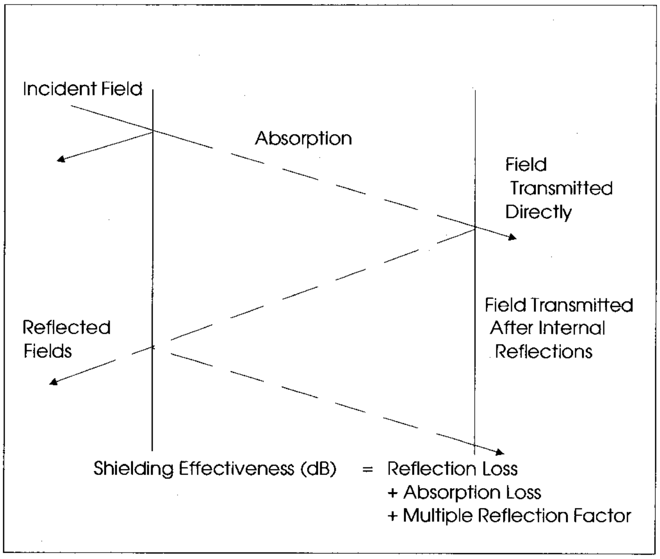

FIGURE 2: Components of shielding.

Practical problems surrounding methods of shielding often concern the more mundane problems of metal compatibility. Chassis are usually made out of steel or aluminum, but steel rusts and aluminum forms a tenacious insulating oxide. Both materials must be covered with a protective coating. Steel is usually run through a phosphate bath before painting, while aluminum is usually anodized. Anodizing is nonconductive, and in order to make contact, it will be necessary to break through the coating. Some coatings that are billed as conductive are in fact conductive only under certain circumstances; for example, black zinc is not conductive and forms a thin surface of nonconductive material. In general, black zinc will not allow a reliable contact when materials are merely pressed up against each other without significant force being applied. If the coating is too thick, which often shows up as a dark colorization or a rainbow-colored surface, a light pressure contact will not provide reliable conductivity. It is best to break through the surface with a positive contact, either a lockwasher, a screw, or pop-rivet.

Almost any type of screening that won't corrode is suitable for vents. Hardware cloth or stainless steel screen are both effective.

Finally, in designing the metalwork of the case, keep in mind that grounding points must be accessible for I/O cables and bypass capacitors. These grounding points will need to be near the point where the I/O cables exit the chassis. A little forethought can make for great savings if flanges and grounding brackets are placed near cable exit points to provide convenient mounting of shielded cables and bypass capacitors.

Using Coated and Conductive Plastics

Plastic is virtually transparent to RF emissions. To shield or provide a chassis ground, it has to be coated or loaded with some conductive material. Conductive paints and sprays are widely used, and conductive plastics are now being introduced.

Nickel acrylic-based sprays are the most common conductive coatings. They offer the advantage of low cost and can be applied with conventional paint sprayers. Although they have inherently higher resistivity than some other kinds of coatings, they can provide 20 to 30 dB of shielding if properly applied. Carbon paints are even less expensive, but their higher resistivity usually makes them ineffective in shielding applications. Keep in mind that conductive coatings may be of only marginal help when the emissions are from another source, such as the I/O cables.

Silver- and copper-based paints are also sometimes used. Silver paint works extremely well, but its cost precludes its use in most applications. At one time, it was difficult to maintain a stable conductive coating with copper. In recent years, however, several manufacturers have produced viable copper-based paints. Their resistivity and shielding effectiveness are generally superior to those of nickel paints but not as good as those obtainable with silver.

While acting as a reasonably good Faraday shield, the coating created by nickel acrylic paint is of high enough resistance that it is not especially good for grounding purposes. Nonetheless, if other means have been used to reduce emissions from the PC board and the I/O cables, and direct emissions are still a problem, nickel acrylic paint can offer an inexpensive, easy-to-use solution. (With nickel as with all paints, compatibility between the paint solvent vehicle and the plastic substrate is essential. It is also a product-safety requirement of UL and other agencies.)

Zinc arc sprays offer higher conductivity and better attenuation than nickel-based paints. They are usually applied by an arc flame spray process, or else the zinc is vaporized and sputtered onto a plastic surface. The grayish coating serves as a good surface for grounding shielded cables and bypass capacitors as well. The disadvantages of zinc arc coatings are that they roughen the surface, are often difficult to apply, and can be hazardous in their vaporized state. Well-trained technicians and careful adherence to OSHA practices are mandatory.

One of the oldest methods of metallization is the vacuum process used to coat soda bottles to make them shiny. Aluminum is usually used, but it is a temperamental metal and forms a thick oxide. Screwing or bolting to the surface can be difficult, since the coating is so thin that it will be worn away by the bolting action. A pressure contact will remain conductive only for a few hours or days and then will become nonconductive as the aluminum forms an oxide. For these reasons, thin layers of vacuum metallization of aluminum should be avoided. However, coating the aluminum with a second layer, such as nickel, can result in an effective shield.

Electroless plating is a recent addition to the family of conductive treatments. In electroless plating, a thin layer (of the order of 50 millionths of an inch) of metal is electroplated onto the plastic surface. The plating leaves the plastic components covered with a thin but extremely conductive layer of pure metal, and the levels of shielding obtainable are limited more by the details of the case construction, such as seams and openings, than by the coating characteristics.

An emerging technology of great promise is conductive plastic. Although this technology was unreliable at first, early bugs seem to have been worked out. The most common form of conductive plastic embeds conductive fibers or particles in the plastic, but usually, these do not reliably reach the surface, as can readily be checked with an ohmeter. Thus, in order to make contact to the conductive plastic, ultrasonically embedded metal inserts must be used.

A recent development by 3M makes the surface of the plastic conductive by melting a layer of metallic fibers carried in a cementing polymer onto the inner surface of the plastic during thermoforming. Although this is a surface layer, it is thermally incorporated into the plastic. The conductive surface can be accessed without the use of inserts, and there is no overspray problem.