Shielding Magnetic Fields

Electromagnetic interference (EMI) disrupts the operation of electrical and electronic equipment, creating malfunctions and faulty readings. It can wreck havoc with instruments, control systems, data-processing equipment, and communications networks. Thus, EMI poses a significant challenge to equipment designers in a world that depends on electrical and electronic devices.

The proliferation of electronics has driven the development of more effective shielding against EMI over a broad range of uses. The more critical and sensitive the equipment, the more important is the need to shield it. Although the basic technology for protecting equipment from the effects of EMI has not changed in the past 50 years, design innovations have resulted in smaller and lighter shields that are the key to today's advanced applications.

EMI shielding is found today in deep space and in innumerable devices in the home, office, laboratory, and factory. Throughout the nation's venture into space, civilian and military satellites have had their sensitive instruments and communications systems protected—beginning with Explorer 1, the first U.S. Earth-orbiting craft, which discovered the Van Allen radiation belts that exist as a result of Earth's magnetic field. EMI shielding is also used aboard U.S. Navy submarines to protect navigation systems, and in applications such as heart monitors, cellular phones, credit-card and check readers, automobiles, and "smart" house-control networks. Indeed, anywhere electronics can be affected by EMI, shielding is needed.

Yet, despite the ubiquitous presence of EMI, many physicists, engineers, and other technologists find themselves puzzled by its basic elements and the shielding materials that protect electronic equipment from it. Therefore, here are basic answers to the most frequently asked questions about EMI and the problems it poses. They provide a quick refresher course in some of the facts about magnetic shielding today.

What is a magnetic field?

A magnetic field results from a source of magnetic flux, the term used to describe the total amount of a magnetic field. The source of a magnetic field might be Earth, a motor, a transformer, an electric-power line, or even a bar magnet. Magnetic fields make transformers and motors function, and they have many other practical applications, including magnetic resonance imaging, which now plays a major role in medical diagnostics.

What is the difference between dc and ac?

Direct-current fields are static. They do not vary or, perhaps, they change only slowly. A dc field might come from Earth, a permanent magnet, or a coil carrying direct current. Alternating-current magnetic fields oscillate in direction at a frequency. The most common ac magnetic fields are the 60-Hz fields emitted by electric-power tools. Other common examples of ac magnetic fields are those emitted by electric-arc furnaces and electric-power generating and transfer stations.

What is ELF?

ELF stands for extremely low frequency and usually refers to magnetic fields at 0.5 to 100 Hz. This range includes the 60-Hz power lines commonly used in the United States to carry electricity into homes. In other countries, the frequency of such power lines might be 50 Hz. ELF fields are also generated by portable generators and small electric motors.

How are fields measured?

We can sense magnetic fields with measuring instruments called gaussmeters. The units for measuring magnetic fields are the gauss (G) and oersted (Oe). Magnetic flux density is measured in gauss, whereas magnetic field strength is measured in oersteds. The ratio of magnetic flux in gauss to magnetic field in oersteds in a material is defined as permeability (μ), which is a measure of the properties that allow a material to absorb a magnetic field. The ratio is high for ferromagnetic materials, ranging up to 100,000. In air, however, μ is 1, making gauss and oersteds numerically identical. This can create confusion, because it leads many people to assume that gauss and oersteds are interchangeable. The International System of Units uses the metric system and replaces gauss and oersteds, respectively, with tesla and ampere-turns per meter.

What blocks magnetic fields?

Nothing. There is no known material that totally blocks magnetic fields. They can only be redirected away from the objects you want to protect.

How does magnetic shielding work?

All EMI shielding materials are manufactured from high-permeability alloys that contain about 80% nickel; the alloys vary in the composition of their remaining metals. They are usually fabricated as foils or sheets and are baked at 2,000 °F in a dry hydrogen-rich atmosphere to anneal them. Annealing significantly improves a material's attenuation, that is, its ability to absorb and redirect magnetic fields.

A shielding alloy works by diverting a magnetic flux into itself. The alloy redirects the magnetic flux away from the sensitive object and returns it to the north–south field. Although the field from a magnet is greatly reduced by a shield plate, the protective alloy itself is attracted to the magnet, but with no ill effects. Closed shapes are the most efficient for magnetic shielding—cylinders with caps, boxes with covers, and similar enclosed shapes are the most effective (see figure).

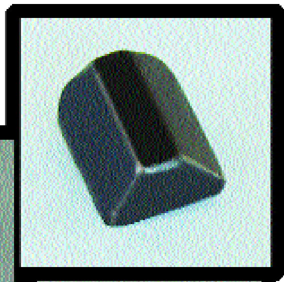
Magnetic shielding materials offer a very-high-permeability path for magnetic field lines to travel through, directing them through the thickness of the shielding alloy and keeping them from going where they are not wanted. It is important that the shield should offer a complete path for the field lines, so that they do not exit the material in a place where they will cause unintended interference.

What is the difference between RF shielding and magnetic shielding?

Radio-frequency (RF) shielding is required when it is necessary to block high-frequency (100 kHz and above) interference fields. RF shields typically use copper, aluminum, galvanized steel, or conductive rubber, plastic, or paints. These materials work at high frequencies by means of their high conductivity. Unlike magnetic shields that use their high permeability to attract magnetic fields, RF shielding has little or no magnetic permeability. However, when they are properly engineered and constructed, magnetic-shield alloys become broadband shields that protect against both EMI and RF interference.

How is attenuation defined?

The attenuation of a magnetic shield is the ratio of the measured magnetic field before shielding to the measured field after shielding is applied. For example, if the field before shielding is 450 mG, and the field measured inside the shield is 10 mG, the attenuation is 450 divided by 10, or 45 times. Attenuation is sometimes expressed using decibels (dB) as the unit of measurement. The ratio in decibels is 20 times the logarithm (base 10) of the shielding ratio.



In the above example, the ratio is 20 × log 45, or 33 dB.

How do I solve a magnetic shielding problem?

One of the most important steps in dealing with EMI is to define the strength and source of the magnetic field. This is best accomplished by surveying the affected area with a gaussmeter, which provides an accurate reading of the field's strength as you move the device through an area. This, in turn, enables you to map the physical size, strength, and source of the magnetic field.

With this information available, you can proceed. Shield-calculation formulas do exist, but they are usually valid only for theoretical conditions of closed shield shapes and well-described interference fields. Sometimes, off-the-shelf shielding can cure EMI problems, but often the solution requires fabricating a prototype shield. This procedure allows you to immediately see the effect of the shielding on the item under test and to then optimize the shield's thickness and shape. Foil shielding is generally preferred for prototype and laboratory-evaluation projects.

Is it better to shield the source of interference or the sensitive device?

The answer to this question depends on several factors that affect cost. If you need to protect against EMI from only one source, say a power box on the wall, it may be less expensive to shield the source of interference. However, shielding the source may involve stronger fields, and, therefore, require thicker and more expensive materials. In addition, all interference sources must be shielded, or the sensitive device will still be affected. So the usual approach is to shield the sensitive device, which will prevent interference from both present and future sources.

Does cutting a shielding alloy destroy its properties?

Modern, vacuum-refined alloys have a low sensitivity to shock and normally can withstand regular handling without a significant loss of properties. Cutting by shearing, electric-discharge machine, water jet, photochemical etching, or die press typically affects only the alloy immediately adjacent to the edge. The rest of the shield will exhibit normal shielding performance. If the alloy had already received its final magnetic anneal, reannealing should not be necessary.

Shielding sensitive instruments and other objects from EMI is a common problem facing millions of users of such items as semiconductor circuits, medical monitors, magnetic compasses, modern automotive systems, and mobile phones. EMI, for example, creates “the jitters” that frequently afflict cathode-ray-tube (CRT) monitors, and most nontechnical users probably never realize what causes the problem. The jitters—the slow movement of an image on the screen, also called swimming, hula, or shimmy—is due to the interaction of an external magnetic field with the sensitive components of the CRT. A building’s electronic infrastructure, or simply adjacent electronic equipment, can cause the problem without anyone being aware of its source. To eliminate or reduce the jitters, CRT makers enclose monitors in a housing made from a magnetic shielding alloy.

Sensitive electronic devices are being introduced into almost every facet of our daily life. They enrich our ability to work and be more productive. As this trend continues, the need to shield electronic systems will grow. EMI has always been an area of some mystery. The fixes are not standardized. Effecting a cure often requires ingenuity and experimentation on an individual basis.

Further reading

Carr, J. J. The Technician’s EMI Handbook: Clues and Solutions; Newnes: 2000; 256 pp.

Gnecco, L. T. The Design of Shielded Enclosures: Cost Effective Methods to Prevent EMI; Butterworth-Heinemann: Woburn, MA, 2000; 204 pp.

Mardiguian, M. EMI Troubleshooting Techniques; McGraw-Hill Professional Publishing: New York, NY, 1999; 300 pp.

Morrison, R. Grounding and Shielding Techniques; John Wiley & Sons: New York, NY, 1998; 216 pp.

B I O G R A P H Y

Arnold H. Green is manager of sales and marketing for Magnetic Shield Corp. in Bensenville, Illinois (agreen@magnetic-shield.com).