ARCHITECTURAL SHIELDING

Architectural shielding is an efficient and cost effective approach to protect electronic systems from EMI.

FREDERICK L. HELENE, EMC SCIENCE CENTER, INC., WEST CONSHOHOCKEN, PA

INTRODUCTION

As the automation of military command, control, communications and intelligence systems continues to expand, the need for shielding facilities to house these systems gains increased importance. In addition to military considerations, the increasing numbers of sophisticated sensitive electronic equipment in government facilities, hospitals, radio stations, television stations, and testing chambers has brought the subject of electromagnetic interference/radio frequency interference (EMI/RFI) shielding to the forefront of the architectural design community. Electromagnetic shielding of a facility involves the complete enclosing of an area within a continuous metal enclosure. The metal enclosure may be free-standing, attached to structural walls, integrated into existing walls, or sprayed onto structural walls.

The basic purpose of EMI/RFI shielding is to attenuate electromagnetic waves, which consist of two oscillating fields at right angles. One of these fields is the electric (E) field, while the other is the magnetic (H) field. In many cases, shielding a facility from electromagnetic waves is necessary to:

- Protect electronic equipment from destructive outside interference
  - High power transmitters (Radar, FM)
  - Nuclear effects-electromagnetic pulse (EMP)
  - Lightning
- Prevent the interception of classified military or industrial information through espionage.
- Protect electronic circuitry from electromagnetic energy that may cause temporary equipment malfunctions.
- Protect humans from hazardous radiation environments.

The goal of architectural shielding is to incorporate building materials within a structure that will protect the contents against the harmful effects of EMI/RFI.

DEFINITIONS

In order to adequately discuss design concepts for electromagnetic shielding of buildings and facilities, it is first necessary to provide an understanding of basic shielding terminology, definitions, methodology of shielding calculations, and analysis and measurement techniques for determining the effectiveness of the shielding employed.

An electromagnetic shield can be defined as any barrier which reduces the level of the electromagnetic field. How well the shield reduces (attenuates) the field is referred to as its shielding effectiveness (SE). The standard unit of measurement for shielding effectiveness is the decibel (dB) where dB is expressed as the ratio of two values of electromagnetic field strength, and where field strengths are compared before and after the shield is in place.

Shielding Effectiveness (SE)=
$$20 \log E_1 E_2$$

where

E_1 = field strength with no shield and

E_2 = field strength after imposing a shield.

For example, if the electromagnetic field measured 10 volts at a frequency of 10 MHz at the outside of the shield and 1 volt at the inside surface of the shield, the SE of the barrier would be

$$SE = 20 \log 10/1 = 20dB.$$

As stated previously, "The electromagnetic shielding of a facility involves the complete enclosing of an area within a continuous metal enclosure. The metal enclosure may be free-standing, attached to structural walls, integrated into existing walls, or somehow sprayed onto structural walls." The overall shielding effectiveness of any structural shroud will depend on the particular type of electromagnetic energy being emitted and the particular metal selected as the shield material.

For purposes of this article, three types of electromagnetic waves will be considered as emitting sources. One is an electric field (E-field), the second is a magnetic field (H-field), and the third is the plane wave. Basic E-fields are generated by high impedance voltage-driven circuitry, while H-fields are generated by low impedance current-driven circuitry. When an electromagnetic wave encounters an enclosing conductive material, the portion of the wave transmitted beyond the shielding barrier is reduced in magnitude by both reflection and absorption by the shielding material. The reflection loss occurs at the two interfaces between the transmitting medium (air) and the shielding material (usually a conductive metal). Absorption takes place as the wave passes through the conductive material. Reflection losses occur due to the wave impedance mismatch between the propagating medium and the conductive metal. Absorption losses occur from dissipative heat loss caused by currents induced in the conductive material as a result of the electric and magnetic fields of the wave passing through. The relationship for shielding effectiveness of a conductive material may be expressed as

E-field

$$R_{dB} = 322 - 10 \log_{10} (\mu_r/6_r)r^2f^3$$

H-field

$R_{dB} = 15 - 10 \log_{10} (\mu_r/6_r)1/r^2f$

Absorption

$A_{dB} = 3.334(t_{in})(\mu_r 6_r f)^{1/2}$

where:

μ_r = relative permeability (1 for air)

6_r = relative conductivity (1 for copper)

r = distance from source of electromagnetic energy

f = frequency in hertz, and

t_{in} = material thickness in inches.

These equations yield values of theoretical shielding effectiveness for an infinite sheet of solid shielding material. The theoretical values obtained could appear to yield shielding effectiveness values in excess of 100dB. However, a shielding building/facility with no openings or penetrations is not a reality. The obtainable shielding effectiveness for a facility will be severely limited by door closures, wall/corner seams, and penetrations (water, air). In addition, cracks in welds/solder joints, corrosion of seam metal-to-metal mating surfaces, and shield penetration by fasteners, such as screws, nails, and rivets, add to shielding effectiveness degradation.

CONSIDERATIONS

There are numerous approaches to possible design techniques, each of which presents its own set of questions. The following general questions should be answered for each approach.

- What is the inherent shielding effectiveness of various standard building designs and structures?
- What are their relative costs?
- How can standard designs be modified via construction methods to improve shielding effectiveness? What are the additional materials and costs?
- What materials are available for magnetic field, electric field, and plane wave shielding? What are the relative costs for the materials?
- What are the various methods of installing shielding materials? How can penetrations be best implemented without undue compromise to the shielding? What are the relative costs?
- How should vents (heat and air conditioning), plumbing, and other openings be treated? What shielding method should be used? What are the relative costs?
- How should power and signal cabling be accomplished? Where should filtering be used and how much? What are the cost reducing factors?
- How should joints between wall panels, wall-to-ceiling/ceiling-to-roof, wall-to-floor be treated? How does this vary depending upon shielding effectiveness, frequency range and cost?
- What factors (i.e., humidity, temperature-environmental conditions) affect the life cycle of the shielding design?
- How can life cycle be estimated, and what are the cost trade-offs?
- How effective are new shielding materials, such as conductive coatings and wire/fabric meshes, and what are their applications? Are they cost effective?
- How should doors be designed to obtain shielding effectiveness goals?
- How should windows be designed to obtain shielding effectiveness goals? Will these windows provide actual inside/outside visability or only light transmittivity?
- Can conductive caulking be used to seal window and wall seams? Can conductive epoxies be used? If so, where?
- What materials providing both magnetic and electric field shielding (i.e., joints, corners, seams) are easiest to work with?
- Can wire mesh (copper, aluminum, steel) be used for wall shielding in place of foil sheets and yield required shielding effectiveness figures? What characteristics (percent open, weave contact, etc.) should the mesh have?
- Will mesh material be too difficult to work with (i.e., joints, corners, seams)?
- On straight wall areas, where foils might be used, is there a minimum foil thickness that must be used for "workability"?
- How are seams to be jointed? How much overlap must be used for seams where foils are used? How much overlap for mesh?
- What level of shielding effectiveness is possible using each listed approach? What are the relative costs and related reliability?
- In the event that adhesives are used to attach foils or meshes to wallboard or concrete, what are the characteristics of the adhesives with respect to adhesion strength, tensile strength, dielectric strength, electrolytic corrosion factors, and temperature characteristics? What are their longevity and relative costs?

Judicious consideration of the questions can result in tabulated results showing:

Shielding effectiveness of various materials and methods,

Cost (labor and material) of various methods, and the

Life cycle of various materials and methods.

In the design of a shielded building or facility, many different shielding methods can be considered. The amount of shielding effectiveness versus frequency will, to a great extent, determine what types of shielding materials and techniques need to be used.

EXAMPLES

There are several companies presently involved in the fabrication of materials for architectural shielding. A complete listing of these companies would be impractical. The following information is supplied to illustrate what is available.

One company offers a copper armored sisalkraft, which consists of a sheet of 3-ounce pure copper tri-directional fiberglass scrim, and heavy-duty extensible kraft that are laminated together with a specialty plastic. The copper is a conductive metal that offers good shielding effectiveness. The scrim imparts good physical strength to the product which enables it to withstand construction job site abuse. The heavy-duty kraft enables the product to adhere to walls, ceilings, or floors without fastener penetrations via a wallboard adhesive. The shielding effectiveness of the system as measured against MIL-STD-285 is in the magnetic wave region, 45dB at 10 kHz to 68dB at 200 kHz, while across the entire electric and plane wave regions, the material yields a minimum attenuation of 100dB. The shielding effectiveness of 3-ounce kraft seamed with solder-seal copper seaming tape is equivalent to that of full-width unseamed copper; thus, the seams do not compromise the shielding effectiveness of the system. (The above figures are based on information obtained from the manufacturer.)

Other companies have recently developed EMI/RFI shielding foil for architectural applications, as well as for shielding existing sites. Foils can be engineered to shield electrical and magnetic fields for low performance specifications up to, and surpassing, MIL-STD-285 testing requirements. The foil can be attached to existing room walls as well as new construction gypsum walls. Seaming is accomplished via solder techniques to ensure shielding integrity equal to that of unseamed foil. It is lightweight, and application through standard construction practices makes this foil product attractive for shielding large installations.

SUMMARY

Several composite metals combining conductive and magnetic alloys (e.g., aluminum-clad steel) have been developed and tested. The composite metals provide effective shielding through a combination of magnetic reflection, absorption within the metal, and conductive reflection. This type of shielding material provides excellent (80dB) shielding effectiveness figures for low-impedance (magnetic) fields in the dc to 10 MHz range. The materials also provide excellent shielding for electric and plane waves.

The search for cost effective architectural shielding design and fabrication techniques which can be used for designing structures requiring overall building shielding or internal facility shielding for new or existing buildings will continue. Specific materials and construction methods should be identified for walls, ceilings, roofs and floor construction. The methodology for barrier penetrations such as doors, vents, windows, power and signal cabling, and plumbing must also be developed.

Basic research should be performed to identify and to evaluate shielding methods and material available for electric field, magnetic field, and plane wave shielding covering the frequency of 10 kHz through 20 GHz. Shielding effectiveness should be categorized by degrees, e.g., 20-40dB, 40-60dB, 60-80dB, and above 80dB, including the inherent shielding effectiveness of standard construction designs. Provisions required for EMP, TEMPEST, and other unique requirements should be included. Cost trade-offs should be calculated, analyzed, and documented, and should consider shielding level, electromagnetic field characteristics, frequency range versus life cycle and reliability for the various shielding methods.

The need for architectural shielding will not diminish in the future. Military development and commerical needs will continue to expand. Electronic equipment will continue the trend towards more complex and sensitive systems. In response, the need for electromagnetic shielding of buildings/facilities will clearly continue to grow. ■

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