EMI/RFI Shielding

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INTRODUCTION

Many electronic devices, potentially emit electromagnetic radiation in the frequency range from less than 60 Hz to more than 1000 MHz. When this radiation reaches another electronic equipment, it interferes with its normal functioning. This is generally referred to as Electro Magnetic Interference (EMI). While EMI refers to the complete frequency spectrum, Radio Frequency Interference (RFI) refers to a small portion of EMI in the frequency range of 0.01 to 1000 MHz. These two terms are often used interchangably.

EMI is not a recent problem. This scientific phenomenon was observed even by the turn of the century. When Nikola Tesla erected a gigantic transmitter in Colrado Prairies, the distant electrical generators were blown off because of EMI.

In recent years, the problems of EMI/RFI have become more serious because of the following reasons:

1) Electronic devices have become more and more complicated, more abundant and more sensitive. A large number of devices are packed in a small space. Even if each device gives off only a small amount of radiation, the total amount of radiation from the whole system becomes considerable. Moreover, high speed, miniaturized, electronic systems are highly sensitive to interference.

2) Design engineers prefer plastic cabinets over metal housings because of some inherent advantages. Plastic cabinets are generally 30 - 50% less expensive and also provide aesthetically pleasing packing and design flexibility. Though plastic cabinets provide physical protection including fire resistance, they do not protect electronics from EMI.

Because of the rapid proliferation of electronic devices amongst masses as well as in high tech applications, the problems of EMI/RFI have increased so much that this is considered as a form of environmental pollution. Since EMI is not selective, it afflicts all applications of electronic devices - medical, business, computers, consumer items, automotive, military etc. Some common sources and receptors of EMI are listed in Table 1. Thus electronic noise caused by EMI can lead to malfunctioning of simple household appliances, or can seriously affect diagonisis of human disorders, or can misguide a missile or can completely erase critical computer information. Since the consequences of EMI can be disastrous, shielding of electronic from EMI/RFI becomes very essential.

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Table 1

Common Sources and Receptors of EMI

Sources	Receptors
Television and Radios	CB receivers
Radar transmitters	Remote-control units
Video cassette recorders	Sensitive test instruments
TV games	Telephones
CD transmitters	Microprocessor containing equipment
Electric Motors	Radio and television recievers
Relay and circuit breakers	Cardiac pacemakers
Engine ignition systems	Computers and large calculators
AC power - line leakage and corona	Navigation equipment
Induction heating units	Audio and high - fidelity equipments
Paging systems	Cash registers
Electronic calculators and Computers	Duplicating equipment
Static electricity	
Remote - control units	
Mobile communication transmitters	
Arc welders	
Electrical appliances	
Lighting	

Federal Communications Commission (FCC) of USA promulgated strict laws and ordered that all digital electronic products that generated or used frequencies between 10KHz to 1000MHz should comply with the regulation of FCC. Other countries as West Germany and Japan also have instituted very stringent regulations. Because of these strict regulations, designers and manufacturers of electronic systems take all necessary primary & secondary measures for shielding the electronic items against EMI.

Measuring Shielding effectiveness

A common method of measuring the shielding effectiveness of a system is to measure the level of attenuation in decibels (dB) needed to provide protection to the system. Attenuation is a function of both electrical conductivity and absorption of the shielding material at various frequencies.

Shielding efficiency is calculated as follows:

$$dB = 20 \log_{10} \frac{E_1}{E_2}$$

where E refers to electric field strength in volts/meter. E_1 is the field strength before the shield is installed while E_2 is the strength after the shield is installed.

Since decibels is logarithmic term, the

Table 2

EMI/RFI	shielding levels
0 - 10 dB	Just barely shielding
10 -30 dB	Minimal level of shielding. Can be used on non - sensitive and low power equipment.
30 -60 dB	Average level of shielding; Is appropriate for moderate levels of EMI/RFI shielding.
60 -90 dB	Better shielding; used to eliminate severe EMI/RFI problems. Special equipment design is needed at this level for effective protection.
90 -120 dB	Maximum level of shielding available. Used in high power and extra sensitive equipment.

figures should be carefully interpreted. A shielding efficiency of 40 dB should not be considered twice as good as 20 dB. It is actually 100 times as good. Every difference of 10 dB between coatings actually means an order of magnitude difference in shielding efficiency. EMI/RFI shielding levels required in different applications are given in Table 2.

Protecting equipment from EMI/RFI

EMI/RFI may be transferred to and from a given electronic systems by two mechanisms

a) Conduction and b) Radiation

Conducted emissions may pass through power, signal or control leads entering or leaving a system. To control conducted EMI, devices like filters, ferrite beads, and the like are generally used.

Radiated emissions may be prevented by

1) Shielding the internal electronics either individually or collectively by the use of metal enclosures, faraday cages etc.

2) Metallizing the cabinet if it is plastic, since plastics themselves have no intrinsic value.

Because of large volume usage of plastics in electronic systems (Table 3), various metallising procedures are being evolved to reduce the EMI.

Table 3

Where Coated Plastics are used for EMI/RFI shielding

Business Machines
Computer housings
Word processors
Cash registers
Connectors
Printers
Airframe
Structural composites
Aerospace
Avionics navigation equipment
Missile and space electronics.
Industrial Applications
Electric motors
Control devices
Microwave components
Automotive
Microelectronic devices
Antiskid braking systems
Radios
Communication
Cellular phones
CB radios
Junction boxes, relays
Paging systems
Video dishes.

EMI Shielding Methods

Plastic cabinets can be made conducting by making the plastic inherently conducting (which are commonly known as conducting plastics) or by a variety of metallization techniques. Though conducting plastics (ie. plastics filled with metallic particles or fibres to make them conductive) may appear superficially attractive, they are still costly and can cause major problems if tool wear in moulding. Accordingly they are less used today but may become the

ultimate solution to the problem of EMI tomorrow. Though, a variety of metallization techniques are available, only sprayed zinc, vaccum metallising, conductive paints, and electroless plating are commercially popular. Electroless plating may take off in the future.

1. Zinc Arc/Flame Spraying

In this method, zinc is deposited on the prepared substrate by flame or arc spray methods. In most common zinc arc spray, two metal wires are fed through an electric arc. Here the metal melts and the melted metal is subsequently sprayed on the part. Flame spray involves a metal powder or wire which is melted by contact with superheated inert gas. With a special spray gun the melt is atomized on the part. Flame or arc sprayed zinc coatings provide good conductivity and is effective over a wide frequency ranges. Thickness of the order of 2 mils are generally recommended for this application. Shielding efficiency is 60 - 120 dB for the frequency 1 - 1000 Mhz. Howèver, coatings produced by this method are not adherent and as a result, metal coating flakes off and falls on the electronic components underneath, leading to unnecessary complications in the systems.

2. Conductive coatings

Conductive coatings are composed of metal particles suspended in an organic resin. When the solvent evaporates, a thin layer of resin and metal remains to form the shield. The resins which are recommended for this type of application are polyurethane, acrylics and to some extent epoxies. Silver, copper, nickel and graphite powders are effective fillers. Coatings are applied with conventional spray equipment.

Effectiveness of the conductive coating depends upon several factors - such as a) conductivity of the inorganic filler material b) thickness of the coating c) adhesion d) ability to survive environmental conditions and e) oxidation of metal powder particles in the film. The above factors should be taken into consideration while formulating the conductive paint. The right proportion of metal particles and solvent is required so as to get high enough particle loading without sacrificing application properties and endurance in service. A dry film thickness of 2 to 3 mil is optimum Generally shielding effectiveness of 30 - 60 dB across 10 KHz - GHz is obtained with 2-3 mils of coating. Excess coating thickness results in wastage of material and also leads to cracking.

Among the coating containing different metal fillers, silver containing coatings provide superior shielding and environmental stability. Shielding can be as high as 70 - 80 decibels. But, because of the high cost of silver, this type of coating is used only in rare applications requiring extreme shielding not achievable by other methods.

Copper has good conductivity but this is not environmentally stable. It has a tendency to oxidise upon aging Therefore shielding efficiency is good initially but lose their shielding properties when exposed to the environment during use. R & D efforts have been made to improve the environmental stability of these coatings. To a large extent, these have resulted in successful new technologies. Neverthless copper containing coatings have not been used in great volume.

Nickel is the most commonly used filler, though it is not quite as conductive as silver or copper. Nickel has less tendency to corrode and oxidise. But it is to be properly treated by heat or chemical means so as to stabilise to withstand stress and to make it very stable upon aging.

Nickel filled coatings are commercially popular because it is an economical shielding method for a majority of plastic enclosures.
Graphite dispersed coatings are generally used against electrostatic discharge because of lower conductivity and lower

shielding capability. It can be used for some low power applications. The environmental stability of the coating is very good.

3. Vaccum metallizing

In vaccum metallizing process, the metal is vaporised in vaccum and the vapour atoms condense on the substrate and form the metal coating. In other words, it is a simple evaporation - condensation process.

Vaccum metallizing process strikes a balance between the advantages and drawbacks. Thin adherent coatings (0.5 - 1.5µm) can be produced by vaccum metallizing process, but it is a capital intensive tool and the coating often requires an undercoat to promote adhesion and a top coat to provide protection against abrasion, oxidation etc.

For this application, vaccum metallized aluminium coatings are generally recommended to provide the necessary conductivity. Multilayer coatings of Cr-Cu-Cr or Cr-Cu-S.S are also being tried: first layer of Cr for promoting adhesion, middle Cu layer for providing effective shielding and Cr or S.S top layer for providing protection against oxidation. Sputtering and ion plating are also being considered for this application.

4.Electroless Plating

Electroless copper and electroless nickel as well as multilayer coating comprising of these two are gaining favour for this application. Coating thickness required are of the order of 1 to 2.5 um. This thickness is very small in comprison with the thichness of nickel paint or arc sprayed zinc. (These are of the order of 50 - 75 um.) This fact is highly advantageous in the sense that no significant weight addition occurs because of plating.
Another obvious advantage of electroless plating is the uniformity of coating thickness. With arc sprayed zinc or Ni paint coatings, it is very difficult to achieve uniform coating; uniformity depends very much on the skill of the operator. This nonuniformity in coating thickness results in variation of shielding efficiency from section to section on the same part and also from part to part.

Nickel paint and zinc sprayed coatings can only be applied on one part at a time whereas electroless methods can be adopted for bulk processing ie. many parts can be coated simultaneously. However, electroless method suffers from a drawback: it is limited to fewer substrates - ABS (foamed & unfoamed) Noryl (foamed & unfoamed), foamed polystyrene, epoxy and polysulpones.

Electroless Copper

Copper has high conductivity and hence offers excellent shielding even at lower thickness. Pure copper coatings can be produced by electroless methods. Formaldehyde based electroless copper baths are generally used. However, since copper coatings tend to oxidise with aging, shielding effectiveness progressively decreases with time.

Electroless Nickel(EN)

EN is not pure nickel but an alloy of Ni-P or Ni-B depending on the nature of reducing agent (hypophosphite or amine boranes). Resistance of EN is high and hence provide only low shielding efficiency. Its shielding efficiency is 100 to 1000 times less than an electroless copper coating of the same thickness. But it provides good long term corrosion resistance. It also has good abrasion resistance.

Table 4

Characteristics of Electroless Copper/ Nickel Shielding

High shielding efficiency 80 dB plus
Excellent environment stability
Extremely uniform coverage
Ability to cover complex geometries
Complete component coverage for selective or single - side application
Little or no degradation of plastics performance properties
Low part - to - part impedence
High surface conductivity
Low - to - high volume bulk processing
Ground plane source
Adjustable metal thickness to meet EMI requirement
Excellent wear/abrasion resistance.

Composite coating of electroless copper and nickel

A composite of electroless copper with an overcoat of electroless nickel seems to combine the advantages of nickel and copper without the disadvantages of either. There is no degradation of the shielding characteristics of copper. Typically 0.75 um of electroless copper provide a shielding efficiency of 65 dB at 1 Mhz and over 100 dB at 1000 MHz. The shielding levels can be adjusted by adjusting the thickness of the copper film.

The top coat of electroless nickel which is relatively thin (0.25 um) provides corrosion resistance and other destrable properties. EN coating thickness can be maintained constant.

Shielding efficiency of the multilayer coating of electroless copper overplated with electroless nickel is very nearly the same as pure copper provided electroless copper film thickness is more than 10 % of the total film thickness. Generally, electroless copper is 25% to 50% of the total thickness and can even be increased to 75% or more depending upon the shielding requirements. This is because of the fact that shielding efficiency is a logarithmic term and not an arithmetic term. So if an electroless copper film has 65 dB of shielding and an electroless nickel film of 40 dB of shielding, the total shielding efficiency is 65.01 dB of shielding, which is nearly the same as that of copper. Thus the synergetic effect of combining these two coatings results in a superior material for cost effective EMI/ RFI shielding. The characteristics of electroless copper/nickel shielding are listed Table 4.

CONCLUSION

Electro Magnetic Interference (EMI) and Radio Frequency Interference (RFI) are electronic noise and seriously affect the functioning of all types of electronic gadgets. Hence to protect them from EMI, control measures are to be adopted. One of the effective way of shielding electronic components which are housed in plastic cabinets is to metallize the plastic with a highly conducting coating. Though a variety of metallizing procedures are available, only zinc arc spraying, conductive paints, vaccum metallizing and electroless plating methods are commercially popular. Each method has its own advantages and also drawbacks. Electroless plating method seems to be very promising.