Basics For Conductive Coating Users

Introduction

Electromagnetic compatibility (EMC) may be a new term to many plastics designers but with the increased selection of structural foam and other plastics for electronic equipment enclosure application, EMC is making its presence felt in a major way. Without compliance to specifications which define EMC performance limits, many new electrical devices may not meet targeted introduction dates, or worse, may not be allowed to be marketed within specific areas without certification.

In the past, manufacturers of electronic devices usually were concerned about EMC only when they had to design equipment for the export market and meet VDE regulations. Now the situation has changed from a detached domestic concern to an active involved concern for the FCC has imposed new guidelines upon the industry. The revision of Part 15 of the FCC Rules and Regulations may require enclosure redesign and/or circuitry changes to allow equipment to meet (acceptable) maximum interference levels in the United States.

By now electromagnetic interference (EMI) is better understood as it has presented an ever increasing problem since plastic enclosures were first used to house electronic equipment. Too often, however, electrostatic discharge (ESD), which is a related problem, is overlooked until field problems occur.

In many cases a static discharge to a plastic cabinet can degrade performance, or in worst cases, destroy sensitive components.

Fortunately for all concerned, there are various paths to follow to attain a FCC type accepted or certified design. This design flexibility allows the plastics designer and electronic systems designer to work together to select the best approach for the electrical device in question. The "best approach" depends upon the susceptibility threshold of the equipment being interfered with, where it is going to have to function in the field (the equipment's ultimate environment) and whether the equipment is susceptible to ESD.

Background—EMC

The ability of electrical devices to function normally without being interfered with, or without interfering with other electrical devices, is what is thought of as Electromagnetic Compatibility. EMC regulations usually emphasize containment of electromagnetic interference (EMI) to specific levels across designated frequency ranges. Every electronic system has some level of electromagnetic radiation associated with it. If the level of electromagnetic radiation is sufficiently strong enough to cause other equipment to malfunction, the radiating device is considered a noise source and is usually subjected to shielding regulations. This is especially true when the EMI occurs within the normal frequencies of communication as with video games and personal computers.

Rejection of unwanted signals which may be causing field complaints due to equipment malfunction has caused the EDP industry to become self-regulating to a degree. When combined with the published figures that show half of all the computer sales made by U.S. companies are overseas, one can begin to understand the economic reasons for shielding!

Provided that the electronic system itself has been properly designed, the metal housing containing it provides shielding by reflecting interfering signals away from the enclosure. It also contains any EMI which may be radiating from the system itself. An unshielded plastic housing enclosing the same device would allow the radiating EMI to exit the housing as well as allow the entry of any stray EMI which may be present.

The electrical energy present in the environment, or radiating from an electrical device can be measured with various detectors (e.g. receivers) and expressed in terms of standards of electrical measurment. These terms are volts/meter for field intensity and watt/meter^2 for power density relating to the electric field. Differences in levels of electrical signals or EMI are expressed as a ratio in decibels as shown below as shielding effectiveness and illustrated in Figure 1.

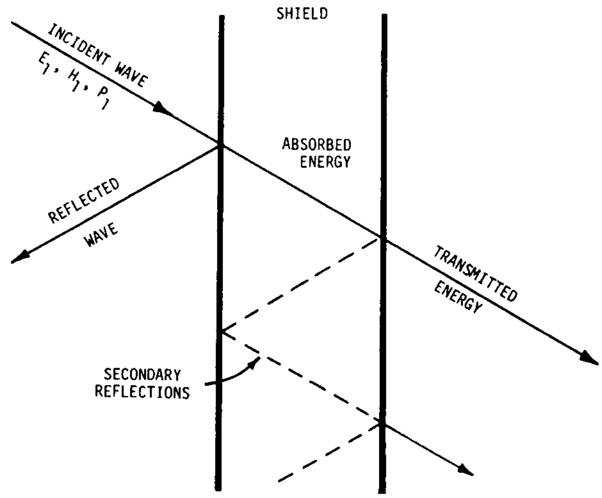


FIG. 1. ATTENUATION OF EMI BY A SHIELD

$$SE = 20 \text{ Log } \frac{\text{V incident}}{\text{V transmitted}} \text{ dB}$$

$$SE = 10 \text{ Log } \frac{\text{P incident}}{\text{P transmitted}} \text{ dB}$$

The above relationships take into consideration both the reflected and absorbed components of the incident wave of EMI and are then the total shielding effectiveness (SE) for any material under examination at a particular frequency. Electrical energy impinging upon a conductive surface will be reflected and absorbed by the surface as a function of the frequency and surface impedance.

The actual amount of additional shielding a system will require, will depend upon how much attenuation is needed to meet a specific emission standard, how susceptible the equipment is to ambient (existing) EMI, and how sensitive the manufacturer is to his costs in field service repair or his lost business due to EMC related performance problems in the field.

Background—ESD

Electrostatic discharge (ESD) affects the plastic industry in much the same say as does EMI. Plastics are generally excellent insulators and therefore do not allow charges to bleed off to ground in a controlled manner. Instead, discharges to the plastic case or accumulated charge and subsequent discharge cause equipment malfunction or failure.

Another major problem is when a person develops a charge which can exceed 15kv via his walking motion and discharges to a grounded object. He may also transfer his charge to the plastic case causing an eventual breakdown and discharge. It is very important to note, that every electrostatic discharge consists of high level RF voltages extending upwards through 100 MHz.

The ESD problem is becoming much more acute due to the development of very high speed microprocessors. More and more functions are being packed into a single chip to reduce the size of the equipment and increase machine speed. Thus, the equipment is becoming increasingly more vulnerable to the RF components of the ESD.

A basic computer functions by communicating on data busses with very precise timing. When an improper pulse or signal is superimposed on the timing or other data busses within the computer, errors result. If the induced voltage generated by ESD is of sufficient magnitude, device malfunction (error) may occur. As little as 100 volts can degrade several types of semiconductor devices commonly used in microprocessors.

Testing Methods—EMI

EMI tests can be performed on the materials under consideration for use for shielding. However, it is always advisable to perform application EMI tests on the individual electronic equipment undergoing design to determine how much shielding is required. The shielding effectiveness figures, usually given to the industry by materials manufacturers, are provided as a guide to show the relative level of shielding performance on an ideal enclosure. Since penetrations and seams will degrade overall shielding, the values should be used for comparisons as one would use the MPG rates for new automobiles.

Flat rectangular panels were evaluated at frequencies from 1 MHz through 10 GHz in a back-to-back screen room test set up similar to that shown in Figure 2. The EMI receiver was enclosed within the confines of a second shielded room to eliminate the possibility of stray radio frequency signals yielding false information. Unshielded plastic, an aluminum reference panel, as well as various conductive coating approaches on plastic were tested. Shielding effectiveness variations were noted in accordance with changes in frequency and electrical resistance, as predicted by microwave theory. As expected, conductivity played a significant roll in EMI shielding. Table I shows the average shielding effectiveness across a range of frequency of 1 MHz to 10 GHz.

A similar test which would allow the more rapid screening of materials was devised. By using a spectrum analyzer which is able to sweep across the desired frequency range, along with antennas and a sample holding fixture, a continuous display of shielding effectiveness could be achieved much in the same way as the more rigorous shielded room testing mentioned above. This particular spectrum analyzer

Figure 2 Typical common wall attenuation test set-up

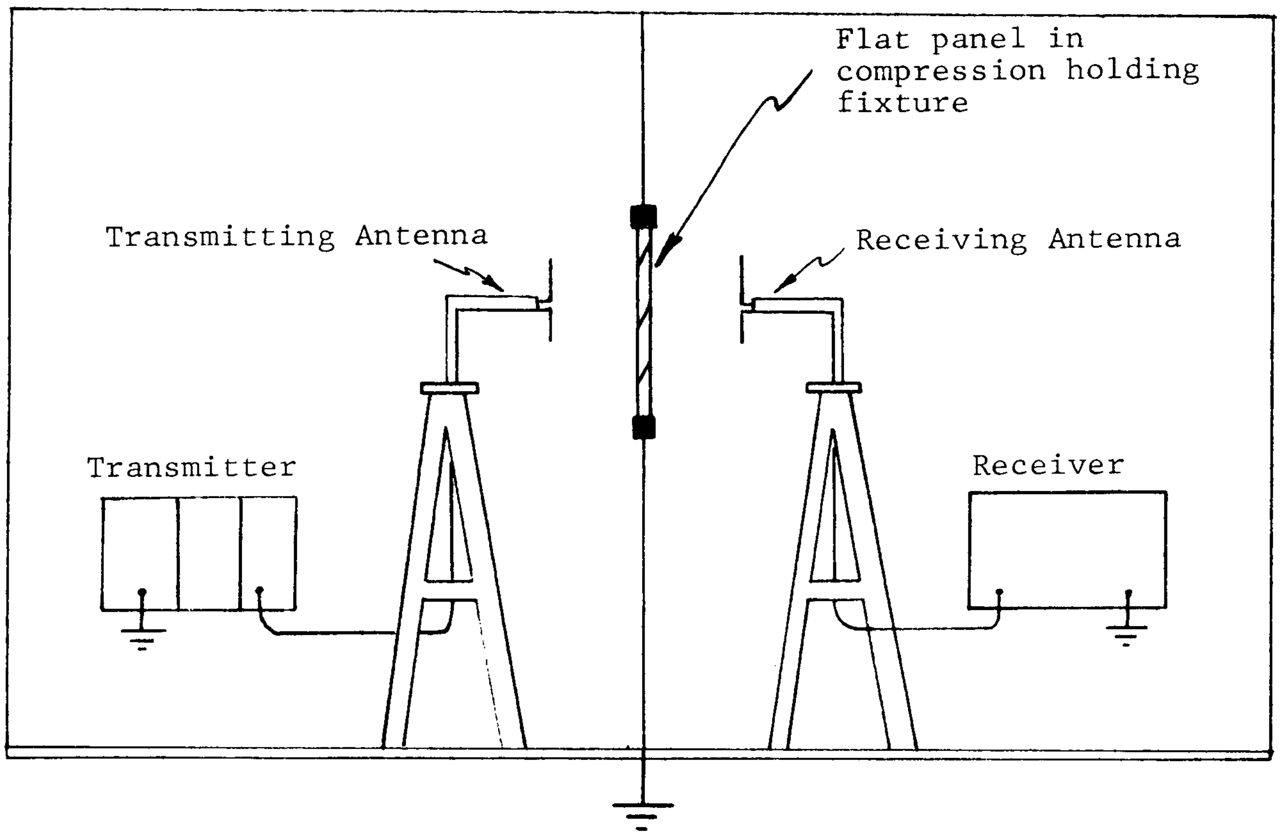


TABLE 1.

MATERIAL	THICKNESS Mils	SHEET RESISTANCE Ohms/Square @ 1 Mil	ATTENUATION db
Sheet Polycarbonate	1/8 inch	—	0
Aluminum Sheet	1/8 inch	0	64 - 80
Silver Paint	1.5 mil	0.01	54 - 70
Silver Graphite (two coat)	0.2/1.0 mil	0.01/100	54 - 77
Copper	2.0 mil	8.0	20 - 54
Copper/Graphite (two coat)	2.0/2.0 mil	8.0/100	27 - 62
Graphite	1.0 mil	100	11 - 60

can display information over a range of frequency from 0.1 MHz to 1.8 MHz. Maintaining good sample ground contact is accomplished in the test fixture via copper spring finger stock.

The correlation of test data taken from both test methods was fairly good. Since the same materials could be retested very easily, *relative shielding performance* was easily measured. Table 2 shows the performance of some more conductive materials compared to their earlier counterparts.

Beware of the Low Resistance Trap

The low resistance—high attenuation has led many designers into a trap. The scenario is as follows: A given system has had interference problems. This is known either from customer feedback or from laboratory evaluation. A designer, considering only EMI, looks over the relative data available from several vendors and concludes the best approach is to choose the method with the lowest possible resistance.

TABLE 2.

MATERIAL	COATING THICKNESS	SHEET RESISTANCE Ohms/Square @ 1 Mil	ATTENUATION db
Plastic	1/8 inch	—	0
Aliminum Q Panel	1/16 inch	0	65 - 70*
Silver Paint	1.0	0.1	65 - 70
Copper (discontinued)	2.0	8.0	30 - 40
Graphite (new)	2.0	4.0	35 - 50
Copper (new)	2.0	0.5	50 - 65
Nickel (new)	2.0	1.0	60 - 65

*Limitation of dynamic range due to fixture, etc., is approximately 70 dB.

This then becomes applied often times without considering alternative approaches. The lowest resistance may well solve the EMI problem especially after some additional circuit work is accomplished. The system now complies to EMI regulations and is released to the field—but again has troubles! Why? Very often the other part of the EMC question is overlooked. Electrostatic discharge, a very common occurence, ESD often causes more field complaints, errors or failures than EMI. The very rapid passage of an ESD pulse to ground can induce broad band EMI pulses and continued EMI problems perpetuate—even with the most conductive shielding approaches. The solution is a trade off in resistance to produce enough EMI shielding and ESD damping to meet *both* considerations.

The problem in the above scenario was demonstrated at a recent National Computer Conference in Anaheim. Many systems at the conference had ESD problems due to the low humidity of Southern California. The solution was a Static Spray of the type that keeps your laundry from sticking together in the drier. This bandaid enabled some systems to come back on line unless they were damaged from the earlier experienced static discharge.

Testing Methods—ESD

Various microprocessor-based equipment encased in plastic housing are susceptible to ESD. A method used to isolate circuits and make a system more immune to ESD is as follows. A high voltage source is used to isolate susceptible circuits and make a system more immune to ESD is as follows. A high voltage source is used to change a capacitor which is placed in series with a resistor. That RC network is then discharged at various places on the system under evaluation. Voltages are raised as the equipment design is improved until acceptible performance is accomplished.

Different firms have various levels of ESD immunity as design goals. One problem occurs in standardizations of the RC network used to simulate a "typical body impedance level". A military ESD study of EEDs (electro explosive devices) defines an RC circuit consisting of a 500 picofarod capacitor in series with a 5000 ohm resistor. Other sources such as the widely used Andy Hish Associates ESD-254 Generator uses 350pf and 100 ohms.

The level of voltage, the energy stored and the rate of discharge all play an important role in determining ESD immunity—and there is no universal standard test technique. Further complicating the design solution is the fact that each system has its own level of ESD susceptibility. Therefore one can not assume that since a 50 ohm/square approach solved an ESD problem on one equipment, that a 50 ohm/square approach will also do so on another different equipment design.

Environmental Considerations

An industry wide search of environmental test methods showed that no two manufacturers had exactly the same testing specifications. Thus, a worst case environmental profile was formulated to which conductive coatings should be evaluated. The many different substrates involved (Foamed Lexan, Foamed Noryl, SMS, BMC, ABS and others) should be considered since it is unclear if they played a role in changing the properties of a shield before and after environmental tests.

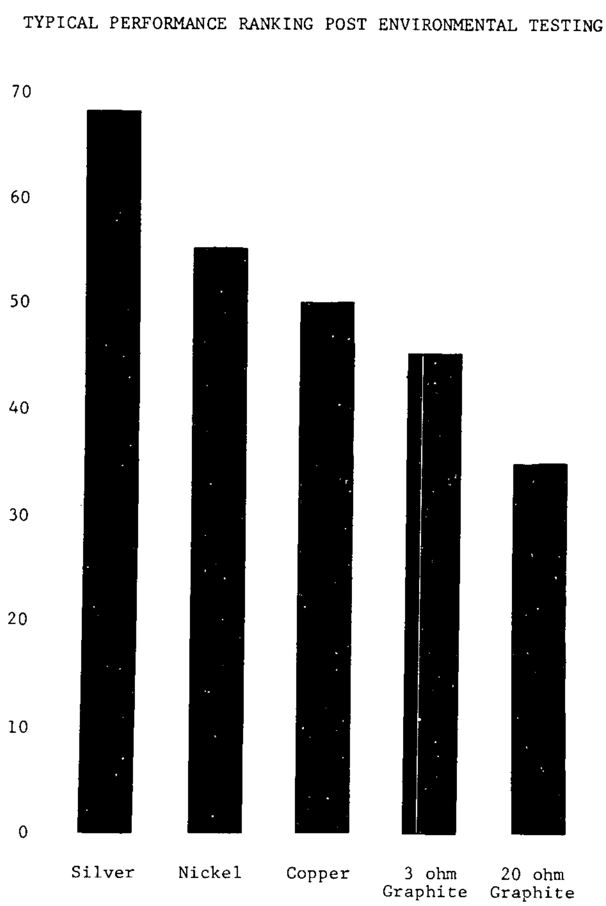
It was found in earlier work that it was necessary to monitor both coating resistance and attenuation to obtain a good indication of the suitability of conductive coatings for use a shields. Also substrates could alter resistance of a coating.

The environmental profiles were established as follows on various types of plastics:

Heat Cycle
-40°F to + 160°F 10 cycles
long term humidity
120°F @ 95% RH continuous (3 months)
Long Term Heat Ageing
160°F continuous (3 months)
Humidity—Heat Ageing
-40°F to +160°F 95% RH 5 cycles
accelerated humidity
72 hr, 150°F, 95% RH
Adhesion before and after above tests.

A typical product performance ranking is shown as Figure 3 for relative shielding of coatings on a polycarbonate substrate before and after environmentals.

Figure 3



The conclusions of the preliminary evaluation of various available systems showed that stable and economical conductive coatings could be made available to the industry. These coatings include copper, graphite, silver and nickel pigmented materials.

Earlier conclusions with respect to thermoplastic formulations of conductive copper oxidation were correct. They *were* unstable and had to be top coated with graphite for oxidation protection. However, a new thermoplastic copper product comes thru the environmental tests with excellent attenuation performance (in the 50 dB range) and excellent stability.

The conclusion by some that graphite products only be considered for use as ESD coatings was premature. Graphite materials have always shown excellent stability and low cost per square foot. Now as a result of the earlier mentioned environmental concerns a new formulation is available in the 3 to 7 ohm range with attenuation in the 40 dB range.

The question of use of silver is one of its dollar impact on design. Environmentally stable, it can be discolored by exposure to sulphur dioxide. However, as long as a ground contact is maintained, the surface condition of the silver has little to do with its excellent performance as a shield. It maintains its performance in the 60 to 70 dB range.

Nickel has gained popularity recently as a pigment in conductive coatings. It is usually formulated in acrylic systems with few products available in polyurethane. Performance for nickel usually is in the 50 dB range. It has shown excellent environmental stability through the earlier mentioned tests. However, one would be well advised to take the necessary safeguards of wearing a protective mask during the spray application of any nickel coating product. It is yet unclear to the industry as to the magnitude of the potential health risks involved with breathing the dry spray, but published government documents consider the safety of nickel worthy of further study.

EMC in the Future

For EMC, the future is now. The next voice you hear may be design systems management asking if the system meets FCC and other regulations. Work continues on a broad front with coatings. Existing regulations may well become more restrictive. Perhaps standardizations of test methods will take place. Circuitry will become more compact and processing somewhat faster, but EMC will continue to play a more important role to the electronics and plastics industry.

Conclusions

Consider the low resistance trap, avoid it and avoid the possible ESD problems associated with a shielding material that is too conductive.

Actual environmental operating parameters may permit use of lower cost materials for compliance to less demanding conditions than those specified by the military standards.

Consideration of the EMC requirements must address EMI and ESD design goals in shielding product selection.

Coatings or metalization methods are only part of the EMC solution. The rest of the solution lies in circuit design, layout, and conventional grounding and filtering considerations which have been in many design arenas left until the system's final days of design—or worse, until after design finalization has taken place and problems occur.

There is no approach which may be assumed to be best, as the best for one system may be enormous over- or underdesign for another system with entirely different susceptibility level.

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