Metallization of Plastics for EMI/RFI Shielding

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METALLIZATION OF PLASTICS FOR EMI/RFI SHIELDING

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Metallization of plastics does not basically involve new fundamental technology, however the use of metallized plastics for EMI/RFI shielding does indeed, involve new technology and new concepts in a highly competitive business. The purpose of this paper is therefore to review this technology as it pertains to the new F.C.C. Regulations, and its interplay with the needs of the marketplace. Much of the market information presented here is based on the results of an in-depth business analysis prepared by Business Communications Co., Inc., Stanford, CT (1).

The fabrication of plastic electronic business cabinetry is one of the fastest growing industries in the American economy today. It has resulted in tremendous growth potential for resin suppliers, molders, and coaters of such equipment. The direction of future growth in this industry is most dependent on the need to shield either parts or the entire fully assembled unit from electromagnetic interference. Electromagnetic radiation is one of the unfortunate by-products of this rapidly growing host of electronic devices. Electromagnetic Interference or EMI can interfere with the functioning of simple household appliances such as garage door openers, microwave ovens and the like (Fig. 1). On a more serious level, EMI can generate disastrous results in large scale computer systems, aircraft guidance systems and medical equipment such as pacemakers and related equipment.

In 1979 the Federal Communications Commission addressed the problem of EMI shielding by announcing the phased introduction of regulations relating to EMI shielding. These regulations allowed companies manufacturing electronic equipment until October, 1983, at the latest to reach full compliance. Further, it is generally recognized that even more stringent regulations will follow.

The impact of the legislation by the FCC poses serious potential problems for producers of electronic equipment in plastic cases or cabinets. The result is that this industry will find that the single most important factor in the design and fabrication of electronic cabinetry will be to develop a method of shielding for EMI while maintaining the other design factors such as attractive appearance, durability and protection of the electronic devices within.

Electronic cabinetry has been produced largely from straight injection and structural foam molded plastics which have provided design engineers of electronic equipment with lightweight, versatile, esthetically pleasing packaging for their products. Further, these plastic enclosures have been steadily replacing metal cabinets in such items as typewriters and CRT terminals.

One of the key weaknesses of plastic materials versus metal is that metals are inherently conductive which, with grounding, can provide electrostatic control and EMI shielding as an inherent property. However, since all machines operate at different power levels, different shielding problems will be encountered. In low power units, there is little advantage with metals over plastics, since the inherent configuration of the electronics tend to provide its own shielding in the cabinetry. However, this equipment may need to be shielded from outside radiation sources rather than from radiation generated from within. Medium power units require shielding to neutralize EMI problems to manageable proportions. The use of a metal enclosure in this category may not involve any further operations of cost to ensure electromagnetic compatibility, but such cabinets may not meet weight or esthetic design requirements. In the case of high power units, neither metals nor plastic materials alone are sufficient to reduce the potential for interference to the regulated level. Even the use of metal as internal shields give rise to the possibility of EMI at the joints and apertures that comprise the total configuration of the enclosure (Fig. 2). Vent holes, cables, gaskets and assembly techniques all play a role in developing an effectively shielded cabinet. The result is that no one form of shielding will dominate the market and that metals will never be completely replaced by plastic cabinetry. However, as is the case in all industry, the most *cost effective* means of controlling EMI in a specific design and application circumstance, will become dominant.

It is critical that all producers in the chain maintain a constant awareness of new and evermore effective techniques for shielding, and maintain a high level of flexibility in their production facilities to maintain a cost effective posture towards this market. Further, the design engineers of plastic cabinetry will have to educate themselves with the newest most cost effective means for shielding EMI, in order not to lose some or conceivably all of these markets to metal cabinets which are often expensive, heavy and esthetically displeasing but in nearly all cases effective.

There are three basic approaches which design engineers can use to control EMI in plastic enclosed equipment.

1. Redesign electronic equipment to reduce the strength of the electromagnetic energy or signal emitted to a point below the regulated standards.
2. Shield the electronic equipment directly to reduce or attenuate the signal emitted at the source through internal shielding enclosures or similar electronic techniques.
3. Shield the plastic cabinet or enclosures used to house the electronic equipment.

Option 1 involves noise generation control and is the least attractive for producing electronic equipment since it affects the ultimate performance of the product. *Options 2 and 3* have received the most attention. *Option 2* has a tendency to be relatively expensive. *Option 3* appears to be the most popular since the packaging decision has the least effect on the circuitry and design of the specific electronic equipment. Differences in the geometry and electrical output of equipment, and the length of the production run of the cabinet itself, all call for different approaches towards shielding. Further, each of the shielding techniques have inherent strengths and weaknesses which also affect the selection of the proper shielding technique.

Some of the various technologies which are being promoted for shielding of plastic parts include arc spray, flame spray, vacuum metalization, conductive paints, electroless plating,

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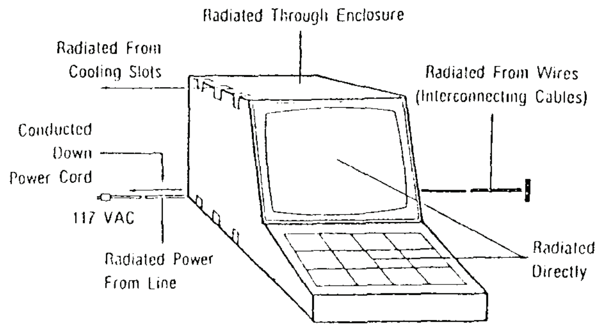
COMMON SOURCES AND RECEPTORS OF EMI

SOURCES	RECEPTORS
Television and Radio Sets	CB Receivers
Radar Transmitters	Remote Control Units
TV Recorders	Sensitive Test Instruments
TV Games	Telephones
CB Transmitters	Microprocessor-Containing Equipment
Electric Motors	Radio and Television Receivers
Relays 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 Equipment
Paging Systems	Cash Registers
Electronic Calculators and Computers	Duplicating Equipment
Static Electricity	
Remote Control Units	
Mobile Communication Transmitters	
Arc Welders	
Electrical Appliances	
Lightning	

Figure 1



EMI LEAKAGE AREAS

Figure 2

ELECTRICAL PROPERTIES OF SELECTED EMI SHIELDING METHODS

Method	Thickness (mil)	Resistivity (ohm/sq.)	Attenuation (dB)
Zinc arc spray	0.5-1	.03	50-60
Zinc flame spray	1	4.0	50-60
Nickel-acrylic paint	2	0.5-2.0	30-75
Silver-acrylic paint	1	0.04-0.1	60-70
Copper-acrylic paint	1	0.5	60-70
Graphite-based paint	1	7.5-20	20-40
Cathode sputtering	0.03	1.5	70-90
Electroplating	0.03	0.1	85
Electroless plating (Cu/Ni)	0.05	.03	60-70
Silver reduction	0.05	0.5	70-90
Vacuum metallizing	0.05	5-10	50-70
Ion plating	1 micron	0.01	50
Conductive plastics[a]	-	75-100	40-60

a 40% carbon filled nylon 6/6 produced by LNP.

Figure 3

ion plating, conductive foils and tapes, conductive fill plastics and inherently conductive plastics (Fig. 3). However, the market is currently dominated by zinc arc spray and conductive coatings such as nickel, copper, graphite or silver based material.

In 1982 EMI shielding represented a $73 million market. By 1987 the market for EMI shielding of plastic business machine enclosures will more than triple to $300 million (Fig. 4). This reflects not only the growth of the electronics industry but also the increased need for EMI shielding, as plastics continue to penetrate previously metal markets, as circuitry densities increase, as downsizing of these parts proceed, and finally, as industry and government regulations tighten to an ever greater extent. The percentage of plastic enclosures which were being shielded in 1982 was approximately 45% of the plastic enclosures which are being produced. In 1987 it is expected that plastic enclosures which are shielded will increase to 64%. The remainder of these enclosures either are being shielded through internal shielding devices or through alterations in the electronics design as alluded to earlier. Of the 45% of electronics cabinetry which are being shielded—approximately 22% of the enclosures are shielded with zinc arc spray and 18% are coated with interior conductive paints. The remaining 5% are coated by various other techniques.

E/M Lubricants currently applies a variety of conductive paints, zinc arc spray and electroless copper/nickel. E/M Lubricants is involved heavily in the development and application of a variety of shielding techniques for the plastic cabinets or enclosures. In addition, to development of products and processes for shielding, E/M Lubricants has developed extensive background in novel masking techniques. E/M Lubricants provides a source for decorative topcoating. E/M

THE MARKET FOR PLASTICS EMI SHIELDING METHODS IN BUSINESS MACHINE ENCLOSURES

	1982	1987
Extent		
Percentage of plastics enclosures shielded	45	64
	1982 Process Value[1] ($ million)	1987 Process Value[1] ($ million)
Method		
Zinc arc spray	44	120
Conductive paints	22.5	108
Vacuum metallizing	2	6
conductive plastics	-	40[2]
All other	4.5	26
Total	73	300

1/ includes raw material and overhead costs of application.

2/ based on the marginal cost of using a conductive filled, as opposed to unfilled, plastic material.

Figure 4

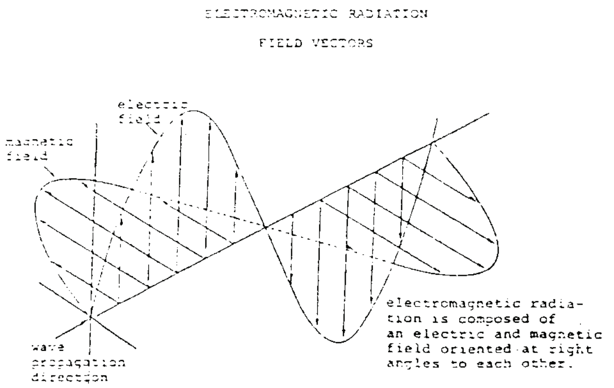


Figure 5

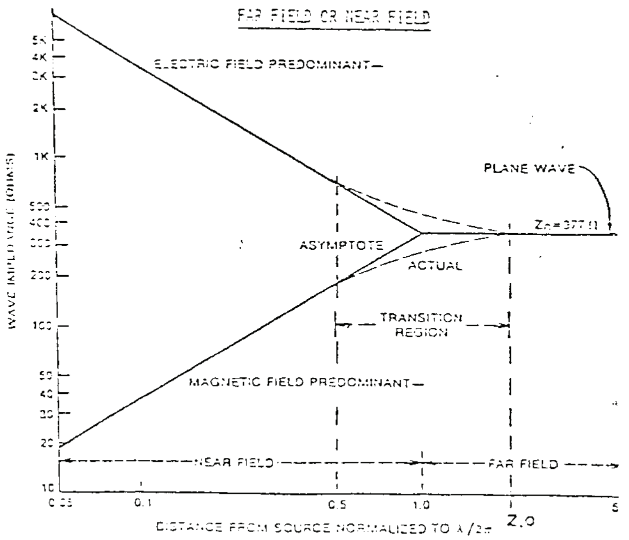


Figure 6

Lubricants, therefore, has the capability to start with raw parts from the molder, and finish with parts ready for final assembly without involvement of additional subcontractors resulting in higher costs to the end user.

THE ELECTROMAGNETIC INTERFERENCE PROBLEM (2)

Electromagnetic Interference is interference from electromagnetic energy. This energy can emanate from any circuit or man-made device which carries electric current as well as lightning, solar energy or any of a number of other natural sources; however, most commonly such electromagnetic radiation emanates from man-made sources.

Electromagnetic radiation is composed of an electric field and a magnetic field oriented at right angles to each other (Fig. 5). Such radiation will fall into one of two situations which are dependent upon the *distance* between the radiation source and the shield, and the *frequency* of the source. These two situations are called far field and near field (Fig. 6). The *transition point* between these two situations is the *distance* from the source equal to the quotient of the *wave* length divided by 2π. When the source to shield distance is less than the transition point distance, the near field situations exists. The near field situation can be described by two energy vectors: E—or electrical field vector, F—magnetic field vector. These two vectors are treated independently. In the near field situation, the E field impedence decreases linearly as the distance increases. The H field impedence increases linearly as the distance increases. The impedence curve for each field converge at the

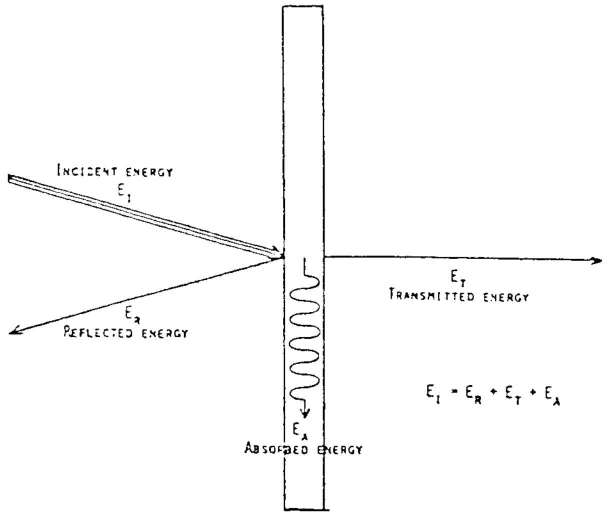


Figure 7

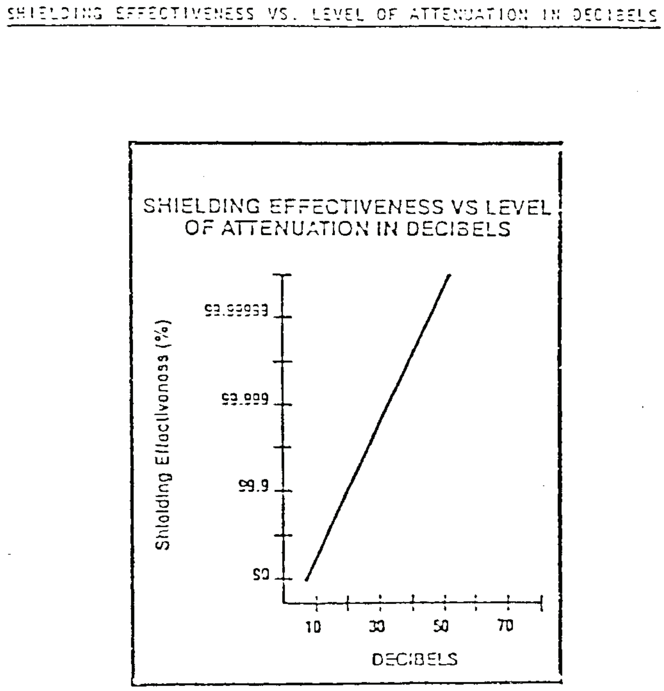


Figure 8

transition point at the impedence value of 377 ohms. Therefore, we see that often shielding in the near field can be accomplished by distance; that is, the farther the receiver is from the omitting electronics the less radiation is received. In the far field situation, a plane wave exists since the impedence is a constant of 377 ohms which is independent of distance.

In providing EMI shielding for electronic cabinetry, we are generally not concerned with shielding from the magnetic component. At frequencies greater than the one megahertz, we are concerned essentially with radio frequency energy. Radio frequency energy is attenuated by three basic methods: a) absorption, b) reflection and c) re-reflection (Fig. 7). Radio frequency energy which is not attenuated is transmitted. These three mechanisms can be added algebraically when using units of decibels to determine the total attenuation. Absorption takes place when the energy has entered the shield and has been converted to thermal energy as happens in a microwave

FCC RULES AND REGULATIONS

Radio Frequency Devices

GENERAL

Any apparatus which generates a radio frequency ($10 KH_z$ to 3,000,000 MH_z) electromagnetic field at any point a distance of $\lambda/2\pi$ from the apparatus shall not exceed 15 microvolts per meter.

Sub Part J

"Computing Devices: Any electronic device or system that generates and uses timing signals or pulses at a rate in excess of 10,000 pulses (cycles) per second and uses digital techniques; inclusive of telephone equipment that utilizes digital techniques or any device or system that generates and utilizes radio frequency energy for the purpose of performing data processing functions, such as electronic computations, operations, transformations, recording, filing, sorting, storage, retreival, or transfer."

Figure 9

oven. Reflection is similar to the reflection of light or sound waves. This energy is reflected off the shield on the source side. Re-reflection is reflection of energy off a second surface of the shield. These three mechanisms behave in a reasonably predictable fashion; the degree to which each contributes to attenuate RF enegy is dependent on the shield material, the source distance, frequency, and shield thickness. Shielding effectiveness is measured in decibels and is related to the level of attenuation (Fig. 8).

THE FCC REGULATION ON EMI SHIELDING (3)

On October 16, 1979, the FCC published in the Federal Register a new technical standard governing computing equipment (FCC Rules and Regulations, Part 15, Sub Part 5) which apply to all equipment manufactured after 10/01/83 (Fig. 9). The new rules define the computing devices as any electronic device or system that generates and uses timing signals or pulses at a rate in excess of 10,000 pulses (cycles) per second and uses digital techniques; inclusive of telephone equipment that utilizes digital techniques or any device or system that generates and utilizes ratio frequency energy for the purpose of performing data processing functions, such as electronic computation, operations, transformations, recording, filing, sorting, storage, retrieval or transfer. The regulations specifically list business and personal computers, data processing equipment, digital weighing scales, switching power supplies, electronic games (including coin operated types), electronic cash registers, digital watches, pocket calculators and digital clocks as examples. It also notes that the list is not meant to be inclusive. These computing devices are divided into two categories:

Class A for use in commercial or the business environment.
Class B for personal use in a residential area.

Restrictions on Class A business systems have actually been relaxed by the new rules as the incidence of interference has been found to be minimum (for self protection and security, business machines are normally shielded from outside interference) (Fig. 10). Limits have been made more strict on Class B type computers for personal use as the Commission considers them to be more apt to disrupt reception without built-in safeguards. A Class A computing device must be tested and verified by the manufacturer as being capable of complying with the regulations. However, certification by the FCC is not yet required. Class A components must be labeled as complying with the FCC Regulation along with a warning as to the potential for interference, if used in a residential area. In stark contrast, Class B personal computing devices require FCC certification and provision for providing pertinent information to the user.

UNDERWRITERS LABORATORIES, INC.
Environmental Testing
Specification 746-C

Test Method:

Samples tested for adhesion (ASTM D-3359B) after treatment:

Condition Samples:	40 hrs. @ 23.0 ± 2.0°C and relativehumidity of 50 ± 5%.
Thermal Cycling:	1 hr. @ 85°C 1 hr. @ 23.0 ± 2°C and R.H. @ 50 ± 5% 1 hr. @ 29.0 ± 2°C 1 hr. @ 23.0 ± 2°C and R.H. @ 50 ± 5% Repeat cycle 3 times.
Temperature Exposure:	85°C for 56 days.
Humidity Conditioning:	35°C ± 2°C and R.H. 90 ± 5% for 56 days.

Figure 12

minor importance and comprise less than 3% of existing shielding techniques:

1. Silver Reduction (4)

Silver reduction is a "wet" multiple silver plating process where silver nitrate solution is sprayed onto the plastic surface. Silver is reduced to pure elemental silver which precipitates onto the part while the nitrate remains as a soluble salt. The silver that does not make contact with the part can be reused. Silver reduction provides good conductivity and relatively low capital investment; however, silver has a tendency to oxidize. Masking is difficult and it is a multi-step process.

2. Foil Application (4)

Pressure sensitive foils manufactured with an adhesive backing are also used. These foils can be die cut and applied to the interior of an injected molded part. Advantages of foil application are that the foil can be precut to the specific part shape. Foil applications are good for experimental work and provide good conductivity; however, complex parts are very difficult to cover and it is an extremely labor intensive process, not conducive to the high production volumes encountered in the computer industry.

3. Vacuum Metallizing (4)

Pure metal, usually aluminum, is used to coat the plastic part which generally has had a primer basecoat applied prior to plating. The metal is vaporized in a vacuum chamber. The vapor is condensed and deposited onto the surface of the parts in the chamber. The advantages of vacuum metalization are that it can be put on plastic. It has excellent adhesion between both plastic and metal film. Provides good conductivity and is not limited to simple designs. The disadvantages are principally the size and cost of the vacuum chamber which is also a limiting factor to productivity. The equipment involved is quite expensive. The base-coat needs to be applied to minimize surface defects which represents a second operation, also raising the cost.

4. Cathode Sputtering (4)

A gas plasma discharge is set up between a cathode made of material to be sputtered and an anode which serves as both an electrode and a support for plastic substrates in a high vacuum environment. Positively charged gas ions are accelerated into the cathode causing atoms of metal (cathode) to be ionized and ultimately condensed on the anode substrate forming the metal film. Advantages of cathode sputtering are that it provides good conductivity and good adhesion. Disadvantages are that the equipment is expensive and power consumption is high. Further, the process is limited by part configuration. In addition, this method is relatively untested as an EMI/RFI shielding technique.

5. Electroless Plated Shielding (4)

Autocatalytic deposition or electroless copper/nickel deposition is the deposition of a metallic coating by a controlled chemical reduction that is catalyzed by the metal or alloy being deposited. E/M Lubricants applies the Attenuplate® (5) System on its electronic cabinetry. The At-