REVIEW OF EMI/RFI SHIELDING REGULATIONS AND HOW CONDUCTIVE COPPER COATINGS MEET THEIR REQUIREMENTS

Advancements in conductive copper coatings will continue to enable design engineers to meet new governmental regulations.

Kimberly A. Stephens, Bee Chemical Company*, Lansing, IL

INTRODUCTION

Governmental regulations and the increased use of plastics for computer cabinetry, have been the two driving forces behind the growth of EMI/RFI shielding methods. Beginning in 1979, when the Federal Communications Commission first announced their proposed regulations on EMI/RFI emissions, until 1983, when all computers had to be in full compliance, a phenomenal growth in various shielding methods has occurred.

This article reviews the existing FCC regulations and recent changes (effective January 1, 1986) in the West German VDE (Verband Deutscher Electrotechniker) standard, and discusses how these affect the choice of shielding methods. A discussion of the market breakdown of various shielding methods ensues with a review of how copper conductive coatings are meeting the needs of the OEM and the finisher.

The VDE is an independent society of German electrical engineers which develops the test standards needed to implement the EMI/RFI standards set by the German Postal Authority (or FTZ). The United States and Germany may be the only two nations which make it unlawful to sell electronics which do not meet their standards. Many other countries have developed guidelines and recommendations for electronics firms within their country or for equipment that is imported, but there is no across-the-board enforcement of these guidelines. The International Electrotechnical Commission, Special Committee on Radio Interference (IEC/CISPR) is actively trying to gain agreement among nations for worldwide standards on EMI/RFI. However, no agreement has yet been reached, although it appears that they are trying to establish limits between those set by the FCC and the VDE.

One of the main reasons behind the original FCC regulations was that television reception was being affected by the EMI/RFI interference from some of the first home computers. As a result, both the FCC and the VDE have imposed separate regulations for electronics used primarily in residential environments and electronics used in commercial environments. Class A is for electronics in the commercial and business environment. Class B is for electronics for personal use in a residential area. Class B tends to be stricter because the danger of interference without built-in safeguards is more likely. Certainly, a glance around a home or office environment illustrates the increased sophistication of electronics on such common items as:

Home
- Mobile & Portable Telephones
- Microwave Ovens
- Vacuum Sweepers
- VCRs
- Automotive Ignition Systems
- Garage Door Openers
- Electrical Appliances
- Stereos
- Electronic Games

Office
- CRTs
- Printers
- Modems
- Electronic Energy Sensors for Heating & Air Conditioning
- Satellite Electronics
- Paging Systems
- Cash Registers
- Copy Machines
- Calculators

Within 10 years, it will probably be difficult to say whether the amount of electronics in an office is greater than that in the home or whether there is much difference between the two.

So, the factors which will affect the trends in EMI/RFI regulations are:

- Population density (higher density makes the likelihood of interference greater),
- Conversion of appliances, cars and other products from mechanical to electronic controls,
- The miniaturization and increase in capacity and power of electronic components,
- Increased sensitivity of components to ESD and EMI, and the percentage of electronic housings made of plastic.

Focusing on just one of these factors illustrates the trend. In 1980, 58 percent of the electronic equipment enclosures were in metal.

	1980	1985
Metal	58%	33%
Plastic	42%	67%

By 1985, 67 percent of the elec-

*See advertisement on page 183.

tronic enclosures were in plastic. Of the enclosures in plastic, it is estimated that:

	1982	1987
Plastic Enclosures Requiring Shielding	45%	64%

Although electrical engineers are gaining more and more expertise in designing around the need for shielding, it is becoming more difficult as electronic housings become smaller, more powerful in capacity and interact more with other systems.

Table 1 shows the current FCC limits for radiated EMI/RFI.

All emissions from the computing device shall not exceed the level of field strength specified. Figures 1 and 2 show the VDE limits for any manufacturer who plans to mass-market computers in Germany and opts to select the Class B general permit, which is much stricter than the Class B for the FCC. The Class A limits are fairly similar for both the VDE and the FCC, and there has been no change in the Class A regulations.

Normally, these measurements are performed at different distances (10, 30 and 100 meters). For simplification, these charts have been scaled to a uniform distance. The Class B limits have changed in that a portion of what previously were "recommended" limits in the frequency range from 10 kHz to 150 kHz are now required.

These new limits for the low frequencies below 30 MHz are to be tested in the magnetic interference field rather than the electric field.

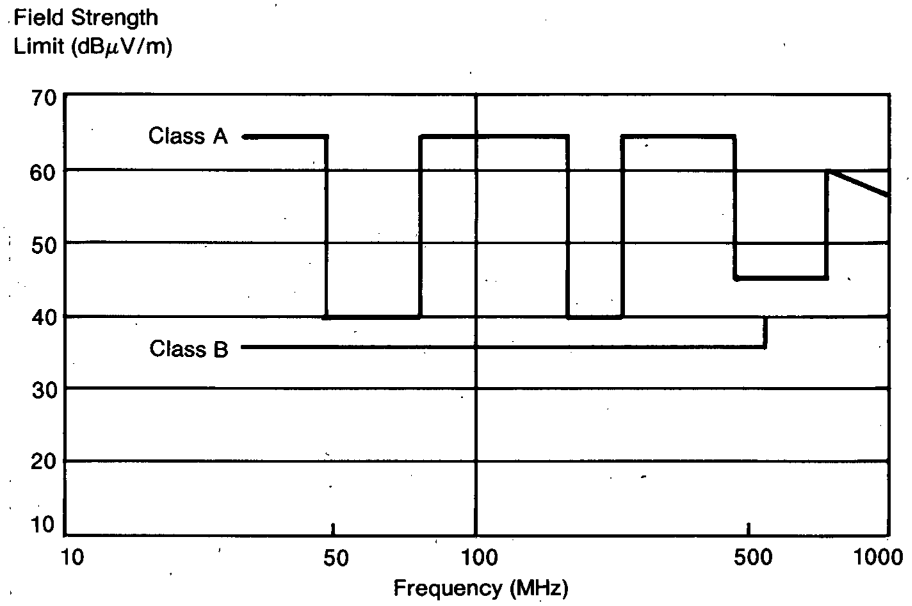
The VDE has allowed the magnetic interference field measurements to be taken at 3 meters instead of 30 meters because magnetic field testing at 30 meters in an urban area would likely be interfered with by underground cables with RFI currents as well as by other transmitters.

Of course, the big question is how these new regulations at the lower frequencies will impact how computer companies choose to shield their units. A design engineer still has three approaches for shielding:

1. Shield the actual source of emissions through the "tin-can" method.
2. Redesign the electronics to reduce the conducted and ra-

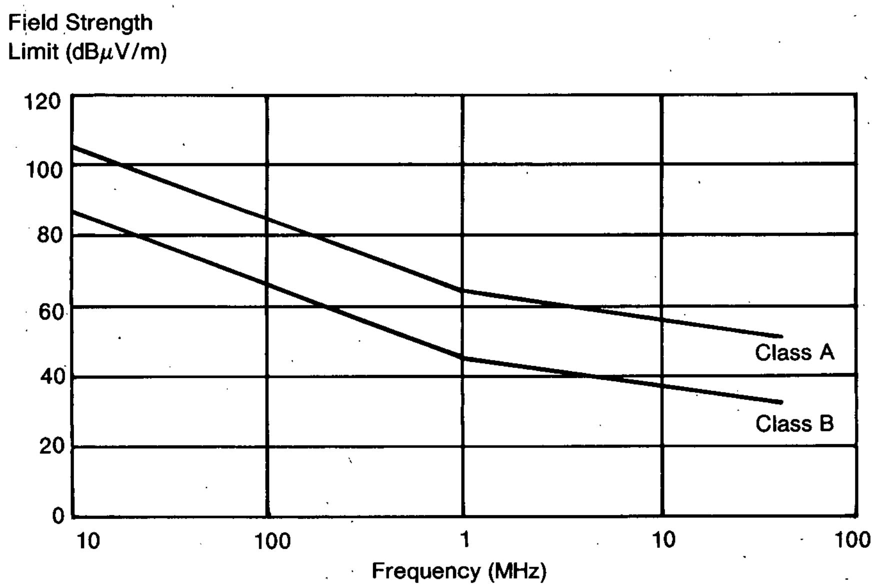
Table 1. FCC Limits for Radiated EMI/RFI.

	MHz Frequency Range	Field Strength (μV/m)
Class A - Commcial & Industrial (measured at 30 meters)	10 - 88 88 - 216 216 - 1000	30 50 70
Class B - Residential Area (measured at 3 meters)	30 - 88 88 - 216 216 - 1000	100 150 200



(Obtained from 1985-1986 Compliance Engineering by Glen Dash)

Figure 1. VDE Radiated Emissions Limits, 30 MHz to 100 MHz (Scaled to 10 meters)



(Obtained from 1985-1986 Compliance Engineering by Glen Dash)

Figure 2. New VDE Regulations for Frequencies, 10 kHz to 3 MHz (Scaled to 3 meters)

diated emissions to below the regulated standard.

3. Shield the plastic cabinet through use of conductive coatings, zinc arc spray, electroless plating or other shielding methods.

The real challenge now facing the design engineer is that the shielding method chosen in the past that works effectively for the electric field (E) is not necessarily going to work equally well for shielding within the magnetic field (H).

It should be understood that a design engineer might need to use all three approaches of shielding to assure that a unit will pass the new VDE standards in the low frequencies. The third approach deals with shielding the plastic cabinet.

There are numerous methods of shielding that are in commercial use today, the most common of which are:

- Conductive Coatings - Nickel and Copper
- Zinc Arc Spray
- Electroless Plating

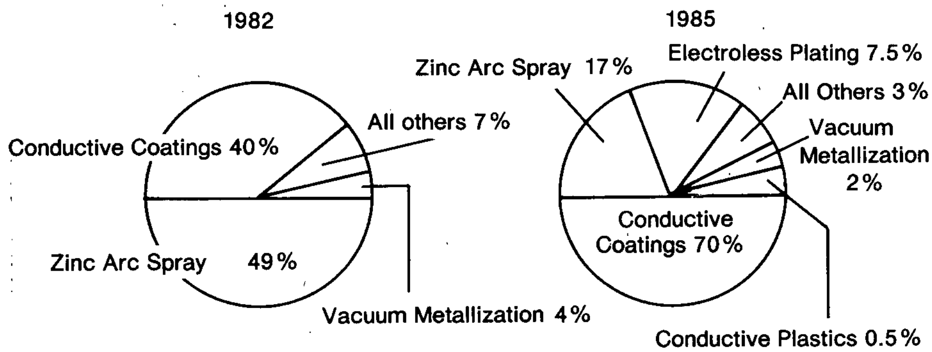
Some of the less common ones that have found a small niche in the market are:

- Conductive Foils
- Molded Conductive Plastics
- Silver Reduction
- Vacuum Metallization
- Cathode Sputtering

In the early 80's, zinc arc spray was the predominant shielding method with about 55 percent of the market. Today, conductive coatings have approximately 70 percent of the market (Figure 3).

The question often is not necessarily which method is best, but which method has the best cost performance ratio to do the job.

It is fairly well accepted in the industry today that conductive coatings have the best cost performance characteristics. However, there are always new technologies being introduced that change this scenario. Below is a comparison of costs for material and labor gathered in 1985 from several applicators. These are expressed as costs per square foot, on the average CRT unit with a surface area of 5 square feet.



(Obtained from Dr. Peter Mooney, Business Communications Company)

Figure 3. Market Share for Shielding Methods.

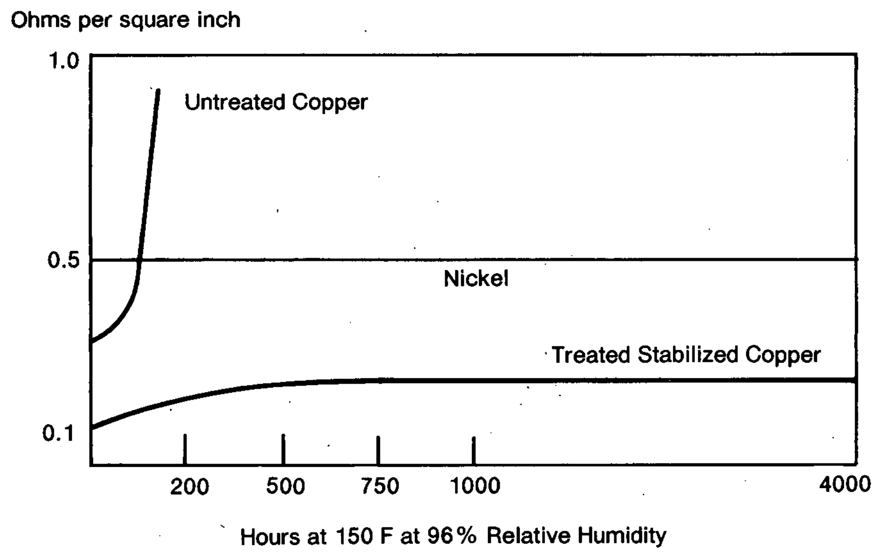


Figure 4. Treated Copper Stability as Compared to Nickel and Untreated Copper.

Conductive Acrylic Coating	\$1.20/sq. ft.
Zinc Arc Spray	\$2.00/sq. ft.
Electroless Copper	\$2.20/sq. ft.
Molded Conductive Plastics	\$2.40/sq. ft.
Vacuum Metallization	\$2.55/sq. ft.

For electroless copper, molded plastic and vacuum metallization, a decorative coating cost of \$1.00 is incorporated into the cost per square foot because an outside decorative coating is needed to make the part aesthetically pleasing. Molded-in color can be used for conductive coatings and zinc arc because they are applied to the inside of the cabinet only.

To compare shielding performance, it is necessary to examine first the relative conductivity of various metals:

Silver	1.05
Copper	1.00
Aluminum	0.60
Zinc	0.20
Nickel	0.20
Steel	0.10

Because of the high cost of silver, the choice of metals becomes copper. Copper can be used in electroless plating where nickel is then plated on top of it to give it protection from oxidation and provide abrasion resistance. The new non-oxidizing copper conductive coatings are another option.

There are two primary reasons

why the computer industry has moved so heavily to conductive coatings.

- Most OEMs are trying to use molded-in color wherever possible to eliminate a decorative coat. This is possible with conductive coatings.
- Cost Effectiveness — Conductive coatings have had no price increases and actual cost per gallon has dropped by about 20 percent over the last 4 years. Also, no capital expense is incurred, whereas a considerable amount of capital is needed to install an electroless plating line.

Figure 4 illustrates the dramatic difference between stabilized and nonstabilized coppers. Within 48 hours, an untreated copper will begin to lose conductivity in a humidity test and will lose most of its effectiveness within 300 hours.

Copper conductive coatings have been put through the tests shown in Table 2.

The EMI/RFI shielding effectiveness of copper conductive coatings is very similar to that of zinc arc spray and is more effective than nickel conductive coatings. Below is a comparison of the shielding effectiveness of the three materials using the new ASTM dual-chamber method. The dynamic range was 100dB at 30, 100 and 1000 MHz, and 115dB at 300 MHz. The shielding effectiveness is defined as the difference between the reference level and the level achieved with the test sample installed. This test deals only with the electric interference field (E).

	30 MHz	100 MHz	300 MHz	1000 MHz
Zinc Arc	67	57	70	73
Nickel	55	56	69	47
Copper	75	63	71	51

It is also interesting to note that copper conductive coatings have the same shielding effectiveness at 1.5 mils as nickel coatings do at 2.0. This can be seen more graphically in Table 3, which compares ohms per square.

To illustrate that technology is not standing still in regards to non-oxidizing copper conductive coatings, Table 4 shows shielding results comparing a commercial copper conductive coating with a new modified copper coating.

Table 2. Tests of Copper Conductive Coatings.

	Adhesion on KJW, FN215 FL900	Ohms/Square Before Test	Ohms/Square After Test
IBM Thermocycle Test 77 F, 47.5% Rh for 4 hrs. 140 F, 92.5% RH rise in 2 hrs. 140 F, 92.5% RH stabilized for 4 hrs. 140 F, 47.5% RH dropped in 1 hr. 140 F, 47.5% RH dropped in 11 hrs. 77 F. 47.5% RH dropped in 2 hrs.	5B*	0.10	0.10 - 0.20
Humidity 56 days at 35 C 90% relative humidity	5B*	0.10	0.10 - 0.20
Heat Age 56 days at 85 C	5B*	0.10	0.10

*ASTM rating after cross hatch and tape tests.

Table 3. Comparison of Film Build, Ohms per Square and dB Attenuation.

Film Build	Shielding Coating	Ohms Per Square Inch	30 MHz	100 MHz	300 MHz
1.0 mil	Copper	0.5 ohm	81dB	73dB	63dB
	Nickel	1.0 ohm	71dB	60dB	61dB
1.5 mil	Copper	0.2 ohm	88dB	77dB	68dB
	Nickel	0.5 ohm	75dB	64dB	68dB
2.0 mil	Copper	0.1 ohm	89dB	78dB	71dB
	Nickel	0.3 ohm	87dB	77dB	80dB

The question that still remains, however, is how well do copper conductive coatings perform in the magnetic field. With the new VDE regulations in the low frequencies, this will be of growing concern.

Three-foot by three-foot panels with 2.5 to 3.0 mils of coating were tested at six different frequency points according to the magnetic field test requirements (Table 5).

Effective shielding in the very low frequencies of magnetic field (H) depends more heavily upon absorption of the energy, as opposed to reflectivity, which plays a more dominant role in the electric field (E).

In the low frequencies, energy can be better absorbed with a greater thickness of the metal. Since electroless plating relies on very thin copper and nickel depositions which provide excellent reflectivity, for electroless plating to have improved shielding performance in the magnetic field, it needs to go to thicknesses two to three times greater than what is needed for the electric field.

Zinc arc also needs to be applied thicker than is normally recommended for improved shielding in the magnetic field because it is a less conductive metal to begin with.

When extremely good shielding is needed at the 10 kHz frequency, the only type of materials that have been proven effective are metals with very high permeability and low conductivity (Table 6).

These metals can be applied to plastic by using an adhesive foil. Unfortunately, they are not effective for shielding in the high frequencies or in the electric field. One of the options available to a design engineer is to use the high permeability metal foils as a tin can around the source, and use copper conductive coatings as the shielding method for overall shielding. It is uncertain how serious the need for shielding is in the magnetic field and whether the high permeability metal foils will be needed for many applications.

What both finishers and OEMs can count on is that the continuing technology advancements in conductive coatings, which first brought us nickel, then non-oxidizing copper coatings, will continue to bring the industry solutions for all types of shielding beyond those needed today. ■

Table 4. Comparative Shielding Results.

	30 MHz	100 MHz	300 MHz	1000 MHz
Copper	75dB	63dB	71dB	51dB
Modified Copper	77dB	76dB	78dB	50dB

Table 5. Comparative Shielding Results.

	10 KHz	100 KHz	500 KHz	1 MHz	10 MHz	30 MHz
Copper Conductive Coating	0	2	7	13	37	47
Nickel Conductive Coating	0	2	5	8	33	39
Solid Steel	50dB					

Table 6. Shielding in the 10 kHz Frequency Range.

Metal	Conductivity Relative to Copper	Relative Permeability
Copper	1.00	1
Hypernom	0.06	80,000
Mu-Metal	0.03	80,000
Permalloy	0.03	80,000
Steel	0.10	1,000

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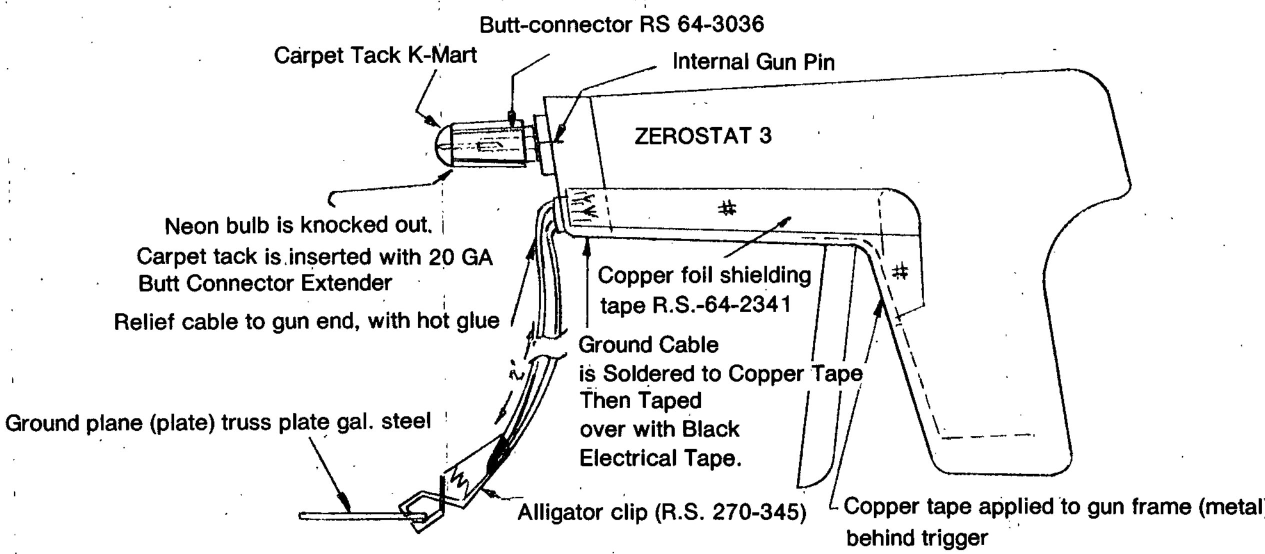

Figure 7. ESD Gun.

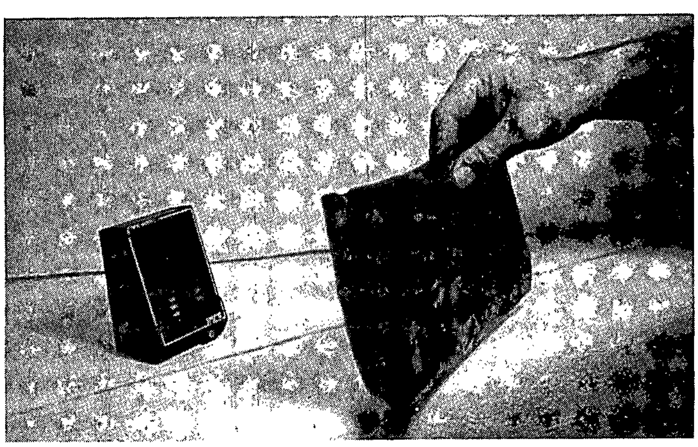

Figure 8. Material Tribo-Electric Charging.

3. The Event Detector board is placed inside the ESD container in question, sealed properly and the container/board is placed in the same location as in #2 above. The ESD gun tip is brought down toward the container and the gun is activated. The alarm should not sound (Figure 11).

ALTERNATIVE APPROACHES

Two faster and more simple methods are available to check ESD container shielding. The first method uses a small AM radio, tuned to a low power station (not a blaster nearby). The radio is put in the container. The audible level (station) is undetectable with well-shielded containers (Figure 12).

Another method involves off-tuning an AM radio (no station-volume up high) on a large wooden table or floor. Using the ESD gun and plate, the plate is arced and the radio is brought in or out until the radio static is just audible. This separation distance is noted. The radio (no changes to frequency or volume) is then placed into the container, and the test is repeated. The radio is brought in until only audible static is heard. The distance is noted. The "no-container distance" is divided by the "in-container distance"; this number is

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Figure 9. Container DC Field Shielding.

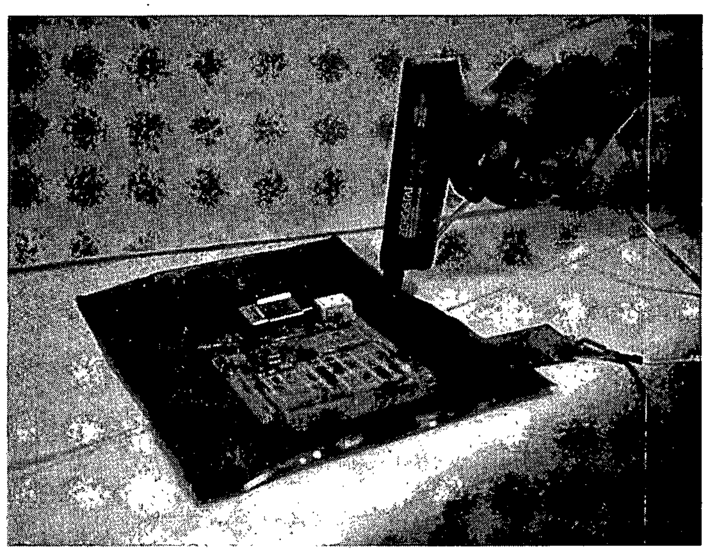


Figure 10. Arc Drawing.

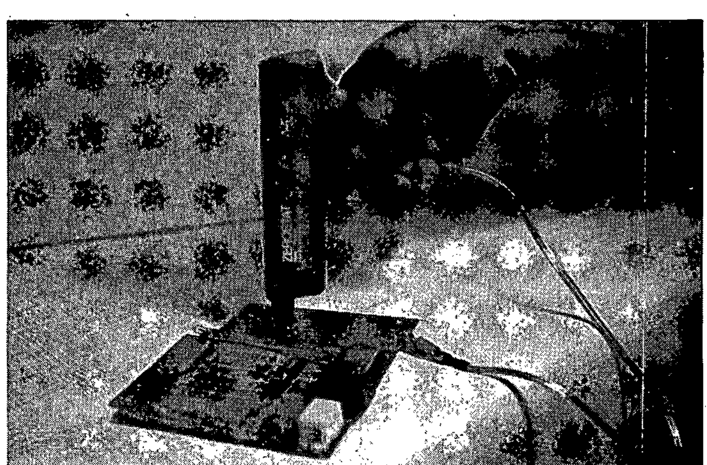


Figure 11. EMI/ESD Shielding, Pre-Test Check-Out.

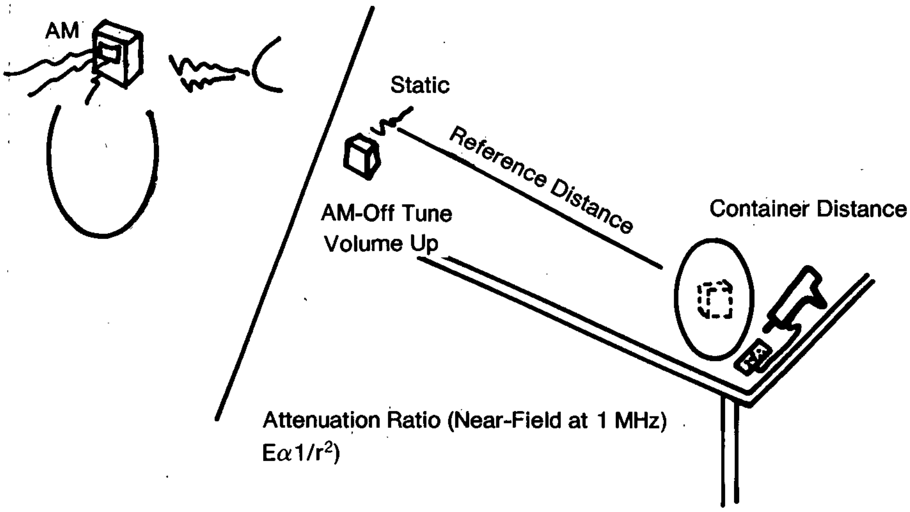
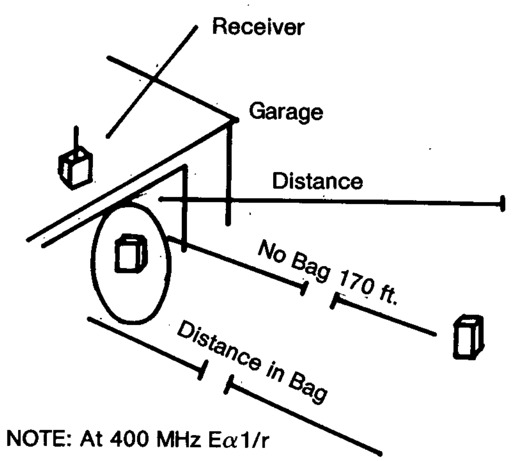


Figure 12. Other Shielding Test Methods.



Garage Door Opener to Garage Door Receiver ($\approx$ 390 MHz)

- Furthest distance that garage door opener triggers door receiver is established and recorded.
- "ON" transmitter is placed inside shielded bag and operator walks toward receiver, trigger "opening distance" is established.
- Shielding is computed at 400 MHz.
- dB shielding = 20 Log distance no bag/distance in bag

Figure 13. How to Test for RF Attenuation at 400 MHz.

squared (in the near-field, the inverse square law is applicable); this is the sample's shielding ratio (Figure 12).

CONCLUSIONS

With a couple of evenings of work, one can build a simple test kit. Cold solder joints should be avoided; the buzzer should be checked with the 9-volt battery before gluing it down permanently.

Readers will probably find large variations in ESD-container characteristics. An outstanding study by British Telecom[4] on ESD bag protection for MOS technology rates bag characteristics versus port degradation. This author has found high-ranking electronic companies using inadequate containers, risking $10,000 boards to save a buck on a container or bag. Most bags on the market today meet only one or two of the goals discussed; some of the newer designs meet four or five goals.

Containers can be rated using a five (5) star system; the 4 goals above are stars, plus a fifth star is awarded if the container provides 20dB+ attenuation (RF shielding) at 400 MHz. The fifth star applies to memory board circuit applications where high level RF fields could cause software type degradation. A simple 400 MHz shielding test method uses a garage door opener (Figure 13). It should be noted that this approach correlates to MIL-STD-285 within 2dB. For the MIL-STD-285 Method, an "ON" transmitter is placed into the container; the RF level emanating to the outside is monitored with an antenna and a spectrum analyzer.■

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Author's Note: No endorsements are implied in this article; any devices or parts described here are based on convenience, availability and cost.

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