TESTING WITH A NEAR-FIELD TABLETOP TESTER

Comparisons of shielding performance data are essential to the design of system components. A near-field testing device expedites the generation of comparative data.

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INTRODUCTION

The development of a tabletop near-field tester enables the design engineer to obtain measurements on the performance of EMI shielding materials. This type of device is similar to double TEM cells or "expanded coaxial wire" chambers designed for testing purposes. However, the near-field tester represents a departure from the devices traditionally used since they exhibit poor performance at lower frequencies because of the impedance mismatch. Now, mismatch differences are less troublesome because the near-field tester produces an interference field with an inductor, and interference produced is characterized by low impedance.

Unlike the tabletop tester, the transmitting elements used in the TEM devices can be described as either the center conductor of expanded coaxial cable with impedance of

$$Z_{coax} = 60/\sqrt{\epsilon}\ \log 10\ (D/d)$$

where D and d are the diameters of the inner and outer conductors respectively and ϵ is the dielectric constant (1.0 for air) (or an open dipole type antenna). Using factor $\lambda/2\pi$ (where λ is the wave length) as the distance the disturbance has traveled, the TEM or similar test fixtures will have Thevenin equivalent impedance in the range of kilo-ohms, whereby a loop antenna will yield milliohms. The surface impedance of the shielding materials (especially metals) is in the milliohms range. Surface impedance is defined as a resistance of the square with the thickness of one depth of penetration. This allows testing of all shielding materials at a higher excitation load.

The tester very closely approximates the conditions of actual use in which the stronger field created by the circuitry should be contained by an enclosure. The EMI shielding properties obtained with the tester can be extrapolated confidently if the material is a metal or a combination of metals, as long as the engineer remembers that the "μ" value will decline as the test frequency increases. Also the skin effect must be considered.

Extrapolation is not easy for high resistivity and high "μ" materials like "Mu-metal" or "1040 alloy." Also, the extrapolated prediction of shielding properties for materials made with flakes or powders is not recommended. If magnetic, this group of

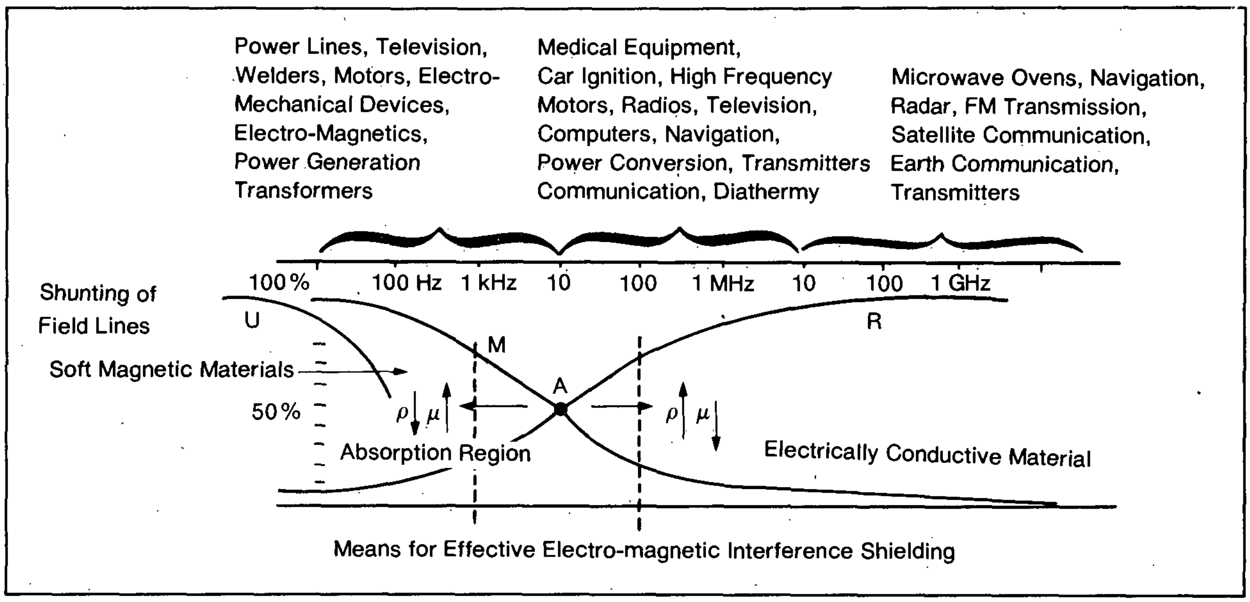


Figure 1. Sources of Interference.

materials will have a large "distributed gap." If made of high conductivity materials, the materials will have very sensitive areas of contacts between the platelets or spheres. At times, as in the case of oxidized copper, the material becomes a rectifier with nonlinear transfer characteristics.

In summarizing the mechanisms of EMI shielding, the following concept is useful. (See Figure 1.) Plotting the frequency of interference along the "X" axis and the efficiency of attenuation along the "Y" axis will reveal three defined regions within the electromagnetic frequency spectrum. For each region, there is a specific method of EMI attenuation which is most efficient. In the dc, very low frequency region, the most important attenuation mechanism is shunting the magnetic lines of disturbance. Specifically, the magnetic lines of the interfering field are rerouted in the high permeability material around the space to be shielded. This area is bounded by the curve "U." At increased interference frequencies, the area in question is bounded by the curve "M." In this area, the main mechanism of attenuation is absorption of the interfering energy. For this process to occur, the interfering energy must be coupled to the absorption media. This coupling process can be carried out efficiently by using a ferromagnetic material with a narrow hysteresis loop (i.e., a soft magnetic material). The actual mechanism of absorption takes place through the initial movement of the Bloch walls and the subsequent rotation of the magnetic domain. At the even higher frequencies depicted in the area bounded by "R", the principal mechanism of attenuation is reflection of energy, which occurs because of the magnetic fields created by the eddying currents within the shielding material. The energy which creates these currents is derived from the interference itself.

The efficiency of a specific mechanism of attenuation is indicated by the percentage value of the given curve. The absorption and reflection curves intersect at point "A." This is an arbitrarily designated point denoting the performance of shielding materials consisting of two components

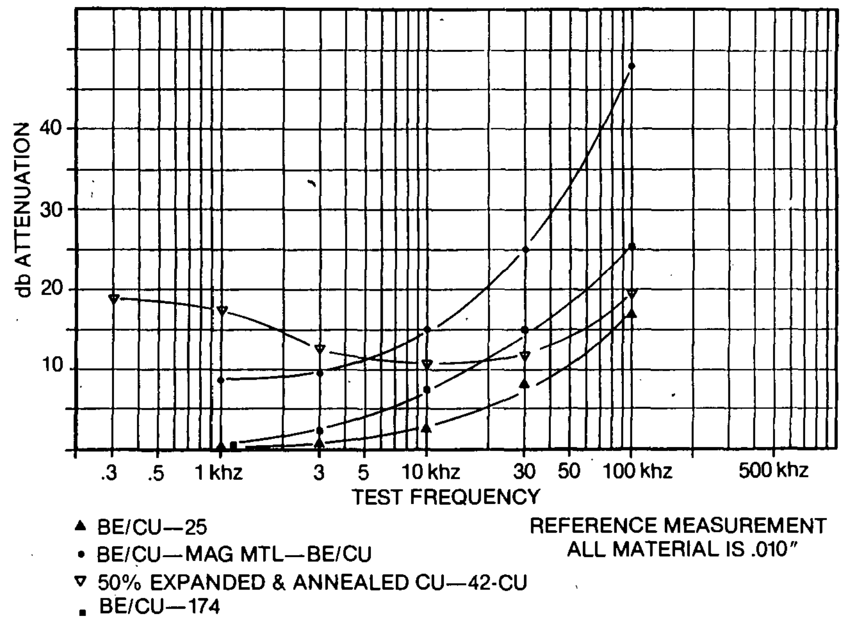


Figure 2. Shielding Performance of Selected Materials.

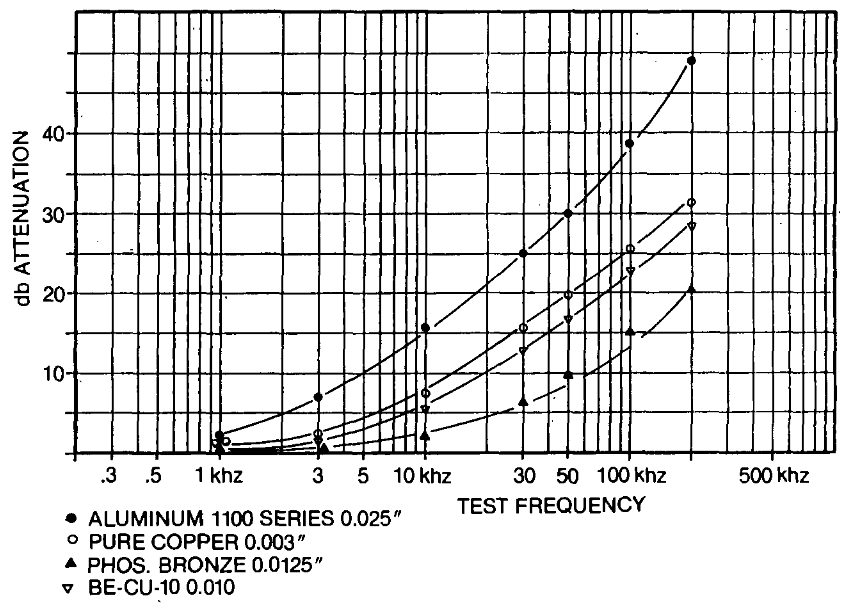


Figure 3. Shielding Performance of Materials.

(viz., high conductivity material and soft magnetic material). The position of point "A" will move to the right if the resistivity of the conductive material increases or if the permeability of the soft magnetic material decreases. Similarly, the inverse of these characteristics causes "A" to move to the left. Thus one sees the problems inherent in the use of a high conductivity material such as copper at low frequencies or in the use of "mu-metal" at high frequencies. These materials shield well at certain frequencies but not throughout the electromagnetic spectrum. If shielding were attempted with a material lacking both mechanisms (e.g., "monel-400" with a conductivity of 3.4 percent IACS (21 °C) and a Curie point suppressed by the copper to 0°) the EMI shielding performance would be minimal.

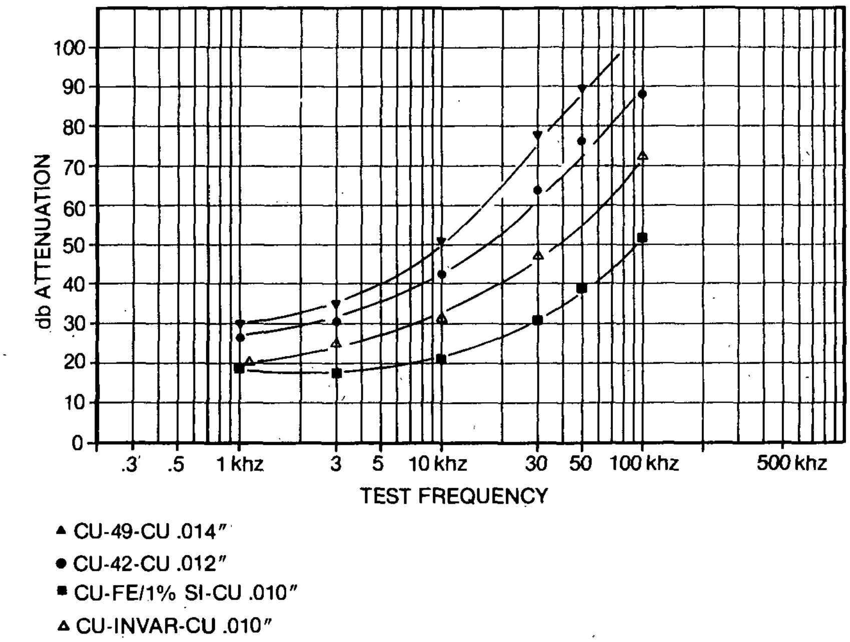


Figure 4. Shielding Performance of Magnetic Trilayers.

TEST RESULTS

Figures 2 through 9 are based on data collected with the near-field tester. Measurements were made in accordance with the procedure outlined in the ITEM Update 1988.[2] Some of the graphs for metals and alloys may look contradictory. This is not the result of inaccurate measurements, however; it is an indication that the tested materials have a different chemical composition or different grades of purity. As a rule, the production variations in manufacturing practices become obvious when the material is used for EMI shielding. Thus, if 1 percent beryllium is added to the copper, its conductivity will be reduced by approximately 50 percent. Likewise, combinations of 0.15 percent arsenic and 0.015 percent phosphor will reduce conductivity by approximately 55 percent. In order of declining significance, elements detrimental to the conductivity of copper are additions of phosphorous, iron, boron, silicon, arsenic, and beryllium. Zinc, gold, cadmium, and silver cause minimal change. High purity aluminum (#1100 series) materials have approximately 62 percent of the electrical conductivity of copper. This conductivity is reduced to 30 to 50 percent by additions of copper, nickel, magnesium, zinc, silicon, etc., and is even further reduced by tempering. It is advisable that when aluminum is used for EMI shielding that the conductivity of a particular alloy and its temper be considered.

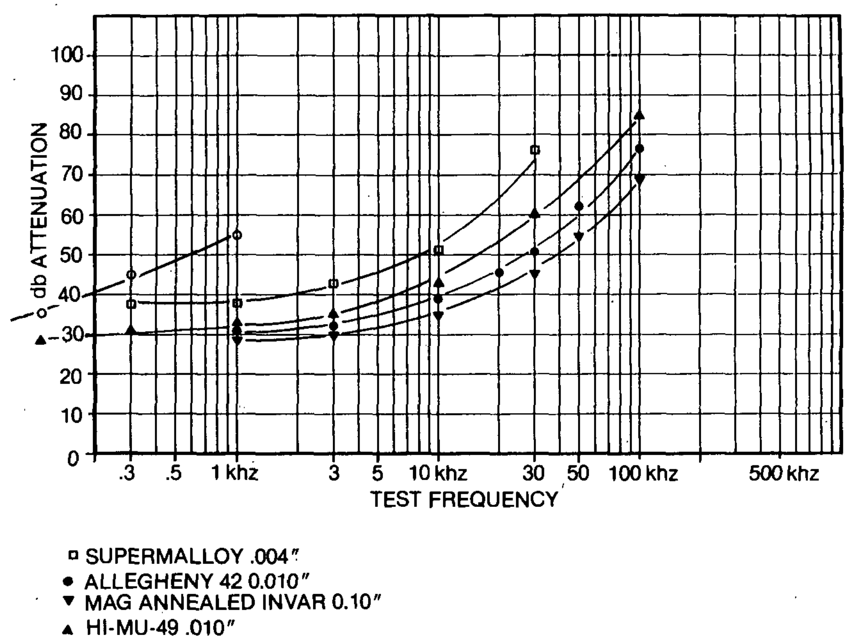


Figure 5. Shielding Performance of Monolayers.

For ferromagnetic materials, the main culprit is carbon — 0.02 per-

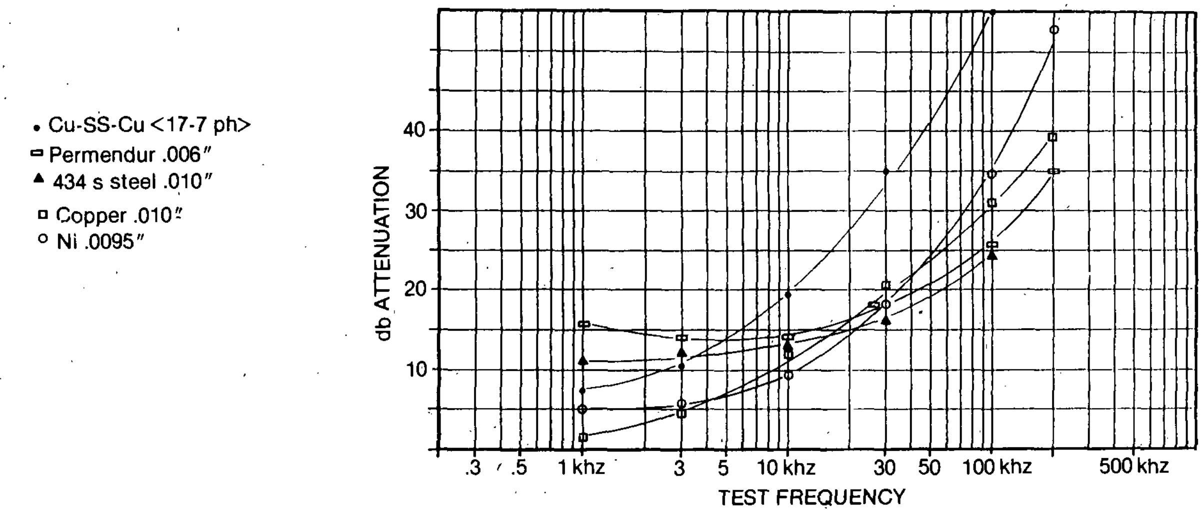


Figure 6. Shielding Performance of Selected Monolayers.

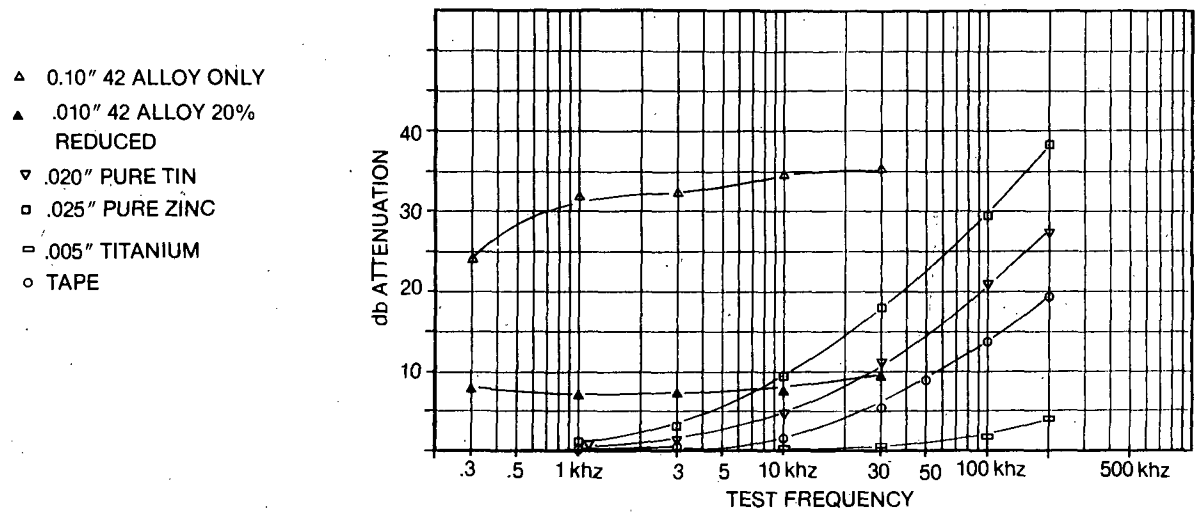
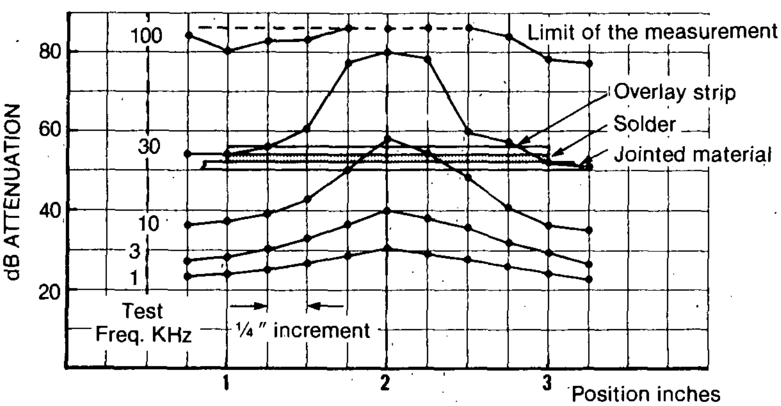


Figure 7. Shielding Performance.



SCAN OF THE JOINT .010″ Cu-42-Cu TO .010″ Cu-42-Cu
OVERLAY .012″ Cu-42-Cu.

Figure 8. Scan of the Joint 0.010″ Cu-42-Cu to 0.010″ Cu-42-Cu. Overlay 0.012″ Cu-42-Cu.

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cent is enough to increase hysteresis losses in iron by approximately 18 times (Bozorth Electromagnetism). The addition of different elements may have a positive or negative influence on the ferromagnetic materials, but the complexity of those relations is far beyond the scope of this article.

Figure 2 depicts the performance of "Berilco-25" (copper alloy #170) with a 1.7 percent nominal amount of beryllium. Be/Cu/Mag ML-Be/Cu is an experimental material made for finger stock. Fifty percent expanded and annealed Cu-42-Cu is a fifty percent expanded trilayer grid. Be/Cu-174 is a copper alloy where some beryllium is replaced by Ni and Co (nickel and cobalt). In Figure 3, aluminum #1100 is 99 percent pure. Pure copper is "Copper #103." Phosphorus bronze has 0.02 to 0.04 percent phosphorus, and Be/Cu-10 has 1.0 percent beryllium and no other additives.

Figure 4 shows the performance of trilayers with designated magnetic material sandwiched between the #103 copper. Figure 5 gives the shielding performance of a supermalloy, Hi Mu-49, Hi Mu-800, Invar and "42 permalloy."

Materials given in Figure 6 are also monolayer form. Cu-SS-Cu have maraging steel with 17 percent chromium and 7 percent nickel. The nickel is soft annealed #201 nickel, and the permendur is 48 percent cobalt and 48 percent iron with 2 percent vanadium, a high purity product.

Figure 7 shows the result of diverse materials found in the laboratory. It has two traces of alloy "42" only. The lower trace is from the same material, which is also 0.10-inch thick but rolled (20 percent reduction). The stressed nickel-iron binary apparently offers poor shielding. The tape is tin alloy-coated, copper-based, embossed scotch tape.

Figure 8 scans shielding performance for butted and overlaid joints. Joints are soldered with a 60/40 alloy.

Figure 9 displays a decline in the shielding properties of Cu-42-Cu, Cu-49-Cu trilayers and of regular Mu-metal under deformation. The stress involved wrapping them 180° on mandrels of different diameters and then flattening them again in the vise. Because of the limited area of resolution of the tester (approximately 4 to 6 cm^2), the difference between the 0.187- and the 0.312-inch mandrel experiments could hardly be distinguished. Copper was stressed by rolling it to 40 percent of its initial thickness (0.25-inch material reduced to 0.010 inch). The resultant change in conductivity brought about a decline in shielding properties of 2 to 4 percent.

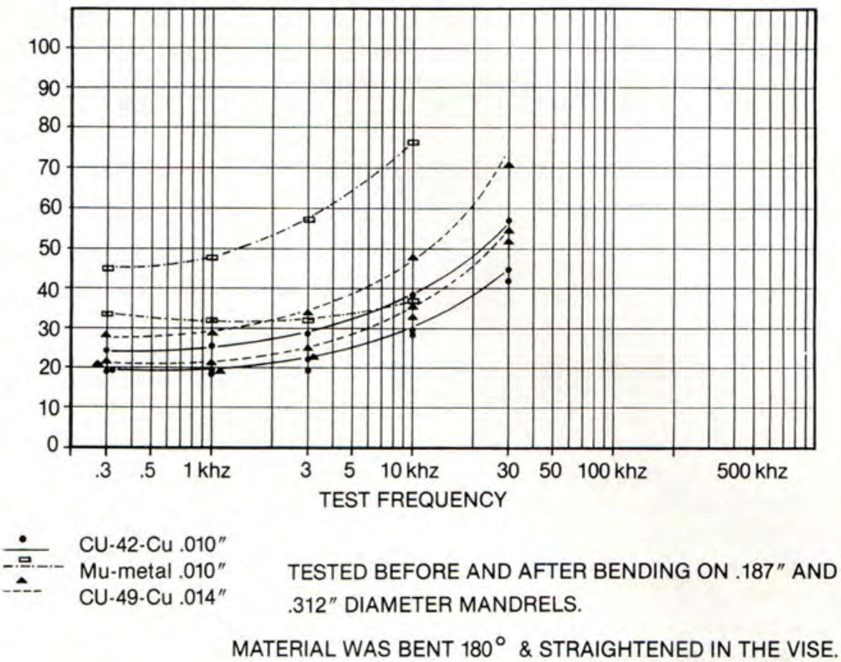

Figure 9. Shielding Performance of Material Subjected to Deformation.

CONCLUSION

Data on the effects of varying the composition of shielding materials are crucial to the design engineer. The near-field tester expedites the generation of these data and simplifies the process by which the shielding performance of varied materials can be monitored. ■

ACKNOWLEDGEMENT

The author wishes to note the valuable contributions to near-field testing data by Dr. Lyle E. McBride of the California State University at Chico. Dr. McBride is the author of numerous articles on EMI testing, including a recent article on a computer program relating the data obtained with a near-field tester to the standard systems such as NSA-65-6.

REFERENCES

1. G. Trenkler, "Shielding Effectiveness of Various Materials as Measured with the Near-field Tester," ITEM Update 1988, 6-12.
2. Ibid, p. 6.