SHIELDING EFFECTIVENESS OF VARIOUS MATERIALS AS MEASURED WITH THE NEAR FIELD TESTER

The use of a near field tester enables the engineer to collect measurements quickly and accurately.

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INTRODUCTION

The test procedures for determining the EMI shielding efficiency of various materials can be complicated. It is almost impossible for a design engineer to obtain quick and accurate measurements on the performance of the shielding materials. This problem can be overcome by substituting a less cumbersome method for the usual test procedures. The data obtained must be compatible with the original method or easily interpreted for use with other systems. To accomplish these goals, a near-field EMI tester has been designed (Figure 1). The tester is a table-top instrument utilizing the inductive coupling of two coils. The amount of coupling is inversely proportional to the electromagnetic shielding property of the test sample.

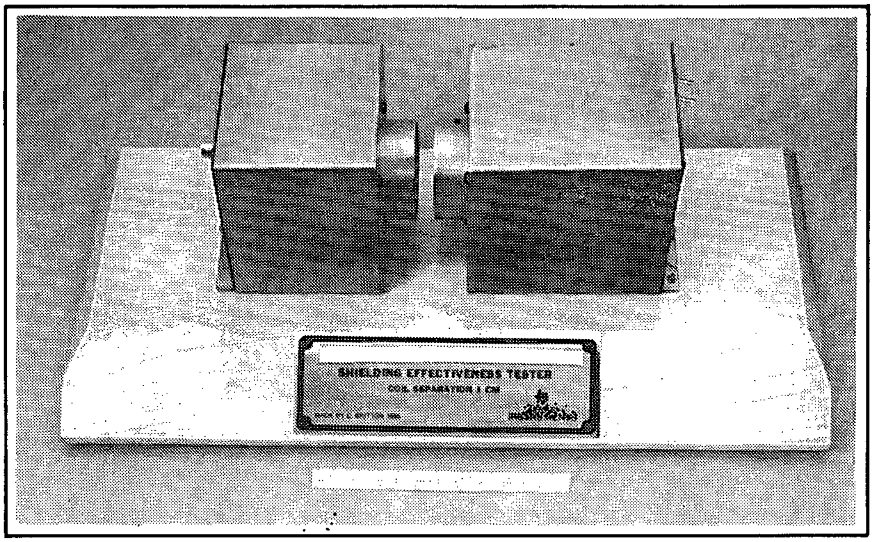

Figure 1. Near Field EMI Tester.

THE NEAR FIELD TESTER

The basic tester consists of a pair of coaxial coils 18.4 mm (0.725 inch) in outside diameter, wound on Teflon cylinders in a groove 5.1 mm (0.2 inch) wide, and 3.2 mm (0.125 inch) deep. Separation between coil faces is exactly 10 mm. Each coil is surrounded by a tubular shield of annealed *mu-metal alloy*. The shield is 50.8 mm (2.0 inches) in diameter and 63.5 mm (2.5 inches) in length. It has a thickness of 0.25 mm (0.010 inch). This first shield is surrounded by a second shield of identical material, with the same thickness and length (the two shields are separated by 0.08 mm [0.003 inch] thick Mylar). Each coil within the shield is surrounded by a 12.5 mm (0.5 inch) layer of silicone rubber in a 1.3 mm (0.050 inch) thick tube of 49 permalloy and enclosed in a box made of 1.3 mm (0.050 inch) copper/invar/copper composite metal. These boxes are mounted on the base so that the axes of the coils are positioned on a single line (Figure 2). One box should be mounted so that the distance between the coil faces can be changed.

The gap between the coils (and between their respective shields) is covered on each side by a sheet of felt to permit easy insertion of samples and to prevent accidental damage to the coils. The felt also provides a means for repeatable positioning of the sample, which is very important for EMI testers with a short gap between coils. The test apparatus has been built in such a way that the pairs of these test coils can be interchanged. Basically three pairs of coils are used:

- 0.125 mHy coils for the frequency range of up to 1.25 MHz (resonance of the coils is at 1.8 MHz).
- 1.25 mHy coils for the frequency range of up to 200 kHz (resonance of the coils is at 0.5 MHz).
- 9.12 mHy coils for low frequency (resonance is at 0.175 MHz).

The excitation coils should be driven from a source of 50 ohms internal resistance or less. A power stage made from an integrated power amplifier is used as the driver and produces a clean sinusoidal output up to 300 kHz. Power for the device is supplied from 12 D-size Ni-Cd cells. The whole stage, including the power pack, is encased in a box made of 0.050-inch thick shielding material (Cu-Invar-Cu), which alleviates problems with leakage of the excitation signal.

TEST PROCEDURE

The measurement starts with the establishment of the zero reference. The excitation coil is fed with a sinusoidal signal, and the output of the sensing coil is monitored. The excitation level input is limited by the physical size of the coil. Optimum output values are between −30 and −10 dB

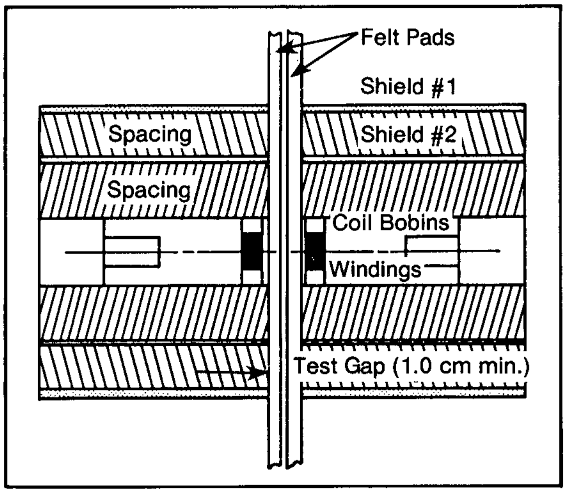

Figure 2. Construction of Near Field Tester.

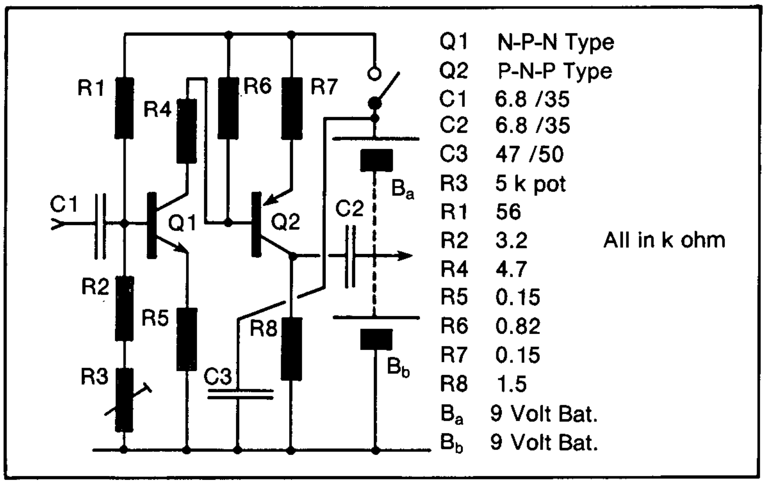

Figure 3. Built-in 30 dB Amplifier.

(as read across the sensing coil -- 0 dB = 0.7746 volts rms). This value corresponds to the field strength of up to a few gauss at the surface of the sample. Obviously, no field strength changes are tolerable while the test is underway. It is possible to provide the tester with the second sensing coil to achieve self-leveling action. However, the use of a stable output oscillator produces a stable zero reading without a second sensing coil. The field tester has a built-in preamplifier, which will provide 30 dB gain over the test range if amplification of the voltmeter is not sufficient (Figure 3). Selection of the output is made with a toggle switch. The initial zero reading is recorded. (For convenience, a zero reading on corresponding scales is used. This designation results in a −10, −20 or −30 scale; but any other number can be used as zero reference.) Considering that the scales of attenuation are very large, all readings are made in decibels, or converted to this measure. Without changing any setting, the sample of the material to be tested is inserted in the slot between the coils. The minimum recommended size of the sample is 4.0 x 4.0 inches, the optimum is 5.0 x 5.0 inches. Also larger size samples can be used but they should be grounded at high frequency. A second reading is taken. The difference between the readings is the amount of attenuation produced by a given shielding material. Readings are taken at all needed frequencies with subsequent readjustment of the zero setting. The measurements can be made in a wide band or a weighted mode. This mod-

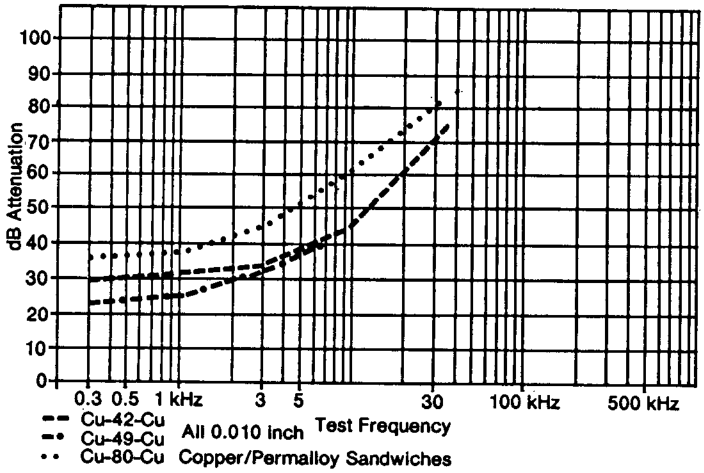

Figure 4. Shielding Performance of Copper-Magnetic Material-Copper Tri-layers.

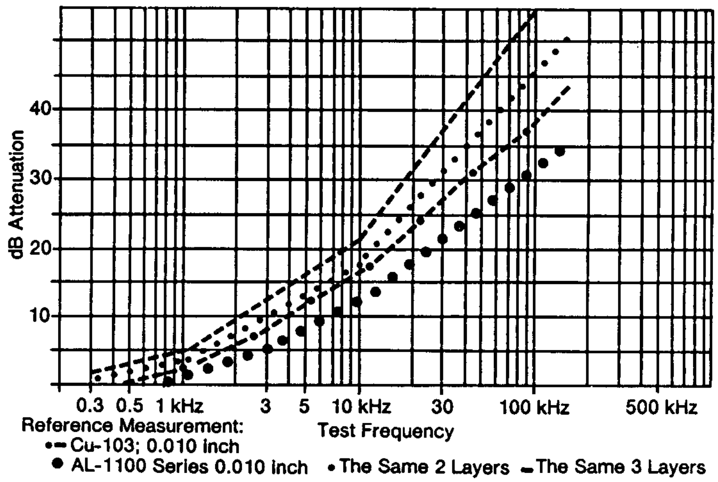

Figure 5. Shielding Performance of Copper and Aluminum Foils.

el of the tester has a dynamic range of up to 85 dB in wide band mode. Obviously, measurements can be made with a signal analyzer for more precise results.

For this setup the following equipment is used: HP #3410-A AC microvoltmeter or an HP #334-A distortion analyzer in voltmeter mode. It is good practice to supply line voltage to the voltmeter through a constant voltage ferroresonant type transformer in order to reduce interference (−40 dB, as measured in one laboratory).

Some peculiarities do occur with this system. First, it does not have an aperture effect, which is unwanted attenuation due to the geometry of the test window. Experience puts this value at 12 dB for a 24 x 24 inch window for the NSA-65-6 test procedure. In other words, after reference measurement in free air is established and after the excitation/sensing coils are positioned through the window, the reading will be lower. Secondly, the resolution area is less than one square inch as compared with four square feet in the standard test procedure. The result is a considerably finer resolution of the material's shielding properties on a certain area of its surface. In contrast, the standard test yields an average shielding performance of the test sample. Specific shielding data measured with the tester are given in Figures 4 through 8.

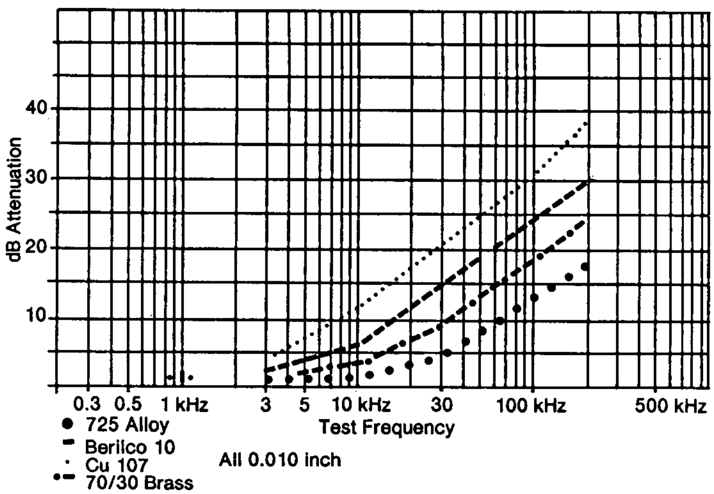

Figure 6. Shielding Performance of 725 Alloy, Berilco, Copper 107 and 70% Cu-Brass.

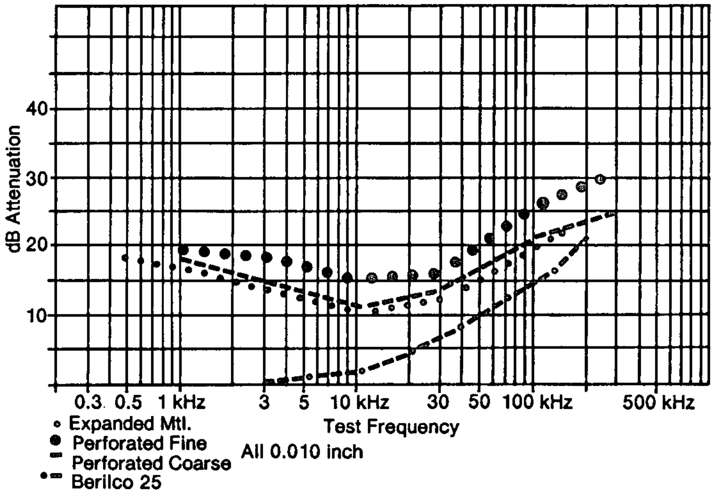

Figure 7. Shielding Performance for Cu-42 Alloy-Cu Sandwich.

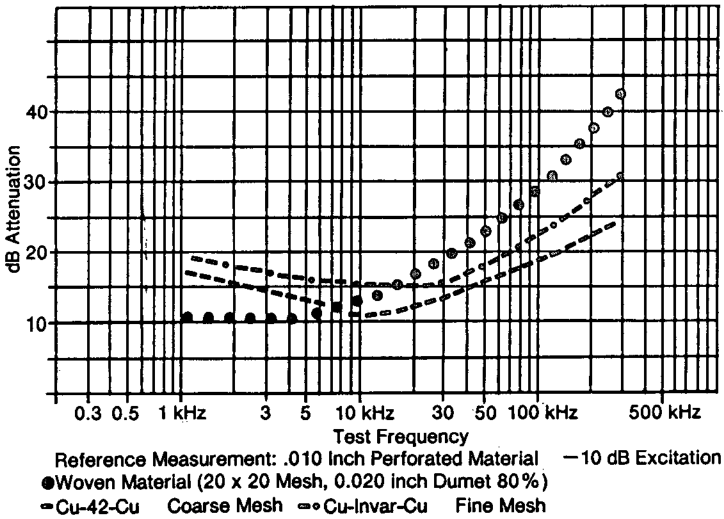

Figure 8. Shielding Performance For Cu-Invar-Cu, Cu-42-Cu, Woven Mesh.

CONCLUSION

A computer program allows conversions from obtained data to the values produced by the other testing procedures. On the whole, the use of the near field tester allows the user to monitor the shielding performance of the material used with minimum cost and time. The device can be used for incoming and outgoing inspection, or as a QC tool between production processes such as annealing. The tester, if built correctly, produces more accurate results than the standard procedures. Testing is limited to the upper limit of 100 to 300 kHz. (However, if an appropriate drive can be provided, this upper testing frequency can be expanded.)

This type of testing is not done at higher frequencies because in this range combinations of shielding materials, copper is used consistently. The reflective mechanism of shielding in which copper or high electrical conductivity materials such as aluminum or silver are used starts at 7.0 to 15.0 kHz. Thus it follows that if shielding material of the copper sandwich type works well in the range of up to 100 kHz, it will do so at any frequency. There is no physical basis for expecting otherwise. It is noted however that this principal does not apply to materials made of fine conductive powders or flakes, where the contact between the particles is not ohmic.

Note

Additional information and correlation of the above described tests to the standard procedures can be found in the proceedings of the IEEE: IMTC-86, "Characterization of Metals as EMC Shields" by G. Trenkler and L. McBride.