A Portable Shielding Enclosure For EMC Testing

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BACKGROUND

Inexpensive solid-state commercial test equipment and personal computers have become standard tools of the trade for troubleshooting sophisticated electrical equipment problems, both in the laboratory and in the field. This equipment revolution has made electrical troubleshooting easier, faster and cheaper than ever. However, the electromagnetic environment in which this equipment must operate is becoming more complex and cluttered every year.

It is not uncommon for test equipment to be exposed to interference field strengths of 5 to 25 V/m. At one time, this level of interference was restricted to the military environment. But the explosion of high technology civilian electronic devices over the last 10 years has increased the potential for test equipment performance degradation from stray electromagnetic fields. Most commercial test equipment is designed to operate in EMI fields of no more than 1 V/m. Thus, the probability of obtaining faulty data or suffering costly time delays due to "phantom" interference in uncontrolled field environments is ever increasing.

Historically, the solution to this problem has involved either custom EMI-hardened test equipment, which is generally single-purpose and which can increase unit cost by 100 to 500%, or standard test equipment in a shielded screen room. The latter solution has the limitation of requiring the equipment under test to be brought to the screen room. Some attempts have been made to scale down the size of the classic screen room and to achieve some degree of portability. Most of these enclosures are still quite large, require extensive setup time, and are quite expensive.

A small, lightweight shielding enclosure is used by the Navy to field-test

In the early 1990s, the U.S. Navy decided that shrinking military budgets could no longer support the custom-built equipment solution. Furthermore, it was recognized that the military's problems always demanded in-the-field solutions, but rarely allowed the time or the space required to set up a portable enclosure. The Navy decided that what was needed was a small Faraday cage which was truly portable. Their goal was to develop a small, lightweight enclosure which could be hand-carried to a test site, set up in a minute or two, and which would protect only the test equipment placed inside. The device had to be suitable for field use by all branches of the Navy (including surface vessels, submarines, and air wings), yet be relatively inexpensive. The finished product was not intended to be a classic military hardened device, but an inexpensive, commercial product that could be discarded and replaced if damaged.

After several unsuccessful attempts to develop a suitable design, a Request for Quotation (RFQ) for a prototype device was solicited from a design manufacturing team. The Navy recognized that this RFQ comprised a wish list, and that a successful solution would encompass as many of the following attributes as possible:

- Protection in accordance with MIL-T-28800
- 40 dB shielding from 100 MHz to 10 GHz
- Weight of less than 5 pounds
- A collapsible enclosure 2′ x 2′ x 2′ with a shielded window on one side to allow viewing of digital displays
- Ability to break down into a small package for handling and storage
- Flame retardance
- Mildew resistance
- Weather resistance
- Cost-effectivness over special-ordered test equipment manufactured with adequate EMI shielding

The design team, working in conjunction with the Naval Warfare Assessment Center, Norco, CA, undertook a development effort to build a Faraday cage which satisfied the intent of the Navy's requirement.

PHYSICAL DESIGN

A successful design was achieved in early 1993, utilizing a new metallized shielding fabric and a unique cage design. The de-

Continued on page 241

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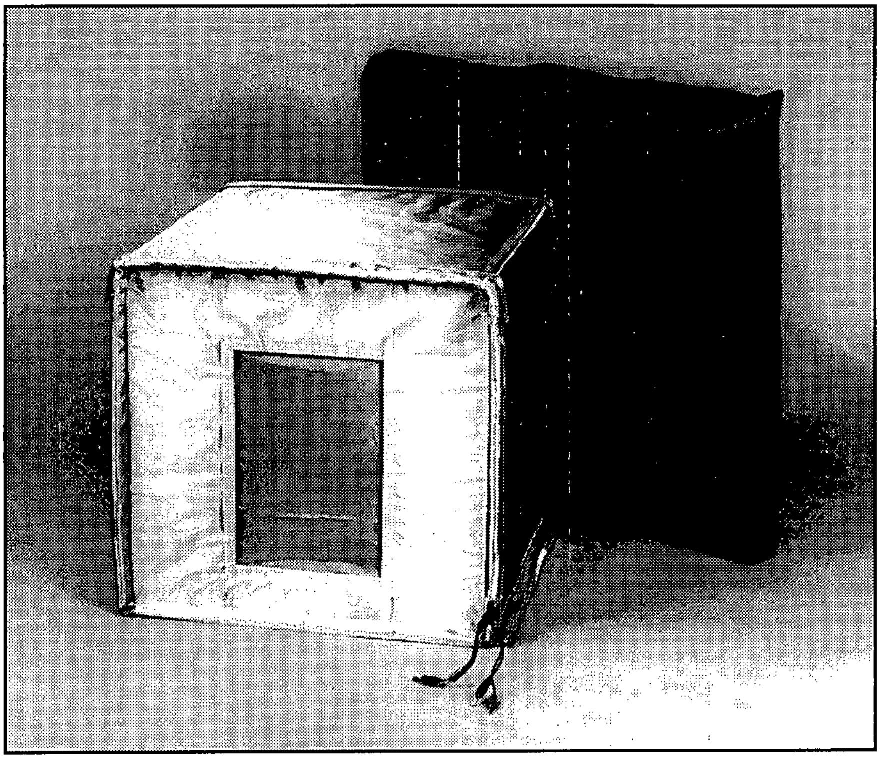

Figure 1. *Portable Testing Device.*

sign resulted in a fully-collapsible, one-piece cage which provides the required internal dimensions of a 24-inch cube, a finished weight of less than 7 pounds and a shielding effectiveness which surpasses the Navy requirement (Figure 1).

The design consists of lightweight plastic panels which are sewn into envelopes of the metal-plated polyester taffeta cloth. The woven shielding cloth contains 0.5 to 0.7 oz/yd of nickel plating over 0.3 to 0.4 oz/yd of copper plating, and in laboratory testing provides an average shielding effectiveness of 82 dB from 10 MHz to 1.7 GHz. The lightweight panels give the cage rigidity and a cubic form which is lacking in earlier unsuccessful designs.

The collapsible design results from having two panels which can be opened, allowing the box walls to collapse and be folded over onto themselves. The two door panels can then be folded in, resulting in an easily transportable package similar in size to a pizza box. Having panels which open and close is desirable for accessing the test equipment and connections, but they create the potential for EMI leakage. This problem was overcome by utilizing electrically conductive Velcro closure seams and a unique inset door panel design. When assembled, the inset doors give the cage an extremely rigid structure and minimize EMI leakage at door seams. The rigid wall design also provides a dimensionally stable surface for the window screen attachment. The window is a metallized mesh of nickel-plated polyester. The mesh has a 34% open area and a shielding effectiveness of 60 to 70 dB in the 100 MHz to 10 GHz range. The window allows CRTs and LED displays to be seen during operation. Two EMI sealed cable access ports are provided, one at each door, to allow power cable entry and data cable exit.

The cage also incorporates a self-contained, 1-inch wide electron" strap to facilitate grounding of the cage during operation. This strap is also utilized as a containment device, holding the

Continued on page 244

collapsed panels together when the unit is not in use. The use of metallized fabric was desirable because of its very light weight and flexibility, but it is also a delicate material, and requires some additional mechanical protection to be useful in a field device. To provide mechanical protection to this material in high wear areas, a 20-mil sheet of flame-retardant polyurethane film was added to the inside cage floor and to the outside bottom of the box.

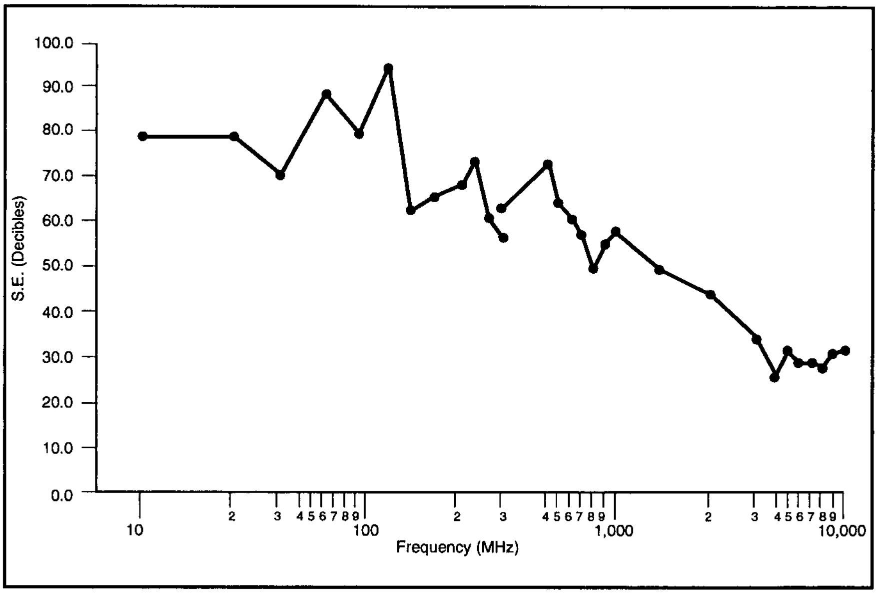

Figure 2. *Shielding Effectiveness of Portable Faraday Cage.*

ELECTRICAL PERFORMANCE

A full-scale EMI testing program was conducted in March 1993, at the National Institute of Standards and Technology (NIST) in Boulder, CO. NIST utilized several facilities to evaluate the shielding performance of the Faraday cage. To test performance from 10 to 300 MHz, a large TEM cell with a spherical dipole radiator was used in three different polarization positions. Performance ranged from a high of 95 dB at 120 MHz to a low of 56 dB at 300 MHz with the E-field perpendicular to the window. Average shielding effectiveness in this range was 73.5 dB with a standard deviation of 10.97 dB (Figure 2). For frequencies from 300 MHz to 10 GHz, a large reverberation chamber and a mode-stirred technique were used. Performance ranged from a high of 70.3 dB at 400 MHz to a low of 50.1 dB at 800 MHz. Average shielding effectiveness from 300 MHz to 1 GHz was 60 dB with a standard deviation of 6.09. Shielding effectiveness averaged over 40 dB from 1 to 3 GHz and around 33 dB in a relatively flat curve from 3 to 10 GHz.

RESULTS

This design met or exceeded all of the Navy's physical, environmental, electrical and cost objectives except for the finished weight. The unit exceeded the goal weight by approximately 1-3/4 pounds. The Navy felt that this was a very minor concession since this design was superior to all previous plans. The EMI performance was considered outstanding; the unit exceeded the performance goal up to 3 GHz. Previous attempts using these types of materials had been 15 to 20 dB below the Navy's goal. Finally, the fact that the shielding effectiveness curve was essentially flat through 10 GHz and only slightly below the design goal made this design fully acceptable.

APPLICATIONS

The U.S. Navy is currently field-testing production units at land-based facilities, on surface ships and submarines, and with aircraft maintenance facilities around the U.S. Modifications based on this field experience will be incorporated into future units procured by the military. Presently, an 18- and 24-inch commercial derivative of this unit is being marketed and a patent is pending. This product is in use in the electronics, testing and commercial aviation marketplaces both in the U.S. and abroad. A large version (8-foot cube), which will also be a self-contained, one-piece field enclosure for electronic communications security, is under development for an off-shore customer.

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