AVOIDING FATAL PITFALLS IN SHIELDED CABINET DESIGNS

The basics of shielded cabinet design should be reviewed in order to select an efficient, cost-effective unit.

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INTRODUCTION

A plethora of technical information has been written on shielding effectiveness in electronic cabinets. Subjects included in these articles range from the types of material used in fabricating cabinets to frame construction techniques and from cabinet joint design to the types and mounting methods of conductive gaskets. However, all these subjects are important only to those who intend to design and to build their own cabinets.

Extensive experience, which spans the great majority of amassed technology and specification development within the electronics industry, has indicated that a significant percentage of companies which require a shielded cabinet in their system are much more preoccupied — and rightfully so — with designing their system. They relegate responsibility for the shielding effectiveness of the cabinet (which will contain that system) to their mechanical engineering support staff or to the company which actually supplies the unit.

Unfortunately, the single most important criteria in designing a shielded cabinet is the point most often missed by system designers and cabinet suppliers alike. Specifically, understanding that all cabinet shielding specifications are *system* specifications and that the only way to confirm the true effectiveness of the shielding is to test the system after it is installed in the cabinet.

One important point — viz. knowing what the real requirements are in terms of shielding effectiveness versus frequency — can mean the difference between success and failure. Also, the more exotic the application, the more costly the price of failure. A cabinet manufacturer cannot calculate this risk since only the system designers are familiar with the electronics which will be installed.

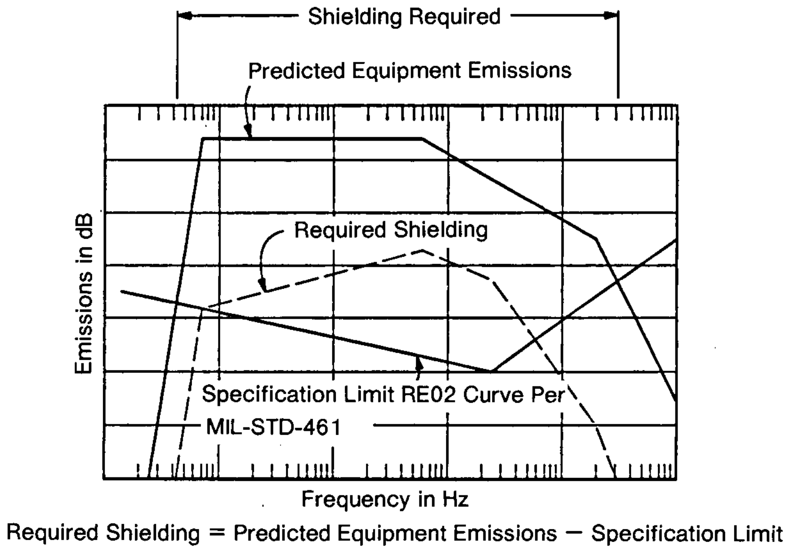


Figure 1. Shielding Effectiveness and Frequency Range of Enclosure.

Shielding requirements called out by FCC, MIL-STD-461 and TEMPEST specifications all define "not to exceed" noise emission levels for the entire system. This requirement means that the cabinet can be tested only after all equipment is installed and after cables are attached. The equipment is then turned on, the associated noise levels are recorded, and these are then compared to the maximum allowable noise levels as defined by the applicable specification for a pass/fail.

AVOIDING THE FLAK WHILE HITTING THE TARGET

The simple fact is that no cabinet manufacturer can state with any degree of assurance that its cabinet will meet FCC, MIL-STD-461 or TEMPEST specifications. These companies can only supply shielding effectiveness data to assist a system designer in making a logical decision. The designer must then predict the equipment emissions and must compare these to the particular specification level with which he is working. The difference between these two levels is the shielding effectiveness of the enclosure, as illustrated in Figure 1.

The most important consideration in choosing an enclosure is selecting only those suppliers who provide actual shielding effectiveness performance on their cabinet, published, in chart form, *with supporting certification that the results presented will be maintained in production units.* Equally important is cabinet cost, which can vary dramatically between suppliers and which should be tied directly to the certification of performance in production units.

An often overlooked, but important, consideration is the ease with which the door can be latched shut. Many of the latching mechanisms employed require the strength of a competitive athlete to close. So what happens if the "real world" operator of the equipment is 5 feet tall and weighs 110 pounds? The last of these major roadblocks to success is side access to the equipment inside the cabinet. Often, panel mounting methods or basic cabinet design prohibit the attachment or removal of side panels. If side access is an important design consideration, the feasibility of side access should be double-checked.

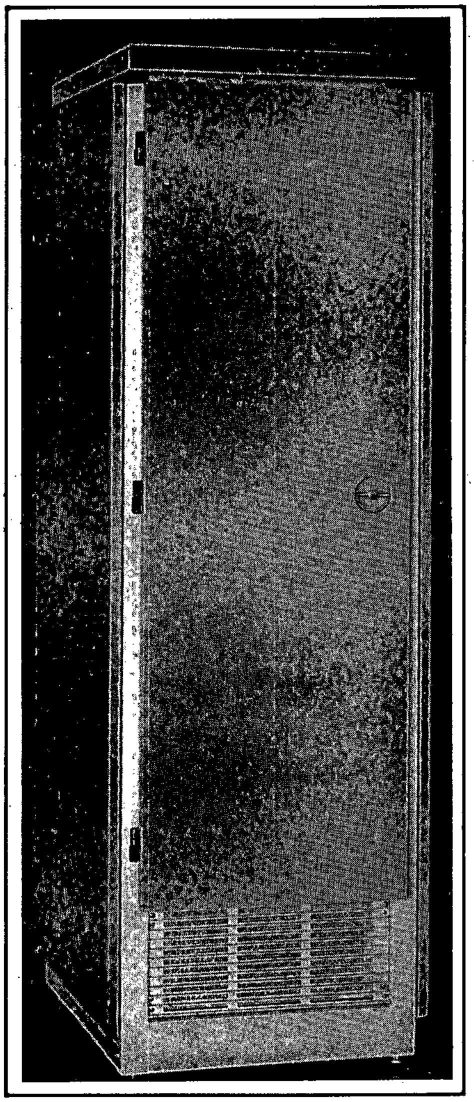


Figure 2. Unreinforced 11-Gauge Steel Cabinet with Two Rows of Gasketing.

CLEARING UP SOME FOGGY ISSUES

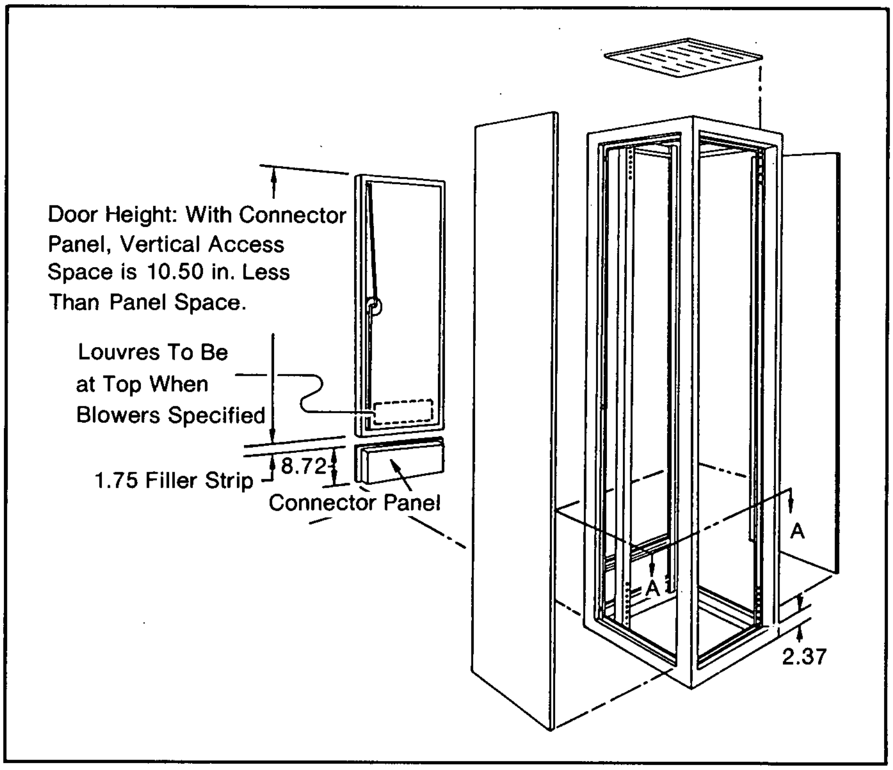
Cabinets are available in many standard ranges of shielding effectiveness. These include those designed to meet FCC requirements shown in Figures 2 and 2A, those meeting general military specifications shown in Figures 3 and 3A, and those designed to meet specifications related to TEMPEST compatible cabinets noted in Figures 4 and 4A. With this broad range of specifications, comes an understandable level of confusion which requires clarification.

The only specification that covers the measurement of the shielding effectiveness of an empty enclosure is MIL-STD-285. This standard outlines the generally-accepted test procedure for measuring the shielding effectiveness of an enclosure. A transmitter is placed inside the cabinet, and a receiving antenna is positioned outside the unit. An open reference is taken with the cabinet door open and is followed by a closed reference with the cabinet door closed. These readings are taken at discrete frequencies in a range from 14 kilohertz to 10 gigahertz in the electric field and plane wave fields and from 1 kilohertz to 30 megahertz in the magnetic field. The difference in these readings is the shielding effectiveness of the cabinet.

It is important to note that if the open reference is made with the transmitting and receiving antennas in open space and if the transmitting antenna is then placed inside the cabinet, then the shielding effectiveness would increase an additional 10 dB. This increase occurs because the cabinet provides a certain level of shielding effectiveness even with the door open.

Determining whether the test was performed with the antenna *inside* or *outside* the cabinet for the open reference can have an important impact on whether the system will be adequately protected. If the data shows that the shielding effectiveness achieved under test is very close to the required shielding levels, it should be ascertained that the trans-

Figure 2A. FCC Shielding Effectiveness Requirements for Cabinets.



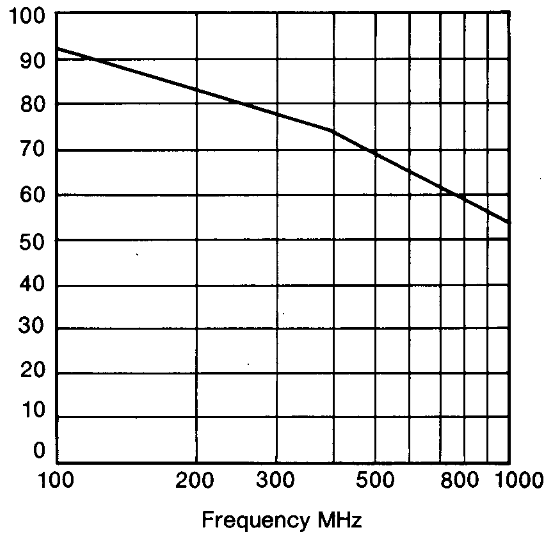


Figure 3A. Cabinet Shielding Effectiveness Requirements for General Military Specifications.

Figure 3. Unreinforced 11-Gauge Steel Cabinet.

mitting antenna was placed inside the cabinet during every phase of the test, including the open reference stage. Otherwise, the safety margin inherent in the correct test method is eliminated, and there exists the real possibility of failure.

Understanding Testing Procedures

Most testing is performed with both a front and rear door in place. If the requirement will not allow a front door, it is important that the cabinet supplier be consulted as to whether the required level of shielding can still be achieved. It is equally important to confirm that the test results obtained from the cabinet supplier were generated on a test unit equipped with proper openings for air intake and exhaust. If not, the results obtained in actual use within the system will probably be less than the shielding level listed by the supplier, and that difference could be extremely costly.

The Price of Oversight

Failure to take these important steps can be disastrously costly because an uneducated guess can result in days of additional laboratory testing and field-fix modifications to a "standard" which ultimately failed system testing. This pitfall generally costs the specifier significantly more than if he had ordered a "custom" design, and the problems could have been avoided by attention to details.

The Cost of Overspecification

Another costly extreme is the assumption that a "worst case" shielding level will be required. The choice of a highly shielded cabinet which is not really needed can be extremely costly. To illustrate the magnitude of cost difference, a cabinet designed to meet the MIL-STD shielding levels can be expected to be two to three times more expensive than that required for compliance with FCC requirements. Further, a TEMPEST-compatible unit might be expected to be three or even four times greater than the MIL-STD cabinet.

Making the Most of the Specifying Dollar

Several factors drive up cost. One of the most important is the use of honeycomb filters rather than perforated screens over openings. In the requirements outlined by Figure 2, perforated sheet is all that is truly necessary. The crucial factor which should be considered in this situation is the percentage opening of the screen, which should be kept at 50 percent.

Cabinets designed to medium shielding levels may require a honeycomb filter, but it should be tin-plated because the honeycomb is made with non-conductive adhesive at the node points of the hexagon cells. The tin plating "jumps" these joints, makes the entire filter more conductive, and eliminates a level of inconsistency that might otherwise cause erratic and unacceptable performance. This feature adds about \$100 to the price.

In cabinets designed to meet the most stringent shielding levels, it is not the performance of the filter as much as the interface between the cabinet and the filter that is of greatest concern. The filter frame, as well as the opening within the cabinet, must be sufficiently rigid so that it will not distort when the units are bolted together. For an efficient interface, a double gasket is generally recommended with about 1-1/2 inches between screws. To assure satisfactory performance, these filters are generally made of steel, and they add approximately $200 to $400 to the cabinet cost.

Another important consideration is the grinding and welding of all joints. In the most basic shielding requirements, joints do not have to be welded, thus making grinding unnecessary. However, in both other levels of shielding, both welding and the cosmetically-acceptable grinding of the welds are required, and these two requirements adds significantly to the cost of the cabinet.

The third and most costly consideration is the structural stiffness of the cabinet itself. The higher the level of shielding, the stiffer the structure needs to be. This structural strength is necessary because a greater pressure on the gasket is required to assure a uniform seal. According to technical support data from gasket suppliers, 80 to 100 psi compression is required on a wire mesh gasket with an elastomeric core to achieve the following:

- 80 to 100 dB shielding effectiveness below 1 MHz,
- 60 to 80 dB shielding effectiveness from 1 MHz to 1 GHz, and
- 40 to 60 dB shielding effectiveness over 1 GHz.

This mesh-over-elastomer style of gasket material should be used in lieu of solid mesh to assure repeatability of performance. Frequent inspection of solid mesh gaskets is required because of its tendency to take a permanent "set" and its lack of resiliency. Units designed for the lowest shielding levels do not require high gasket pressure so lighter gauge material can be used and structural reinforcement is not necessary. The unit in Figure 2 is made with 16-gauge steel with no reinforcement. Figure 3 shows a cabinet of heavier 11-gauge steel, which forestalls the need for any additional reinforcement. Figure 4 shows a cabinet of 11-gauge steel but with considerable reinforcement to compensate for potential deflection caused by the high pressures necessary to seal the gaskets. In fact, the Figure 4 cabinet has two rows of gasketing 3/4-inch wide, doubling the pressure (as well as the cost) of the gasket seal. With only a single row of gasketing, the shielding effectiveness of the cabinet at 10 GHz would be reduced by 30 dB.

Another vital consideration involves the mechanisms for latching doors. In low shielding applications, a three-point latching mechanism with a standard wiping pawl is all that is necessary. No special reinforcement is required. The cabinet in

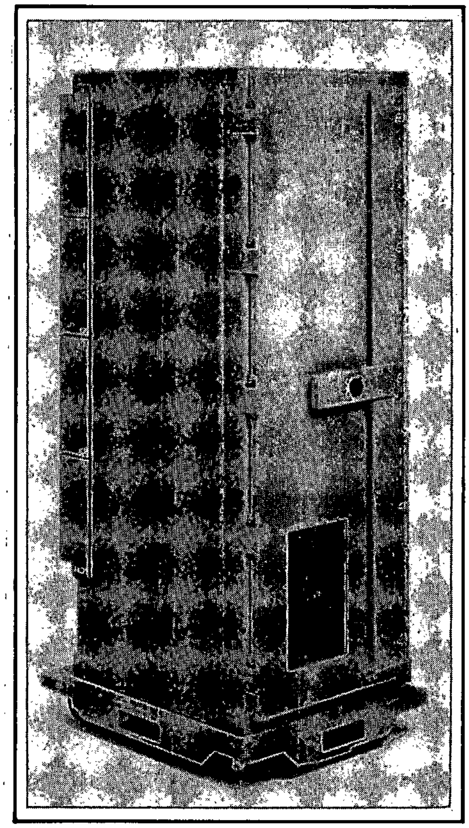


Figure 4. Reinforced 11-Gauge Steel Cabinet with Two Rows of Gasketing.

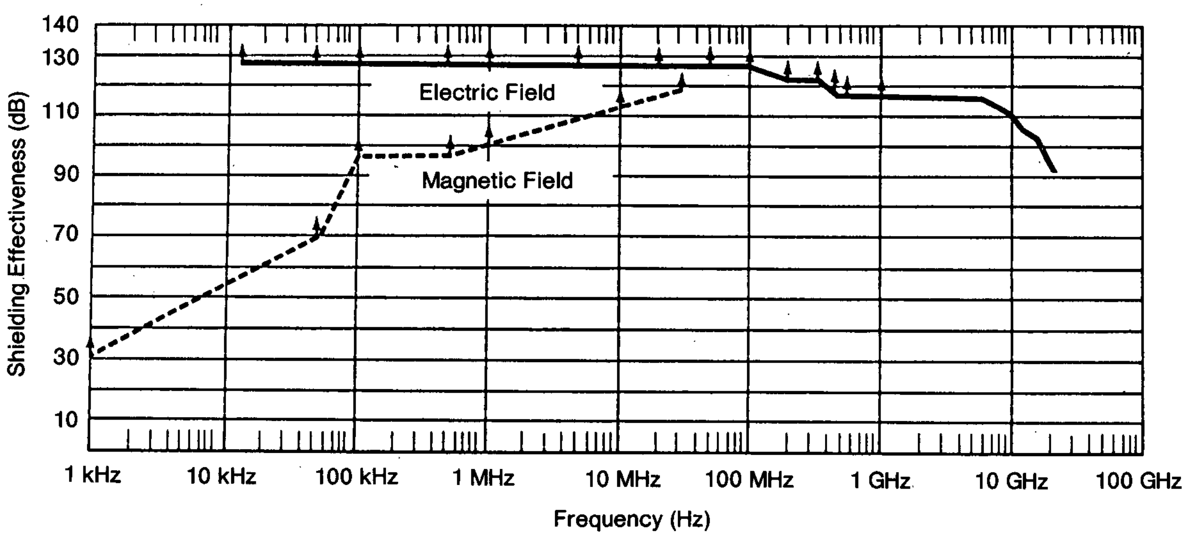


Figure 4A. Cabinet Shielding Effectiveness Requirements for TEMPEST Specifications.

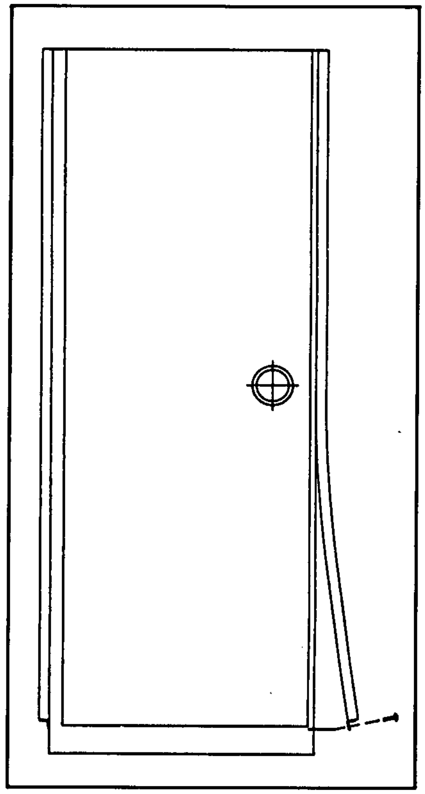


Figure 5. Cabinet Which Meets Low Level Shielding Requirements.

Figure 3 utilizes a four or five point latching mechanism, with the latching points utilizing ball bearing rollers, cams or other mechanical means to close the door while keeping it "user friendly". The highly-shielded cabinet in Figure 4 employs a continuous latching mechanism down the entire side of the door and utilizes a specially-leveraged lever to close the door. This unit also has special reinforcements so the door or the cabinet frame will not deflect and proper pressure will be maintained along the entire gasket. Obviously the higher the level of shielding effectiveness, the more sophisticated — costly — the latching mechanism.

A final point regarding latching is assuring that small people, as well as large strong ones, can latch the cabinet door properly. A mechanical design which assures a tight seal while permitting the easy latching of the cabinet door is essential to success. Generally, a closing torque of 80 to 90 pounds is acceptable. Anything beyond that warrants a close look at alternatives.

Accessibility — The Often-Overlooked Pitfall

Side panel access for equipment service or installation is often taken for granted. However, in highly-shielded cabinets, removable side panels are not available because they would impose potential opportunities for a shielding failure over time on an otherwise solid design.

Side panels on cabinets designed for middle and low level shielding effectiveness add significantly to unit cost. This cost reflects the additional fabrication of the panels themselves, additional gasketing, and installation expense. One should also be aware that most side panels are attached from the inside of the cabinet for cosmetic reasons, making access difficult if not impossible when the unit is fully loaded because of the inaccessibility of screws.

There is an answer to this dilemma for low-level shielding requirements, as noted in Figure 5. The side panel is hung on brackets attached at the top. A deliberate curve is put in this panel that works to "draw down" the panel as it is secured to a bottom flange by two externally-accessible screws. When locked into place, the panel maintains a secure seal around its perimeter to assure satisfactory shielding levels for less critical applications.

DETERMINE THE REAL NEED, THEN SPECIFY CLEARLY

The most important point in selecting a cabinet is determining the exact shielding level required. Compare this with published shielding effectiveness performance data (don't forget to study the test procedures) from cabinet and enclosure manufacturers. If side access is a necessity, make certain that the cabinet selected has been designed with this provision. In every step of the selection process, overspecification should be avoided while necessary openings, hardware, and ease of access are included in the enclosure chosen. ■