

Designing Enclosures for EMC Compliance

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While Science Has Devised New Models and Computerized Methods for EMC Design, Your Best Tool for Enclosure Design May Still be Your Thumb

We will start with the enclosure shown in Figure 1. It is a cube 50 cm in length, width and height with a removable front panel into which an aperture can be cut. The coaxial feed through is used to place a source inside the enclosure so radiation outside can be measured and the shielding effectiveness (SE) can be derived. The coaxial tube is for the insertion of fiber optic cables to be attached to sensors placed inside the enclosure. The tube functions as a waveguide below cutoff.

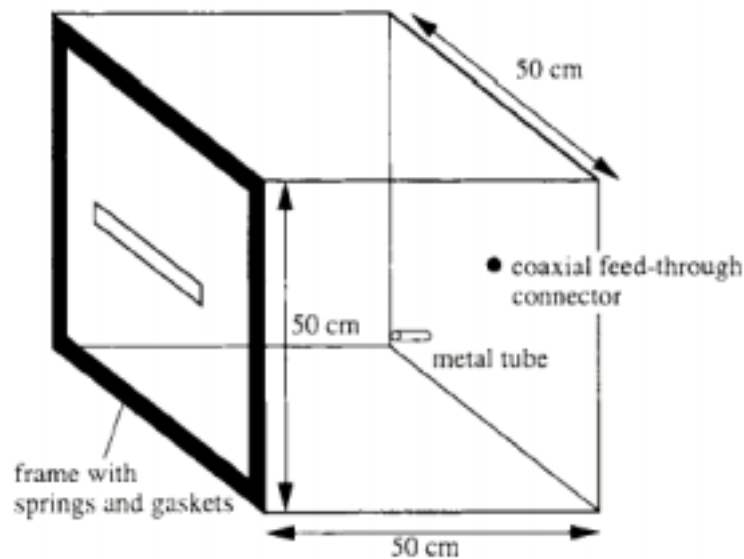


Figure 1: Geometry of a test enclosure (after Reference 2). Copyright 1999 IEEE.

Some of the formulas proposed by writers to predict SE are based on rather simplistic assumptions. For example, Ott's formula for a slot in an otherwise complete shield is (Reference 1):

$$SE = 20 \log_{10} \left(\frac{\lambda}{2l} \right)$$

Where:

λ = Wavelength in meters

l = Longest dimension of the slot in meters

The advent of computer modeling offers a new approach to the problem of predicting SE. Shielding effectiveness can be modeled using a combination of Finite Difference Time Domain (FDTD) and Method of Moments (MOM) techniques,.

In a study described in Reference 2, the enclosure of Figure 1 built and was its SE measured. Five walls of the enclosure were welded, and the wall holding the aperture connected to the rest of the enclosure with a conductive gasket. The wall consisted of a brass plate 1.5 mm thick.

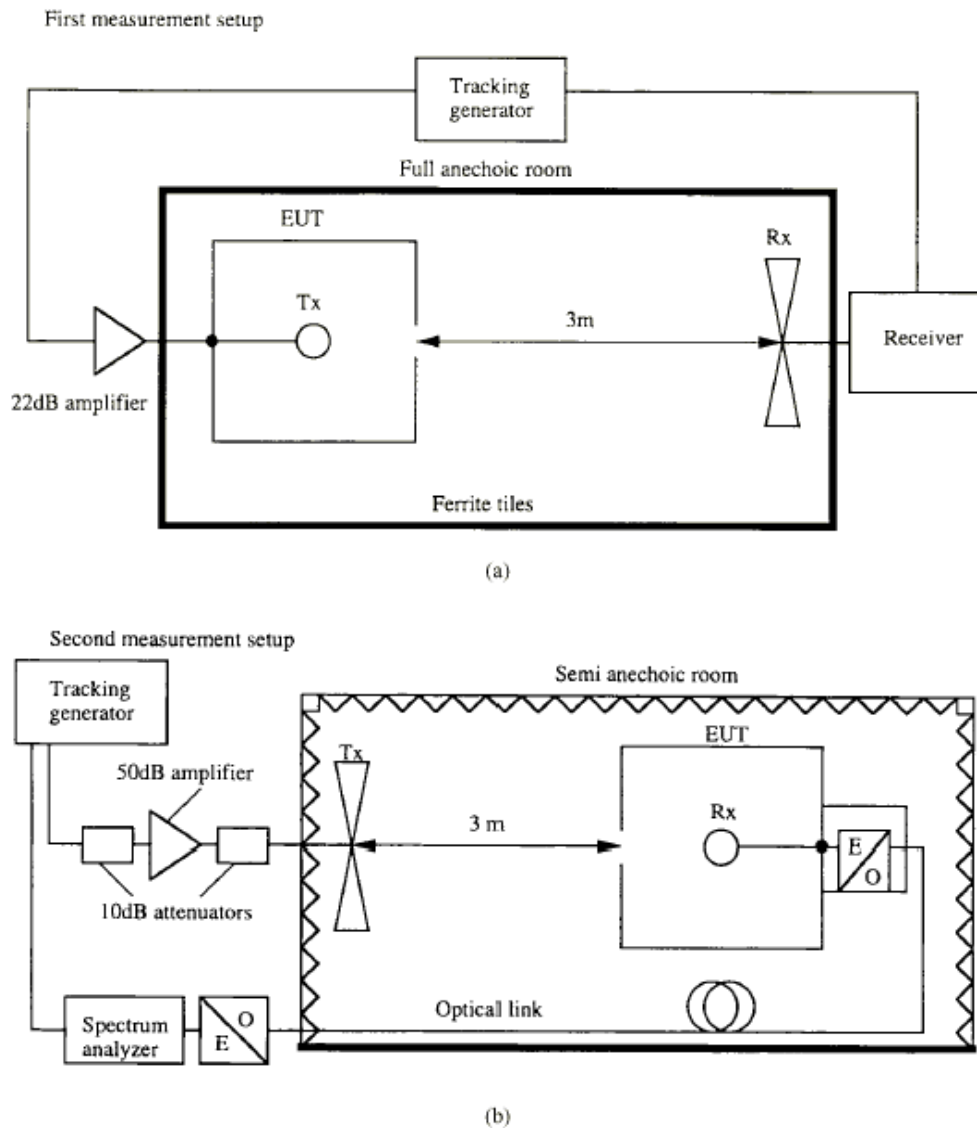


Figure 2: Measurement setups. Setup (a) is in a full anechoic room and (b) in a semi-anechoic room. Note that the transmitting antenna in (a) is within the enclosure and in (b) outside of it. Copyright 1999 IEEE.

Two setups were used to measure shielding effectiveness, as shown in Figure 2. Figure 2a shows a fully anechoic room of 7 by 3 by 3 meters. The transmitting antenna, Tx, was an EMCO “H diameter six” antenna placed in the center of the enclosure. In the second setup, Figure 2b, a semi-anechoic room of 13.4 x 4.7 x 3 meters was used. Here, the transmitting antenna was placed outside the enclosure, and a field probes placed inside.

For their first experiment, the authors used a front panel with a 50 by 200 mm aperture placed in the center of the panel. The results are shown in Figure 3.

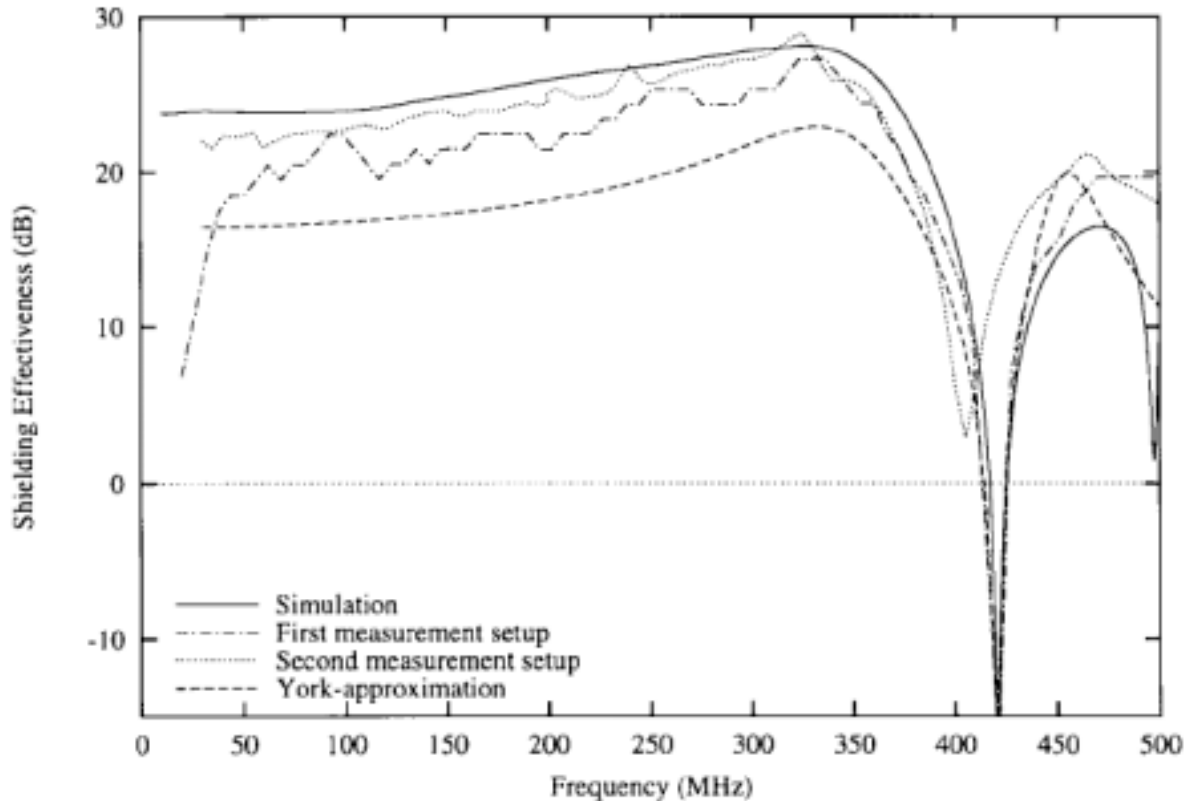


Figure 3 Shielding effectiveness measured using the two setups of Figure 2, compare with an electromagnetic simulation with the CONCEPT II program and an approximation known as the York Method. The front panel had a 50 mm by 200 mm aperture. Copyright 1999 IEEE.

The two setups produced similar results. These were compared to an analytical technique known as the “York Method” (Reference 3,4) and a simulation using the CONCEPT II full wave frequency domain electromagnetic simulator developed by the Technical University of Hamburg in Hamburg, Germany.

The researchers also simulated the shielding effectiveness of the enclosure with front plate removed completely using the CONCEPT II program. The results are shown in Figure 4. Note that this five-sided box provides very little shielding. In fact, over much of the frequency range, the shielding effectiveness is negative, indicating that the enclosure was providing gain. A sharp resonance is noted at approximately 500 MHz. The results in Figure 4 were used as a baseline to derive the SE shown in Figure 3.

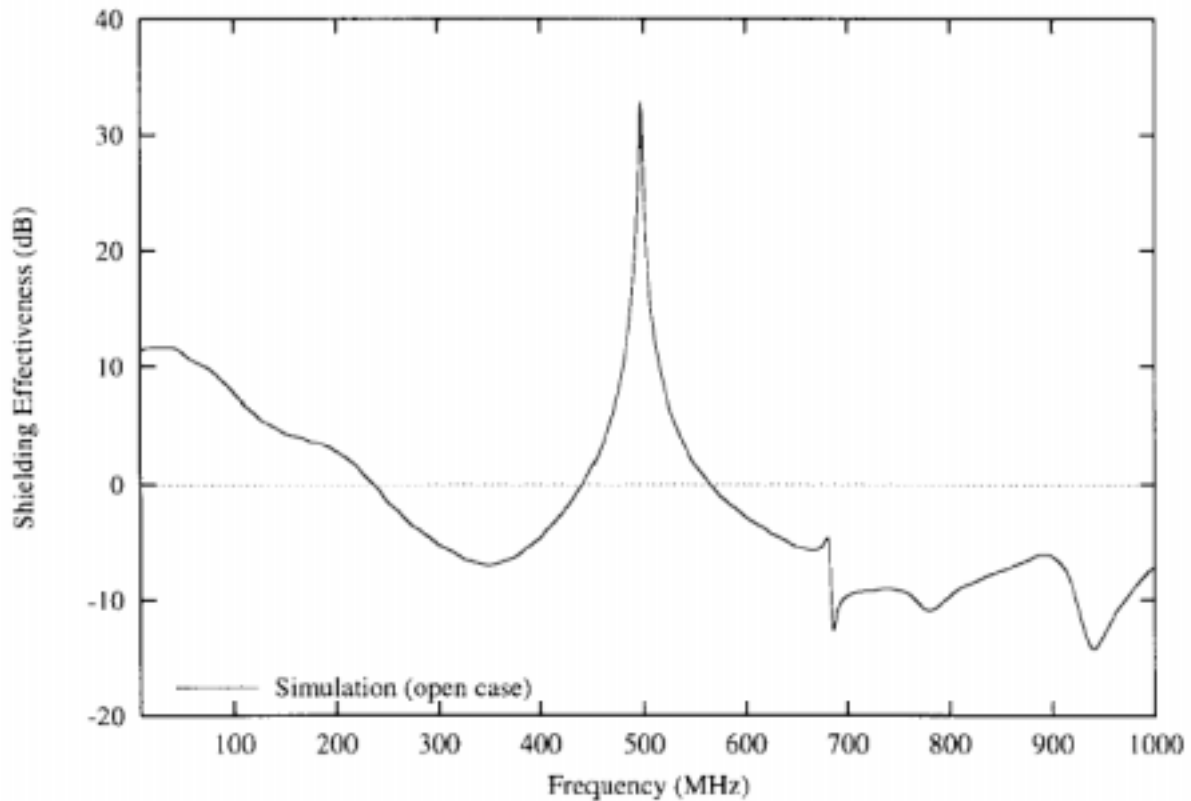


Figure 4 Shielding effectiveness simulation with the front plate removed. The enclosure does not provide shielding at most frequencies, but in fact provides gain. Copyright 1999 IEEE.

Below 350 MHz, Figure 3 shows that the measurements, predictions and numeric simulation all agree to within 10 dB. The enclosure provides between 20 and 30 dB of shielding effectiveness when the front panel is in place compared to when it is removed.

The effect of moving the transmission source of Figure 2a within the enclosure is shown in Figures 5. It changes the result in the manner one would expect. When the source is closer to the aperture, the shielding effectiveness below the first resonance drops. The resonant frequency at 420 MHz remains largely unchanged.

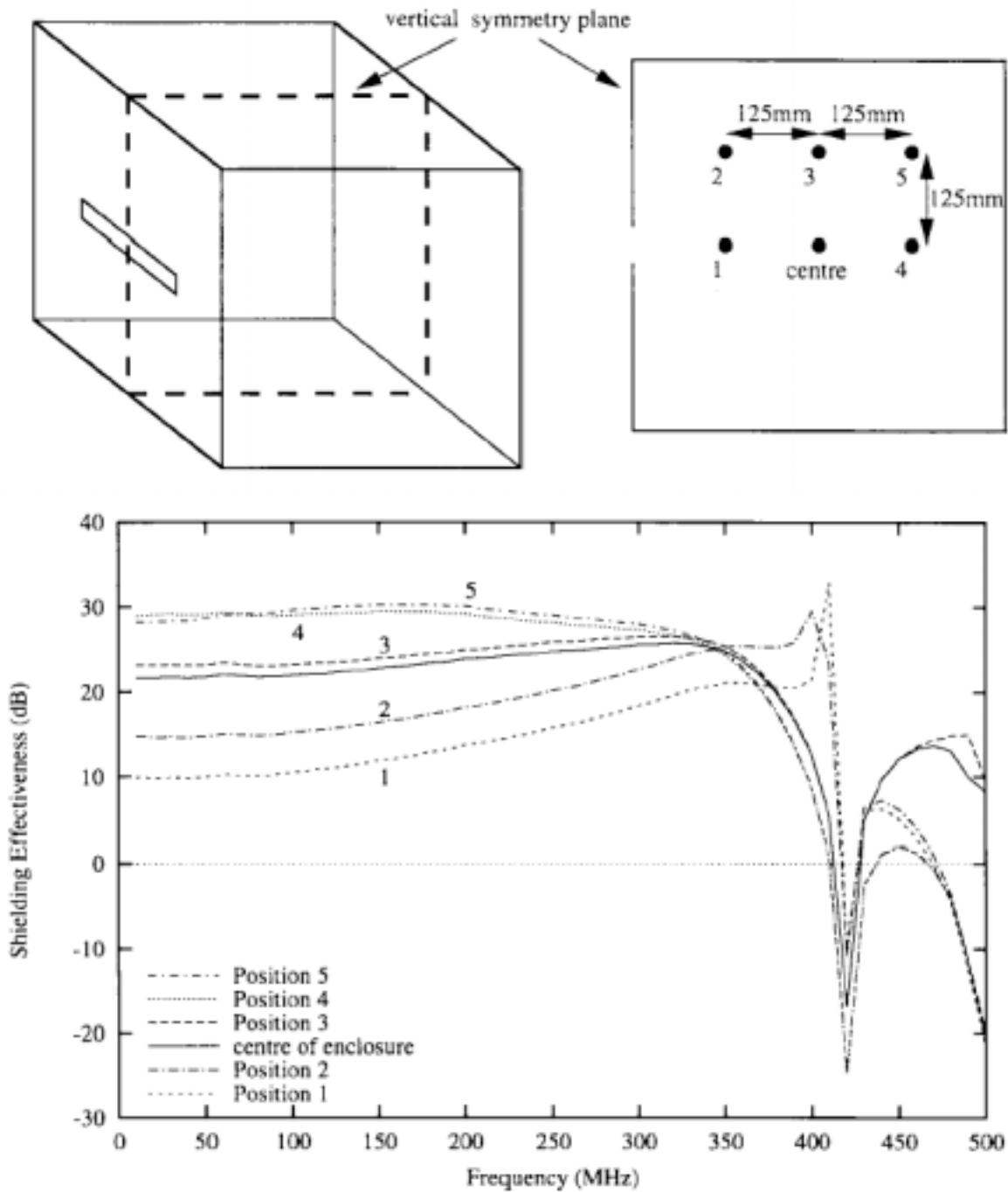


Figure 5 A variation in source positions varies the shielding effectiveness below the first resonant frequency. As expected, shielding effectiveness goes down as the source is moved closer to the aperture. Copyright 1999 IEEE.

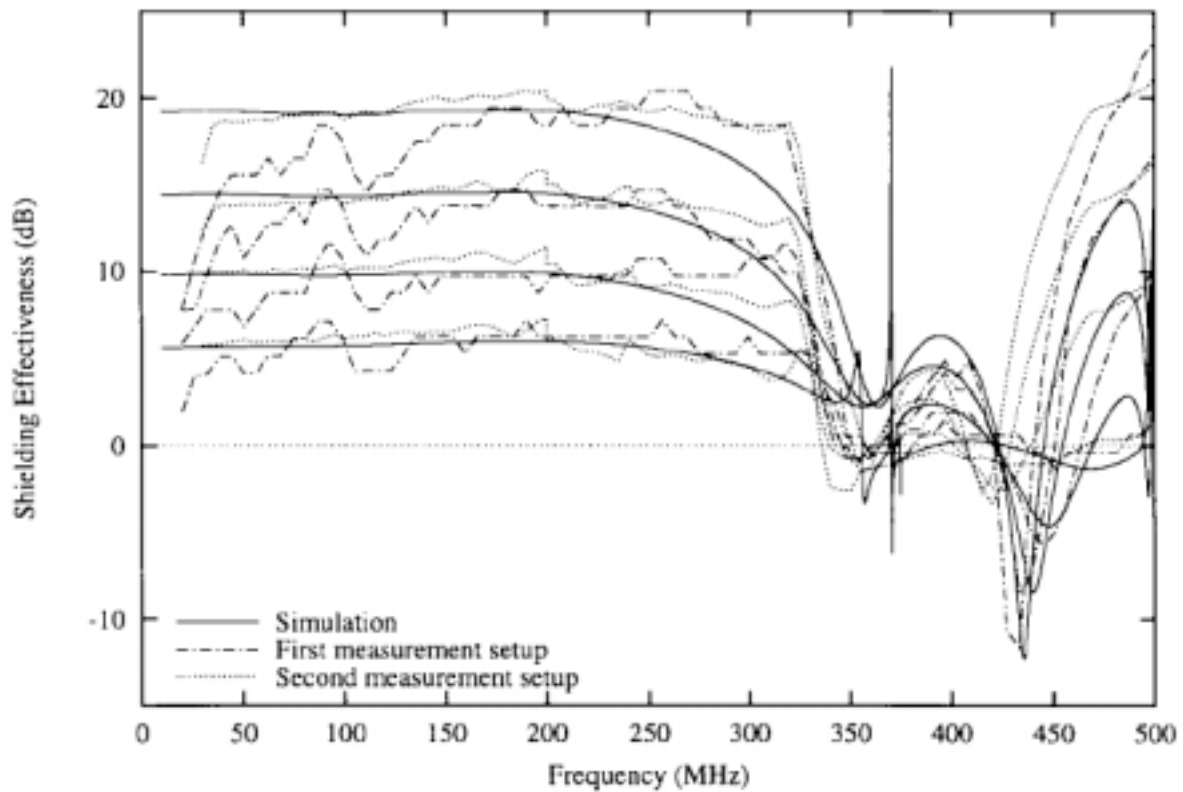


Figure 6 Shielding effectivity for front panels with one, two, four and eight slots of 400 mm by 2 mm. Copyright 1999 IEEE.

Figure 6 shows the simulated results when one, two, four and eight slots of dimension 400 mm by 2 mm are used, all horizontal, parallel, centered and spaced by 5 cm.

To the designer the resonant frequencies are a special cause for concern. Spending money on a metallic enclosure only to provide *gain* at certain frequencies is quite unacceptable. Fortunately, there is a straightforward solution to this problem, and it often occurs by default. Figure 8 shows shielding effectiveness as computed and measured for an enclosure with four slots. Five cm of absorbing material was then placed at the back of the enclosure. At the resonant frequencies the results are dramatic.

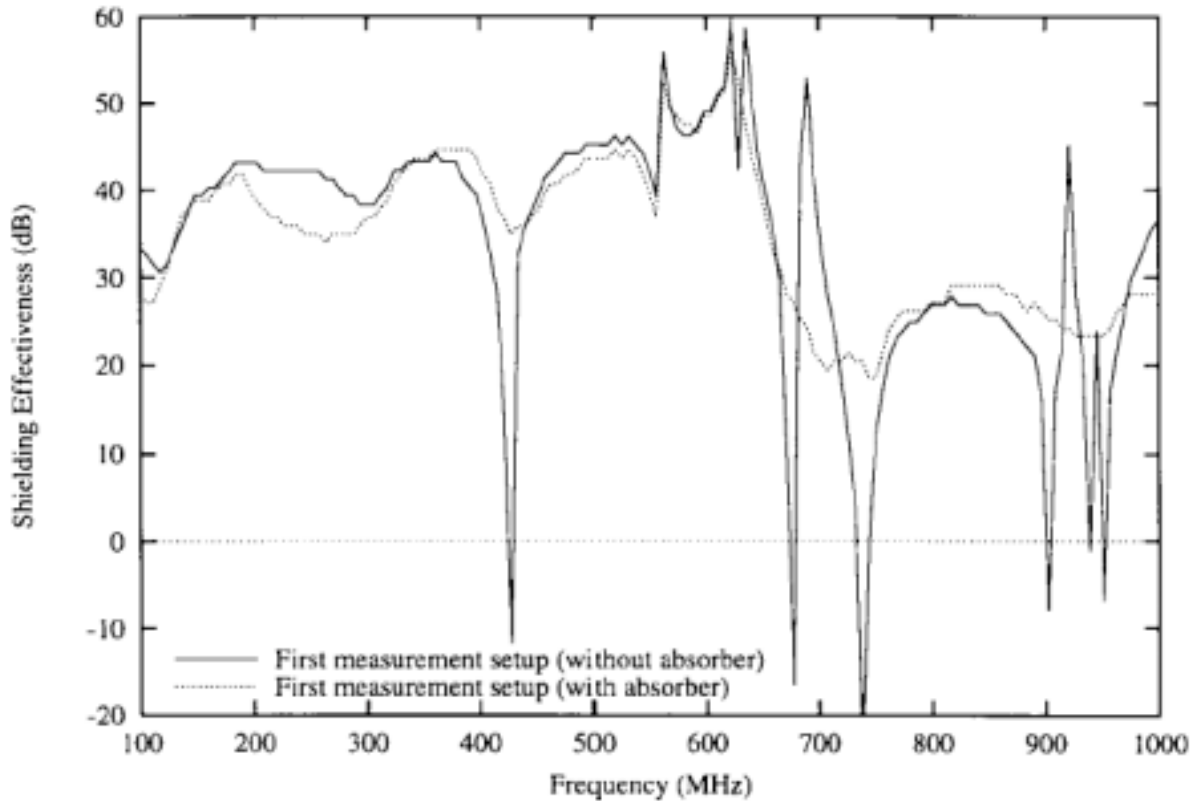


Figure 7: Shielding effectiveness measured with and without absorber material placed within the enclosure. The front panel had four slots of 100 mm by 2 mm. The effect of even a small amount of absorbing material on resonances is dramatic. Copyright 1999 IEEE.

It turns out that it does not take much to lower the Q of the cavity significantly. In practice components inside a metal enclosure, such as the printed circuit boards, also lower the enclosure's Q significantly.

In conclusion, the authors state:

“To predict the shielding effectivity of a realistic enclosure requires accurate knowledge of the geometry of the enclosure, position and distribution of sources inside the enclosure and the position of larger metal objects. Often this results in the need for impractical computer resources. At the same time it is concluded that the formulation of simple design rules for estimating the shielding effectivity of enclosures is virtually impossible, except for some general rules such as, for example, the fact it is better to use a large number of small holes than a few larger ones.”

In other words, the most efficient approach may be to use well-known rules of thumb such as these:

1. Many small holes are better than a few large ones.

2. Holes are better than slots.
3. For more challenging designs, those radiating significant energy above a few GHz, honeycomb filters are better than holes. They act as waveguides below cutoff.
4. Wires leaving even the best enclosures will likely need to be dealt with by using shielded cable properly bonded to the box or some filtering mechanism.
5. Lids, doors and other areas creating unavoidable slots may need finger stock or gaskets to break up the slot. (This is an area where Ott's formula can be used for guidance.) Chemical compatibility and mechanical stability are of great importance here.

References:

Reference 1: H.W. Ott, Noise Reduction Techniques and Electronic Systems, Wiley Interscience, Second Edition, 1998.

Reference 2: F. Olyslager et al, "Numerical and Experimental Study of the Shielding Effectiveness of a Metallic Enclosure," IEEE Transactions on Electromagnetic Compatibility, Volume 41, Number 3, August 1999.

Reference 3: Robinson et al, "Analytical Formulation for the Shielding Effectiveness of Enclosures with Apertures," IEEE Transactions on Electromagnetic Compatibility, Volume 40, Number 3, August 1998.

Reference 4: Robinson et al, "Shielding Effectiveness of a Rectangular Enclosure with Rectangular Aperture," Electronic Letters, Volume 32, Number 17, page 1559, August 1996.

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