York EMC Services Ltd

AN004

Shielding Effectiveness of Enclosures Using a CGE

Overview

Enclosures are used within a product to shield small internal components as well as shielding the finished product. The majority of enclosures are fabricated from a metallic material the mechanical and electrical properties of which are well understood. In practice, the primary limitation in shielding effectiveness is with the seams, holes and cable penetrations which cannot be avoided. Increasingly, the electronics and telecommunications industries are making use of plastic and conductive plastic enclosures to reduce weight and cost. Coupled with an increase in the operational frequency of modern electronic devices electromagnetic compatibility (EMC) becomes an important issue.

The Comb Generator Emitter (CGE) was designed to investigate the shielding effectiveness of small to medium sized enclosures, examples of which are presented in this article.

Function of the Enclosure

Enclosing circuitry in a shielded enclosure is a good way to control radiated emissions, the shield acts as a barrier to unwanted electromagnetic radiation. The material and construction, including seams and apertures, of the enclosure determines its properties as a shield. In the majority of cases, enclosures are used to contain fields generated in a system as a by-product of the system's operation, thus avoiding interference to nearby systems. However, the enclosure also protects system components from internally or externally generated interference.

Shields function on the basis of two major electromagnetic phenomena: reflection from a conducting surface and absorption in a conductive volume. An electromagnetic wave striking a metallic surface encounters both types of losses. Part of the wave is reflected while the remainder is transmitted and attenuated as it passes through the medium. The combined effect of these losses (reflection and absorption) determines the effectiveness of the shield material and enclosure construction. The required level of shielding is between 40 to 60dB depending on the application.

Shielding Effectiveness

The shielding effectiveness of the base material is determined using an insertion-loss method. This technique (described in ASTM D4935) involves irradiating a flat, thin sample of the base material with an electromagnetic wave over the frequency range of interest.

A reference and load measurement are performed on the same material. The shielding effectiveness is determined from Equation 1, which is the ratio of the incident field to that which passes through the material.

$$SE=20\log(E1/E2) \qquad \text{Equation 1}$$

where E1 is the field strength measured before shielding and E2 is the field strength measured after shielding.

For the evaluation of large flat samples, test methods based on IEEE-STD 299 are used. The test method requires a shielded enclosure with an open window. An initial measurement is performed with the enclosure, and another is performed with the window covered with the conductive material.

Enclosures

The most common technique for evaluating the shielding effectiveness of an enclosure is the twin-antenna method. This method requires either the use of an emitter and a receptor (both antennas) or the use of a combination of a noise source and receive antenna or a combination of a transmit antenna and a receiver (such as an isotropic field probe).

The twin-antenna method involves positioning a receptor (usually a dipole antenna) inside the enclosure and placing a transmitter outside the enclosure. The basic setup simulates the enclosure's performance in shielding the enclosed components against interference. Placing the emitter within the enclosure and placing the receptor at some distance away simulates the shield's ability to inhibit the transmission of electromagnetic waves from the enclosed circuitry to neighboring devices or equipment. Appropriate positioning with respect to field polarization and the direction of induced current enables the acquisition of relevant shielding effectiveness data.

The procedure requires an initial measurement without the enclosure. The reference value is the coupling measured between the emitter and the receptor antennas. The measurement is then repeated with only the enclosure in place. IEEE-STD 299 requires measurements at various positions within the enclosure and specifies that the transmitting antenna be positioned outside the enclosure, however this standard only applies to enclosures whose smallest linear dimension is no less than 2 m. Techniques for smaller enclosures are currently under development.

Review of the CGE

The CGE is a broadband stable noise source that generates a harmonic comb of frequencies over the specified frequency range. There are three models available operating from 50MHz to 40GHz.

The unit is powered from a bespoke battery pack which removes any possible effects from interconnecting cables, however where size is restricted the CGE can be powered from an external power supply reducing the height from 90mm to 40mm.

Applications include:

- Shielding effectiveness of small enclosures
- As a reference source for radiated measurement systems:
    - Daily pre-test checks
    - Long term performance monitoring
- Investigation of measurement environments such as Anechoic Chambers and GTEMs

	CGE01 50MHz to 12GHz 50MHz, 80MHz or 100MHz step size
	CGE02 250MHz to 26GHz 250MHz or 256MHz step size
	CGE03 500MHz to 40GHz 500MHz step size

CGE Response

A typical output of the generated spectrum for the CGE01 is shown in figure 1. This plot represents the radiated response measured in a Fully Anechoic Room (FAR) at a distance of 3m the test setup is shown in figure 2.

For measurements made above 1GHz it is common to have a preamplifier in the test set-up as this improves the signal to noise ratio, this is demonstrated in figure 3 which shows the CGE measured without the preamplifier.

Dymanic Range

The signal to noise ratio of the test set-up determines the dynamic range achievable and therefore the level of shielding effectiveness that can be measured. As the frequency increases this becomes a dominant factor in system capability. The

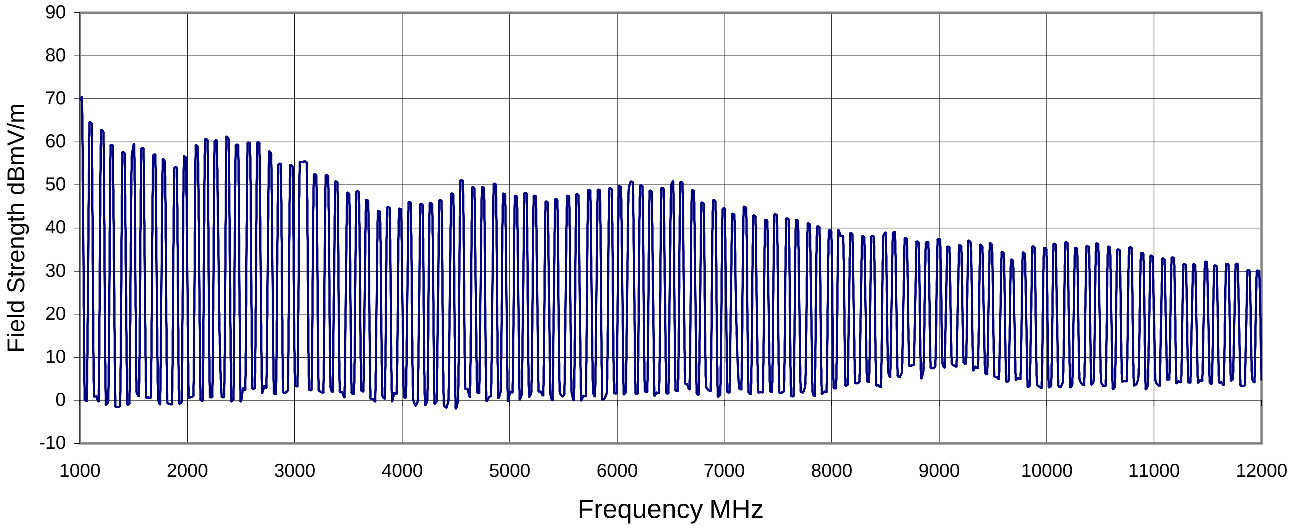

Figure 1

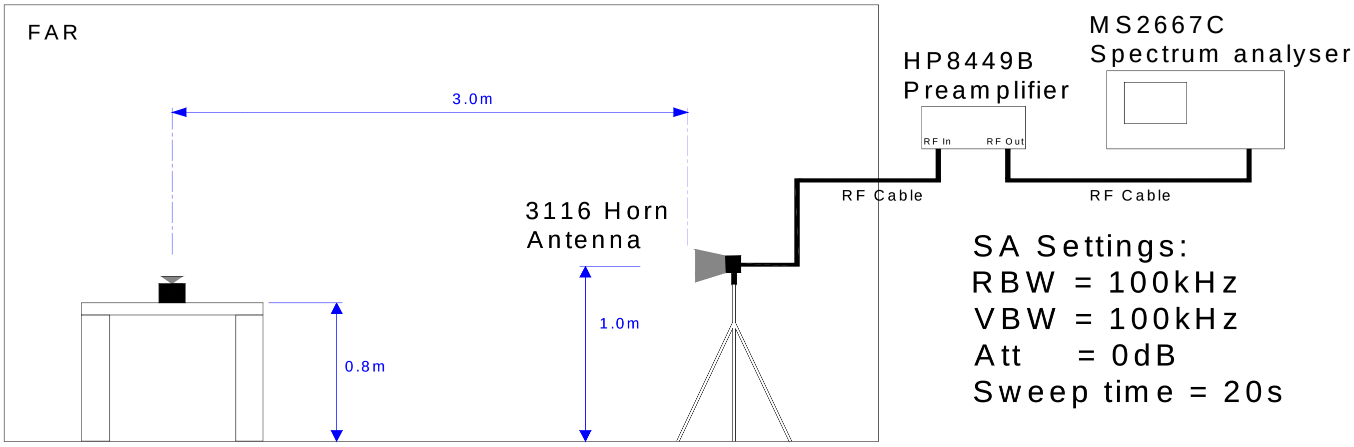

Figure 2

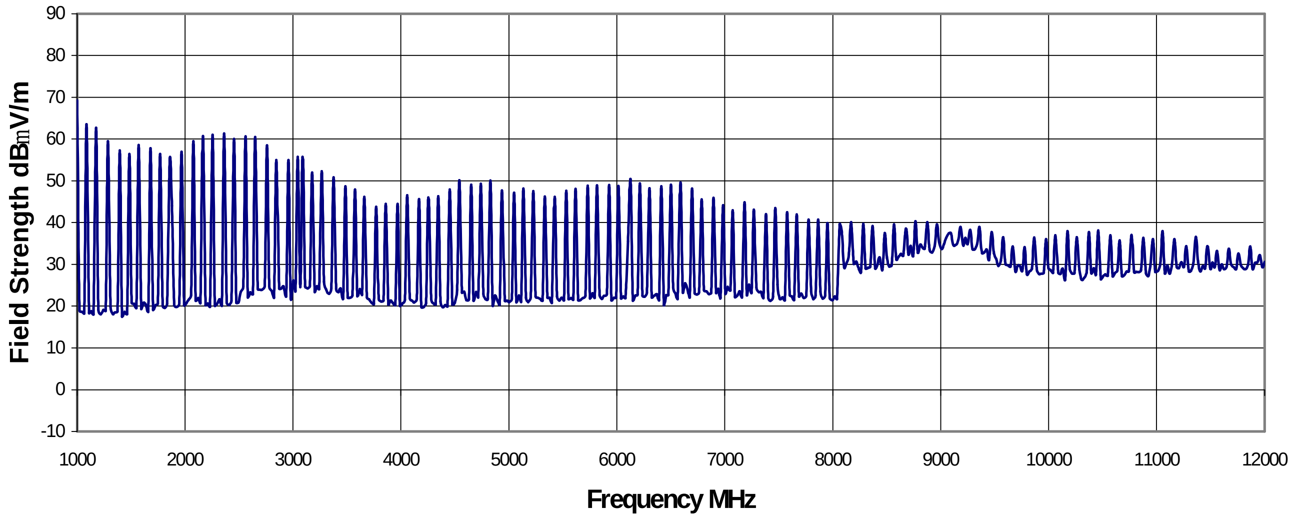

Figure 3

specification of the antenna gain, amplifier gain, cable losses, receiver noise floor, amplifier location in relation to the antenna and test distance all have an impact on the system dynamic range. Figure 4 shows the dynamic range for the CGE01 and CGE02 over the frequency range 1 to 12GHz. Reducing the test distance from 3m to 1m shows an increase in the dynamic range by approximately 10dB, however care must be taken to ensure that the preamplifier is not driven into saturation.

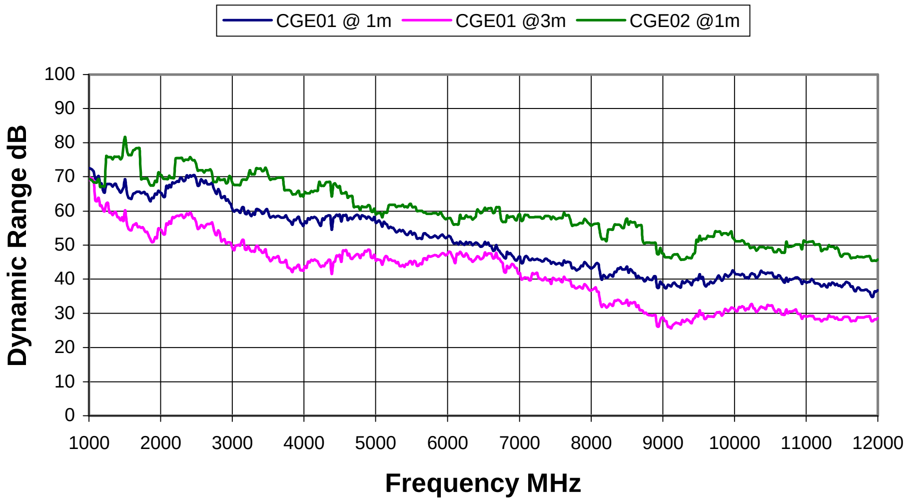

Figure 4

Example 1

Basic SE Measurement

The CGE was placed inside an ATX computer case with associated circuitry as shown in figure 5. The measured response is shown in figure 6, it can be seen that the case only offers an average of 10dB shielding over the frequency range measured, this is perhaps not very surprising since it was never intended to house a processor of more than a few hundred MHz, however it does demonstrate the problem that exists if the same cases were used for higher frequency processors.

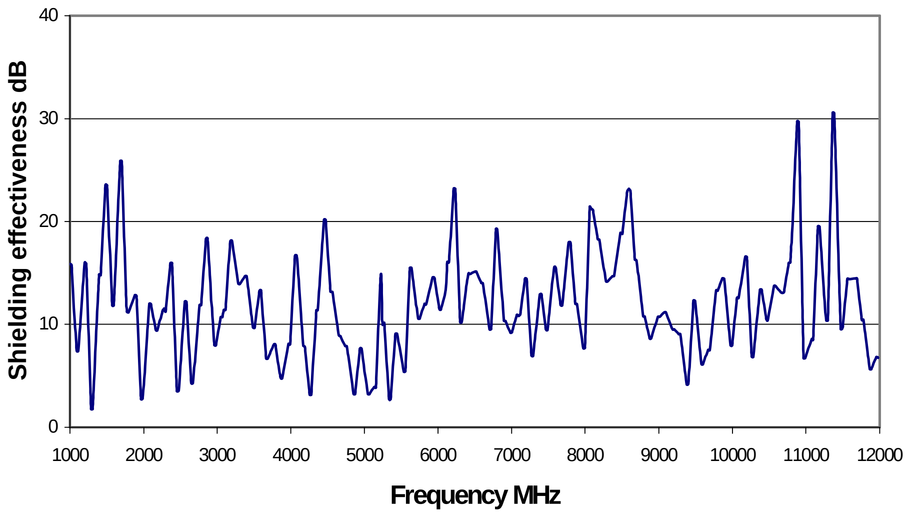

Figure 6

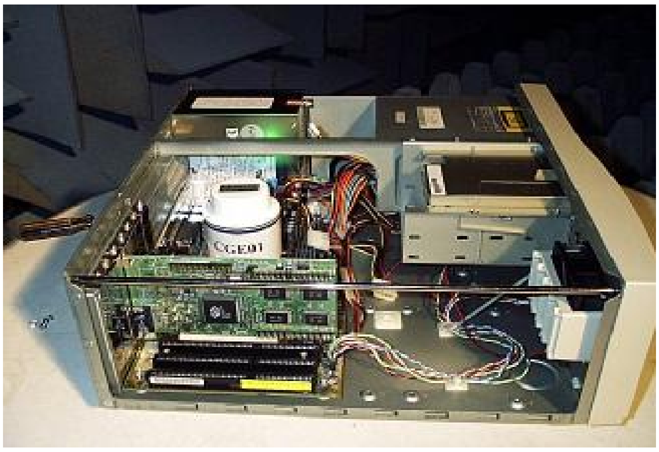

Figure 5

Example 2

Effect of Aperture Shape

Many electronic products include the use of a fan which requires ventilation, this next example demonstrates different hole patterns and the effect on shielding. The enclosure used measures 300mm square by 120mm high. The front face has been modified to include a rectangular cut out measuring 220 by 90mm. Three plates were made to investigate the shielding effect of a hole pattern compared to a slot pattern referenced to a blank plate as shown in figure 7a and 7b.

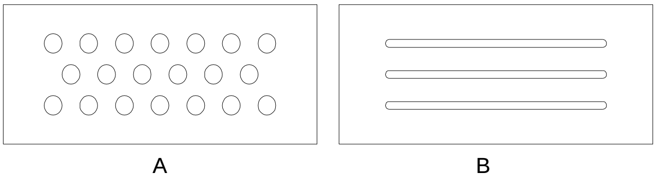

Figure 7

The CGE was placed inside the box with the front plate removed and a reference measurement was made. A measurement was then made with plates A and B and also the blank plate. The plate with holes has good shielding properties between 5 and 7GHz, as shown in figure 8 below 5GHz some leakage is seen at spot frequencies. In practise the hole diameter and spacing could be optimised to improve the performance over the frequency range of interest. The plate with slots offers very little shielding, this is because the slots act like antennas and therefore radiate at the frequency range measured. The blank plate was included to show that there is very little leakage due to the seal around the plate itself.

Example 3

Source Position Within the Enclosure

The ATX case was used again to investigate the effect of moving the CGE within the case. This demonstration uses a CGE02 over the frequency range 10 to 18GHz. A PCB was manufactured the size of a standard ATX

Figure 9

motherboard, provision was made to mount the CGE in nine different positions, as shown in figure 9. The CGE is powered via the PCB using the computer power supply.

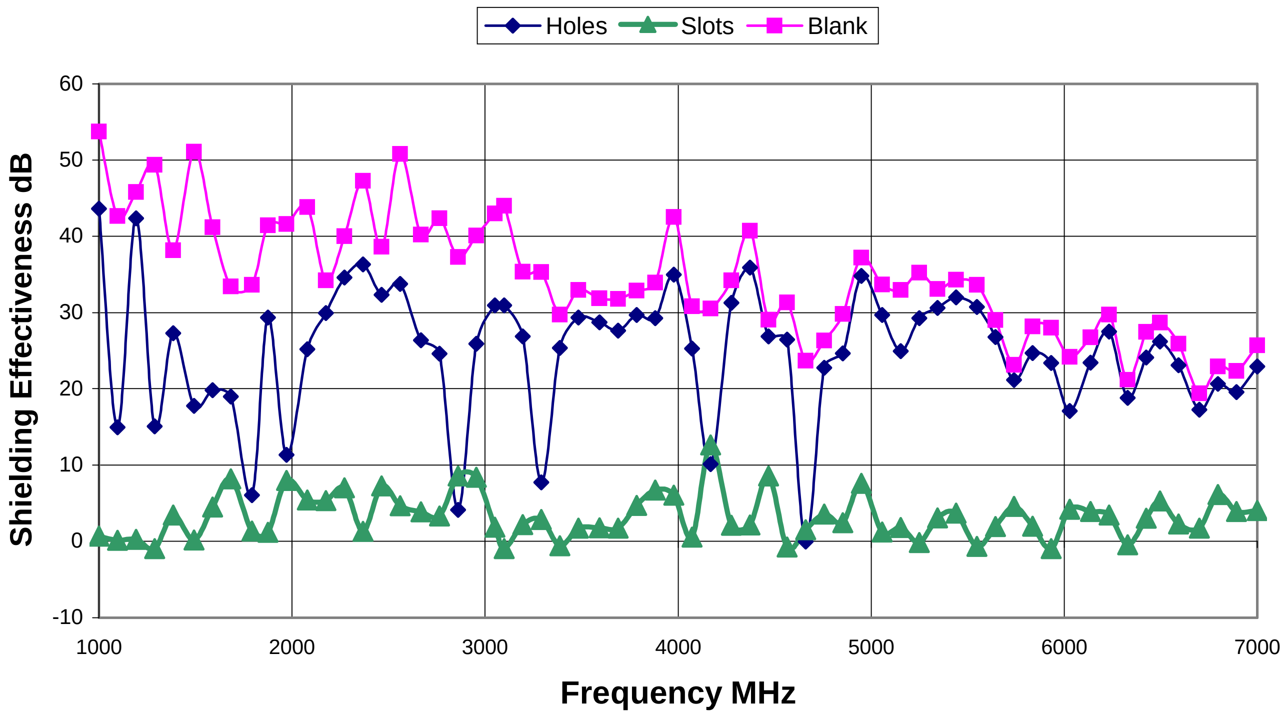

Figure 8

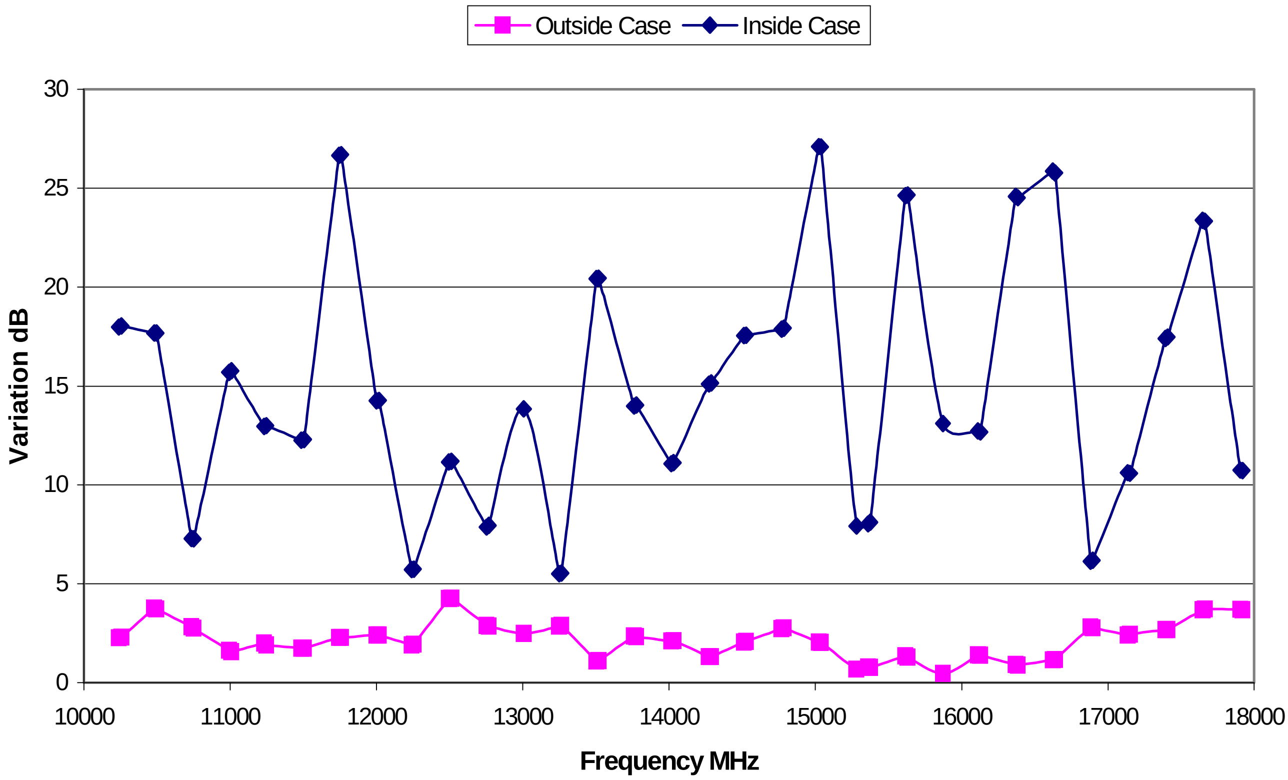

Figure 10

Measurements were made in each of the nine positions both outside the case and inside the case.

The ATX case has already been shown to have poor shielding, this example demonstrates the complexities involved with electromagnetic wave reflections within an enclosure. Figure 10 shows the variation In amplitude between the different positions rather than the shielding effectiveness. When the CGE is placed inside the case the variation is significantly larger than the variation outside the case. The proximity of the CGE to the enclosure walls and other objects within the enclosure will generate a different reflected wave pattern effectively attenuating different frequencies in each position and therefore increasing variation.

The enclosures shielding effectiveness not only varies with frequency and enclosure geometry but also positioning within the enclosure, angle of incidence and polarisation.

Summary

Measurement of shielding effectiveness of equipment enclosures is particularly important as clock frequencies escalate and gaps and holes in enclosures become effective slot antennas. The Comb Generator Emitter devices have been designed so that enclosure manufacturers can proactively test for adequate shielding. Proactive testing creates the opportunity to develop a computer or electronics system with a longer product life, as well as save time and money on traditional, "right before launch" emissions testing. Comb Generator Emitters can simulate the emissions of an entire system before the availability of key system components.

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