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Alternatives to Gaskets in Shielding an Enclosure

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Abstract

It is well known that a properly placed conductive gasket can complete an enclosure to yield good shielding. But often there are reasons, e.g. control of mechanical dimensions that this cannot be achieved. For these cases, one may want to avoid using a gasket that requires contacts. This paper will analyze alternatives to continuously contacting gaskets such as overlap structures, overlapping structures with different lossy and non-lossy materials, and overlaps with grounding points. It will compare structures by sufficient shielding for a typical class B product, high frequency (1-3 GHz) and low frequency (below 1GHz) performance.

Keywords

Shielding effectiveness, gaskets, overlap, grounding points, lossy materials.

INTRODUCTION

Conductive gaskets are quite often used to prevent electromagnetic radiation from being emitted from the metallic assemblies of electrical and electronic devices. Shielding efficiency is essentially determined by the quality of gasketing and the design of the various fed-throughs, not by the sheet metal walls. Conductive gaskets and enclosures generally are superior at controlling emissions as long as contact between conductive parts of the enclosure is continuous and the interfaces between parts of the enclosure are of low impedance. Especially at higher frequencies (larger than approximately 1 GHz), but also at low frequency for magnetic shielding, most shielding design tries to obtain good continuous contact.

But insufficient control of the mechanical dimensions and tolerance of the shielding, the aging of gasket materials used to maintain contact between parts, corrosion and wear of moving parts of the shielding, and insufficient control of the surface coating for OEM-modules make it difficult to ensure the effectiveness of the conductive shielding over time. To avoid these problems with gasket materials, one may want to avoid using gaskets for shielding. Shields without contacting gaskets are common, at least for a narrow high frequency range, for example, in microwave ovens [1], [2], [3]. It is also intuitively clear that an overlap with sufficient depth will provide some shielding and other authors have modeled some of these structures [4], [5], [6]. Narrow-band enhancement can be achieved using $\lambda/4$ deep corrugated edges [7], [8], similar to the surface wave suppression used in some horn antennas.

In this paper, different overlap structures are analyzed. Using shielding measurements the effect of the depth, the length and the air-gap within an overlap is investigated. Also, the effects of grounding points and lossy materials in the overlap are examined.

EXPERIMENTAL CONFIGURATION

1.1 Geometry of the test enclosure

Different enclosures have been analyzed. Figure 1 shows a front view of aluminum PC-size box that was used as the test enclosure for the data presented. The internal dimensions of the enclosure are $0.4\ \text{m} \times 0.18\ \text{m} \times 0.5\ \text{m}$. Five walls of the box were carefully assembled together. Copper tape was used to seal the interior seams of the enclosure.

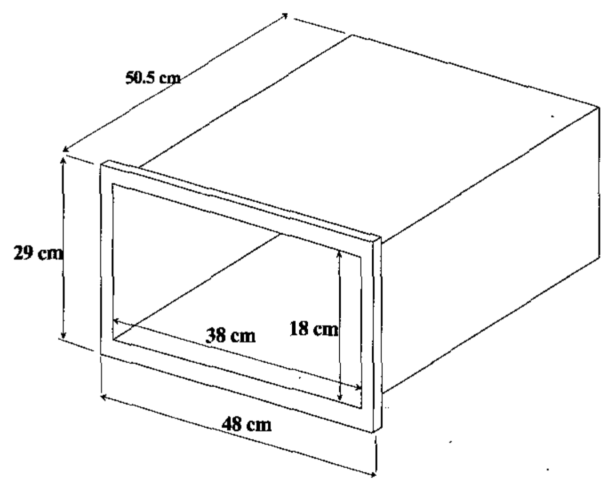

Figure 1. Enclosure used for the tests.

The enclosure was constructed so that different lids could easily be attached and reattached for multiple measurements. To create an overlap between the box and the lid, three different sized lips were used. The depth of the overlap between the lid and the box could be adjusted by changing the size of the lip used.

Depending on the experiment, different materials were placed between the lid and the box. A cross-section of the enclosure is shown in Figure 2. In most experiments, square conductive foam gaskets were used, on the top and

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the bottom edge, to seal the box to the lid and to avoid electromagnetic leakages from those areas.

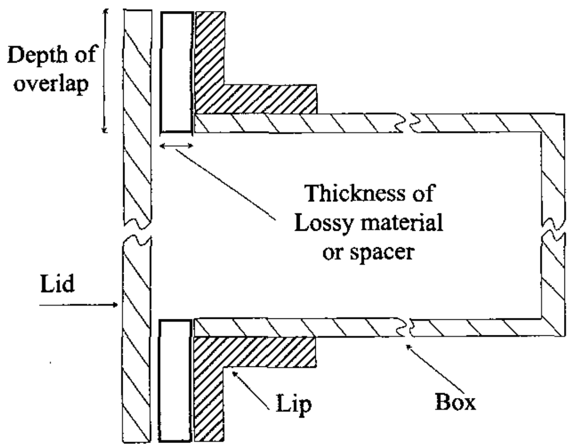

Figure 2. Top view cross section of the enclosure

1.2 Measurement setups

The experimental setup is shown in Figure 3. All of the shielding measurements were performed within a 3-meter semi-anechoic chamber.

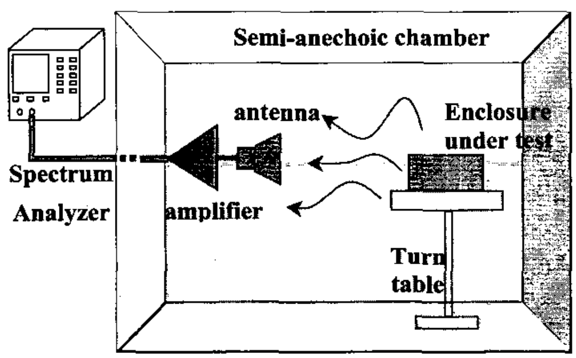

Figure 3. Experimental setup

The enclosure under test was placed on a remotely controlled turntable in the chamber and a log-periodic antenna was positioned 2 meter from the enclosure. The log-periodic antenna is connected to a spectrum analyzer via an amplifier. A homemade battery-powered signal generator was connected to a small loop antenna. The signal generator sweeps frequencies between 10 MHz and 12 GHz. The output power, up to 12 GHz, is shown in Figure 4.

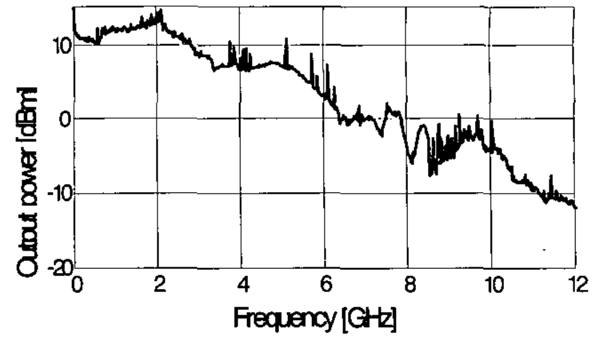

Figure 4. Output power of the sweeper.

The signal generator and the loop antennas used for the measurements are shown in figure 5.

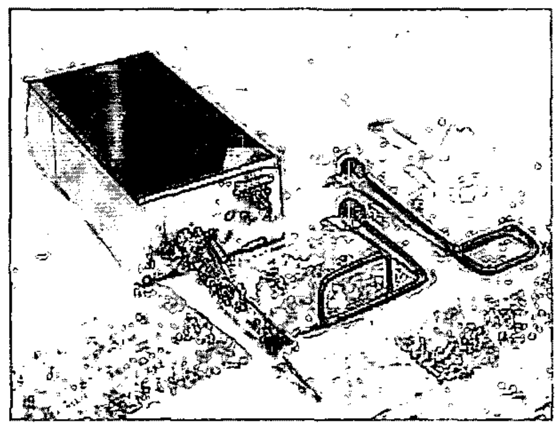

Figure 5. The signal generator and the loop antennas used

The reference level was obtained by placing the signal generator on the turntable, without any enclosure, while measuring the emissions when the spectrum analyzer was set in the 'peak hold' mode. To capture the worst-case emissions, the measurement was performed while rotating the signal antenna on the turntable 360° degrees and receiving the emissions in both the horizontal and vertical polarizations of the receiving log-periodic antenna. The same procedure was used to measure the emissions when the source is placed inside an enclosure. Every measurement takes about 3-4 minutes. To de-clutter the results, all of the data obtained from the measurements were filtered with a worst-case algorithm that connects peak values. An example of the measured data and the filtered data is shown in Figure 6.

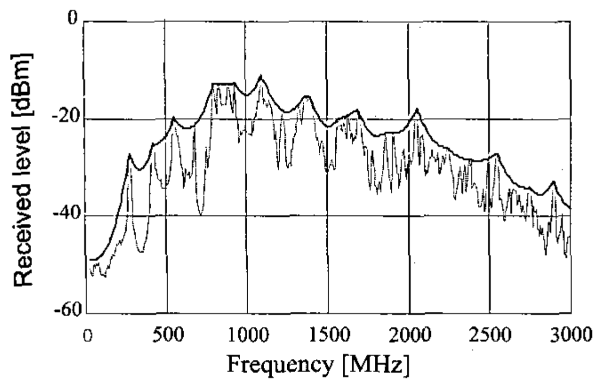

Figure 6. Example of measured and the data filtered by a worst-case algorithm

For the reference measurement, multiple measurements were taken, placing the signal generator and his antenna in different positions on the table. The reference measurement was rather independent of the antenna position indicating that the turntable rotations and the polarization change were sufficient to capture the strongest emissions. Three different measurements, one for each different antenna position, are averaged. This average is then used as the reference measurement. All measurements and the averaged waveform are shown in Figure 7.

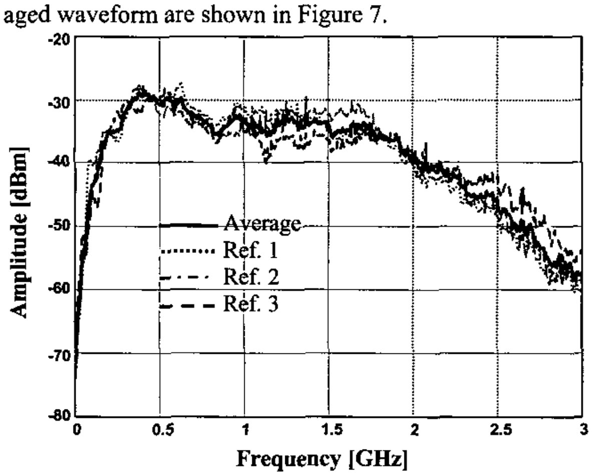

Figure7. Different references signal and their average.

The shielding effectiveness is defined as the difference between the reference measurement and the worst-case emissions obtained after placing the source into the enclosure of interest.

EXPERIMENTAL RESULTS

1. Overlap without Lossy materials

The signal generator, with his own antenna and battery, was placed inside the box. Conductive gaskets were then placed on the top and bottom edge of the lip and polyethylene (PE) spacers were placed on the side edges the lip. A metal lid was then placed on the lip of the box. This way, two vertical slots remained on the side. Their depth and their length characterize the slots.

Using three different sized lips, the emissions from the enclosure with three types of overlaps were measured and compared to the reference so that the shielding effectiveness could be calculated. The depths of the overlap between the lip and the lid were 6.35 mm, 17.0 mm and 48.0 mm respectively for the small, medium and large overlap. One layer, six layers and twelve layers of 0.13 mm thick polyethylene, for a total thickness of respectively 0.13 mm, 0.76 mm and 1.52 mm, were used to emulate the effect of an imperfectly closed lid. The polyethylene was used for its well-known dielectric constant and for its mechanical strength (to better control the thickness of the air-gap). All the measurements were repeated with some absorbing materials inside the enclosure to decrease the quality factor for the electrical characteristics of the enclosure. The results obtained basically didn't differ. The Q-factor of the enclosure was already sufficiently low. It is reduced by the aperture radiation, by the coupling between the enclosure and the excitation antenna (feed from a 50 Ohm source) and by the lead-acid battery of the source. See [9] for a detailed discussion on the loss mechanisms. Only the results for the configuration without absorbing materials are presented.

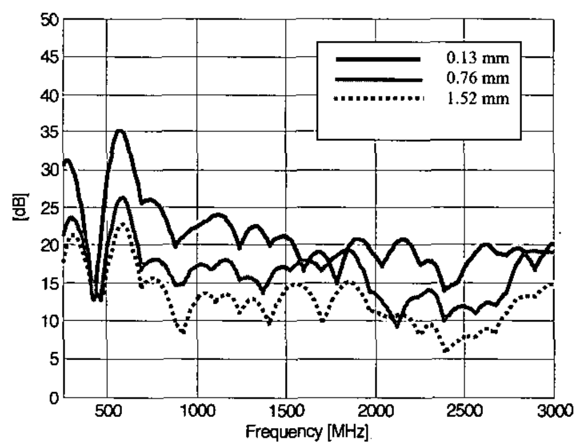

Figure 8. Comparison of shielding effect for different thickness of PE filling for the small overlap (6.3 mm)

The shielding provided for the overlapped structure varies between 5 and 20 dB for the frequencies above 1.5 GHz and is in between 10-35 dB for the frequencies up to 1.5 GHz.

Is clearly visible that reducing the air-gap between the lid and the box can improve the shielding effectiveness, but even for the thinnest PE, the shielding effectiveness is no better than 15 dB at the resonant frequency. Relative to commercial enclosures (e.g., PCs) that have been measured using the same procedure, this value seems to be too low to pass FCC class B requirements.

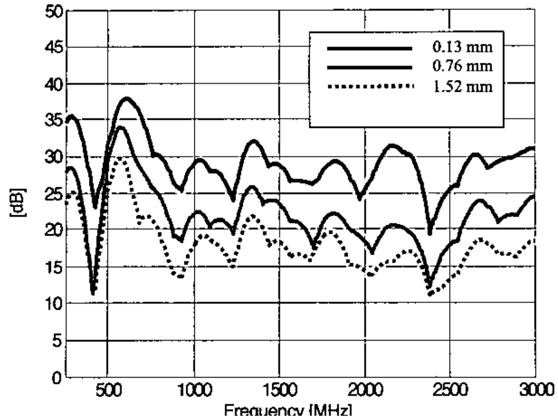

Figure 9. Comparison of shielding effect for different thickness of PE filling for the medium overlap (17 mm)

For the enclosure with a medium sized overlap, 17 mm, the shielding effectiveness is 10-30 dB, depending on the thickness of PE for the frequencies above 1.5 GHz. The shielding effectiveness is between 12-37 dB for the frequencies below 1.5 GHz.

At the resonant frequencies of the slot, the overlapped structure provides only 12 dB of shielding.

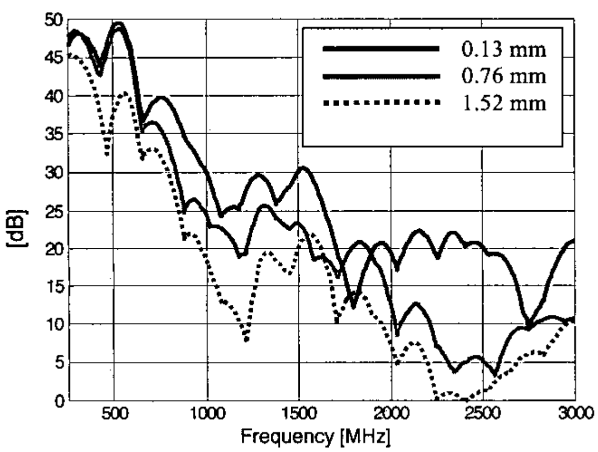

Figure 10. Comparison of shielding effect for different thickness of PE filling for the large overlap (48 mm)

For the enclosure with a large overlap, 48 mm, the shielding effectiveness is good below 1 GHz, even for the resonant frequencies of the slot. At higher frequencies, the shielding effectiveness decreases significantly (almost 20 dB) for all gap widths measured. These values are more what is typically seen when evaluating PC-like enclosures. Overall, it can be stated that a pure overlap structure, without lossy material or grounding points, would either need an unrealistically wide overlap or a moderately deep overlap with a very small gap between the lid and lip.

2. Grounding Points

To emulate grounding points pieces of conductive foam gaskets were placed between the lid and the lip. Again, PE was used as a spacer to maintain a uniform overlap height of 0.76 mm. For this experiment, the depth of the overlap was chosen as 17.0 mm because the small overlap produced insufficient shielding and the large overlap is probably not realistic for a product design. First no grounding points were used, and then several grounding points were slowly introduced. The positions of the grounding points on the lip are shown in Figure 11. A, B, C are the locations of the grounding points. First only the grounding point labeled with A was used. Then the grounding points of A and B were used. Finally the grounding points A, B and C were used for a total of 7 grounding points.

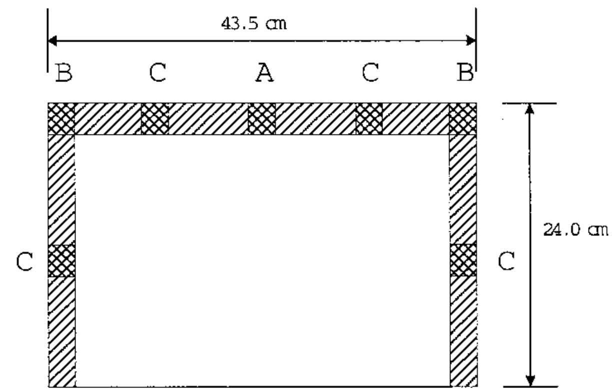

Figure 11. The set up for the grounding points test.

For each grounding point setup, the PE spacers were 0.76 mm thick.

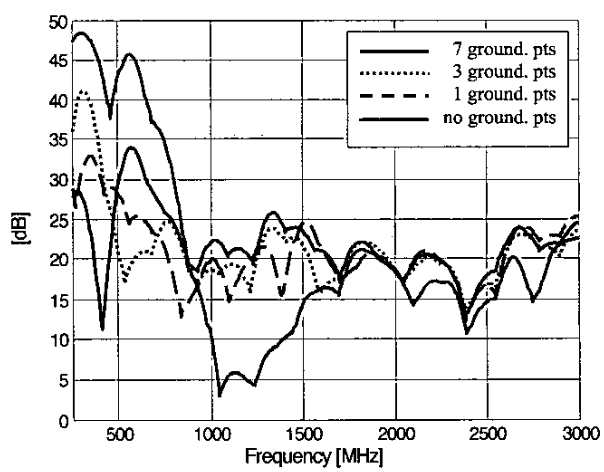

Figure 12. Comparison of the Shielding effect for different number of grounding points. (0.76 mm PE fill-

The data in Figure 12 shows that adding some grounding points strongly improves the shielding effectiveness at low frequencies. The shielding effectiveness is strongly reduced around the resonant frequencies of the slots created by the grounding points. Around those frequencies, the shielding effectiveness can be worse than the case when no grounding points were added. At frequencies above 1.5 GHz, there is no improvement with 1, 3 or 7 grounding points.

3. Lossy Materials

Many different kinds of lossy materials (conductive PE, ferrite loaded silicon, iron loaded materials) were placed between the lip and the lid to reduce the emissions. All the materials used were tested with small and the medium depth overlaps. A typical result, for the Intermark lossy material, is shown in Figure 13.

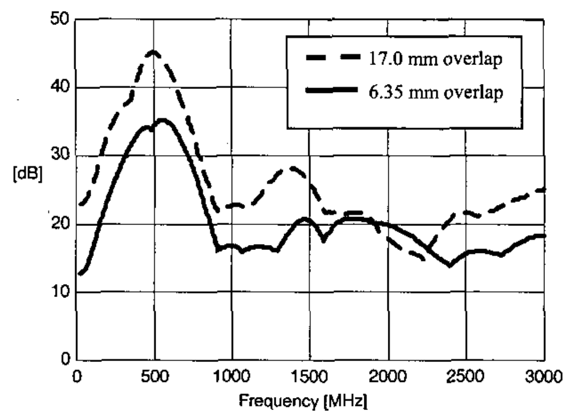

Figure 13. Comparison of the Shielding effect for different size of overlaps with lossy materials

The Intermark lossy material was 0.76 mm thick so this result can be compared with the results obtained for the grounding points and the overlap without lossy material. The lossy overlap structures achieve a reasonable shielding effectiveness that may be sufficient for different applications. The shielding effectiveness is also quite constant above 1 GHz where conductive gaskets with interruptions usually perform poorly.

CONCLUSIONS

The results of the experiment presented in this paper show that for some applications, especially for frequencies below 1 GHz, grounding points or overlaps or lossy materials can be used instead of gaskets if no more than 30 dB of shielding is needed. For many enclosures, no more than 30 dB of shielding effectiveness is required for gaskets because airflow apertures, I/O cable penetration and others intended apertures dominate the emissions at high frequencies. A pure overlap structure, with a reasonable depth, will provide, at least 5 to 12 dB of shielding effectiveness depending on the thickness of the air-gap. Adding a few grounding points can strongly improve the shielding effectiveness at low frequency. They may worsen the emissions at higher frequencies. Lossy materials can also be used, depending on the shielding required, when is difficult to have a good continuous contact between parts and subassemblies.

REFERENCES

[1] Benjamin Vera Valles, "*High temperature resistant door seal for a microwave oven*", U.S. Patent 3 846 608, Nov. 5, 1974.

[2] David S. Brombal, Charles B. D. Bunner, Nickolas S. Gulis, John P. Luszczek, "*Electronic apparatus with electro-magnetic interference screening*", U.S. Patent 4 631 641, Dec. 23, 1986.

[3] Peke Jan de Vries, Jacobus Bernardus Visser, "*High-Frequency oven door seal*", U.S. Patent 3 196 242, July 20, 1965.

[4] Larry W. Warne, Kenneth C. Chen, "*Slot apertures having depth and losses described by local transmission line theory*", IEEE Trans. Electromagnetic Compatibility, Vol. 32, No.3, pp.185-196, August 1990.

[5] Larry K. Warne, Kenneth C. Chen, "*A simple transmission line model for narrow slot apertures having depth and losses*" on IEEE Trans. Electromagnetic Compatibility, vol.34 No. 3, August 1992.

[6] Larry K. Warne, Kenneth C. Chen: "*Slot apertures having depth and losses described by local transmission line theory*" on IEEE Trans. Electromagnetic Compatibility, vol. n. 32, No. 3, August 1990.

[7] J.Carlsson, P.S.Kildal, "*Transmission through corrugated slots*", IEEE Trans. Electromagnetic Compatibility, Vol.37, No. Feb. 1995.

[8] J.Carlsson, P.S.Kildal, "Analysis of corrugated soft edge to reduce scattering from gaps between reflecting panels", Antennas and Propagation Society International Symposium, 1993. AP-S. Digest, 1993, pp. 394-397 Vol.1.

[9] Keith D. Masterson, David R. Novotny, Galen H. Koepke, "Electromagnetic Shielding Characteristics of Optical-Fiber Feedthroughs", IEEE Trans. Electromagnetic Compatibility, Vol. 43, NO. 2, May 2001