Shielding Effectiveness Measurements using a Reverberation Chamber

Frank B.J. Leferink
Thales Netherlands
Hengelo, The Netherlands
frank.leferink@nl.thalesgroup.com
University of Twente
Enschede, The Netherlands
frank.leferink@utwente.nl

Hans Bergsma
Thales Netherlands
Hengelo, The Netherlands
hans.bergsma@nl.thalesgroup.com

Wim C. van Etten
University of Twente
Enschede, The Netherlands
w.c.vanetten@el.utwente.nl

Abstract
Shielding effectiveness measurements have been performed using a reverberation chamber. The reverberation chamber methodology as we1l as the measurement setup is described and some results are given. Samples include glass reinforced plastic panels, aluminum panels with many holes, wire mesh, among others. The reverberation chamber setup gives very repeatable measurement results.

Keywords
Shielding Effectiveness, Reverberation Chamber

INTRODUCTION

Shielding effectiveness (SE) measurement methods have been in use over decades. [1][2][3][4][5][6][7][8][9] Every method has its disadvantages. As an example, the conventional MIL-STD 285 [1] test setup used for measuring SE of gaskets is drawn in Figure 1.

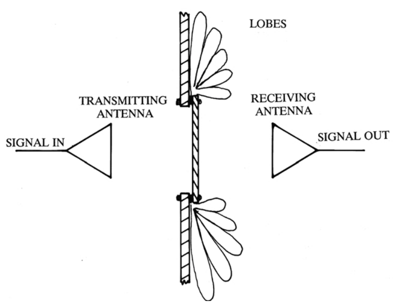


Figure 1: Lobes at high frequencies

At high frequencies, where the dimensions of the test setup are larger than the wavelength of the test signal, beams are formed. The position of the beams are dependant of pressure and size of the gaskets, and the received power is dependant of frequency and position of the antenna. These effects affect the measurement results and repeatability is drastically reduced. These disadvantages can be overcome when using a reverberation chamber.

Reverberation chambers have been used for decades. The basic objective was the creation of high field strength [10][11]. But already in 1971 [12] the reverberation chamber was used for measuring shielding effectiveness, in this case a missile.

The objective of the reverberation chamber is to obtain a field which is constant on average, which has many polarisation directions, and which is statistically uniform [10][11][13]. This can be achieved by means of either the mode-tuned or the mode-stirred technique, or by varying the boundary conditions of the whole chamber. The mode stirring technique has been used in this work. Mode stirring means that the maximum electromagnetic field level in the chamber is measured while a mode stirrer is moving [14]. The received power in a rectangular chamber without a (rotating) mode stirrer is shown in Figure 2. If the stirrer rotates, the received power is as shown in Figure 3. Although this is a frequency dependant pattern, one can reason that a similar pattern can be observed when the leakage lobes of a gasket are measured as function of the radial position at a fixed frequency.

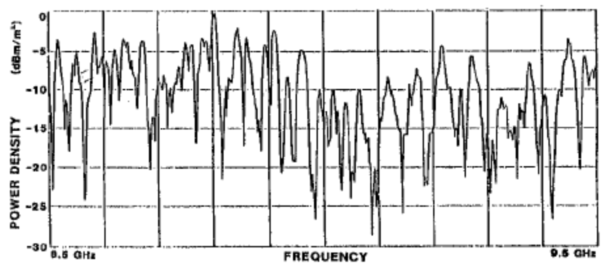


Figure 2: Power density inside reverberation chamber when the mode stirrer does not rotate

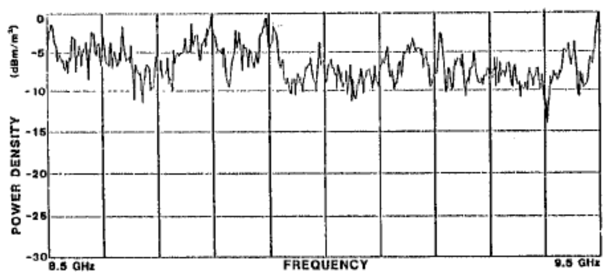


Figure 3: Power density inside reverberation chamber when the mode stirrer rotates

In [15][16][17] a reverberation chamber test procedure has been given using a nested chamber, as shown in Figure 4. This method needs a much higher frequency for proper operation due to the limited size of the test fixture, compared to the method as described in this paper.

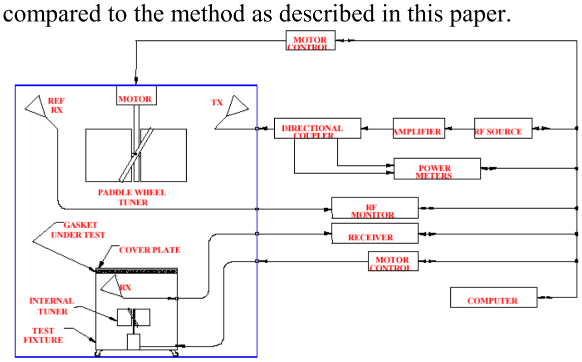


Figure 4: Nested Chamber method as described in [15](details of the text can be found in [15]

The procedure we applied is described, and some test results are presented.

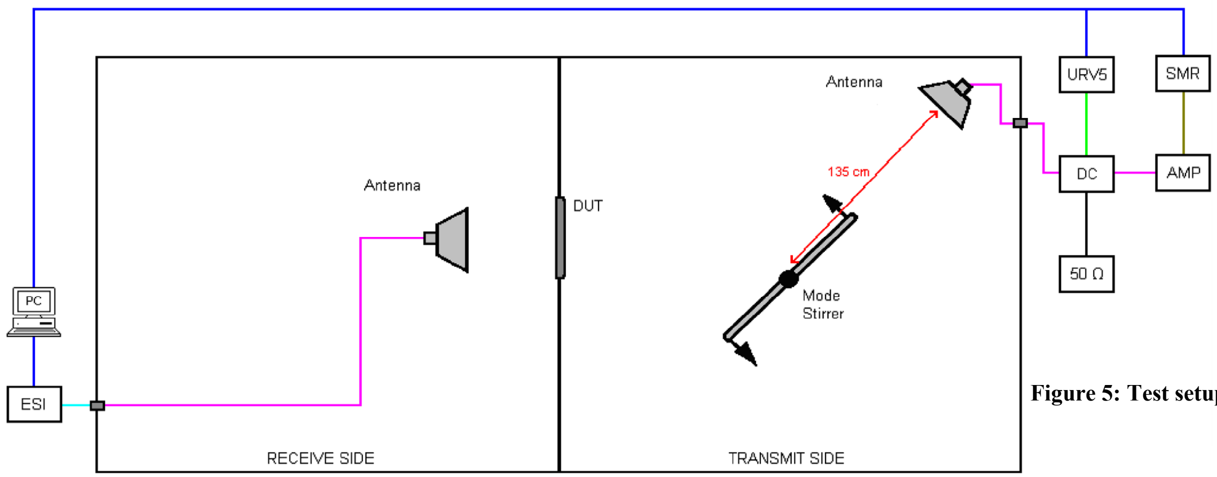


Figure 5: Test setup

SETUP

The test setup described in [20] used is shown in Figure 5. The transmit chamber (right) is the reverberation chamber. In many cases, the field in the receive chamber (left) does not have to be made reverberant, and then a stirrer is not used. The receive antenna is always positioned such that the highest level is measured.

For SE measurements we are only interested in the difference in power density levels in the receive chamber without and with a panel mounted, although one could argue on this, stating that the hole is a part of the shielding (at low frequencies).

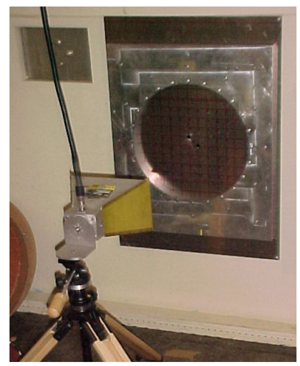
The useable frequency range of the test setup is very wide; At frequencies where the reverberation chamber is small with respect to the wavelength of the test signal, the chambers are just shielded chambers. When the chamber size is in the order of a wavelength and the test signal resonates, the results are less repeatable. At even higher frequencies, the reverberation chamber becomes effective because sufficient modes are available so then an uniform field is obtained via the rotating stirrer. The high frequency limit is the frequency at which the shielded enclosure starts to leak so that the quality factor Q of the room is too low for accurate measurements, although not a very high Q is needed for accurate measurement results.

The enclosure used for the experiments is 3.42 x 2.85 x 2.22 m and can be used as reverberation chamber for frequencies above approximately 80 MHz (3 modes).

PROCEDURE

A fixed power level, generated by a tracking generator and amplifier and transmitted by an antenna, is fed into the reverberation chamber. The transmitted and reflected power is measured via directional couplers as shown in Figure 5. If the reflected power is more than half of the transmitted power, which is the case when the quality factor Q is very high, then the measurement results are less accurate. A small antenna is connected to a measuring receiver linked to the tracking generator. The measuring time is longer than the time needed for 360^o rotation of the stirrer, so that the maximum amplitude is measured.

A reference measurement is carried out by measuring the power density Pd_t in the reverberation chamber with the Device Under Test (DUT) in place. The transmitted level Pd_r is measured in the receive side. The points of maximum leakage are searched for by the receiving antenna.



To determine the SE of a material or construction a correction is needed for the shielding effectiveness of the hole in the wall itself [22]. Therefore the power density in the reverberation chamber and at the receive side are measured when the hole is open. The difference between these levels is the SE_h of the hole in the wall.

TEST SAMPLES

The test setup has been used to measure the shielding effectiveness of many samples, including

- Composite panels (Glass Reinforced Plastics, GRP) with woven metallic textile
- Composite panels with carbon fibers
- Composite panels with metal paint
- Composite panels with thin metallic fibers
- Honeycomb panels
- Joined panels
- Various wire mesh
- Panels with multiple holes, and
- Aluminum panels with various gaskets

In order to fix the DUT in a repeatable manner, an aluminium pressure ring is applied. The screws are fixed with a torque wrench adjusted to torque 4.

The shielding effectivess of several GRP panels are given in Figure 6. The repeatability was tested by measuring, removing and again measuring a similar panel several times. The result of such a repeatibility test is shown in Figure 7. For comparison, the difference in measurement results obtained using the conventional MIL-STD 285/IEEE299 method could be upto 40 dB in some cases.

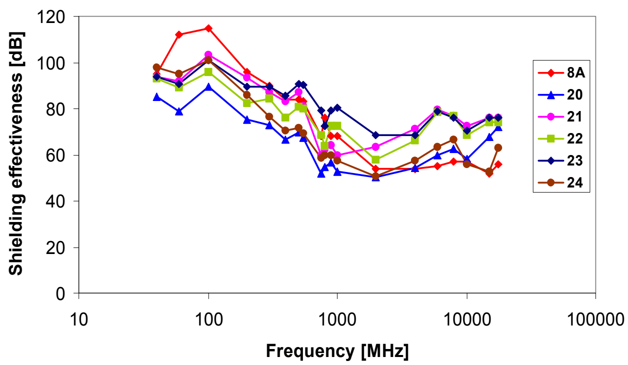


Figure 6: Shielding effectiveness of several GRP panels

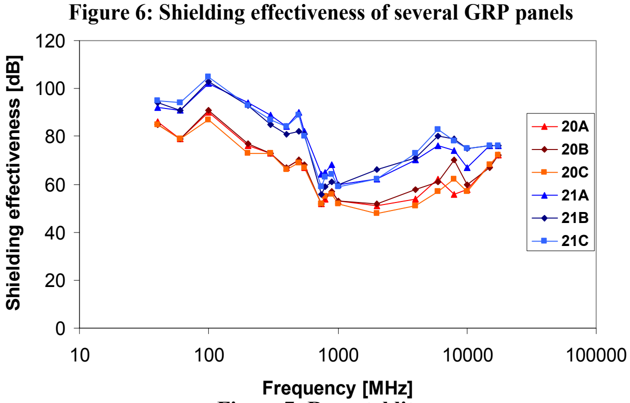


Figure 7: Repeatablity

The GRP panels have been deliberatedly damaged and repaired. The impact on shielding effectivenss has been shown in Figure 8. The subscript *d* denotes damaged, while the subscript *r* denotes repaired.

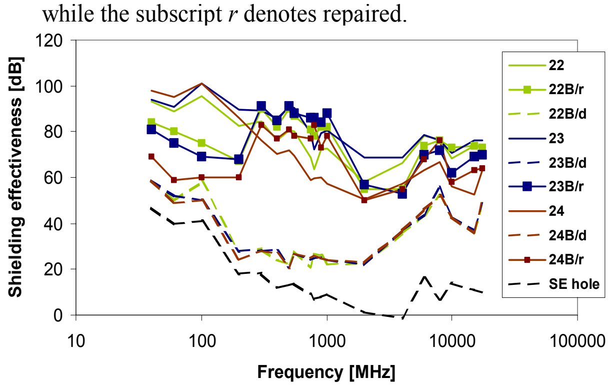


Figure 8: Shielding effectiveness of several GRP panels, before damage, after damage and after repair

Repairing a GRP panel was effective for high frequencies, while at low frequencies the SE was reduced after repair. The reason for this was that if was difficult to make electrical contact with the metallic layers in or on the GRP. This reduced the SE at lower frequencies. One would argue that without electrical contact, the seams would be dominant at high frequencies. However, at high frequencies the capacitive effect between the layers dominate.

The shielding effectivenss of one hole is well known: it is open (0 dB) if a half-wavelength equals the largest dimension of the hole. If multiple holes are applied, then several models give different answers, ranging from 0log *N*, 10log *N* to 20 log *N* with *N* being the number of holes. To investigate the effect, a panel has been used with an increasing number of holes of 15 mm diameter, separated by 35 mm, in a aluminum panel of 2 mm thickness.

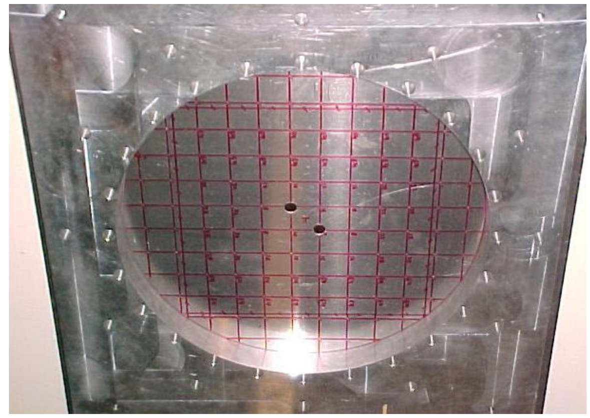


Figure 9: Aluminum panel with 2 holes, with markings for the remaining holes to be drilled.

Measurements have been performed and repeated twice, and the mean value of the three measurements has been used. Measurements have been performed with 1, 2, 4, 8, 16, 32, 64 and 112 holes and the shielding effectiveness is drawn in Figure 10. The variation between the 3 measurement results, i.e. the absolute difference between the maximum and minimum value has been drawn in Figure 11.

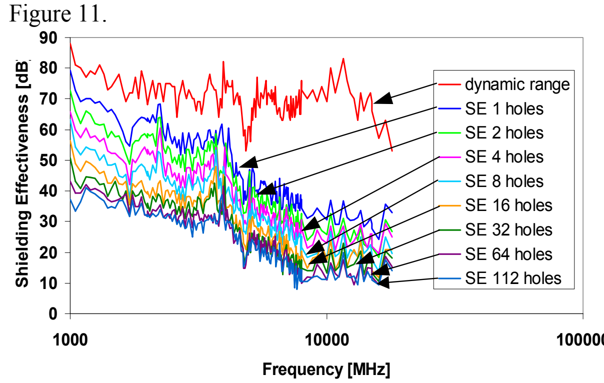


Figure 10: Shielding effectivess of panel with holes

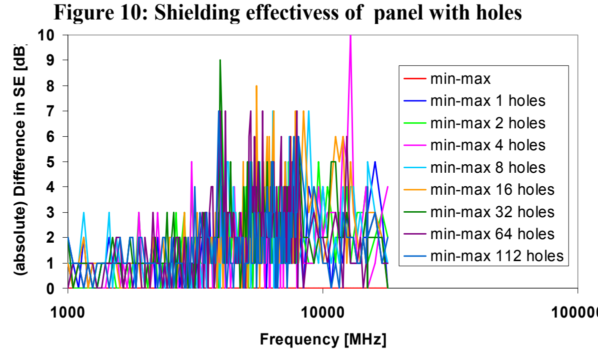


Figure 11: Difference between 3 SE measurement results

The interesting observation is that shielding effectiveness is decreased with 6 dB with a doubling with the number of holes at frequencies where the wavelength is small with respect to the wavelength. At higher frequencies, the holes apparently act as coherent Huygens sources, because the SE decreases only with 3 dB. Note that in literature various statements are made. A discussion however is out of the scope of this paper.

The repeatability is at low frequencies, i.e. less than 5 GHz excellent. For higher frequencies the repeatability is still good, and excellent compared to conventional test techniques like MIL-STD 285.
Several wire meshes have been measured. As an example, the SE of some retail wire meshes ('chicken wire') woven wire mesh and a mesh used in radar antenna reflectors has been shown in Figure 12. The raw data and a 10 point moving average trend line is shown. The wide frequency range of the test setup and the SE variation are clearly visible; At low frequencies, the SE gives a flat curve. In the mid frequencies, where the chamber size is equal to a wavelength, resonances occur. At high frequencies, the reverberation effect smooths out the resonances.
The objective of the mesh material is to show mechanical design engineers that even chicken mesh is capable to shield electromagnetic fields.

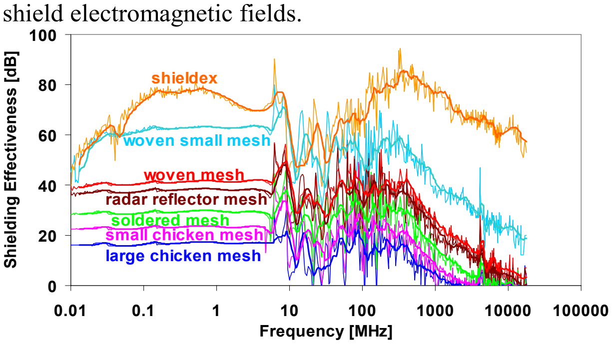


Figure 12: SE of various wire mesh

Conclusion

Shielding effectiveness testing at high frequencies, i.e. wavelength smaller than enclosure size, using conventional test techniques gives large variations in results. Reverberation chambers are much more suitable. The shielding effectivenss measuring method using the reverberation chamber has been described and some results are shown. The measurement results obtained are very repeatable and not dependant of size and quality of chambers. Some interesting conclusions can be drawn. For instance, the leakage of holes in a panel appeared to be either a function of 10 log N and 20 log N, N being the number of holes, depending of the size of the holes with respect to the wavelength.
More measurement data on gaskets, honeycomb ventilation panels and labyrinths will be published in the near future.

References

[1] MIL-STD 285, Method of attenuation measurements for Electromagnetic Shielding Enclosures for Electronic Purposes, 1956
[2] IEEE STD 299-1997, IEEE standard for Measuring the Effectiveness for Electromagnetic Shielding Enclosures
[3] GAM T20, Method of testing shielding effectiveness and shielded rooms
[4] VG 95373-15, Elektromagnetische Verträglichkeit - Elektromagnetische Verträglichkeit von Geräten - Teil 15: Messverfahren für Kopplungen und Schirmungen
[5] ASTM ES7-83,Test Method for Electromagnetic Shielding Effectiveness of Planar Materials, American Society for Testing and Materials, West Conshohocken, PA, withdrawn 1988
[6] ASTM D4935-99, Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials, 1999.
[7] ASTM E1851-97, A Test Procedure to Evaluate Shielding Effectiveness of a Shielded Enclosure, 1997
[8] NSA 65-6, R.F. Shielded Enclosures for Communications Equipment: General Specification, National Security Agency, October 30, 1964
[9] IEC/TS 61587-3, Mechanical structures for electronic equipment - Tests for IEC 60917 and IEC 60927 - Part 3: Electromagnetic shielding performance tests for cabinets, racks and subracks, 1999
[10] H.A. Mendes, A New Approach to Electromagnetic Field Strength Measurements in Shielded Enclosures, Wescon Technical Papers, Western Electronic Show and Convention, Aug. 20-23, 1968, Los Angeles.
[11] P. Corona, G. Latmiral, E. Paolini, L. Piccioli, Use of a reverberating enclosure for measurements of radiated power in the microwave range, IEEE Transactions on Electromagnetic Compatibility, vol.EMC-18, no.2, May 1976, p.54-59
[12] MIL-STD 1377, Measurement of Effectiveness of Cable, Connector and Weapon Enclosure Shielding and Filters in Precluding Hazards of Electromagnetic Radiation to Ordnance, 20 august 1971
[13] M.L. Crawford, G.H. Koepke, Operational Considerations of a Reverberation Chamber for EMC immunity Measurements - Some Experimental Results, IEEE Symposium on EMC, 1984
[14] F.B.J. Leferink, J-C Boudenot, W.C. van Etten, Experimental Results Obtained in the Vibrating Intrinsic Reverberation Chamber, IEEE Symposium on EMC, Washington DC, 2000, pp. 639-644
[15] IEC 61000-4-21, Electromagnetic compatibility (EMC) - Part 4-21: Testing and measurement techniques - Reverberation chamber test methods, 2003
[16] M.O. Hatfield, Shielding Effectiveness Measurements using Mode-Stirred Chambers, a Comparison of Two Approaches, IEEE Transactions on EMC, aug 1988, pp. 229-238
[17] C.L. Holloway, D. Hill, J. Ladbury, G. Koepke, R. Garzia, "Shielding effectiveness measurements in a nested reverberation chamber, IEEE Trans. on EMC.
[18] G.J. Freyer, and M.O. Hatfield, Comparison of gasket transfer impedance and shielding effectiveness measurements, part I, IEEE Int. Symposium on EMC, Anaheim, CA, August 1992, pgs 139-141.
[19] M.O. Hatfield, and G.J. Freyer, "Comparison of gasket transfer impedance and shielding effectiveness measurements - part II, IEEE Int. Symposium on EMC, Anaheim, CA, August 1992, pgs 142-148.
[20] F.B.J. Leferink, B.R.M. Puylaert, Accurate Shielding Effectiveness Measurements using a Reverberation Room, 10th International Zurich Symposium and Exhibition on Electromagnetic Compatibility, 1993, pp. 635-640
[21] J.P. Quine, Distortion of radiation pattern for leakage power transmitted through attenuation cover panels and shielding gasket – need for reverberation chamber measurement of total leakage power, IEEE Int. Symposium on EMC , Chicago, August 1994, pgs 285-290.
[22] M. Backstrom, T. Martin, J. Lorén, Analytical Model for Bounding Estimates of Shielding Effectiveness of Complex Resonant Enclosures, IEEE Int. Symposium on EMC, 2003, Istanbul