

High Intensity Electromagnetic Field Generation using a Transportable Reverberation Chamber

Frank Leferink
Thales Netherlands – University of Twente
P.O. Box 217, 7500 AE Enschede, The Netherlands
leferink@ieee.org

Abstract

A reverberation chamber can create very high field strength with moderate input power. Existing chambers are making use of a paddle wheel to change the resonant modes in the chamber. A transportable reverberation chamber with vibrating walls will be presented. Inside this Vibrating Intrinsic Reverberation Chamber (VIRC) a diffuse, statistically uniform electromagnetic field is created, without the use of a mechanical, rotating, mode stirrer. This chamber results in a better homogeneity and increased field strength compared to conventional mode stirred reverberation chambers. This test setup is very suitable for cost effective intentional electromagnetic interference (I-EMI) tests.

1. INTRODUCTION

A reverberation chamber generally consists of a rectangular test room with metal walls and one or two mode stirrer(s), usually in the form of a large paddle, near the ceiling of the chamber, as shown in Figure 1.

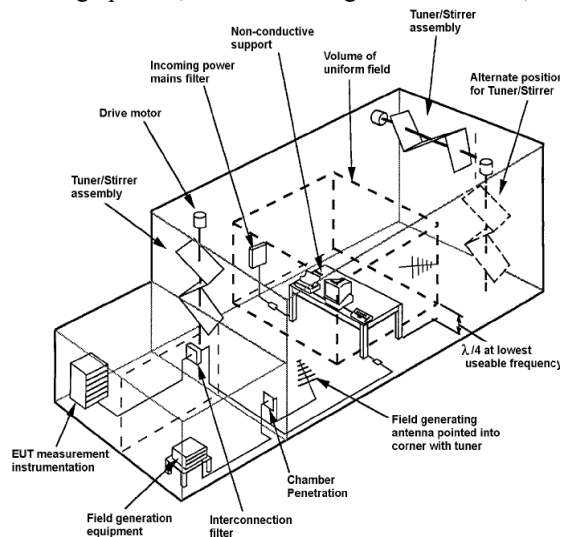


Figure 1: The reverberation chamber as described in IEC-61000-4-21

The equipment under test (EUT) is placed in the chamber and exposed to an electromagnetic field while the stirrer slowly revolves. The average response of the EUT to the field is found by integrating the response over the time period of one revolution of the stirrer. The metal walls of the chamber allow a large field to be built up inside the chamber. The EUT is therefore exposed to a high field level consisting of several different polarizations [1,2,3,4]. The most significant quality of a chamber is its ability to create an EM environment equal in strength to the environment needed to test the equipment. This provides an electromagnetic environment which is spatially uniform (energy density in the chamber is everywhere the same), randomly polarized (the phase, and thus polarization, between all the waves, is randomly distributed), and isotropic (the energy flow in all directions is the same).

It has been shown [5, 6, 9, 10, 11, 12, 13, 14] that the variation of the boundary conditions deviate the resonant behaviour of a reverberation room. For proper mode separation we need asymmetric structures. On the other hand, circular structures result in focussing of rays and thus degrade the spatial uniformity. Wall irregularities and wall-floor angle irregularities show that the spatial uniformity and isotropicity can be improved.

By changing all angles of the wall-floor-ceiling of a reverberation room in a high velocity compared to the classic mode stirrer in mode stirred reverberation chambers we can use all beneficial effects. This technique is called Vibrating Intrinsic Reverberation Chamber (VIRC). The VIRC is a reverberation chamber where the walls are made of flexible conducting material. It is mounted in a rigid structure and connected to that structure via flexible rubber strings, as shown in Figure 2.

By moving one or more ridges or one or more walls the modal structure inside the chamber is changed. Because the frequency shift is much larger compared to what is possible with a conventional mode stirrer, the frequency range of the chamber is extended to lower frequencies compared to conventional (mode stirred) reverberation chambers with equal dimensions. Note the natural corrugation of the flexible walls in Figure 2 which is beneficial for the spatial uniformity too. Another advantage is that the flexible chamber can be erected inside a standard anechoic chamber where the EUT has been installed for standard EMI tests. Furthermore the VIRC does not need extra space inside the laboratory: it can be folded and put away fast. The most important advantage of the flexible structure of the VIRC is that it can be installed in-situ. The technique has been described in [16, 17, 18 and 19]. Some applications and experience gained in practice, related to radiated emission and high-intensity susceptibility EMI testing, will be discussed.

The conventional chamber makes use of a stirrer or tuner. If the stirrer is rotated continuously, we call it a mode stirred chamber. In this case the field variation is fast. The mode tuned technique makes use of a stepper motor for rotating the tuner. In this case, the field is stable for some time. This type of reverberation chamber is called mode tuned reverberation chamber.

The mode stirred is much faster in measuring than the mode tuned, but for some applications where the equipment under test has a long dwell time the mode tuned is preferred.

For these cases we can use the Tunable Intrinsic Reverberation Chamber (TIRC). It is a VIRC but the walls are not moving or vibrating continuously. The walls can be moved using a stepper motor, or the modes can be changed using a conventional paddle wheel driven by a stepper motor. The fields can therefore be mode tuned in a TIRC, instead of mode stirred in a VIRC.

A picture of a prototype is given in Figure 3.



Figure 2: The VIRC: a flexible tent with irregularly shaped walls. The field is stirred by moving the walls



Figure 3: A Tuneable Intrinsic Reverberation Chamber, lower left outside, right inside

2. IN-SITU TESTING USING A VIRC

A VIRC has been designed and built for in-situ testing of an active phased array antenna. Pictures of this VIRC are shown in Figure 4. The dimensions of this VIRC are 5x3x3m, resulting in a first resonance frequency of 58 MHz. The VIRC was fabricated by a tent manufacturer from the basic material we supplied. The walls were made from metalised (copper) fabric. The seams were overlapping, using double stitch. The interface with the EUT was made via a circumferential galvanic connection, as shown in Figure 4.

All cable feedthroughs are either a waveguide-beyond-cutoff penetration for non-conducting parts, or a circumferential electrical connection for all conducting parts, such as cables. The vibration has been created by using automobile wiper motors with an excentric arm which is connected to the VIRC by means of an elastic rope. The VIRC has been validated before actual EMI test were performed. Details can be found in the references. An important parameter is the spatial field uniformity (SFU). The SFU gives the ability to generate an isotropic, randomly polarised field, which is stochastic equal in the whole volume of the chamber, except near the walls. In

Figure 5 the vectorial sum of the magnitude of the field strength in the three orthogonal directions, with respect to the mean field strength, per measuring position has been drawn as function of the frequency. From this figure we can conclude that the field strength is within the 0-6dB range for frequencies higher than 150 MHz.



Figure 4: The VIRC as built for in-situ testing

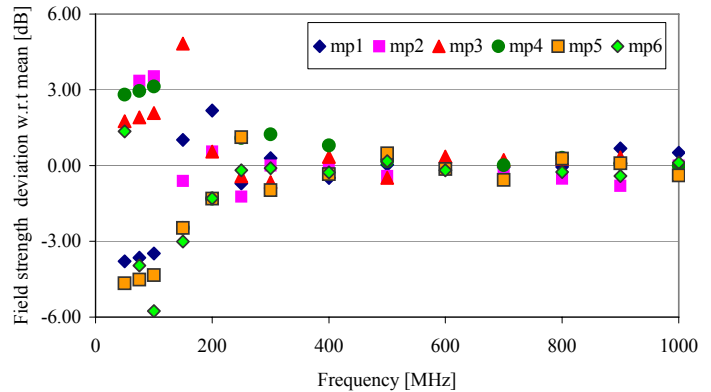


Figure 5: Field uniformity, 6 measuring positions

The Equipment Under Test (EUT) is the multifunctional Active Phased Array Radar (APAR). Due to the fact that APAR is a classified product we can present only simplified data. The VIRC was attached in front of the radar antenna making a galvanic connection over the whole circumference.

Radiated emission measurements and radiated immunity measurements have been performed. The field strength has been measured as function of frequency. Average and peak detectors were used simultaneously. The measured field strength was corrected by means of the experimentally obtained Chamber Factor: $E = E_{measured} - CF$

For frequencies below 10 MHz the CF equals 0. The radiated emission measurements performed in this frequency range therefore result in the same field strength as would be obtained in an anechoic chamber or free space environment. For frequencies above 10 MHz, the chamber factor is positively valued. Therefore the CF corrected field strength in the VIRC is much lower compared to the field strength which could have been measured in a free space environment!

Ambient measurements have been carried out to determine if the VIRC shielding effectiveness was retained. Only EMI receiver noise has been measured. This was also the case with the EUT activated. This means that the radiated emission was below the receiver noise upto 1 MHz, and even 20dB below receiver noise for frequencies higher than 10 MHz. Inside the VIRC the maximum power, as available in our laboratories, was generated, for immunity testing. This includes for instance 2500 W in the frequency band 10kHz-200MHz, 500 W 200 MHz- 1 GHz, and 200 W in the frequency band 1-18 GHz.

The generated field strength can be calculated via the chamber gain, or obtained via measurements. The measured maximum average field strength was beyond 1000 V/m, while the maximum peak field strength was nearly 10.000 V/m. The EUT did not show degradation of performance.

For some applications it is needed to have a stable field strength for a minimum period of time. This can be achieved using the mode tuning technique. In this case we cannot vibrate the VIRC, but have to use a stepper motor moving the walls in discrete steps, or using a paddle wheel with a mode tuner, as shown in Figure 3.

3. IN-SITU TESTING USING A VIRC, SOME OTHER EQUIPMENT

Other equipment has been tested. Some products are shown hereafter.





4. CONCLUSION

A new type of reverberation chamber to create a spatial uniform and isotropic electromagnetic field is the Vibrating Intrinsic Reverberation Chamber (VIRC). The major benefits of the VIRC are the extremely high field strength which can be generated for Intentional EMI testing. The increased dynamic range for emission testing is also beneficial, while the user-friendliness of the technique for in-situ testing has been shown.

References

- [1] 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.
- [2] 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, May 1976, p.54-59.
- [3] M.L. Crawford, G.H. Koepke, Operational Considerations of a Reverberation Chamber for EMC immunity Measurements - Some Experimental Results, IEEE Symposium on EMC, 1984.
- [4] M.L. Crawford, G.H. Koepke, Design, Evaluation and Use of a Reverberation Chamber for Performing Electromagnetic Susceptibility/ Vulnerability Measurements, NBS Nt 1092, 1986.
- [5] F.B.J. Leferink, J.C. Boudenot, W. van Etten, The Vibrating Intrinsic Reverberation Chamber: an Optimal Use of Geometrical Change in Boundary Conditions, Report University of Twente, EL-TEL, sept. 1999.
- [6] Y. Huang, Conducting triangular chambers for EMC measurements, Meas.Sci.Technol, 10, 1999, L21-L24
- [7] D.A. Hill, Electromagnetic theory of reverberation chambers, NIST Technical note 1506, dec. 1998.
- [8] J.M. Dunn, Local, High-Frequency Analysis of the Fields in a Mode-Stirred Chamber, IEEE Transactions on Electromagnetic Compatibility, Febr. 1990, pp. 53-58.
- [9] F.B.J. Leferink, High field strength in a large volume: the intrinsic reverberation chamber, IEEE Symposium on EMC, 1998, pp. 25-27.
- [10] A.C. Marvin, J.A.S. Angus, J.F. Dawson, J. Clegg, 'Enhancements to Stirred Mode Chambers by the Use of Pseudo-Random Phase reflection Gratings', Int. Symposium on EMC, Rome, Italy, 1994, pp. 218-221.
- [11] J. Clegg, A.C. Marvin, J.A.S. Angus, J.F. Dawson, 'Optimal Phase Reflection gratings and the Effect on Fields in a Mode Stirred Chamber', Int. Symposium on EMC, Rome, Italy, 1996.
- [12] M. Petirsch, A. Schwab, 'Optimizing Shielded Chambers Utilizing Acoustic Analogies', IEEE Symposium on EMC, 1997, pp. 154-158.
- [13] E.A. Godfrey, Effects of corrugated walls on the field uniformity of reverberation chambers at low frequencies, IEEE Symposium on EMC, 1999, pp. 23-28.
- [14] Y. Huang, D.J. Edwards, An investigation of electromagnetic fields inside a moving wall mode-stirred chamber, IEE Conference on EMC, Edinburgh, 1992.
- [15] M. Hatfield, Visualisation of Electromagnetic Fields in a Rev. Chamber, Experiments Session IEEE EMC Symposium 1998.
- [16] F.B.J. Leferink, W.C. van Etten, The Vibrating Intrinsic Reverberation Chamber, IEEE Tr. on EMC, 2001.
- [17] 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 D.C. 2000.
- [18] F.B.J. Leferink, W.C. van Etten, Optimal Utilization of a Reverberation Chamber, 4th European Symposium on Electromagnetic Compatibility, Brugge, 2000.
- [19] Patent WO34795, NL1010745, AU18605 etc, Test Chamber, Hollandse Signaalapparaten B.V., Netherlands.