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STATISTICAL BEHAVIOUR OF TRANSMIT ANTENNA ORIENTATION IN A REVERBERATION CHAMBER

Aizan Ubin, Mohd Zarar Mohd Jenu and Waddah A. M. A.
Research Center for Applied Electromagnetics, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia
E-Mail: aubin@uthm.edu.my

ABSTRACT

Reverberation chamber (RC) is one of the electromagnetic compatibility (EMC) facilities for radiated emission and radiated susceptibility test. The RC is unique because it allows many directions for illumination an object with a higher field strength compared to conventional techniques, for the same input power. The field uniformity and statistical behaviour of the field are crucial in a reverberation chamber. Transmit antenna is one of important components in the RC. The proper orientation of transmit antenna orientation contributes to the performance of RC. This paper presents an evaluation of the performance for three different antenna orientations inside a 2.50 m x 2.55 m x 4.00 m reverberation chamber. The evaluation was done in the frequency range from 100 MHz to 1000 MHz. The simulation results show that by implementing proper transmit antenna orientation; the field uniformity inside a reverberation chamber can be improved.

Keywords: reverberation chamber, transmit antenna, stirrer, field uniformity.

INTRODUCTION

A reverberation chamber is a cavity resonator whose fields are perturbed by a stirrer in order to generate fields that are statistically uniform and isotropic. The advantage of the reverberation chamber as compared to other facilities for EMC measurements is that only a small amount of input power is required to generate high intensity electric field inside the room. This enables immunity testing to be conducted to a much higher electric field to ensure proper operation of the equipment under test. This is useful for radiated immunity test for components related to automotive, defence and avionic industries. The reverberation chamber needs to be evaluated before use, especially by its field uniformity and statistical behaviour inside the working volume as described in the standard reverberation chamber test method, IEC 6100-4-21 (IEC, 2003). Transmit antenna or field generating antenna is one of the main component for reverberation chamber. This transmit antenna essential for calibration of the reverberation chamber or radiated emission test.

Many studies have been conducted using simulation and experiment to evaluate the transmit antenna in the reverberation chamber. However, the studies were performed using different methodologies and techniques. The influence of different position, orientation and polarization of the transmit antenna on the performance of reverberation chamber has been analysed by measuring the scattering parameter of the chamber (He, Sun G., Sun Z., Liu, Zhu, and Zhou, 2011). The transmit antenna was setup in different heights and directions. They found that the antenna orientation has a significant influence on the performance of the chamber.

(Fan, Cui and Liu, 2010) described an investigation into the influence of transmit antenna position and direction to the field uniformity of reverberation chamber. The reverberation chamber of 10.5 m x 8.0 m x 4.3 m was simulated using FEKO software. The transmit antenna was placed at two different position and the working frequency was 150 MHz and 200 MHz. They found that the antenna pointing to the corner of chamber produced better field uniformity.

Another study by (Cui, Wei, Fan, Liu, and Pan, 2010), they investigated into the field uniformity of the reverberation chamber excited by single antenna and two emission antennas at 80MHz and 120MHz. The results show that the field uniformity of chamber was improved when using two antennas. The reason is that two separate electromagnetic fields simultaneously generated by two antennas are superimposed.

(Liang, Xu, Ding, and Huo, 2010) implemented source stirring reverberation chamber (SSRC), which changes the excitation source to create an evenly homogeneous and isotropic field. It is different from the traditional mechanics stirring reverberation chamber (MSRC) which changes the boundary to achieve the same field. 8 antenna locations, 4 antenna locations and 2 antenna positions were used to evaluate the field uniformity. The field uniformity of the test region gradually improves with the number of antenna locations increasing.

(Cerri, Priamani and Russo, 2010) described an analytical model applied to study the behaviour of an antenna moving inside a resonant cavity. It is the basic step to develop a source stirring mode reverberation chamber. The source stirring technique proposed is theoretically based on the movement of a feeding antenna inside the cavity. However, the main difficulty in the source stirring technique is the choice of the positions of the antennas that change with the cavity geometry.

In this paper, three different antenna orientations for reverberation chamber were modelled and the field uniformity was calculated. Orientation 1 is orientation to the corner of chamber, orientation 2 is orientation to the working volume and orientation 3 is orientation to the stirrer.

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CHAMBER MODEL

Introduction

The simulation model of the reverberation chamber was developed using CST Microwave Studio which uses Finite Integration technique for solving Maxwell's equation. There are three main components in the simulation model. The components are chamber walls, transmit antenna and stirrer. The structure of the chamber was modelled using six sheets of perfect electrical conductor (PEC). Antenna and stirrer also were modeled using PEC material. The chamber is 2.50 m in width, 2.55 m in height and 4.00 in length. Figure-1 shows the cross section of simulation model of the RC with log periodic antenna.

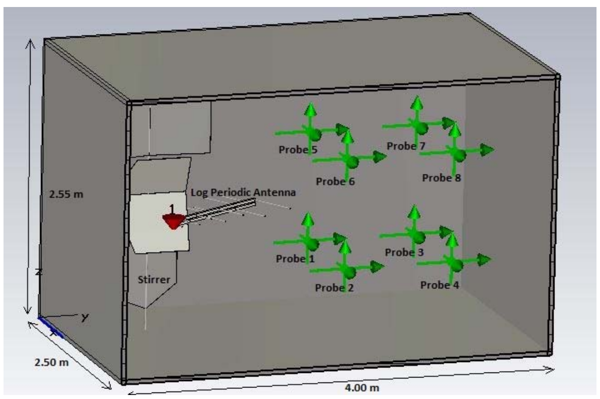

Figure-1. The cross section of the simulation model of the reverberation chamber.

Transmit antenna

The transmit antenna as an excitation source must have higher directivity in order to reduce unwanted direct coupling between the transmit antenna and equipment under test. It also requires a large frequency range and large dynamic range. Antennas in reverberation chambers do not need any gain, but the losses should be low and the dimensions should be small (Vogt-Ardatjew, Van de Beek and Leferink, 2012).

The reverberation chamber was excited using log periodic antenna. A log periodic or any other linearly polarized antenna system is recommended as an excitation source inside the chamber. It consists of several dipoles of different length and spacing that are fed from the single source at the small end. The transmission line is criscrossed between the feed points of adjacent pair of dipoles. The length of the dipoles and their spacing are related in such a way that adjacent elements have a constant ratio to each other. The design ratio, τ for the log periodic is 0.8. The eight element log periodic antenna was designed to operate in the frequency band ranges from 100 MHz to 1000 MHz. It is located 1.35 metres from the chamber's floor. Figure-2 shows an eight element of log periodic antenna.

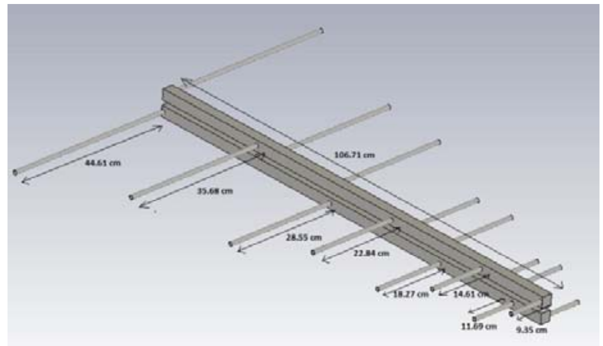

Figure-2. Eight element log periodic antenna.

Antenna orientation

The simulation models for reverberation chamber were developed for antenna facing to the corner of chamber, antenna facing to the working volume and antenna facing to the stirrer. Electric field probe data were collected from the eight locations that form the corners of the working volume. The distance of each probe was spaced 1.0 metre from each other. Electric field data were analysed to determine the field uniformity within the working volume. The simulation models for three different antenna orientations are shown in Figure-3, Figure-4 and Figure-5.

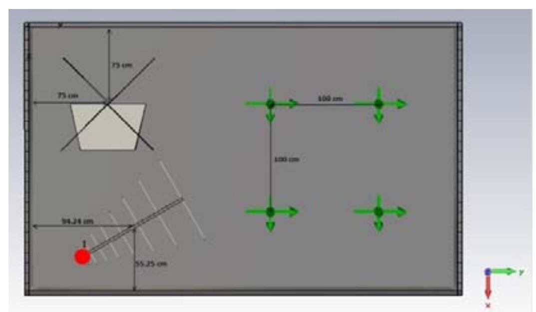

Figure-3. Top view of simulation model with antenna facing to the corner of chamber.

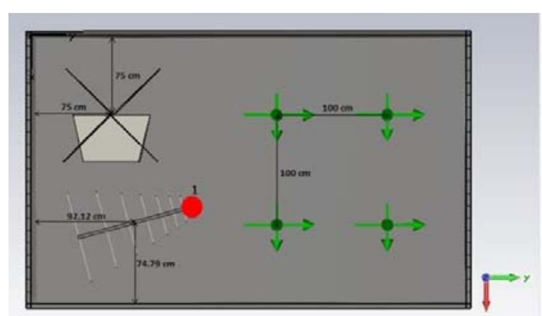

Figure-4. Top view of simulation model with antenna facing to the working volume.

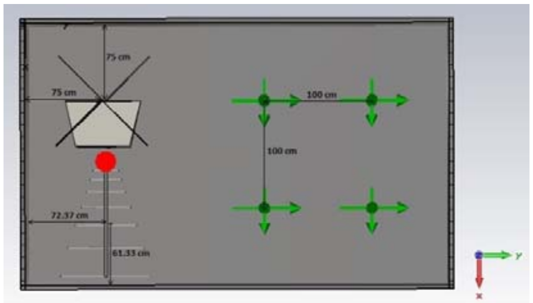

Figure-5. Top view of simulation model with antenna facing to the stirrer.

Stirrer

The function of stirrer is to vary the boundary condition inside the reverberation chamber. The choice of the kind of the stirrer as well as the position inside the chamber where it is fixed to operate is basic parameters for determining the stirrer effectiveness. The electromagnetic environment that derives from this situation is statistically uniform and statistically isotropic when it is considered as the average value for a sufficient number of stirrer positions. The stirrer can be operated in continuous rotation or in series of discrete steps. If the stirrer moves continuously, the chamber is called mode stirred chamber, while if the stirrer moves at distinct positions the chamber is called mode tuned chamber.

Stirrer set consists of three pairs of V shape stirrer. The shape of blades is trapezium and the bases of each trapezium-shaped blade are 0.7 metres and 0.5 metres, while the height is 0.6 metres. They were arranged in asymmetrical order to obtain the highest number of independent positions (Moglie and Primiani, 2011). The total height of the stirrer is 2.10 metres. Stirrers are rotated anticlockwise about the z axis at 360 different rotation angles. Figure-6 shows the stirrer set which is positioned in vertical orientation in the reverberation chamber.

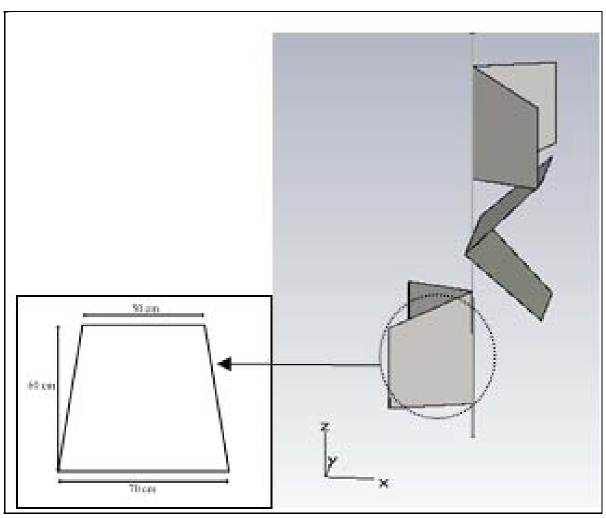

Figure-6. Stirrer model.

SIMULATION RESULTS

Statistical analyses for three different antenna orientations have been performed to compare their performance in the frequency range from 100 MHz to 1000 MHz. The goal of a reverberation chamber is to generate a statistically uniform environment, within some bounded uncertainty, for most locations within the defined working volume. The field within the chamber is considered uniform if the standard deviation is within 3 dB above 400 MHz, 4 dB at 100 MHz decreasing linearly to 3 dB at 400 MHz, and within 4 dB below 100 MHz (IEC, 2003). The standard deviation of the field can be evaluated by (1) (Rothenhausler and Ritter, 2003).

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(x_i - \bar{x}\right)^2} \tag{1}$$

where N is the number of sample, x_i represent the magnitude of a component of the electric field at the test points, i is the test point number and $\bar{x}$ referring to the mean values of samples. In order to represent the standard deviation in decibel, it can be written as in (2) (Rothenhausler and Ritter, 2003).

$$\sigma_{[dB]} = 20\log_{10}\left(\frac{\sigma + \bar{x}}{\bar{x}}\right) \tag{2}$$

Figure-7, Figure-8 and Figure-9 shows the standard deviation of electric field data for three different antenna orientations. The chamber is considered to pass the field uniformity requirements provided that the standard deviation for both the three individual electric field components (E_x, E_y and E_z) and the total data set (E_{abs}) are within the IEC limit in a red line. The magnetic field components are not considered since the definition of field uniformity in the IEC standard is focused on electric field data. In Figure-7, the electric field for z component, (E_z) was found to be above the IEC limit at frequency of 165 MHz. The same phenomenon occurs for electric field for y component (E_y) at frequency of 185 MHz as shown in Figure-9. This result is expected since number of modes for the chamber in lower frequencies is low. The chamber dimension determines the lowest usable frequency (LUF) of the chamber. LUF is the parameter of the reverberation chamber which is related directly to the field uniformity. This frequency occurs at a frequency slightly above three times the first chamber resonance. In the IEC 61000-4-21 standard, LUF is assumed to be the lowest frequency above which the field uniformity requirements are achieved. The LUF for the chamber is approximately occurs at frequency of 209.28 MHz using three times of the first chamber resonance definition.

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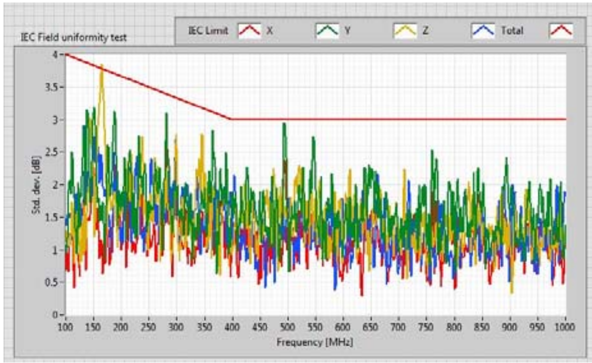

Figure-7. Standard deviation of E -field components for antenna facing to the corner of chamber.

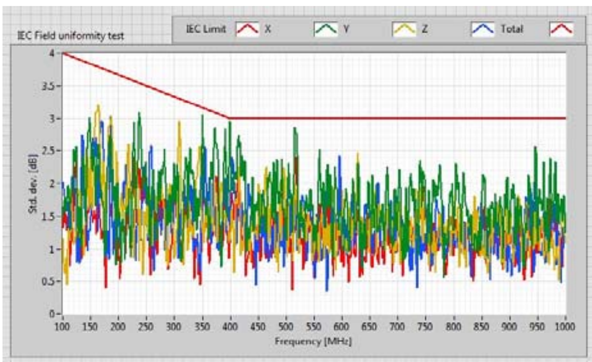

Figure-8. Standard deviation of E -field components for antenna facing to the working volume.

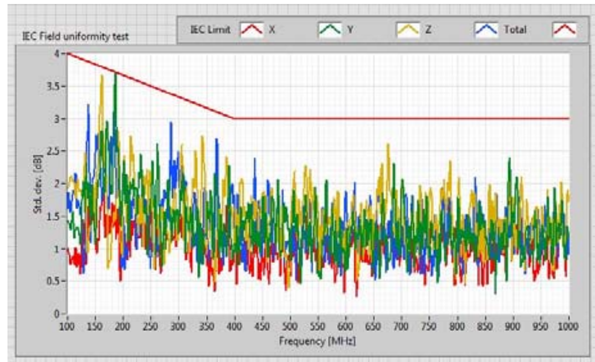

Figure-9. Standard deviation of E -field components for antenna facing to the stirrer.

The comparisons of three different antenna orientations are summarized in Table-1. It shows the number of frequency points and its percentage. There are 901 frequency points between 100 MHz and 1000 MHz frequency range. The comparisons were made by comparing the standard deviation value in dB which was greater than another at every frequency point. For example, the comparison between antenna facing to the working volume and antenna facing to the corner of chamber, it was found that there were 534 frequency points for antenna facing to the working volume. It contributes 59.27 % from 901 frequency points. The higher the percentage of frequency points, the less likely it will produce the good electric field uniformity. The same comparison concept was used to compare the remaining antenna orientations. In Table-1, antenna facing to the stirrer exhibits the best electric field uniformity, followed by antenna facing to the corner and to the working volume.

Table-1. The comparison of standard deviation value in dB for total electric field between each antenna orientation.

Antenna orientation		No of frequency points	Percentage
Working Volume (WV) vs Corner (C)	WV	534	59.27 %
	C	367	40.73 %
Working Volume (WV) vs Stirrer (S)	WV	640	71.03 %
	S	261	28.97 %
Stirrer (S) vs Corner (C)	S	357	39.62 %
	C	544	60.38 %

CONCLUSIONS

The statistical behaviour has been evaluated for three different antenna orientations in a reverberation chamber namely; orientation to the corner of chamber, orientation to the working volume and orientation to the stirrer. The simulation results show that by implementing proper transmit antenna orientation; the field uniformity inside a reverberation chamber can be improved.

The IEC 61000-4-21 field uniformity test, run on the simulated data, has shown that the antenna orientation to the stirrer has the best performance, followed by antenna orientation to the corner and to the working volume. The field uniformity improvement is at 18.54 percent and 42.06 percent for antenna facing to the corner and antenna orientation to the stirrer, respectively. The improvement is from the perspective of the antenna orientation to the working volume.

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