Reverberation Chamber with an Asymmetrically Positioned Load

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Abstract – In this paper we present the influence of the load position, represented by a metallic cube, inside the uniform zone of a compact reverberation chamber when it is placed asymmetrically to the chamber's wall. The measurement standard test of the uniform zone requires an empty chamber. The measurements of the chamber statistical electrical field uniformity are made accordingly the IEC61004-21 standard. Unfortunately, no guarantee of the field uniformity is assured when the equipment is positioned inside.

Keywords – Reverberation chamber, position influence, electrical field uniformity, asymmetric position, quasi-isotropic probe.

1. INTRODUCTION

Reverberation chambers (RC) have been widely used in measurements of electromagnetic compatibility such as radiated-immunity testing of wireless devices [1, 2]. This measurement environment provides a statistically isotropic, randomly polarized, uniform field across a large proportion of the chamber volume caused by a stirrer revolution [3].

The chamber is an electrically large, high-quality resonant cavity, whose boundary conditions are varied by means of a rotating conductive tuner or stirrer in order to obtain a statistical uniform field. Inside the chamber the electromagnetic field at any point is the vector sum of all direct and reflected waves arriving in this point, where each one has different phase and magnitude due to various reflections. By a judicious choice of the stirrer shape and its number of revolving the path lengths and the number of reflections of the waves will change to produce, into a volume of the chamber, a total perturbed field with known statistical distribution. A RC test is quite realistic because the equipment's operational environment is often similar to the resonant cavity of the chamber; for example in a train, car, airplane, elevator, auditorium or shielded room.

Measurements of the statistical uniformity of the field [4, 5] and the influence of metallic loads within the chamber have been presented in [6]. However, that work is limited to investigate the load influence that is positioned parallel (or symmetric) to the chamber's wall. Possible changes on the field uniformity in the presence of an asymmetric load could not be verified.

In this paper, we present a calibration setup for measuring the statistical field uniformity of a compact reverberation chamber based on IEC 610004-21 standard. The influence of a metallic cube (i.e., an equipment) can be achieved by putting it inside a RC uniform volume and break its parallelism with the chamber's wall. It gives us more acquaintance about the field uniformity maintenance in the presence of a load.

The load asymmetry, represented by its asymmetrical position, can generate a non uniform field or mask the field uniformity when the points of measurements are only the Uniform Field Volume (UFV) edges.

The reverberation chamber characteristics used in this work is discussed in section II, the calibration setup and the load influence in section III, and section IV presents the preliminary conclusions.

2. THE COMPACT REVERBERATION CHAMBER

The used reverberation chamber [5] has the following physical dimensions:

Width: b=85cm;
Length: d=90 cm;
High: a=80 cm.

This chamber has been constructed to have a Lowest Usable Frequency (LUF) of 800 MHz and a Uniform Field Volume (UFV) with boundary at $\lambda/2$ (λ is the wavelength of the LUF) of any metallic element (wall or stirrer). Considering that the optimized stirrer is positioned at 5 cm from one of the chamber wall, the final UFV dimensions are:

Width: 47.5cm;
Length: 47.5 cm;
High: 42.5 cm.

To verify the LUF and the number of supported modes inside a RC we can use the same formulation used for Rectangular Resonant Cavity (RRC). The (1) and (2) have been used for the dominant mode TE_{011}, where the index *m*,

n and p are used to identify any TE_{mnp} and a, b and d are the high, width and length cavity dimensions, respectively.

$$f_{ressonance} = 3\frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2} \quad (1)$$

$$N_s(f) = \frac{8\pi}{3} abd\left(\frac{f}{c_0}\right)^2 - (a+b+d)\frac{f}{c_0} + \frac{1}{2} \quad (2)$$

It has been found that LUF is 728.28 MHz and 91 possible modes, confirming that the RRC can be used as a Reverberation Chamber.

The chamber and the stirrer have been made of aluminum due its good electromagnetic properties and relative low cost. Fig. 1 shows a representation of the stirrer and in Fig. 2 we can see a photo of the compact reverberation chamber built.

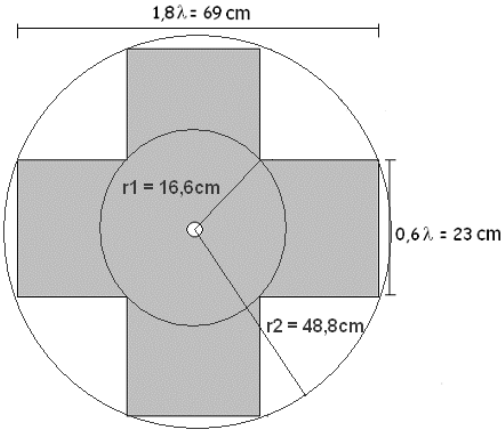

Fig. 1. Metallic stirrer's shape and dimensions in cm [5].

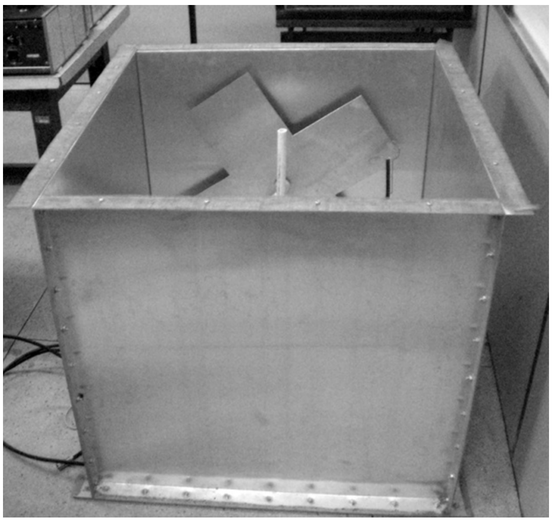

Fig. 2. The Compact Reverberation Chamber (RC) built.

3. CALIBRATION SETUP AND LOAD POSITION

The statistical measurements of the field uniformity have been made accordingly to the IEC610004-21 standard. The procedure consists to verify the global standard deviation of the maximum electrical field intensity at the Uniform Field Volume (UFV) by measuring the field at the edges of UFV. The standard stipulates an acceptable tolerance to this deviation of ± 3dB [7].

3.1 Measurement with empty cavity

For measurements with empty cavity the only elements inside the RC are the stirrer, a probe and the transmitter antenna. The transmitter antenna has been fixed in one of the RC edge (cavity corners) and has been connected to a signal generator at 800 MHz. The antenna placement was chosen to obtain the best field uniformity. The receiving antenna's (or probe) position used to map the field distribution has been moved into the eight edges of the UFV. The field measurement at 800 MHz was made with a spectrum analyzer, R&S model FSH3.

To evaluate the standard deviation in decibels units the equation (3) is used:

$$\sigma_{i(dB)} = 20\log\left(\frac{\sigma_i + \left\langle E_i^{\max}\right\rangle}{\left\langle E_i^{\max}\right\rangle}\right), i = x,y,z \quad (3)$$

where σ_i is the numerical standard deviation of the eight field intensity maximum values at the vertices and $\left\langle E_i^{\max}\right\rangle$ is the mean of these maximum values.

As a result, using (3), the standard deviation obtained for the empty UFV has been of 1.55 dB that is an acceptable value compared to the recommended tolerance of 3 dB.

The champ uniformity can also be influenced by the stirrer 2-D shape, then the same stirrer was slightly changed for having a 3-D geometry, however the best result was obtained with the original stirrer configuration.

3.2 Influence measurement of a load in the RC

After verifying the UFV field uniformity without the load, a metallic cube, to represent any circuit or equipment, with 8 cm of side (512 cm^3) has been used as load in the UFV.

First, the cube has been positioned at the UFV center with its sides (cube faces) parallel to the chamber walls. The measured resulted of 4.18 dB standard deviation, which is unacceptable to be considered as uniform field.

With this result one can conclude that with a little perturbation, one tenth of UFV dimensions and symmetrically positioned, the field uniformity is destroyed.

Now, the same cube is rotated and translated of same degrees from the reference plane (RC axis). With this new position, still remaining at the UFV center, the cube sides (faces) are in an asymmetrical position with the chamber walls (reference). The standard deviation result obtained was 2.10 dB. Fig. 3 shows a photo of the chamber with the load in an asymmetrical position.

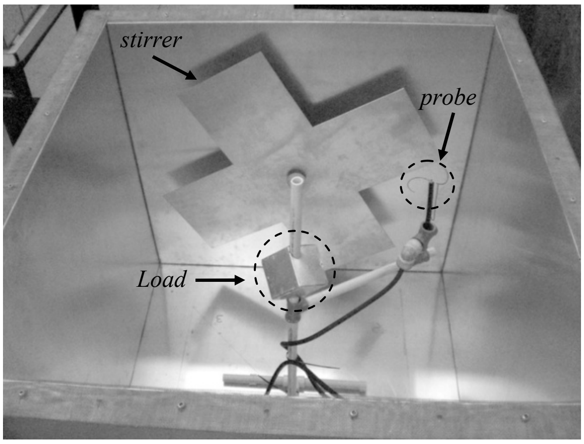

Fig. 3. Load within the chamber in an asymmetrical position.

Table 1 presents the comparison of the standard deviation results between the three studied cases: without load, symmetric load and asymmetric load.

TABLE 1. LOAD POSITION INFLUENCE - MEASUREMENTS

Load Presence/Position	Global Standard Deviation (dB)
Without Load	1.55
Load in symmetrical position	4.18
Load in asymmetrical position	2.10

It seems clear that the introduction of a perturbation (metallic object), even little, in the middle of UFV can produce a degeneration of the field uniformity. By the way, the load presence, in an asymmetrical position, changes the global standard deviation. It is probably due to the fact that the metallic cube generates more reflections breaking the generation of standard waves between the chamber's wall and the load.

The standard IEC61004-21 does not establish any suggestion to verify the field uniformity in a presence of a load. The load geometry has a great influence to the field distribution, since the field uniformity has changed from an unacceptable value (above 3dB) for an acceptable one (under 3dB) only by changing the load position.

4. SIMULATIONS

To compare with the measurements results, numerical simulations based on Finite Differences in Time Domain (FDTD) have been done using an open source software [9].

Table 2 summarizes the numerical results from simulations and Fig. 4 presents the software environment with the chamber and the load inside it.

TABLE 2. LOAD POSITION INFLUENCE - SIMULATION

Load Presence/Position	Global Standard Deviation (dB)
Without Load	1.98
Load in symmetrical position	4.67
Load in asymmetrical position	2.44

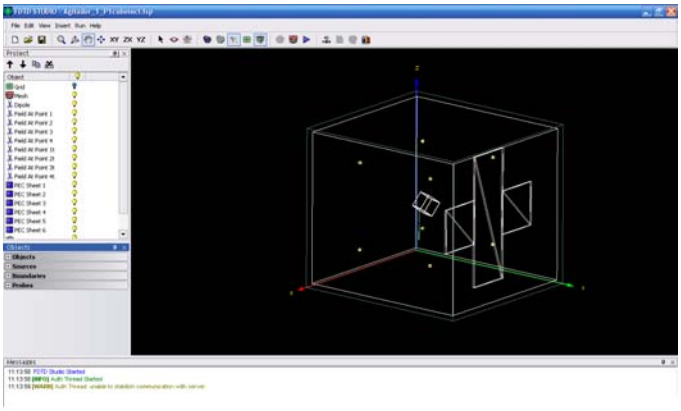

Fig. 4. Software environment with the compact chamber and charge.

Observing the numerical results, one can conclude that the load indeed has an important influence in the electromagnetic champ homogeneity. The differences between the results were achieved because cables and the probe support inside the chamber were not modeled for simulation.

5. CONCLUSIONS AND FUTURE WORK

In this paper the statistical field uniformity of a compact reverberation chamber has been measured based on IEC61004-21 standard in three different ways. The first one has been the field measurement without load; the second with a load (metallic cube) in a symmetrical position referring to the chamber walls; and the last one with the load in an asymmetrical position.

The results from these measurements then from simulation have been mainly proved that we could obtain, with the standard procedure, the field uniformity by only changing the load position. It seems important to revise the standard to guarantee the field uniformity during the immunity test in a reverberation chamber.

Another measurements are been done with a different 2-D shape stirrer to investigate the field uniformity inside the chamber. Fig. 5 shows a representation of the new stirrer.

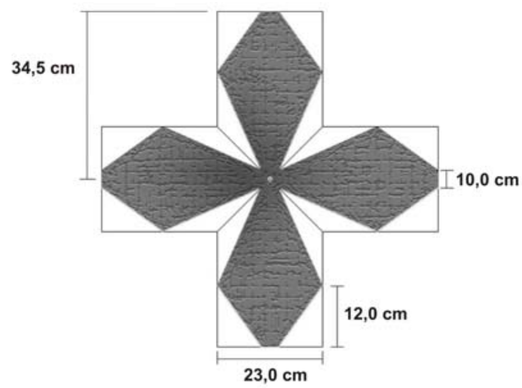

Fig. 5. New stirrer's shape and dimensions in cm [8].

At this time, with the UFV defined and calibrated with the first stirrer, measurements with real electronic equipments can be done to test their electromagnetic compatibility conformance and load position influence can also be studied with the new stirrer.

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