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The Working Volume Position on a Non-Canonical Reverberation Chamber

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Abstract — This paper presents a procedure for evaluating the performance of reverberation chambers by applying statistical and optimization techniques. The chambers configurations evaluation is based on the trends of geometrical and physical constraints, like the ones related to the internal E-field distribution recommended by standards. The importance of the present work is related to the development of a non-canonical reverberation chamber configuration, whose excitation is carried out by transmission lines, instead of antennas plus paddles and shows the advantages of using free-placed working volumes instead centre-fixed ones.

I. REVERBERATION CHAMBER

A reverberation chamber is a shielded room often used to perform electromagnetic immunity tests [1]. Although a set of EMC measurement procedures are recommended for a frequency range from 80 MHz up to 1 GHz, other procedures are required for a lower frequency operation. In this work, the reverberation chamber excitation is carried out through wires. It should be mentioned that, as wires support TEM fields, this approach allows to excite, besides the TE and TM common modes, the TEM mode within the chamber [2]-[3]. This widens the generated frequency range regarding the resulting LUF. Fig. 1 shows one of the proposed chamber configurations (5.20 x 4.6 x 2.70 m), with three wires placed along the x, y and z-axis [2].

The main objective of the proposed methodology is to evaluate the compromise between the objectives of Working Volume (WV) maximization and E-field maximization by modifying the configuration of the chamber. In [4], the method feasibility and the correlation between parallelepiped results and ellipsoid volume were verified. Here, we search to study the asymmetry of the chamber excitation, the WV can result as not being placed at the centre of the chamber. Different wire configurations are compared by Pareto-front technique.

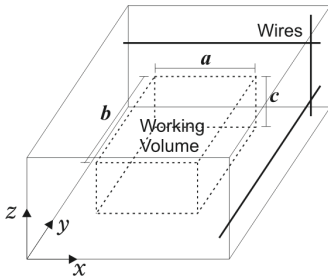


Fig. 1. Sketch of the three-wire reverberation chamber configuration

II. ELECTROMAGNETIC AND STATISTICAL ANALYSIS

In order to evaluate the chamber performance, the resulting internal field homogeneity is taken into account. The field within a Mode Stirred Chamber (MSC) is considered uniform if the standard deviation of the E-Field

samples satisfies the following conditions: 4 dB in the range from 80 MHz until 100 MHz [1]. It should be mentioned that values below 80 MHz are not considered in this regulation. In this work it was assumed the maximum standard deviation value 4 dB to have a feasible WV.

For this purpose, the standard deviation values are calculated based on the individual and combined arithmetic per-axis means, as given by:

$$\bar{E}_k = \frac{1}{N} \sum_{j=1}^N E_{k,j} \quad (1)$$

$$\bar{E}_{x,y,z} = \frac{1}{3N} \sum_{k=\{x,y,z\}} \sum_{i=1}^N E_{k,i} \quad (2)$$

where \bar{E}_k is the arithmetic mean of the k -component of the maximum electric field E_k , $\bar{E}_{x,y,z}$ the arithmetic mean of the electric field considering the three single components, and N the number of the obtained samples. The magnitude of the k -component of the electric field is defined as the square root of the sum of the squares of its real and imaginary parts:

$$|E_k| = \sqrt{(\text{Re}\{E_k\})^2 + (\text{Im}\{E_k\})^2} \quad (3)$$

Based on the presented equations, the individual σ_k and combined $\sigma_{x,y,z}$ standard deviation values in decibel notation are [1]:

$$\hat{\sigma}_k = 20 \log_{10} \frac{\sigma_k + \bar{E}_k}{\bar{E}_k} \quad (4)$$

$$\hat{\sigma}_{x,y,z} = 20 \log_{10} \frac{\sigma_{x,y,z} + \bar{E}_{x,y,z}}{\bar{E}_{x,y,z}} \quad (5)$$

The WV is the recommended test volume where the equipment will be placed. It is considered by standards as a parallelepiped in which the electric field homogeneity should satisfy pre-defined limits calculated by (4) and (5), for frequencies below 80 MHz.

The computation of E-field was performed by applying commercial software based on Finite Integration Technique (FIT) [2], [5]. The chamber walls and wires are set to perfect conductor and the space inside the chamber is set to vacuum, with 1W power injection at each wire. The field calculation was performed only for 10MHz frequency that is approximately four times lower than the first resonance value (43.5 MHz) [6].

III. RESULTS

Multiobjective Genetic Algorithm [4] has been used to understand this problem. Multiobjective optimization allows us to know the compromise between the searched objectives (max E-field and max WV). When these objectives-functions are antagonist – for every increasing of E-field value we have a decreasing of WV – we do not

have only one solution, but a solution group that expresses this compromise. This group is called Pareto-front.

Moreover, instead of analyzing a parallelepiped, its inscribed ellipsoid is considered, since it allows a straightforward process to evaluate if a point is inside or outside it [4]. Then the problem of evaluation of the maximum WV is turned into the maximization of the volume of an ellipsoid that could be defined until six variables: three radii and three parameters associated to the ellipsoid translation from the chamber's center.

A. Working Volume optimization considering ellipsoid centre fixed at chamber centre

In order to verify the results when the center of WV is the chamber center, the optimization variables are set as: radii $\{R_x=0\sim 5.2, R_y=0.1\sim 4.5, R_z=0.3\sim 2.3\}$. The ellipsoid translation is fixed at $\{D_x=0, D_y=0, D_z=0\}$ and the excitation wires are fixed at positions $\{Y_1=2.5m, Z_1=2.4m; X_2=0.3m, Z_2=2.3m; X_3=0.3m, Y_3=4.2m\}$. For these conditions the Pareto solutions are plotted at Fig. 2.

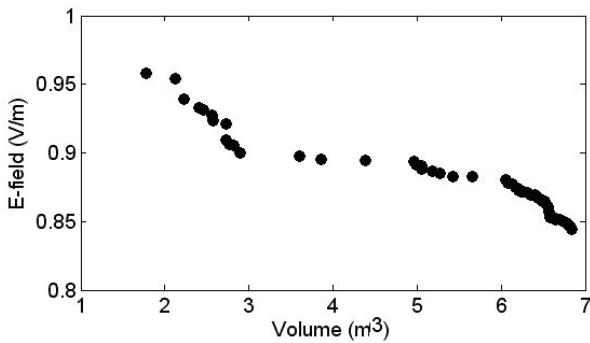


Fig. 2. The Pareto Set for ellipsoid centre at $[x=2.6; y=2.2; z=1.35]$

B. Working Volume optimization without fixed position for ellipsoid centre

In order to verify the results when the WV center is free to vary into a predefined range, the optimization variables are set as: radii $\{R_x=0\sim 5.2m, R_y=0.1\sim 4.5m, R_z=0.3\sim 2.3m\}$ and ellipsoid translation $\{D_x=-2.6\sim 2.6m, D_y=-2.3\sim 2.3m, D_z=-1.35\sim 1.35m\}$. The arrangement of excitation wires are fixed at same positions $\{Y_1=2.5m, Z_1=2.4m; X_2=0.3m, Z_2=2.3m; X_3=0.3m, Y_3=4.2m\}$ as III.1. For these conditions the results are plotted at Fig. 3.

The decision-making could be done based on an E-field equal to 1.00 V/m [the closest point is 1.007V/m and $3.11m^3$]. This result can be refined searching for better conditions around this goal point. Then the new limits for search are radii $\{R_x=1,35\sim 1,75, R_y=0,95\sim 1,25, R_z=0,20\sim 0,60\}$ and ellipsoid translation $\{D_x=1,75\sim 2,15, D_y=1,95\sim 2,35, D_z=1,25\sim 1,65\}$. This procedure was performed to search the best solution near the objective (E-field = 1V/m) and to verify the chosen solution sensibility.

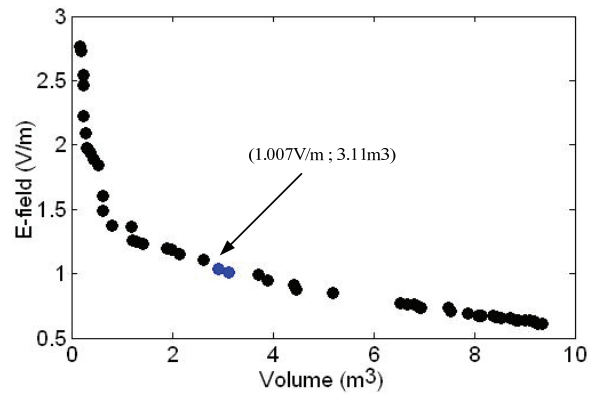


Fig. 3. The new Pareto Set with the ellipsoid center as an optimization variable

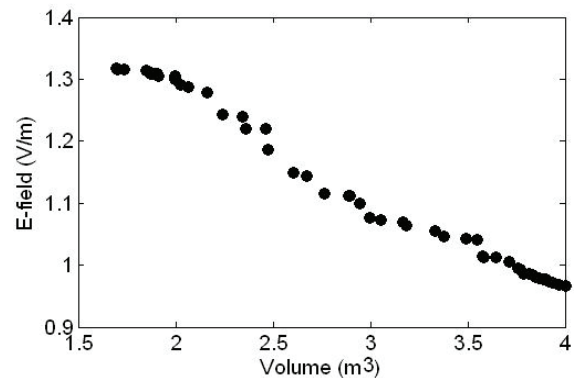


Fig. 4. Pareto Set with free ellipsoid center around the decision solution.

Comparing the results showed at Fig. 2 and Fig. 4, the "free ellipsoid center" gives a better compromise between max WV and max E-field. The solutions show that E-field value that fulfills the uniformity conditions does not reach 1V/m at Fig. 2. This E-field limitation is disadvantageous because one needs more power injection to reach the desired value.

IV. CONCLUSIONS

The non-canonical reverberation chamber shows a particular property: the working volume, i.e., a space inside the chamber where the electric field uniformity is high is not centered in the chamber.

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