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# Conductor Positions Optimization of a Transmission Line Excitation Chamber

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**Abstract** — This paper presents a multi-objective optimization approach based on numerical, statistical and fitness evaluation concerning the conductor positions in a Transmission Line Excitation Chamber (TLEC). The field profile and the related indexes of merit, like the statistical ones, regarding the working volumes are used to evaluate the chamber configuration performance. The compromise between working volume and E-field standard deviation are show through the Pareto's Front.

## I. INTRODUCTION

In previous works the Transmission Line Excitation Chamber (TLEC) performance evaluations have been carried out using different approaches. These were presented in[1] and [2] in which FIT and TLM, and also an optimization tool were used to evaluate the field uniformity within the working volume on a predefined TLEC configuration. The TLEC configuration here presented is based on three-conductor phase-shifting excitation configuration and proposed as an alternative when low frequencies are taken into consideration[3]. Fig.1 shows a sketch of a three-wire reverberation chamber configuration. Thus, the optimization problem aims to maximize the working volume and the E-field, which is restricted to uniformity constraints.

In this work, the main focus is to find the better transmission lines configurations, i.e., wire positions, which present the best TLEC performance related to the aforementioned indexes. A good TLEC performance is associated to a high working volume and E-fields average values. To obtain the wire configuration and the corresponding TLEC performance, a numerical approach has been implemented by applying multi-objective optimization. Deterministic and statistical approaches are applied in the analysis.

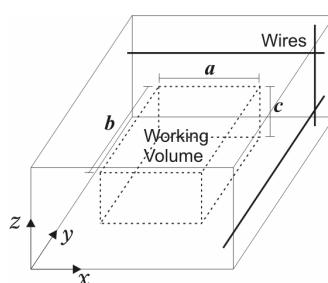


Fig. 1. Sketch of the three-wire reverberation chamber configuration

## II. OPTIMIZATION PROCEDURE

A working volume is assumed to be a region inside the reverberation chamber (Fig. 1) were the homogeneity of the electric field attains a prescribed level. EMC tests could be performed only with this minimum homogeneity level, and the mean value within the working volume should be as high as possible considering low input power.

In this work, the main interest is to understand how the reverberation chamber works when associated to a set of transmission lines positions and its related working volumes. It should be mentioned that when the working volume increases the mean electric field decreases. This means that a multi-objective optimization algorithm should be employed (two or more antagonistic goals).

Here, the optimization problem has twelve optimization variables: three pairs coordinates (TL positions), two equatorial radii, polar radius and three parameters associated to the ellipsoid translation (shift) from the chamber's centre (these six last variables define the working volume). In this set, inside some working volume the electric field is high, whereas the volume is low.

There are other working volumes, which belong to this set, but have low electric field and high volume. Inside the working volumes the field homogeneity is constrained by pre-defined values. When the chamber characterization is performed, the engineer could make a choice to obtain the most suitable set of TL to design the TLEC.

In order to solve it, the optimization problem is assumed as an unconstrained optimization problem, where inequality constraint was treated as a penalty function.

### A. Modeling the chamber

The mean E-field ( $\bar{E}_x$ ), the Standard Deviation ( $\sigma_x$ ) and Standard Deviation in dB ( $\hat{\sigma}_x$ ) are calculated by (1), (2) and (3)

$$\bar{E}_x = \frac{1}{N} \sum_{k=1}^N E_{xk} \quad (1)$$

$$\sigma_x = \sqrt{\frac{1}{N-1} \sum_{k=1}^N (E_{xk} - \bar{E}_x)^2} \quad (2)$$

$$\hat{\sigma}_x = 20 \log_{10} \left( \frac{\bar{E}_x + \sigma_x}{\bar{E}_x} \right) \quad (3)$$

## 4. Electromagnetic Compatibility.

Similar equations could be obtained to the y-axis, z-axis and to the combined E-field [1], [2] and it is assumed a value equal to 4 dB as the standard deviation for defining the working volume at frequencies lower than 80 MHz.

### B. The Optimization Problem

The conductor position problem could be written as an optimization problem as follows:

$$\begin{cases} \text{Max Working Volume} \\ \text{Max } \bar{E}_{x,y,z} \end{cases} \quad (4)$$

S. t:  $\text{Max } (\hat{\sigma}_x, \hat{\sigma}_y, \hat{\sigma}_z, \hat{\sigma}_{x,y,z}) \leq 4\text{dB}$

In order to bounder the optimization parameters, Fig 2 illustrates and shows a cross-section of the chamber to be analyzed. First of all, it is assumed that each wire is parallel to one of the three axis of the chamber as Fig 1 shows. So, each wire could only be placed in the grey region, because it could not be close to the wall, due to the standards. On the other hand, if we put it on the center of the chamber (the forbidden area) the associated working volume will be small. Thus the TLs can only be moved inside a space “close” to the walls in order to avoid solutions that are impossible for practical utilization.

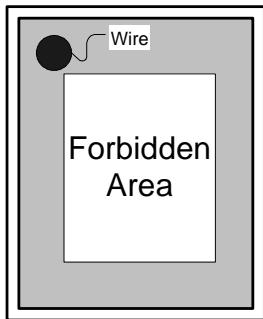


Fig.2 Chamber Cross Section: the position wire

Multi-objective optimization (4) seeks to optimize the components of a vector-valued cost function. Unlike single objective optimization, the solution to this problem is not a single point, but a family of efficient points called Pareto-front. Each point on this surface is optimal in the sense that no improvement can be achieved in a cost vector component that does not lead to degradation in at least one of the remaining components. Each element in the efficient set constitutes a non-dominated (non-inferior or non-superior) solution to the multi-objective problem. With this set of solutions it is possible to understand the dependence between each objective.

The Pareto-set of this multi-objective problem was obtained by using the Multi-objective Genetic Algorithm (MGA)[4]. The MGA is derived from the Genetic Algorithm, which is a stochastic procedure based on the concepts of natural selection in genetics.

### C. Coupling the Field Computation Software and the Optimization Environment

The adopted procedure has six fundamental steps:

- Random positions for TL are generated, as well the working volumes and ellipsoid radius;

- TL positions are charged to the field computation software, that uses FIT [5];
- The field computation inside the reverberation chamber is performed with FIT [5];
- The values of the E-field are exported considering a regular grid;
- The working volume is calculated. For the determination of a particular working volume, Eq. (1) should be solved, and
- The indexes of merit are applied to decide which one are the better TL configurations.

The third and fourth steps are computed by applying the FIT [5]. At the end of step iv a file is exported to our optimization environment.

The EMC standards adopt a parallelepiped as a working volume[7]. In this work we have adopted another solid to characterize the volume: an ellipsoid[2].

## III. RESULTS

Fig. 2 shows some results which allow us to know the compromise among the searched objectives (max E-field and max working volume), the constraints and the conductor positions.

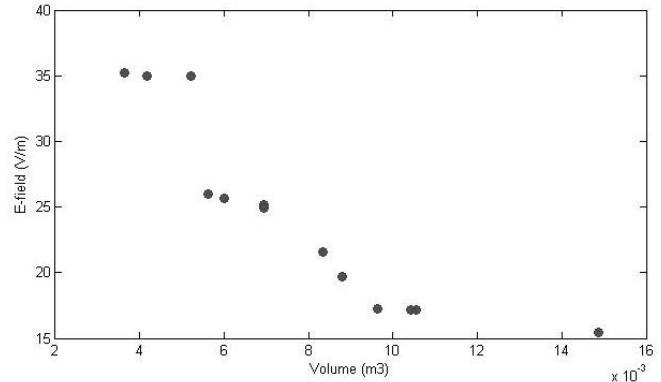


Fig. 2. Compromise between working volume and E-field.

By inspection of Fig. 2 the maximal working volume, taking into account a defined E-field level, can be chosen. For instance, it yields approximately  $15 \times 10^{-3} \text{ m}^3$  for an E-field level of  $15 \text{ V/m}$  considering the total chamber volume equal to  $0,432 \text{ m}^3$ .

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