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Design and Experimental Validation of a Stochastic Diffractor for a Multiple Monopole Source Stirring Reverberation Chamber

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Abstract

This paper deals with the use of stochastic diffractors in a reverberation chamber to improve the stirring of the electromagnetic field. In particular, the stirring technique is achieved by varying the feeding of an array of monopole antennas mounted on the chamber's walls.

1 Introduction

Reverberation chambers (RCs) are metallic enclosures where the electromagnetic field is stirred using many techniques [1] in order to achieve in a sub volume, called working volume, a statistically isotropic, random polarized and uniform electromagnetic field. These environments are ruled by standard [2] to be used as a test site for electromagnetic tests for emission and immunity.

RCs are lower limited in frequency by a lowest usable frequency (LUF), that, according to the standard, is related to the electric field uniformity and therefore to its statistics. A possible way to enhance the statistics of the electromagnetic field in a RC is the insertion of chaotic diffractors close to the metallic walls [3] – [6].

The aim of this paper is to investigate the effect of these diffractors in a RC where the multiple monopole source stirring technique (MMSS) is implemented. This technique [7] consists in an array of monopole antennas placed onto the RC's walls; one antenna is fed at a time, and the stirring action in achieved by varying the transmitting antenna over all the possible positions. The effectiveness of this stirring technique was experimentally validated [8] [9] and applied in EMC immunity [10] [11] and emission [12] scenarios.

The paper is organized as following: Section 2 describes the scenario; Section 3 reports the numerical simulation and the statistical analysis based on eigenmode modal spacing, aimed to design the geometry of the scatterers; Section 4 describes experimental setup and results; finally Section 5 reports conclusions and future development of this research activity.

2 Scenario

The scenario consists in a rectangular cavity, dimensions 800 mm × 900 mm × 1000 mm made by galvanized steel, where 20 holes are made in each face to insert a monopole antenna so achieving the MMSS action. From these dimension the first eigenmode occurs at 225 MHz, therefore the analysis was performed from 675 MHz to 6 GHz.

Figure 1. The Reverberation Chamber

3 Scatterer design

In order to design the stochastic scatterer, a commercial numerical tool was used [13]. The scatterer's performance is studied through the statistical analysis of eigenmodes' spacing of the RC with the aid of CST commercial software. For our purpose, the most efficient, among the CST solver, is the Eigenmode one. In these simulations, the monopoles on the RC's walls and the relative holes are not considered because it is assumed that their presence does not affect significantly the eigenmode frequencies of the structure. This assumption was already adopted [7] and validated [8] for the MMSS technique.

Four scenarios were simulated: a) no scatter inside the RC; b) 1 hemisphere having radius equal to 150 mm; c) 2 hemispheres having radius equal to 150 mm; d) 1 hemisphere having radius equal to 400 mm.

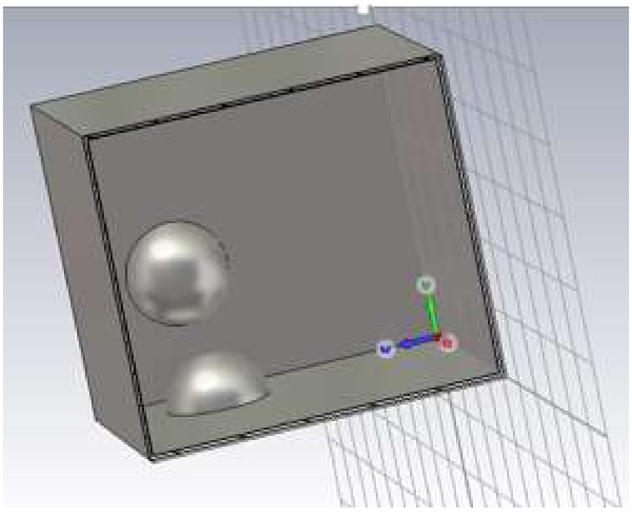

Figure 2. Nemerical model of the RC and the scatters

Figure 3 reports the cumulative distribution function (CDF) of the normalized eigenmode modal spacing (s) for the above scenarios, where [14] $s_n = \frac{\Delta f_n}{\langle f_n \rangle}$, being f_n the eigenfrequencies that are assumed to be ordered in the ascending order ($f_n \geq f_{n-1}$) and the angular brackets $\langle \dots \rangle$ denote ensemble averaging.

The curves are compared to the Wigner distribution [5] that represents a chaotic behavior of the RC. It can be noticed that there is no evident advantage to use the hemisphere with radius r = 400 mm respect to the smaller one, so r = 150 mm is adopted for the experimental validation.

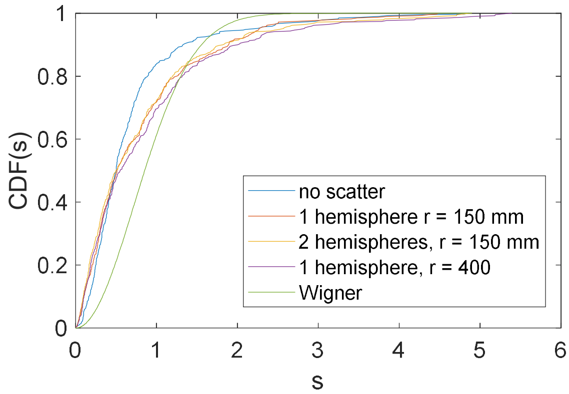

Figure 3. Cumulative distribution functions for the 4 scenarios compared to the Wigner distribution

For better comparison of the effect of one or two hemisphere, the probability density functions (PDF) of *s* were compared with three theoretical functions: the Poisson (1), the Wigner (2) and the Brody [15] [16] (3) PDFs.

$$P_{poisson}(s) = e^{-s} \qquad (1)$$

$$P_{wigner}(s) = \frac{\pi}{2} s \, e^{-\frac{\pi}{4} s^2} \qquad (2)$$

$$P_{brody}(s) = C_1 s^{\beta} e^{-C_2 s^{\beta+1}} \qquad (3)$$

where C_1 and C_2 are two parameters (4) depending by β

$$C_1 = (\beta+1) C_2, \quad C_2 = \left[\Gamma\left(\frac{\beta+2}{\beta+1}\right)\right]^{\beta+1} \qquad (4)$$

and Γ is the gamma function.

These functions have been chosen because [17], the normalized eigenfrequency spacing assumes different behavior depending on the chaotic level of the RC chamber. In particular, it resemble a Poisson distribution in absence of stochastic diffractors or a Wigner distribution in case of a purely chaotic RC. In the other cases, it assumes a Brody distribution with the parameter β that indicates the level of chaotic behavior. For β = 0 Brody distribution becomes a Poisson, whereas for β = 1 it becomes a Wigner.

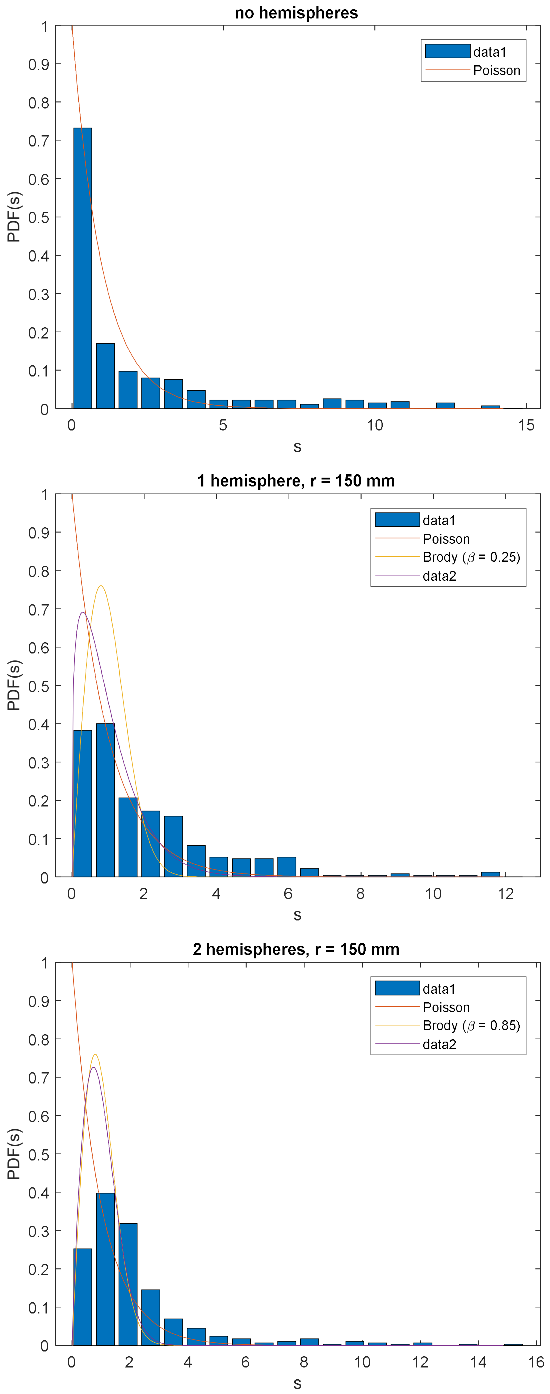

Figure 4. Probability distribution functions of the normalized eigenfrequency spacing in case of a) no diffractor, b) 1 hemisphere (r = 150 mm), c) 2 hemispheres (r = 150 mm)

Fig. 4 shows that in absence of stochastic diffractors the PDF assumes a Poisson distribution, whereas in case of one hemisphere (r = 150 mm), PDF is fitted by a Brody distribution with β = 0.25 and in case of two hemispheres (r = 150 mm), PDF is fitted by a Brody distribution with higher value of β. It means that the chaos inside the RC increases progressively inserting one or two stochastic diffractors, even if the Wigner distribution is not reached.

4 Experimental Results

The statistical analysis based on the modal spacing predicted by numerical simulation suggested us to use hemisphere having radius equal to 150 mm. It has similar performance compared to the one with r=400mm, but occupies less space in the working volume.

The experimental setup consists in the RC described in Section 2; the transmitting monopole is fed by a vector network analyzer (VNA) with 0 dBm output power, and a broadband (double ridge horn) antenna is placed into the RC's working volume and connected to the other port of the VNA. 1601 frequency points are considered in the frequency range 675 – 6000 MHz.

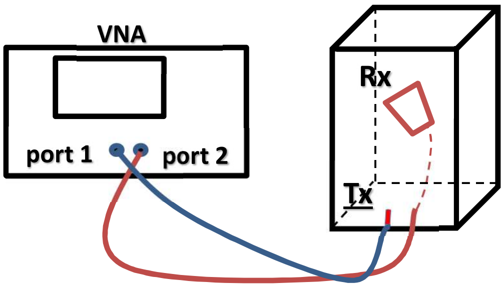

Figure 5. Experimental setup

S_{21} parameter was statistically analyzed and its CDF compared with the expected CHI2DOF adopting the Kolmogorov Smirnoff (KS) test as a goodness of fit (GOF) test.

Figure 6 compares the KS test failure events for three configurations: a) with two hemispherical diffractors; b) with one hemispherical diffractors; c) with no diffractors. Measurements confirm that the use of hemispherical diffractors enhances the performances of the chamber especially in the lower frequency range**.**

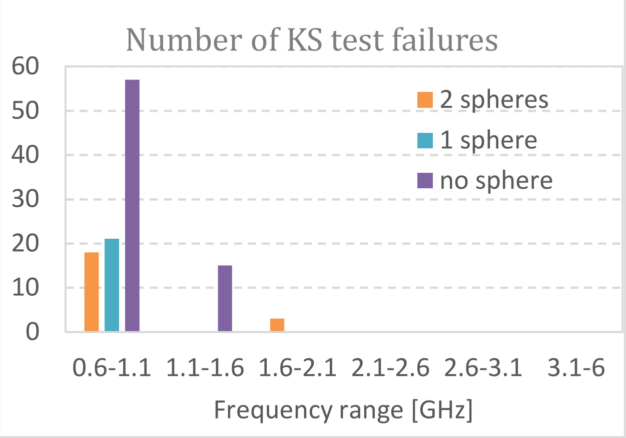

Figure 6. KS failure events

5 Conclusions

The use of stochastic diffractors to enhance the performance of a RC, where the MMSS technique is implemented, was investigated. Both numerical simulations and experimental measurements confirm that the statistics of the analyzed parameters of the RC is improved, even if the chaotic condition is not completely reached. Future works will extend the analysis to a wider set of indicators.

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