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Comparison of Different Loading Configurations and Numerical Models of Reverberation Chambers

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Abstract

Reverberation chambers are often loaded with lossy objects. In this paper we compare two numerical models of the chamber losses; a concentrated load and a uniform volume loss. The statistics of the coupling between two dipoles in many random positions over a frequency band is used to compare the two cases. It is shown that the two cases gives similar statistics.

1. Introduction

A reverberation chamber (RC) is a metal cavity used for electromagnetic measurements [1]–[3].

The RC has losses due to lossy objects and antennas placed in the cavity, as well as leakage and finite conductivity of the cavity walls [4]. The desired loss (loading) depends on the measurement application.

The electromagnetic fields in the cavity must be stirred in order to create a statistical field environment. The averaging of the stirred fields makes it possible to extract free-space parameters of antennas measured in the cavity [5], [6].

A numerical model of RCs can be a good tool when designing them. However, it can be a quite challenging numerical computation task, since the cavities are large in terms of wavelengths. Therefore techniques for reducing the computation time is of interest.

We have previously developed a simplified numerical model of the RC which is very fast [7]. The code is based on the method of moments (MoM) [8] and a rectangular cavity Green's function calculated with the Ewald method [9]. We refer to our code as G3DC (since it computes the Green's function of three-dimensional cavities).

Losses can be modelled as uniform loss in the cavity volume, without introducing any unknowns, which will save computation time. However, in a real RC, lossy objects are concentrated to small portions of the cavity volume.

The purpose of the present paper is to show that a uniform loss is a reasonable simplification that can be used when modelling RCs. Thereby losses can be included without increasing the computation time.

The present paper uses a full-wave commercial MoM code called WIPL-D [10] to compare the statistics of a cavity with a concentrated load and a cavity with uniform volume loss. The calculation of the case with uniform loss is also done with G3DC, to demonstrate the speed improvement.

2. Numerical Experiment

The RC we study in this paper is a rectangular metal cavity with the dimensions 1.8 m × 1.2 m × 1.75 m. The frequencies we study are from 820 MHz to 960 MHz with a step of 1 MHz, which gives 141 frequency points.

We place two dipoles in the cavity in 60 different random positions and orientations, and calculates the coupling between them (the scattering matrix). This is a simple way to stir the fields in the RC, that can be referred to as "perfect three-dimensional position stirring" for 60 positions. The positions and orientations of the dipoles, as well as the lossy sphere that are used in one of the calculated cases, are

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Table 1: Computation times for the computed cases on an Intel Pentium CPU with 3 GHz clock speed.

Simulation technique	Computation time
Concentrated load (WIPL-D)	180 hours
Homogeneous load (WIPL-D)	75 hours
Homogeneous load (G3DC)	0.085 hours

shown in Fig. 1. (Note that the subdivision of the sphere surface is for illustration only, and does not correspond to the divisions into basis functions by WIPL-D.)

The length and wire radius of the dipoles are of convenience changed with frequency, so that they are always perfectly matched for free-space (i.e., they are slightly less than half a wavelength long).

The dipoles are always placed at least a half wavelength away from each other, the cavity walls, and the lossy sphere. This is commonly done in reverberation chambers.

First, we calculate the S-parameters for the 60 positions when we have a lossy sphere placed in the cavity. The sphere has a radius of 25 cm and a conductivity of 0.1 S/m. (The real part of the permittivity is that of free-space.) This case is computed by WIPL-D and it is the most time consuming case to calculate since unknowns are needed on the surface of the sphere. Also, the rectangular cavity walls must be modelled with unknowns in WIPL-D.

Secondly, we take away the lossy sphere and instead introduce a uniform loss of 1.78×10^{-4} S/m in the whole volume of the cavity. In this way we reduce the number of unknowns WIPL-D must solve for. However, this is less realistic since in practice losses are concentrated to small portions of the cavity volume.

Finally, the second case is also computed by our software G3DC, which is much faster than WIPL-D since it uses a cavity Green's function, thereby avoiding unknowns at the cavity walls.

The dipoles have exactly the same 60 positions for all computed cases.

3. Results and Conclusion

The coupling between the dipoles (S_{21}) varies with position of the dipoles and frequency. The amplitude of S_{21} should follow the Rayleigh distribution. Fig. 2 and Fig. 3 plots the cumulative distribution functions (CDF) and the probability density functions (PDF) obtained with the different numerical models and theory. All cases are in agreement with the theoretical Rayleigh distribution. It is important to note that the homogeneous loss case gives equally good agreement with theory as the more realistic concentrated loss case. This suggests that we indeed can model a RC with homogeneous loss, and thereby reduce computation time significantly.

The power levels averaged over the 60 positions of the dipoles is plotted in Fig. 4 for the various calculated cases. Also, a theoretical curve [4] is shown. The curve for the concentrated load has a rather high mean level compared to theory. This is probably due to the relatively small number of unknowns on the surface of the sphere. Anyway, the mean level of the curves are not critical, since this often can be freely adjusted to reach the desired level. The important thing to note is that the curves are clearly correlated. This means that the peaks and dips of the transfer level (as a function of frequency) is due to intrinsic properties of the cavity, and how we load the cavity does not matter much.

Table 1 shows the rather big reduction in computation time that can be obtained by using uniform loss, and the enormous reduction in computation time obtained with G3DC that uses a cavity Green's function instead of unknowns at the cavity walls.

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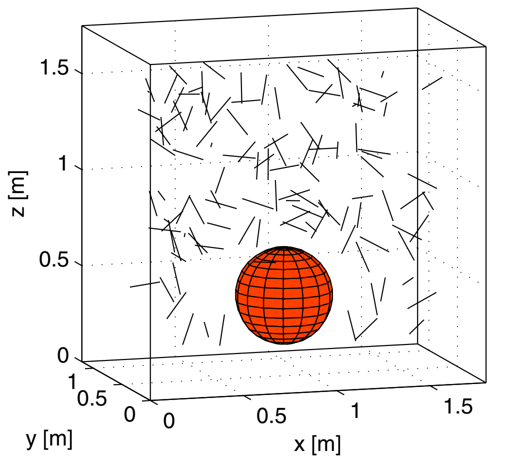

Figure 1: The figure shows the simulated rectangular cavity with the 60 different positions and orientations of the dipoles. The lossy sphere used in one of the simulated cases is also shown.

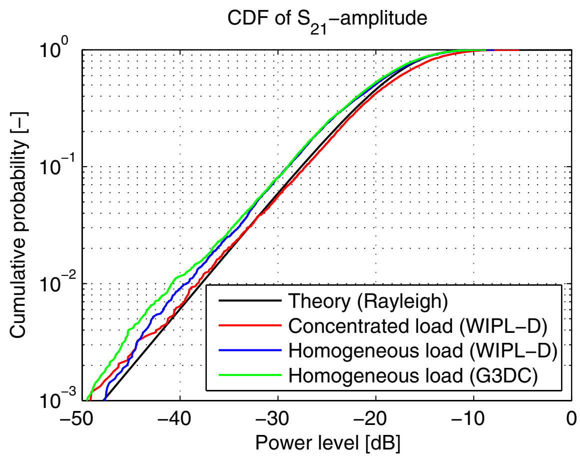

Figure 2: The figure shows the cumulative distribution functions (CDF) of the S_{21}-amplitudes for the various cases simulated, as well as the theoretical Rayleigh curve.

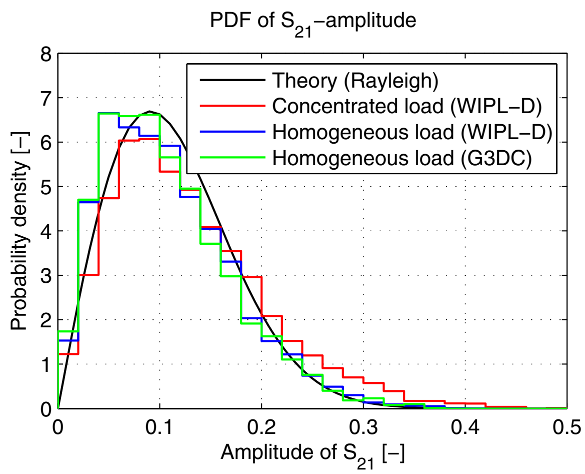

Figure 3: The figure shows the probability density functions (PDF) of the S_{21}-amplitudes for the various cases simulated, as well as the theoretical Rayleigh curve.

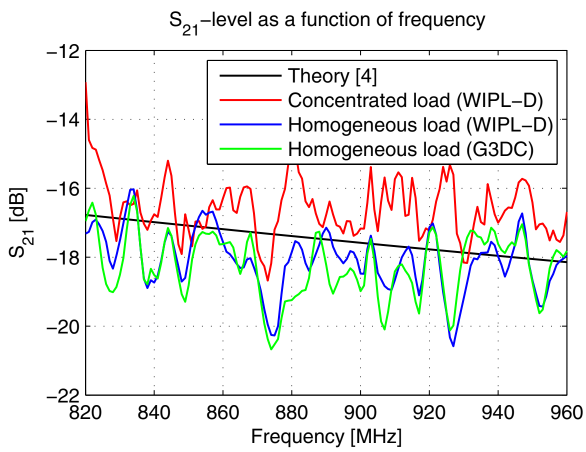

Figure 4: The figure shows the position stirred S_{21}-levels for the various cases simulated, as well as the theoretical level obtained from [4].