Efficient Modeling of a Small Reverberation Chamber Using FDTD Method

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1. Introduction

Reverberation chamber (RC) is a large cavity surrounded by metal walls which can be used to measure the performance of the antenna. Without the stirrer, the RC itself is only a resonator with high Q and it will create standing waves inside the chamber. Therefore one or more mode stirrers are required inside the chamber to eliminate these standing waves and to measure the antenna parameters using the RC. By rotating the mode stirrer, boundary conditions inside the RC will change which leads to the creation of different modes inside the chamber and eventually the channel inside the chamber will have Rayleigh distribution with zero mean and equal variance. Platform stirring can also be used to increase the statistics of the received power [1]. Recently, the finite difference time domain (FDTD) method was presented in simulating and modeling the RC [2]-[4].
In this paper, FDTD method is used to model the RC. Not only the rotation of the stirrer but also the platform stirring is modeled and simulated to check the validation of FDTD method. Rayleigh distribution for any of the electric field components will ensure the normal distribution of the electric field [5]. Received power samples of the receiving antenna for FDTD simulation were compared to both actual measurements and the CDF of Rayleigh distribution.

2. Geometry of the Chamber

Fig 1 shows the geometry of the overall chamber. The dimension of the chamber is 1850 * 1260 * 1445mm^3 for x, y and z direction. The resonant frequency of this chamber at the dominant mode is about 132MHz. According to 61000-4-21 Standard [6], the LUF of the chamber is slightly 3 times higher than the dominant mode's resonant frequency meaning that the LUF of this chamber is about 400MHz.
Z-shaped stirrer is used for this chamber. The dimension of the stirrer's plates which are parallel to the x-y plane is 450$\times$450mm^2. The dimension of the plates which are inserted diagonally between the parallel plates is 450$\times$640 mm^2, and the overall height of the stirrer is 1270 mm.
Diameter of the platform which is used for platform stirring is 500mm. This platform which will help to increase the uniformity of the receiving power will rotate simultaneously as the stirrer rotates.
Dipole antenna operating at 750MHz which will be used as Rx antenna is placed 20cm away from the center of the platform. As a result, Rx antenna will change its position by making a circle of 20cm radius.

3. Simulation Procedures for FDTD

We developed a software, so called IM-FDTD based on CAD library and the FDTD code to simulate the FDTD and to make the Yee grid of RC including the stirrer, platform and dipole antenna for Tx and Rx. 750MHz sine wave was excited through E_z component at the center cell of the transmitting antenna. Fig 2 shows the design and the generation of Yee grid for stirrer using IM-FDTD. Stirrers with two different positions are overlapped to show the different stirrer geometry

that will be used for FDTD simulation. The size of the spatial grids for x, y and z directions were uniformly set to 2cm which is smaller than $\lambda/10$.
In order to realize the rotation of the stirrer for FDTD calculation, one full rotation of the stirrer was set to consist of 72 discrete positions where each discrete positions of the stirrer rotates 5 degree relative to the rotation axis of the stirrer. The Yee cells of the overall RC was given by $92\times63\times72$, and the temporal step for the FDTD was chosen as the greatest number that guarantees the numerical stability.
FDTD simulation was done for 4 different cases. First of all, three different cases were done by aligning the receiving antenna to three different directions (x, y and z direction) without using the platform stirring.
The last case was done by using the platform stirring and the antenna was aligned to z direction. In other words, the position of the antenna was changing as the stirrer was rotating. The antenna on the platform was rotating by making a circle with radius of 20cm on the x-y plane. Fig 3 shows the design of the platform and the trajectory of the moving antenna on the x-y plane which will be included in the FDTD calculation.

3. Results and Discussion

Fig 4 shows the FDTD simulation results compared to the actual power samples measured inside the chamber using a network analyzer. CDF of a Rayleigh distribution based on measured values are drawn as a criterion. For figures from 4(a) to 4(d), the curves based on FDTD simulation are shifted slightly towards right compared to the Rayleigh CDF curve due to the loss which exists in actual chamber. This will cause some difference to the results as a certain amount of offset.
By looking at figures from 4(a) to 4(c), it can be seen that the field distribution for three orthogonal directions are not exactly normal distribution indicating that the frequency we used needs additional stirring to achieve uniform distribution of power samples.
Especially, the power samples for case 4(c) are tended to have higher values compared to 4(a) or 4(b) cases. This can be explained by the fact that since both Tx and Rx antennas are aligned to z direction, they act as coplanar antennas. However, when platform stirring is introduced, the received power samples tend to be normal distributed since the rotating platform will help to receive more random signals and eventually becomes Rayleigh distribution for both measured and FDTD simulated cases.

4. Conclusion

This paper presents a method of modeling the rotation of a stirrer and the platform stirring using FDTD method. Frequency used for the source signal was 750MHz. Four different simulations were done in different conditions to show the validation of FDTD method. Three cases were done by aligning the antenna in three different directions and one last case was done by introducing the platform stirring. From Fig 4, it can be shown that FDTD method is valid to model the platform stirring and shows the advantage of this stirring method.

Acknowledgments

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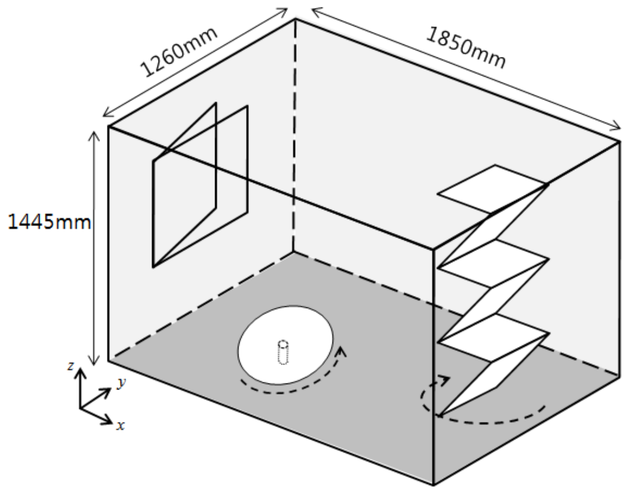


Figure 1: Overall Chamber Geometry

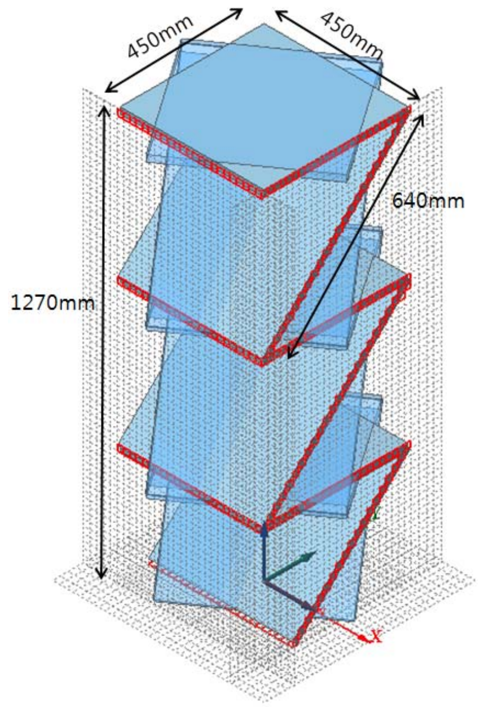


Figure 2: Stirrer Design

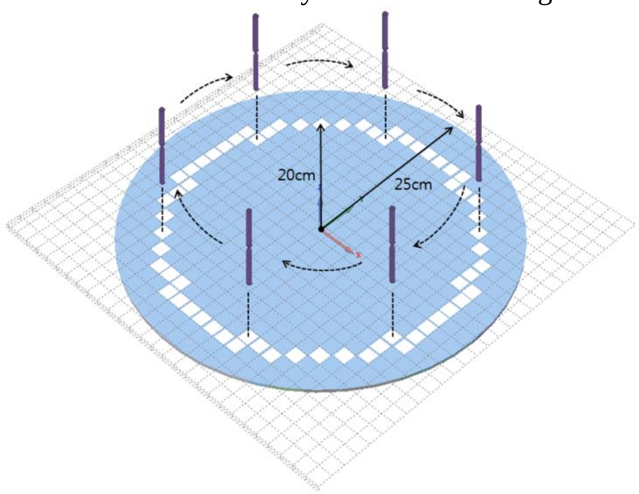
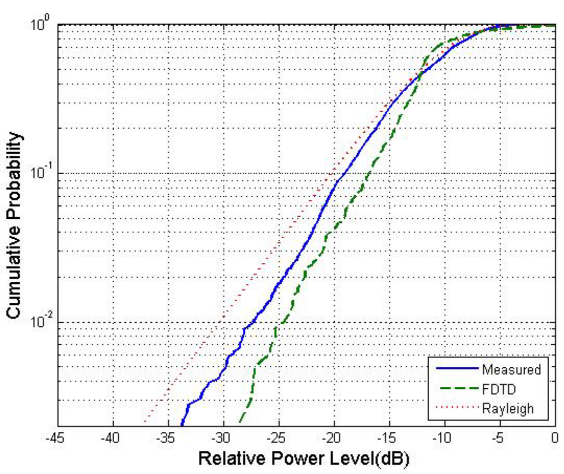
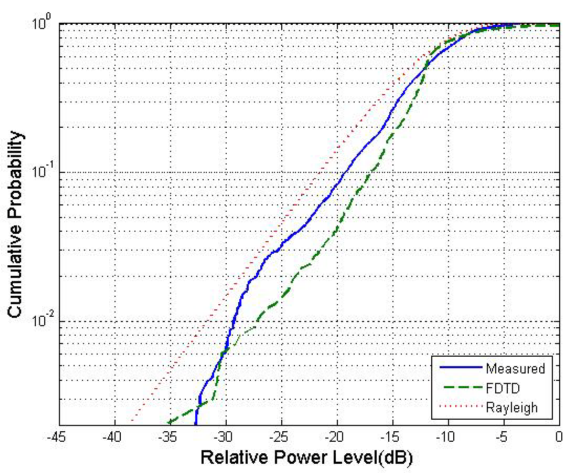


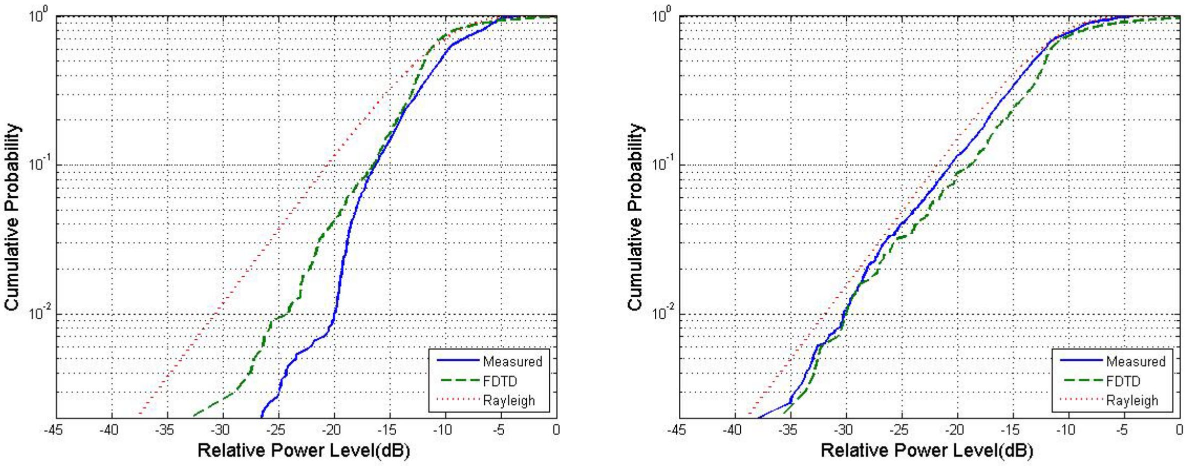
Figure 3: Trajectory of the antenna locations on the platform



(a) Rx dipole aligned in x direction



(b) Rx dipole aligned in y direction



(c) Rx dipole aligned in z direction

(d) Rx dipole aligned in z direction with platform stirring

Figure 4: Comparison between simulated and measured results where time step $\Delta t = 3.85*10^{-11}$ sec for FDTD

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