

Field Uniformity Characteristics of a Reverberation Chamber with Dispositions of Diffuser sets

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Abstract: This paper presents an electromagnetic field analysis for a reverberation chamber which is used as an alternative of a shielded anechoic chamber. Schroeder Diffuser is applied to produce uniform field characteristics inside of a rectangular chamber with the volume of 2,086,695 cm³. Using FDTD (Finite-Difference Time-Domain) method, the field characteristics were analyzed with dispositions of diffuser sets. Due to the limitation of computing time and required reasonable reliability, 75 % of entire test points were analyzed. The results show that all 3 different types of diffuser sets show within ± 3 dB tolerance of field uniformity characteristics, and the structure type 3 shows best results among them.

Key Words: Field Uniformity, Reverberation Chamber, FDTD, Diffuser

1. Introduction

Various types of diffuser sets inside of a rectangular reverberation chamber are used to get improved mode distributions. Instead of using mode stirrers, Schroeder diffusers [1]~[3], which are commonly used in acoustic chambers, are applied to get EM field uniformity inside of a chamber. The number of sidewalls where diffuser sets are attached is increased to 2, 4, and 5 to enhance the effects of Schroeder diffusers. The number of total possible modes is extracted through numerical formulas, and a diffuser is designed as shown in the Figure 2. FDTD method is applied at 2.5 GHz band. Through the simulated electric field strengths inside of a test volume, the changes of field distributions by structural variance are analyzed to investigate the efficiency of Schroeder diffusers. The characteristics of field uniformity on 75% of total test points is studied with numerical analysis

2. Design of a Reverberation Chamber

A reverberation chamber should have an appropriate volume for required multi-modes to satisfy field uniformities at LUF (Lowest Usable Frequency). In this paper, a rectangular chamber of Fig. 1. is used.

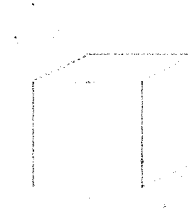


Fig. 1. Dimensions of a reverberation chamber

2.1 Mode Analysis in a chamber

To study mode distributions inside of a reverberation chamber, resonant frequency should be known. When the medium in a reverberation chamber is air, resonant frequency of a reverberation

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chamber can be calculated by a formula (1) and number of total resonant modes by a formula (2). [3]

$$f_{\max} = 150 \sqrt{\left(\frac{m}{d}\right)^2 + \left(\frac{n}{e}\right)^2 + \left(\frac{p}{f}\right)^2} \text{ MHz} \quad (1)$$

$$N(f) = \frac{4\pi}{3} def \left(\frac{150}{f}\right)^3 \times \frac{1}{8} \times 2 = \frac{\pi}{3} def \left(\frac{150}{f}\right)^3 \quad (2)$$

NBS (National Bureau of Standards) Technical Note 1092 (1986, USA) suggests at least 60 modes to satisfy the field uniformity requirement.

2.2 Design of a QRD(Quadratic Residue Diffuser)

In this paper, in order to get field uniformities, a rectangular reverberation chamber with Schroeder diffusers is used, and details of Quadratic Residue Diffusers [5] are shown in the Fig. 2.

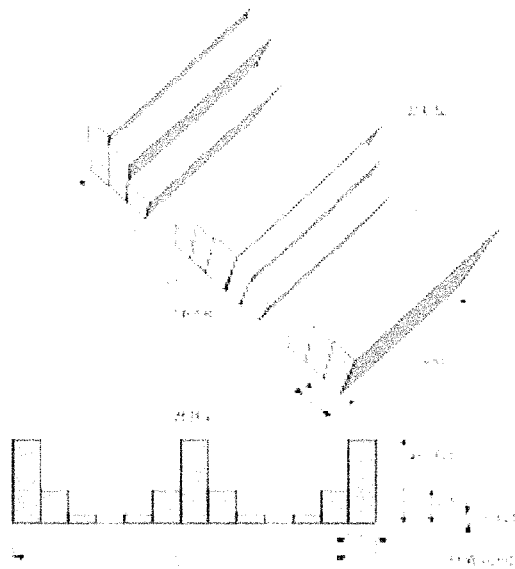


Fig. 2. Designed Quadratic Residue Diffuser

2.3 Design of Diffuser set

Using QRD of Fig. 2., a diffuser set of Fig. 3. is designed.

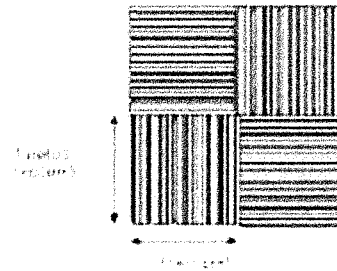


Fig. 3. Designed diffuser set

3. Modeling

3.1 Modeling of a Rectangular Reverberation Chamber

To study field distributions in a reverberation chamber, FDTD method is commonly used, and the structure of a reverberation chamber is modeled as shown in the Fig. 4. (a). For the simulations, frequency is set to 2.5 GHz, and Yee's cell unit is set to 1 cm \times 1 cm \times 1 cm. The size of the reverberation chamber is 123.4X \times 145.4Y \times 117.4Z. Sinusoidal point source is used for field generating source and is positioned at cell (68, 81, 47). Since 1 unit cell is enough for shielding electric fields, outside of the reverberation chamber is with 1 unit cell of PEC (Perfect Electric Conductor). For the diffuser sets in the reverberation chamber, PEC is also assumed for the surface as an outer boundary condition. Inner space is assumed free space. Diffuser set of Fig. 3. is placed at the center of x-y plane and electric field strengths at test planes of Fig. 4 (b). are sampled for the analysis of field distributions.

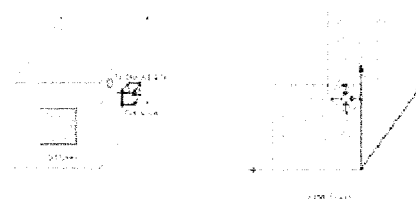


Fig. 4. Modeling of the reverberation chamber and test planes for simulations

3.2 Modeling of a rectangular reverberation chamber with various diffuser sets

3 different types of a reverberation chambers with designed QRDs are shown in the Fig. 5. By using FDTD, Yee's algorithm [6], and finite differential equations, electromagnetic fields for time and space is simulated. Diffuser set of $w=60$ cells, $l=36$ cells as shown in the Fig. 3. is attached on the walls of the reverberation chamber. Type 1 with 2 sets, type 2 with 4 sets, type 3 with 5 sets, the diffusers are attached on the walls. For the type 1, center point of diffuser set is $(68, 23, 72)$, $(71, 141, 72)$. To satisfy CFL (Courant-Friedrick-Lewy) conditions [1, 2], a discrete time interval is set to 19.25 ps ($= \Delta t$) and the total numbers of time step are 20,000.

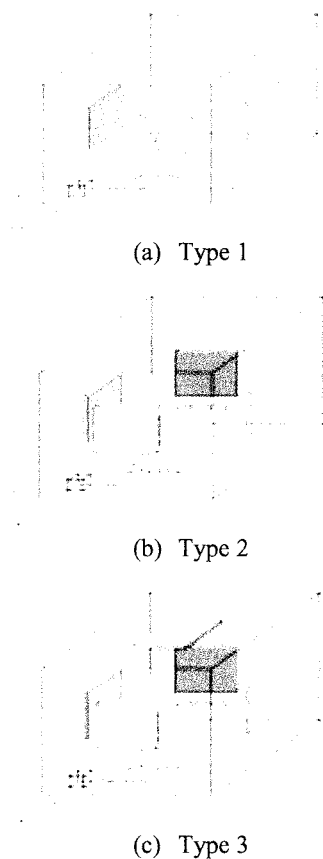
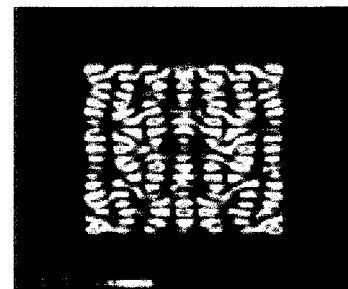


Fig. 5. Modeling of a rectangular reverberation chamber with various diffuser sets

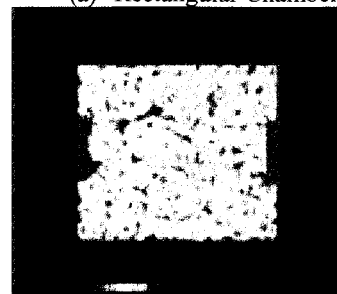
4. Results of simulation

4.1 Reverberation chamber

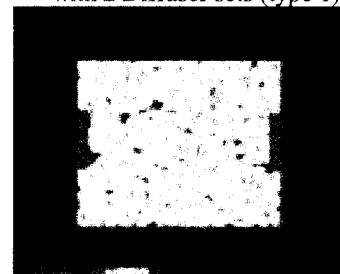
Electric field distributions at $x = 75$ in y - z plane inside of a reverberation chamber with diffuser sets, and also without diffuser sets, are shown in the Fig. 6.



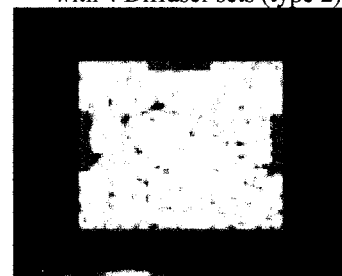
(a) Rectangular Chamber



(b) Rectangular Chamber with 2 Diffuser sets (type 1)



(c) Rectangular Chamber with 4 Diffuser sets (type 2)



(d) Rectangular Chamber with 5 Diffuser sets (type 3)

Fig. 6. Results of simulation at y - z plane

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Simulation results show that much enhanced field uniformity can be achieved with the designed diffuser sets attached. The average, maximum, minimum values of E , standard deviation, and tolerance of 75 % sampled [5] electric field intensity for line 1, 2, 3 are shown in the table 1 and Fig. 5.

Table 1 75% of sampled electric field intensity for lines 1, 2, 3.		
E [dBV/m]	Chamber w/o diffusers	Chamber with diffusers
Average	5.82	7.36
Maximum	13.2	9.96
Minimum	0.3	4.43

Standard deviations	3.40	1.32
Tolerance [dB]	2.9	5.53

Table 2 Standard deviations of E_x, E_y, E_z			
E [V/m]	E_x	E_y	E_z
Chamber w/o diffusers	0.49	0.08	2.42
Chamber with diffusers	0.51	0.67	0.55

Table 1., 2. show that the electric field strengths increase as 2~ 3 dB and the field uniformity is improved by using the designed diffuser sets in the chamber.

5. Conclusion

75 % of sampled data in test volume were analyzed to investigate the field characteristics inside of a rectangular chamber. The analytical results show that

the field uniformity and polarization characteristics inside of a reverberation chamber with diffuser set is improved with the increased number of diffuser sets. The results show that reverberation chambers with 3 types of diffusers have below ± 3 dB tolerance of field uniformity characteristics and type 3 shows better results among them. The results also show that the field uniformity condition required by IEC technical report was obtained by using designed diffuser sets.

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