Comparison of FDTD and Ray-Tracing Method for Site Attenuation Analysis of Compact Anechoic Chamber

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Abstract: In this paper, the FDTD method and the ray tracing method have been applied to analyze the site attenuation of a compact anechoic chamber in the frequency range from 30 MHz to 200 MHz. For FDTD analysis, half-wave dipole antenna, shortened dipole antenna and EM absorber were modeled by using large-cells, which were larger than the diameter of antenna element and the thickness of EM absorber. For verification, the site attenuation of a compact anechoic chamber was measured and compared with the calculated values through the FDTD method and the ray tracing method. As the results, the calculated values through the FDTD method agreed well with the measured ones within 2 dB and the calculated values through the ray tracing method have larger deviation in the frequency range less than 180 MHz.

Key words: FDTD method, Anechoic chamber, Classical site attenuation, Shortened dipole antenna, Ferrite tile

1. Introduction

Recently, emission radiated from electric and electronic equipment has interfered with surrounding radio communication equipment so much that emission levels and testing method have been specified by CISPR [1]. In order to pass the conformity test, emission level from EUT (Equipment under Test) must be mitigated below the defined limit. In many cases, preliminary test is performed in compact anechoic chambers. However, it is difficult to make clear the relations among different test sites because, particularly in compact anechoic chambers, reflection from EM absorber much influences the test results.

In order to evaluate relations among test sites, it is useful to computationally analyze the site attenuation of anechoic chambers. The ray tracing method has often been utilized to this analysis [2], but it is difficult to be applied for evaluation in the low frequency where wavelength is longer than the size of anechoic chamber. On the other hand, the FDTD method has been developed to calculate the site attenuation in the frequency range from 30 MHz to 100MHz [3]. However, the frequency scope was not clear. Then, it is important to estimate the frequency scope of two methods.

In this paper, we investigate the frequency range where the FDTD method should be used to calculate the site attenuation. The FDTD method was applied to calculate the site attenuation in a compact anechoic chamber. The calculated results were compared with the measured ones and the calculated ones through the ray tracing method to investigate the frequency scope.

2. Calculation of site attenuation of compact anechoic chamber

2.1 FDTD modeling of antenna

The calculation model of the site attenuation (SA) is illustrated in Fig. 1. The compact anechoic chamber is covered with EM absorber on the all walls. Ferrite tiles are used as the absorber. The SA is defined by the propagation characteristics between transmitting and receiving antenna in the chamber. Therefore, the SA mainly depends on antenna characteristics and reflection from the absorber, so that the modeling of antennas and the absorber is very important to calculate the SA.

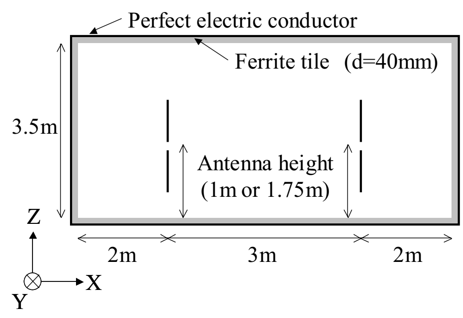


Fig. 1 FDTD analysis model of fully compact anechoic chamber.

A half-wave dipole antenna cannot be used in the compact anechoic chamber in the low frequency range because the antenna element length is longer than the size of the chamber. Then, a half-wave dipole antenna whose element length is adjusted to 80 MHz is used as shorten dipole antenna to evaluate the SA of the chamber in the frequency range from

30 MHz to 70 MHz [4]. A half-wave or tuned dipole antenna is used in the frequency range from 80 MHz to 1000 MHz [4].

The sub-cell method [5] was used for the modeling of the shorten dipole antenna. The optimum diameter was determined so that the input impedance through the FDTD method might coincide with the one through the method of moment. The optimum diameter of 3.2 mm was used for FDTD calculation using VHAP as shorten dipole antenna when the cell size was about 40 mm [3].

The sub-cell method did not be used for the modeling of half-wave dipole antennas, because the optimum diameter could not be determined. The antenna factors through the method of moment were used to compensate the calculated results through the FDTD method. These compensation values, α_{FDTD}, were used for FDTD calculation using VHAP as half-wave dipole antennas [3].

In order to evaluate the validity of these compensation methods, the CSA (Classical Site Attenuation) in free space was calculated through the FDTD method in the frequency range from 30 MHz to 200 MHz. Two dipole antennas, whose distance was 3 m, were used. To terminate the computational domain, a PML (Perfectly Matched Layer) was applied.

On the calculation, the CSA_{FDTD} (in dB) was calculated using following equation.

$$CSA_{FDTD} = SA_{FDTD} + \alpha_{TX} + \alpha_{RX} - 2\alpha_{FDTD} \quad (1)$$

Where α_{TX} (in dB) and α_{RX} (in dB) are balun loss of antenna, α_{FDTD} (in dB) is compensation value using half-wave dipole antenna (using shorten dipole antenna: $\alpha_{FDTD} = 0$). And the SA_{FDTD} is propagation loss between antennas, which is calculated through the FDTD method. The cell size of about 40 mm was employed for calculation.

As the calculated results shown in Fig. 2, the calculated values through the FDTD method with these compensation methods agreed with the ones through the method of moment within about 0.5 dB. Consequently the effectiveness of the modeling of dipole antenna using these compensation methods was revealed.

2.2 FDTD modeling of anechoic chamber

Ferrite tile is generally used as EM absorber of compact anechoic chambers. The ferrite tile was modeled for FDTD calculation. However it is difficult to set the cell size to the thickness of the ferrite tile (6.3 mm). Thus, the ferrite tile was modeled using the equivalent conversion as follows, where the thickness of the ferrite tile was set to 40 mm.

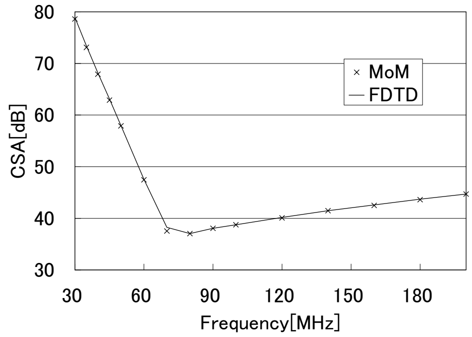


Fig. 2 Calculated results of CSA in free space.

The outline of the equivalent conversion is shown in Fig. 3. The reflection coefficient R is given in (2), where Z_ω is the impedance of the ferrite tile, γ is its propagation constant, d is its thickness, and Z_0 is the free space impedance.

$$R = \left| \frac{Z_\omega \tanh \gamma d - Z_0}{Z_\omega \tanh \gamma d + Z_0} \right| \quad (2)$$

The conditions for the equivalent conversion are given in (3), where γ', d' and Z'_ω are the converted constant of the ferrite tile.

$$\left. \begin{aligned} \gamma d &= \gamma' d' \\ Z_\omega &= Z'_\omega \end{aligned} \right\} \quad (3)$$

γ and Z_ω are given in (4).

$$\left. \begin{aligned} \gamma &= j\omega\sqrt{\mu\varepsilon} \\ Z_\omega &= \sqrt{\mu / \varepsilon} \end{aligned} \right\} \quad (4)$$

From (3) and (4), the material constants of the ferrite tile converted by the equivalent conversion are derived in (5).

$$\left. \begin{aligned} \varepsilon' &= \frac{d}{d'}\varepsilon \\ \mu' &= \frac{d}{d'}\mu \end{aligned} \right\} \quad (5)$$

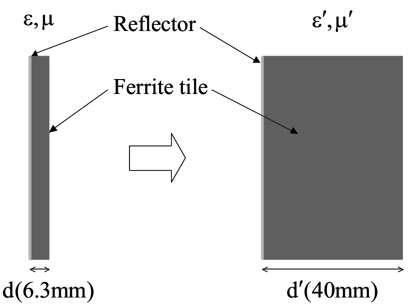


Fig.3 Outline of equivalent conversion.

In order to evaluate the validity of the equivalent conversion, the material constants of the ferrite tile were measured and the measured reflection coefficient of ferrite tile was compared with the one calculated through the FDTD method using the equivalent conversion. As shown in Fig. 4, the calculated values agreed with the measured ones within about 1 dB. Consequently the effectiveness of the modeling of ferrite tile using the proposed equivalent conversion was revealed.

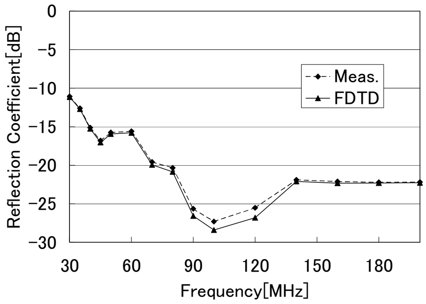


Fig.4 Reflection coefficient of ferrite tile.

2.3 Site attenuation through ray tracing method

The ray tracing method is widely used to calculate the SA. In this method, the wall of the chamber presented by perfect conductive walls, and the image positions of the transmitting and receiving antenna are determined from the assumption. The reflection of the absorber is considered with the trace from image antenna through the wall. In this calculation, we considered the multiple reflections and used the measured reflection coefficient.

3. Verification of analysis method

3.1 Measurement of CSA

To consider the deviations between the FDTD method and the ray tracing method, we compare the measured values with the calculated ones. The anechoic chamber, whose size is 7 m long, 4 m wide, and 3.5 m high, was used for experiment. The chamber is covered with the compounded EM absorber [6] on the all walls.

The CSA measurement system is shown in Fig. 5. A pare of VHAP were used for transmitting and receiving antenna as shortened dipole antennas or half-wave dipole antennas. Their distance was 3 m, the height was 1 m or 1.75 m, and the polarization was horizontal and vertical. The measured CSA (in dB) is given in (6), where V_D is the received voltage at cable direct connection, and V_{SITE} is the one at propagation between antennas.

$$CSA_{MEAS.} = 20\log_{10}\frac{V_D}{V_{SITE}} \qquad (6)$$

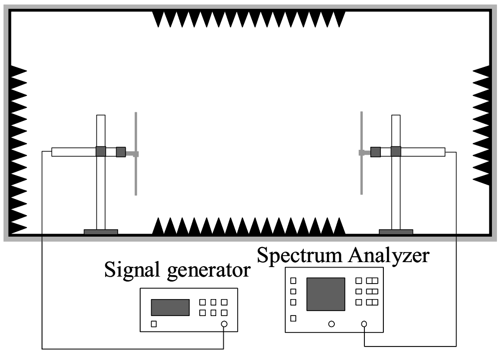


Fig.5 CSA measurement system.

3.2 Calculation of CSA

The model for analysis is shown in Fig. 1. The cell size was set to about 40 mm. The compensation values α_{FDTD} were applied for half-wave dipole antennas, and the shortened dipole antenna was modeled by the optimum diameter. The absorber is constructed with the two types of ferrite, which were ferrite tile and pyramidal ferrite. In this calculation, the ferrite tile only was modeled as EM absorber using the method describing in close 2.2 because the reflection coefficient of the absorber using ferrite tile is less than -20 dB in the frequency range up to 200 MHz. It is considered that this value is sufficient to construct an anechoic chamber.

For comparison, it was also calculated through the ray tracing method.

3.3 Evaluation of two methods

Figure 6 shows the deviation from the CSA in free space to the measured values and the calculated ones through the FDTD method and the ray tracing method. From Fig. 6, the following results are obtained;

1) The calculated values through the FDTD method agree with the measured ones within 2 dB in the frequency range from 30 MHz to 200 MHz.

2) The calculated values through the ray tracing method have larger deviation in the frequency range less than 180 MHz.

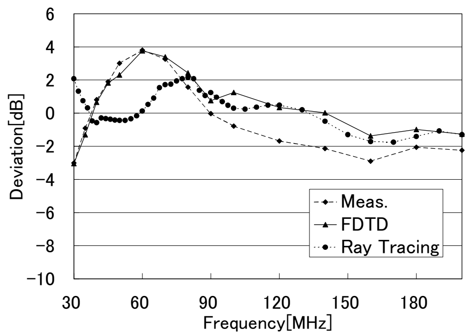
3) The calculated values through the ray tracing method almost agree with the ones through the FDTD method in the frequency range 180 MHz or more.

These results indicate that the FDTD analysis method should be used less than 180 MHz for the chamber in Fig. 5 if we should maintain the deviation within 2dB.

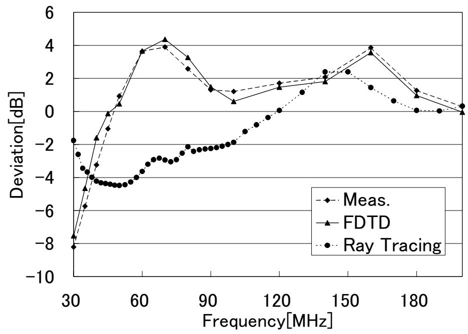
4. Conclusion

In this paper, we investigate the frequency range where we should use the FDTD method to calculate site attenuation (SA). Initially, half-wave dipole antenna, shortened dipole antenna and EM absorber were modeled by using large-cells. In order to compensate the deviation caused by the cell size, the antenna factor through the method of moment was used as the compensation value for half-wave dipole antenna. For shortened dipole antenna, the optimum diameter was adjusted so that the input impedance might coincide with the one through the method of moment. Furthermore, the thickness of EM absorber was changed to be equal to the size of large-cells maintaining the reflection coefficient.

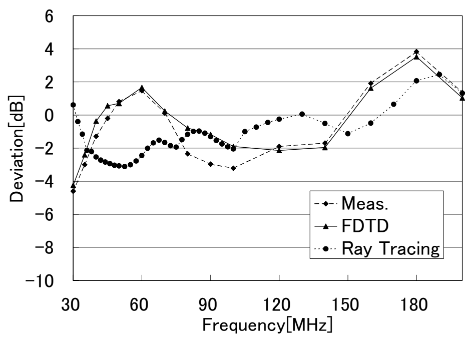
The SA of the compact anechoic chamber was calculated through the FDTD method and the ray tracing method in the frequency range from 30 MHz to 200 MHz, and they were compared with the measured one. As the results, the calculated values through the FDTD method agreed well with the measured ones within 2 dB. The calculated values through the ray tracing method agreed with the ones through the FDTD method in the frequency range 180 MHz or more.



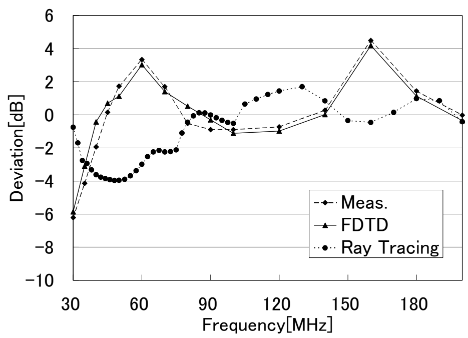
(a) Horizontal polarization at 1 m antenna high



(b) Vertical polarization at 1 m antenna high



(c) Horizontal polarization at 1.75 m antenna high



(d) Vertical polarization at 1.75 m antenna high

Fig. 6 Deviation from CSA in free space to measured and calculated values through FDTD and ray tracing method.

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