

# NSA Calculation of Anechoic Chamber Using Method of Moment

T. Sasaki, Y. Watanabe, and M. Tokuda  
Musashi Institute of Technology, Japan

**Abstract**—NSA characteristics of an anechoic chamber were calculated by using the MoM (Method of Moment), and they were compared with those calculated by the FDTD method as well as the measured results in fully anechoic chamber. Next, we calculated of an anechoic chamber with complicated shapes. We found that first imitating a wave absorber using wire meshes with a limited electric conductivity is effective by controlling the wire interval. The NSA characteristics calculated by the MoM are as well as those calculated by the FDTD method. The NSA characteristics calculated by the MoM also agree with the measured results. And NSA characteristics of an anechoic chamber with complicated shapes were able to be calculated by using the MoM. Based on the results, it is confirmed that the MoM can be used to calculate NSA characteristics for an anechoic chamber.

## 1. Introduction

An anechoic chamber is a test room specially designed for completely shielding out external disturbances and for suppressing the echo caused by internal electromagnetic waves. The anechoic chamber for the radiated emission measurement specified by CISPR is usually evaluated by NSA (normalized site attenuation), which is a measure of the transmission characteristics between the standard antennas set inside the anechoic chamber. NSA is usually analyzed by using the ray tracing method [1], but the analytical accuracy of the NSA deteriorates in the low frequency band below several hundreds MHz because the ray tracing method approximates an electromagnetic wave as an optical ray. However, the FDTD (finite difference time domain) method is an analytical method that treats electromagnetic waves purely as waves. Therefore, the FDTD method can analyze NSA characteristics in the low frequency band below several hundreds MHz. The NSA of the anechoic chamber using the FDTD method was obtained by Holloway [2] and Takiguchi [3].

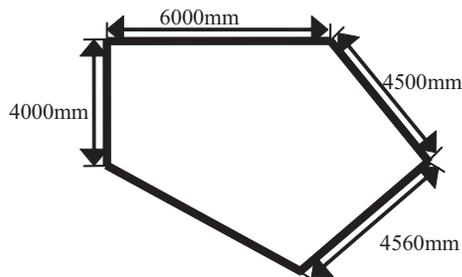


Figure 1: Anechoic chamber of analysis schedule.

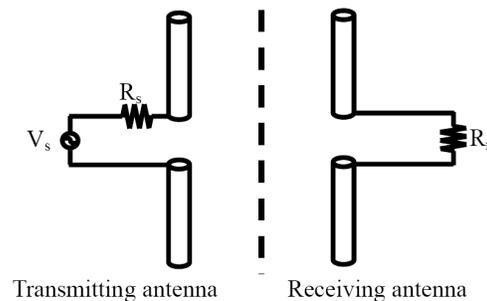


Figure 2: Modeling of transmitting and receiving antennas.

The purpose of this research is to construct and calculate an anechoic chamber that can measure below 30 MHz because we will measure the characteristics of a PLC (power line communication) system that operates between 2 to 30 MHz. Therefore the ray tracing method is not suitable for this calculation. The FDTD method is suitable, but it cannot be used to calculate the NSA of an anechoic chamber with a cross section of a non-rectangular shape, as shown in Figure 1. The non-rectangular shape is preferable because internal resonance of an anechoic chamber with such a cross section is lower than one with a rectangular cross section. Another way to calculate for the fully electromagnetic wave method is MoM (method of moment), which can calculate the NSA of an anechoic chamber with a non-rectangular cross section.

In this paper, we report on our comparison of calculations of the NSA of an anechoic chamber using the MoM and the FDTD method. In addition, we report on calculations of the NSA of an anechoic chamber with complicated shapes (pentagonal anechoic chamber) using the MoM. First, the NSA calculation of the antenna factor of transmitting and receiving antennas is presented. Second, we describe the modeling method of the anechoic chamber when we calculate the NSA characteristics using MoM. Third, we describe calculation

results of NSA characteristics of the anechoic chamber is provided. Fourth, the calculation results obtained by the MoM are compared with those obtained by the FDTD method. Almost the same results were obtained. Finally, we calculated Characteristics of pentagonal anechoic chamber and showed that NSA characteristics of the pentagonal anechoic chamber are better than cuboid anechoic chamber.

## 2. Antenna Factor

Both transmitting and receiving antennas are set in the chamber to measure the NSA characteristics and then a modeling of antenna is required in a simulation. A half-wave dipole antenna was used by Takiguchi [3] for measuring the NSA characteristics of the anechoic chamber as transmitting and receiving antennas. Therefore, we have to model the half-wave dipole antenna by using the MoM. The modeled antennas are shown in Figure 2. In Figure 2, we modeled the transmitting antenna by putting the transmitting voltage ( $V_s$ ) and the resistance ( $R_s$ ) in a gap between two elements of the antenna. In Takiguchi's study [3],  $V_s$  was 1 V, and both  $R_s$  and  $R_r$  were  $50\ \Omega$ , and the diameter of an antenna element was 7 mm.

Next, we examined the antenna factor modeling of a half-wave dipole antenna. The antenna factor AF represents the ratio of the electric field (abbreviated E-field) of an incident electromagnetic wave arriving at an antenna to the voltage induced by the incident wave between the antenna elements, as shown in (1).

$$AF = 20 \log_{10} \left( \frac{E_0}{V_r} \right) \quad (1)$$

Where  $E_0$  is the E-field strength at the antenna, and  $V_r$  is the induced voltage of the antenna. The E-field strength distribution near the antenna needs to be uniform when measuring the antenna factor. It is examined how many distances between the transmitting and receiving antennas is needed when calculating the antenna factor by using the MoM. Because the E-field strength at the receiving antenna does not depend on the frequency, we calculated the dependence of the E-field strength on the distance between the transmitting and receiving antennas at a frequency of 30 MHz as shown in Figure 3. In Figure 3, the difference in the E-field strength is negligible beyond 400 m. Therefore, we set the distance between the transmitting and the receiving antennas to 1 km.

A comparison of the calculation results of the antenna factor using the MoM with the antenna factor from Takiguchi's study is shown in Figure 4 [3], and their antenna factors clearly agree and have sufficient accuracy. Therefore, we used these calculated values.

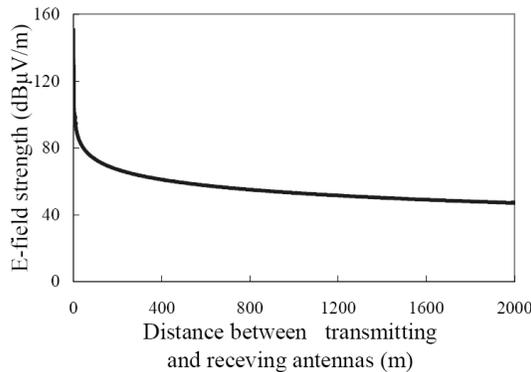


Figure 3: Dependence of E-field strength on the distance between transmitting and receiving antennas.

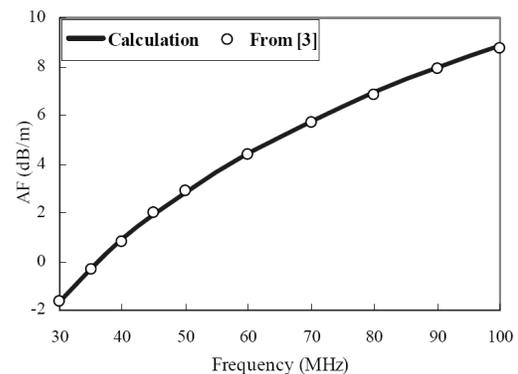


Figure 4: Calculation results of antenna factor by using MoM.

## 3. Modeling of Anechoic Chamber Using MoM

### 3.1. Modeling of Anechoic Chamber's Walls

The anechoic chamber had electromagnetic wave absorbers set on the walls and ceiling to suppress internal echo within the chamber. Two kinds of anechoic chamber were used, fully anechoic and semi anechoic.

In the fully anechoic chamber, all of the walls, the ceiling, and the floor are covered by wave absorbers, as depicted in Figure 5. However, in the semi anechoic chamber, the walls and ceiling are covered with the wave absorbers, but the floor is covered metal plates instead. Therefore, we had to imitate the wave absorbers to calculate the NSA characteristics for these anechoic chambers. We used a wire mesh with limited electric conductivity to imitate the wave absorbers for this study, as shown in Figure 6.

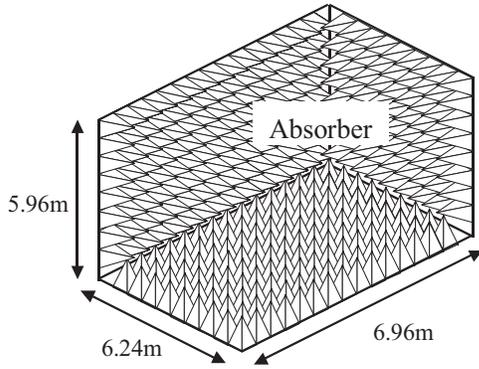


Figure 5: Construction of fully anechoic chamber.

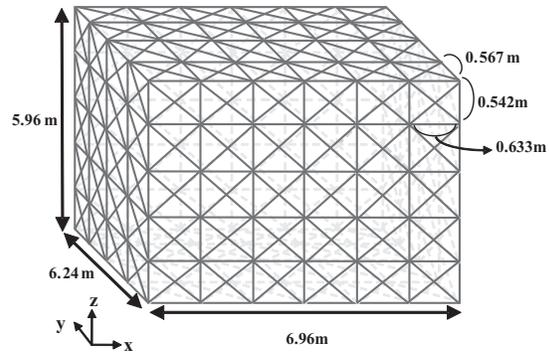


Figure 6: Modeling of fully anechoic chamber using MoM.

We chose the anechoic chamber used by Takiguchi [3] as a calculation object. The dimensions of the chamber are  $W = 6.24\text{ m}$ ,  $L = 6.96\text{ m}$  and  $H = 5.96\text{ m}$ . The walls, ceiling, and floor are composed of wire meshes with intervals of  $W = 0.567\text{ m}$ ,  $L = 0.633\text{ m}$ , and  $H = 0.542\text{ m}$ , as shown in Figure 6, and the wire meshes also have diagonal wires. The interval of the wire meshes was a bit large comparing with the wavelength of the electromagnetic wave sent from the transmitting antenna to the receiving one. It should be small at a higher frequency, especially around 100 MHz, which was the highest frequency for this calculation. To make segment length  $\lambda/10$  or less, the number of segments set here is 8706 in fully anechoic chamber and 7202 in semi anechoic chamber. The calculation model of the fully anechoic chamber is shown in Figure 6, but in the one for the semi anechoic chamber, the floor is modeled using a perfect ground.

### 3.2. Modeling of the Wave Absorber Reflection

The wave absorber imitates the wire mesh with a limited electric conductivity, which was calculated from the wave absorber's reflection coefficient. In this paper, we made reflecting plate and calculated reflection wave to transmission wave using MoM and obtained the limited electric conductivity corresponding to the amount of reflection. Figure 7 shows the calculation model of reflection. We set the distance between the transmitting antenna and the reflecting plate to 1 km. The reflection level is controlled by changing limited electric conductivity. The calculation method of the reflection is used space standing wave method [4]. This method is calculated from maximum and minimum electrical field strength ( $E_{max}$ ,  $E_{min}$ ), as shown in (2)

$$|\dot{\Gamma}| = \frac{1 - \rho}{1 + \rho} \quad \rho = \frac{E_{max}}{E_{min}} \quad (2)$$

where  $\Gamma$  is reflection coefficient, and  $\rho$  is standing wave ratio. In (2),  $\rho$  was adjusted by changing limited

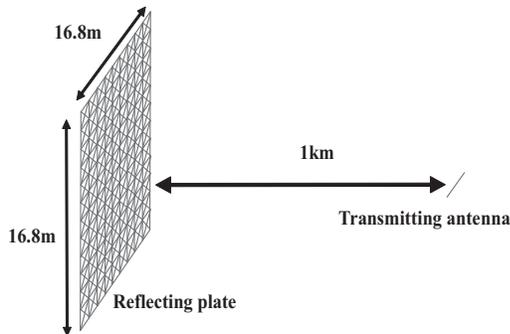


Figure 7: Calculated model of reflection.

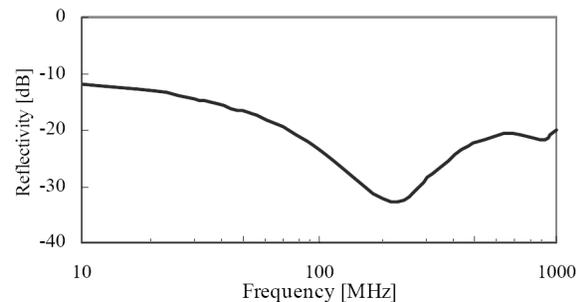


Figure 8: Reflectivity of wave absorber.

electric conductivity, and  $\Gamma$  was set as well as wave absorber's reflection by changing  $\rho$ . From here onwards, wave absorber was imitated by wire mesh with limited electric conductivity corresponding to wave absorber's reflection. In this paper, we calculated limited electric conductivity corresponding to reflection from 30 MHz to 100 MHz.

### 3.3. Reflectivity of the Wave Absorber

Figure 8 shows the reflectivity of the wave absorber measured by the rectangular coaxial air-line method. The reflectivity of the wave absorber is 20 dB above 70 MHz and reaches 30 dB near 200 MHz. For this calculation (30 to 100 MHz), it is supposed that a pyramidal foamed ferrite is not effective. But we have only the characteristics of synthesis of pyramidal foamed ferrite and ferrite tile. Therefore, we calculated using this characteristic.

## 4. NSA Calculation of Anechoic Chamber

### 4.1. Calculation Method of NSA

NSA represents the transmission characteristics between the transmitting and receiving antennas on the test site, and it is calculated by (3) [3]

$$NSA = V_{DIRECT} - V_{SITE} - (AF_T + AF_R) - \Delta NSA \text{ (dB)} \quad (3)$$

where  $V_{DIRECT}$  is the received voltage of the measuring receiver when the connecting cables for a signal generator and the receiver are connected directly and  $V_{SITE}$  is the maximum receiving voltage of the measuring receiver when the cables are connected to the transmitting and receiving antennas and when the receiving antenna is swept between 1 and 4 m.  $AF_T$  and  $AF_R$  are the antenna factor of the transmitting and receiving antennas.  $\Delta NSA$  is the correction value by direct coupling between the antennas, including image coupling between them through the metal ground plane. In this calculation, we used a half-wave dipole antenna at 30 MHz because this kind of dipole antenna was used in calculating the NSA with the FDTD method [3], and our intention is to compare the MoM and the FDTD method. In using MoM,  $V_{site}$  are measured at 5 points as shown Figure 9 and fully anechoic chamber,  $\Delta NSA$  is zero [3].

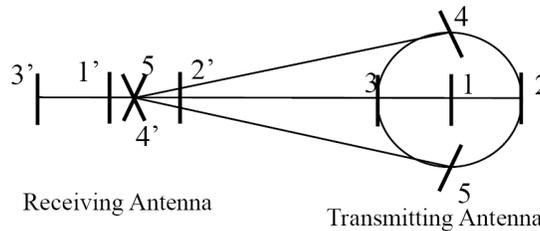


Figure 9: Position of transmitting and receiving antennas.

### 4.2. NSA Characteristics for Fully Anechoic Chamber

Figure 10 shows the calculation results for the NSA characteristics in the fully anechoic chamber where the MoM is used, and (a) is the vertical polarization, and (b) is the horizontal one. Curves from 1-1' to 5-5' are the calculation results using MoM for antenna position as shown Figure 10. In addition, the calculation results using the FDTD method and the measured results obtained from Takiguchi's study [3] are shown in Figure 10. The NSA characteristics calculated by the MoM in the frequency range from 30 to 100 MHz is similar to the measured results. The NSA calculation results using MoM hardly depend on various antenna positions. Especially, NSAs for 2-2' and 3-3' reached almost the same value as well as NSAs for 4-4' and 5-5'. However, the calculated NSA using the FDTD method does not agree with that using MoM. But, it is thought that the calculation accuracy using MoM is better than that using FDTD, because the humps existing the measured value is also appeared in NSA using MoM as shown Figure 10(a). NSA using MoM from 30 MHz to 60 MHz is fitted to the measured value more than NSA using FDTD. As the results, it is clear that the NSA characteristics calculated by using the MoM is more accurate than that calculated by using the FDTD method.

### 4.3. NSA Characteristics for Semi Anechoic Chamber

We also calculated the NSA characteristics of the semi anechoic chamber as shown in Figure 11. In Figure 11, (a) shows the vertical polarization, and (b) shows the horizontal polarization. In addition, for the semi anechoic chamber, the  $\Delta NSA$  from the VCCI [5] was used. The NSA characteristics calculated by using the MoM for the semi anechoic chamber agree with the measured results. The difference among the calculation results using MoM for various antenna positions was not so many. The measured results of the NSA characteristics in the semi anechoic chamber have humps, and the calculated results using the MoM also appeared though it was not plenitude. Regardless, it is clear that the NSA characteristics calculated by using the MoM agrees with the measured results.

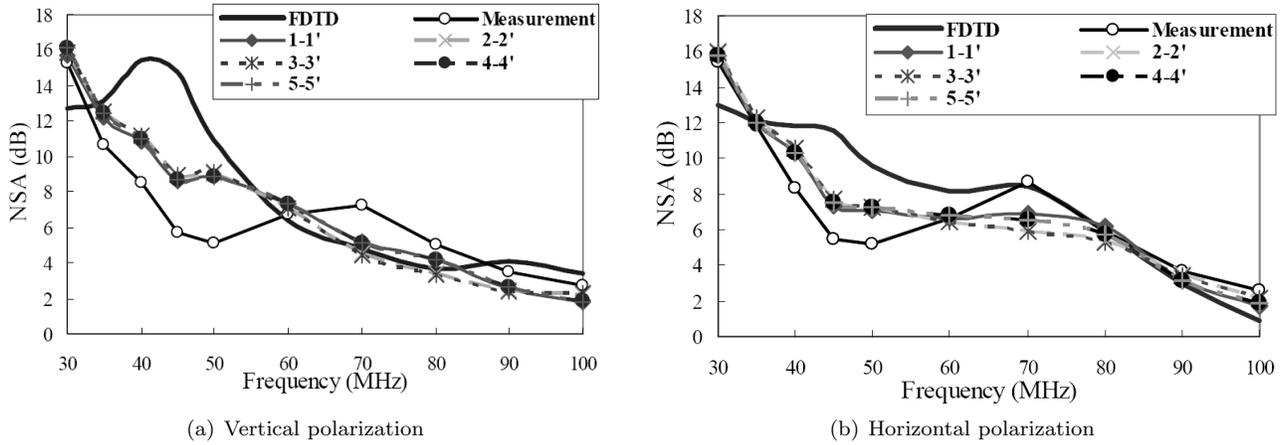


Figure 10: NSA characteristics of the fully anechoic chamber.

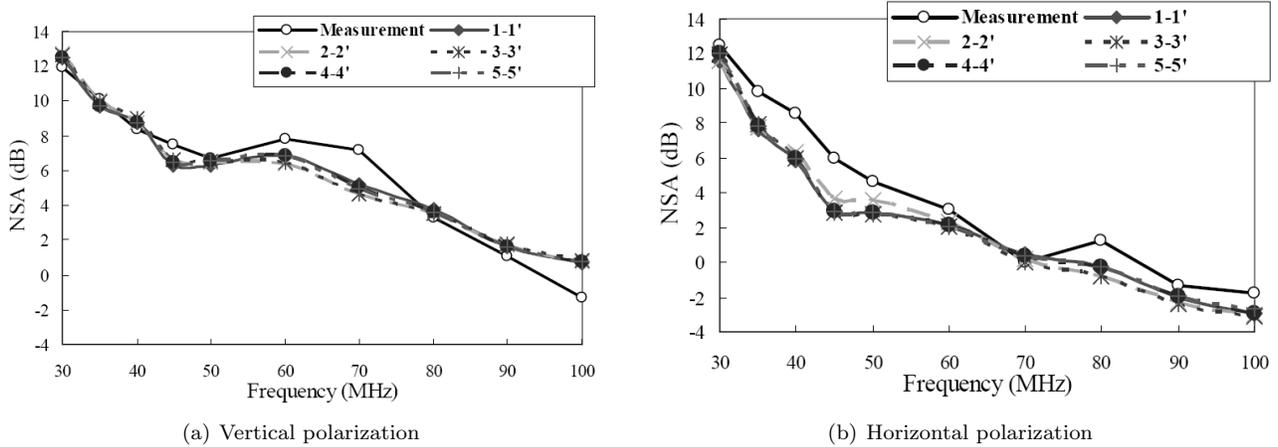


Figure 11: NSA characteristics of semi anechoic chamber.

#### 4.4. Characteristics of Pentagonal Anechoic Chamber

Next, we calculated the characteristics of the pentagonal anechoic chamber, as shown in Figure 12, using the MoM. The base area in the pentagonal anechoic chamber is given as the same that in the rectangular anechoic chamber as shown in Figure 6, and heights of the both chambers are also set as the same value. The reason is to calculate only the modification effect by changing the shape of the anechoic chamber from rectangular to pentagonal. The modeling method of an echoic chamber is similar to that in the case of Figure 6, and the calculation method of antenna factor for the shortened dipole antenna is also similar to that in the case of Figure 7. In this paper, we estimated the fully anechoic chamber using the NSA because we could not calculate the  $\Delta NSA$  when calculating the NSA using a shortened dipole antenna.

Figure 12 shows the calculation results of the NSA characteristics in the fully anechoic chamber. In Figure 13, “Theory” was calculated as shown in (4).

$$NSA = 20 \log_{10}(D) - 20 \log_{10}(F) + 32(dB) \tag{4}$$

Where, D is the distance from transmitting to receiving antenna (m) and F is frequency (MHz). (4) is analysis of geometrical optics in free space.

In the vertical polarization as shown in Figure 13(a), the NSA characteristics appeared to be high in the frequency range from 60 to 80 MHz comparing with the Theory. But the maximum difference value between the Theory and the calculation results using MoM is 2 dB, and this value exists in a permissible value. In the horizontal polarization, the NSA characteristics appeared to be high from 30 to 70 MHz, and become almost the same values as the Theory from 60 to 100 MHz. But the maximum difference value between theory and calculation using MoM is 2 dB. The NSA characteristics of both vertical and horizontal polarizations in the pentagonal anechoic chamber are better than that in the rectangular anechoic chamber as shown in Figure 10.

As a result, it is confirmed that the NSA characteristics can be improved by changing to a pentagonal shape in a fully anechoic chamber.

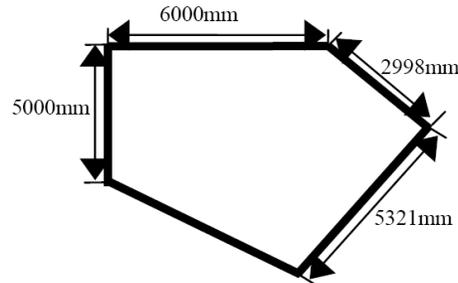


Figure 12: Outline of anechoic chamber.

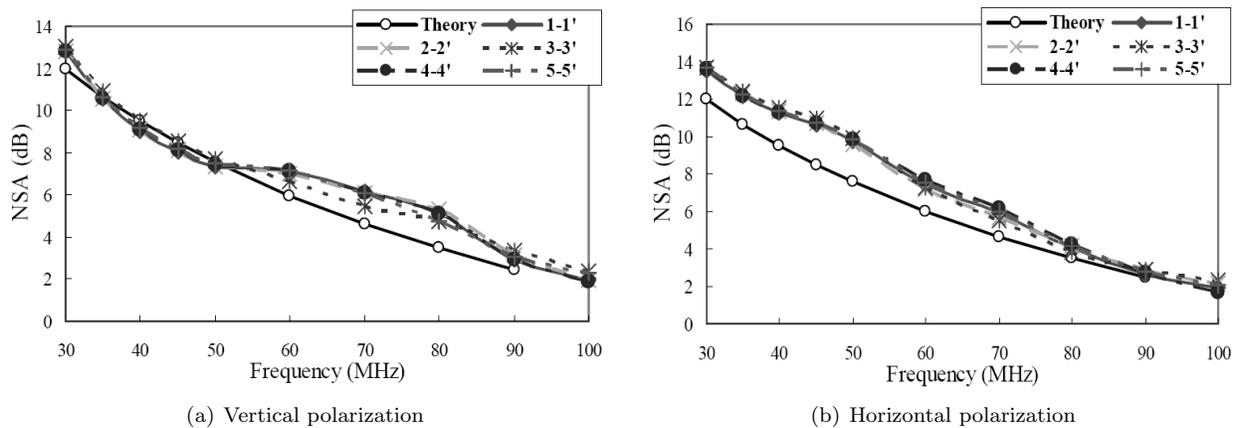


Figure 13: Characteristics of fully anechoic chamber for the pentagonal anechoic chamber.

## 5. Conclusion

In this paper, we calculated the NSA characteristics of an anechoic chamber using the MoM and compared them with the characteristics using the FDTD method as well as the measured results. The following items were clear.

- 1 Imitating a wave absorber using wire meshes with limited electric conductivity is effective by controlling the wire interval.
- 2 The NSA characteristics calculated by using the MoM are more accurate than those using the FDTD method.
- 3 The NSA characteristics calculated by using the MoM agree with the measured results.
- 4 Calculation of NSA characteristic using MoM is available in anechoic chamber with complicated shapes.

Future tasks are improvement of calculation accuracy and NSA calculation for the semi anechoic chamber with a pentagonal base.

## REFERENCES

1. Inokuchi, M., E. Kimura, and M. Tokuda, "Analyzing and improving characteristics of anechoic chamber using ray tracing method," *Euro EMC 2000*, Session: absorber lined chambers, in Belgium, 2000.
2. Holloway, C. L., P. McKenney, and D. A. Steffen, Finite-difference time-domain modeling for field predictions inside rooms," *IEEE 1997 International Symposium on Electromagnetic Compatibility*, in Austin, 1997.
3. Takiguchi, Y., E. Kimura, and M. Tokuda, "NSA characteristics of anechoic chamber using FDTD method," *4th European Symposium on Electromagnetic Compatibility (EMC Europe 2000 Brugge)*, Vol. 1, 257-262, 2000.
4. Hashimoto, O., "Introductio to wave absober," Morikita Shuppan Co., Ltd., in Japanese, 1997.
5. Voluntary Control Council for Interference by Information Technology Equipment (VCCI), constitutions and regulations, Japanese.