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Evaluation of the correlation between RF immunity test facilities using a conductive sphere

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Abstract

Various RF immunity test facilities, such as the semi-anechoic chamber, the giga-hretz TEM cell (GTEM cell) and the TEM cell, have been developed. However, the correlations among the test results measured in these facilities has not been clarified. This paper evaluates these correlations by comparing the calculated values of the electric field scattered by a conductive sphere in free space and the measured values in these facilities. The investigation shows that the deviation of measured value becomes smallest when measured in the semi-anechoic chamber.

1. Introduction

The immunity of information technology equipment for radiated radio frequency disturbances, such as those from TV broadcasting stations and illegal CB radio stations, needs to be tested in order to prevent malfunctions. Various RF immunity testing facilities such as the semi-anechoic chamber[1], GTEM cell[2] and TEM cell[3] have been used. The correlations among the test results measured in these facilities, which includes scattering caused by the equipment under test (EUT), should be clarified for the validity of the test results.

Such correlation has been investigated for a telephone set[4]. However, it is difficult to get the repeatability of the evaluated correlation result by using an EUT because correlation result depends on the EUT.

This paper proposes a new method to evaluate the correlation which uses a conductive sphere in free space is calculated using vector mode functions, and the scattered field is also measured by using an electric field sensor in these facilities. The correlation is obtained by comparing the calculated and measured results between the semi-anechoic chamber, GTEM cell and TEM cell.

2. Evaluation of the correlations among the RF immunity test facilities

In order to evaluate the correlation, the calculated scattered electric field by a conductive sphere in free space was compared with that measured in these three facilities.

2.1 Calculation of the scattering electric field

The electric field scattered by a conductive sphere can be calculated using vector mode function[5]. The coordinates used for the calculation is shown in Fig. 1.

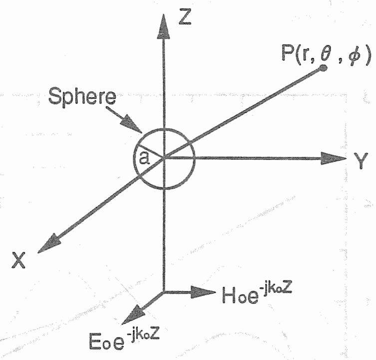


Fig.1. Coordinates of the calculation

The electromagnetic wave is incident on the sphere from the -Z direction. The incident wave is assumed to be a plane wave, because RF immunity test facilities are designed to apply the plane wave to the EUT.

The incident and scattered electric fields components (E^i and E^s) are represented by using vector mode functions M_{o1n} and N_{e1n}, which given by

$$E^i = E_o \sum_n^{\infty} (-j)^n \frac{2n+1}{n(n+1)} (M_{o1n}+N_{e1n}) \quad (1)$$

$$E^s = E_o \sum_n^{\infty} (-j)^n \frac{2n+1}{n(n+1)} (a_n^s M_{o1n}+jb_n^s N_{e1n}) \quad (2)$$

$$a_n^s = -\frac{j_n(\rho)}{h_n^{(2)}(\rho)} \quad (3)$$

$$b_n^s = -\frac{[\rho j_n(\rho)]'}{[\rho h_n^{(2)}(\rho)]'} \quad (4)$$

Here, $\rho = k_0 a$, a is the radius of the sphere, Eo is the amplitude of the incident field, $h_n(\rho)$ is a second kind Hankel function and $j_n(\rho)$ is a spherical Bessel function. The number of vector mode functions is selected to get the sufficient conversion in the calculation frequency range. The amplitude of the total scattered electric field is the sum of the incident and scattered components, which given by,

$$|E| = \sqrt{|E^i|^2 + |E^s|^2} \quad (5)$$

Example of the calculation are shown in Figs. 2 and 3. The calculation parameters are listed in Table 1. Figure 2 shows the relationship between the scattered electric field strength normalized by that of the incident wave and the distance from the sphere surface. In this figure, the diameter of the sphere is 50 cm.

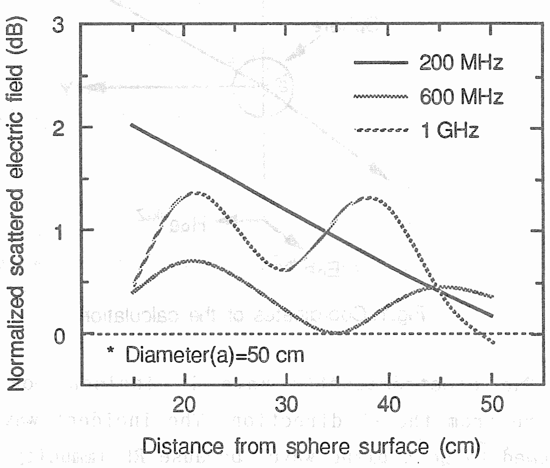
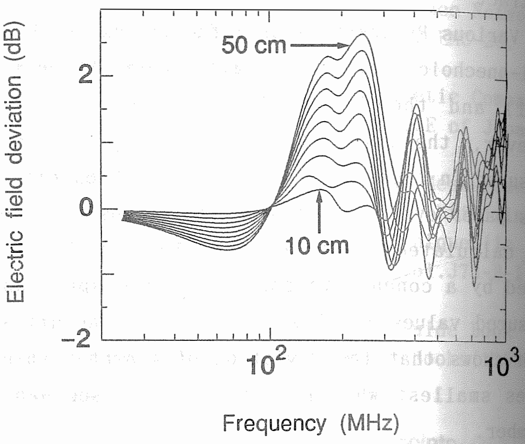


Fig.2 A calculation result of scattered electric field

Figure 3 shows the difference between the electric field strengths with and without the conductive sphere as a function of distance from the sphere surface. This figure shows that the electric field deviation is less than 1 dB when the incident wave-length is than ten times the sphere diameter.

Table 1. Calculation parameters

Frequency	20 MHz - 1 GHz
Sphere diameter	30, 50 cm
Calculated position	5 cm steps between 10 and 50 cm from sphere surface
Calculated direction	+Y and +Z axes in Fig.1.



Distance from the sphere : 10 - 50 cm

Fig. 3 A result of the calculation (Diameter(a)=50 cm, +Z direction)

2.2 Measurement of the scattered electric field

The scattered electric field strength was measured in a semi-anechoic chamber, a GTEM cell and a TEM cell. The results were compared with the calculated values. Figure 4 shows the experimental setup for the GTEM cell. The scattered electric field was measured with an electric field sensor

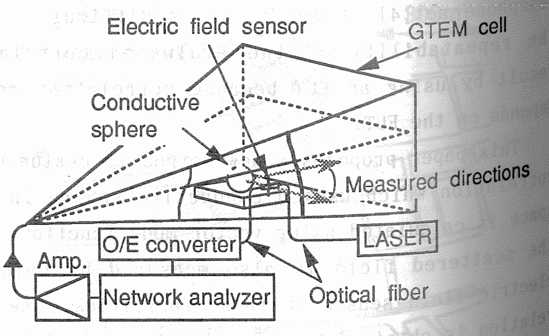


Fig.4 Setup for scattering field measurement in GTEM cell

using a LiNbO3 optical modulator[6]. This sensor has an optical fiber link and high-impedance resistive loading elements to improve the operating bandwidth. The sensor was moved from 10 to 50 cm from the sphere surface in 5 cm steps. The measured frequency range is from 20 MHz to 1 GHz for the semi-anechoic chamber and the GTEM cell, and from 20 to 200 MHz for the TEM cell. The dimensions of the facilities on experiment are summarized in Table 2.

Measurements for the GTEM cell are shown in Fig. 5. First, the deviation between the scattered electric field with and without the sphere were measured as a function of sensor position. Second, the electric field deviation normalized by that at the distance of 50 cm is represented in this figure. The deviation increases when the frequency increases.

Table 2. Size of the test facilities used in this investigation

	Size (length×height×depth)	Distance between septum and outer conductors
Semi-anechoic chamber	20 m × 8 m × 15 m	———
GTEM cell	7.7 m × 2.8 m × 4.0 m	1.5 m
TEM cell	3.8 m × 2.0 m × 2.0 m	1.0 m

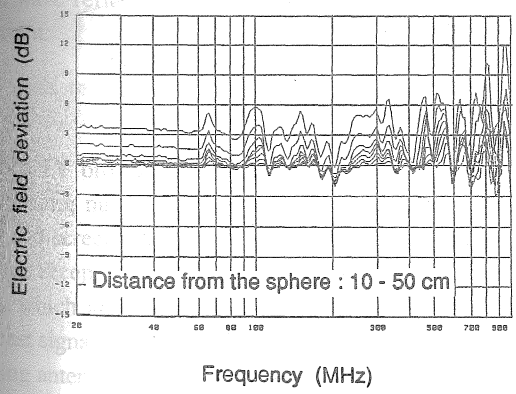


Fig.5 A result of the measured scattered field (Diameter(a)=50 cm, +Z direction)

2.3 Investigation of the correlations

The calculated and measured scattered fields were compared to investigate the correlations among the semi-anechoic chamber, the GTEM cell and the TEM cell. Figures 6 and 7 show the maximum deviation between calculated and measured scattered field for these three facilities.

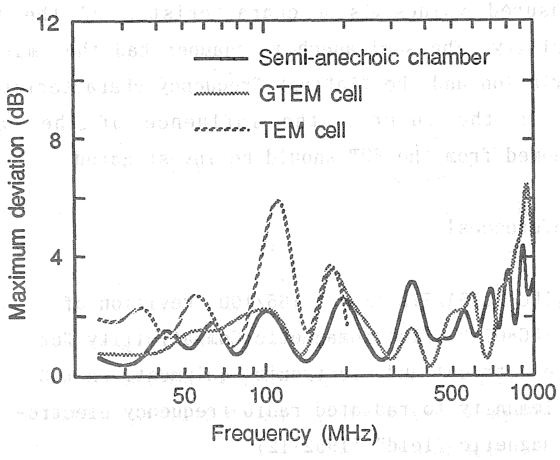


Fig.6 Maximum deviation between measured and calculated scattered field (Diameter(a)=30 cm)

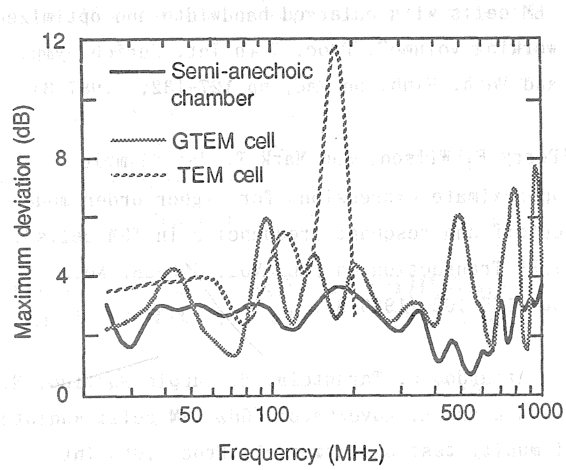


Fig.7 Maximum deviation between measured and calculated scattered field (Diameter(a)=50 cm)

The deviation of the TEM cell remarkably increases at frequencies above 100 MHz. This means that the higher-order modes are easily generated in the TEM cell. The deviation on the GTEM cell is larger than that of the semi-anechoic chamber because of the influence of the reflection from the septum and outer conductor.

This investigation reveals that the difference between the electric field with and without the conductive sphere is the smallest when the semi-anechoic chamber is used.

3. Conclusion

The correlations among test results obtained from various test facilities were evaluated by comparing calculated electric fields scattered by a conductive sphere in free space and the measured scattered field in each test facility. The result shows that the deviation between calculated and measured values is a characteristic of the test facility. The semi-anechoic chamber had the smallest deviation and the flattest frequency characteristic.

In the future, the influence of the cable stemmed from the EUT should be investigated.

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