A Study of RF Absorber for Anechoic Chambers Used in the Frequency Range for Power Line Communication System

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Abstract—Power line communication (PLC) system is spreading as a new communication system without providing new infrastructure for network communication. However, It is needed to investigate the EMI problem caused by PLC, and it is often tested in an anechoic chamber and an open area test site (OATS). The semi anechoic chamber lined ferrite tiles used for EMC testing is not generally designed in the frequency range from 2 MHz to 30 MHz used for PLC system. This paper presents characteristics of conventional ferrite absorber which are used for a semi anechoic chamber (SAC) and site attenuation of the semi anechoic chamber in the frequency range used for PLC system.

1. Introduction

Recently, power line communication (PLC) system is spreading as convenient communication without providing new infrastructure for network communication. PLC system is using utility-owned power lines in the low-voltage mains grid to provide broadband Internet access in areas that are mostly residential. PLC uses unshielded, low-voltage power line distribution cables inside and outside of buildings as transmission media with high speed rates. Because PLC system uses the frequency range from 2 MHz to 30 MHz in order to communicate information, it becomes a subject of discussion to influence other electrical or electronic device. Therefore RF emissions from PLC system have been investigated in an anechoic chamber or an open area test site (OATS). Ferrite absorber with thickness from about 6 mm to 7 mm without some kind of pyramidal absorbers is used for 3 m or compact anechoic chamber (CAC), because the ferrite absorber has excellent absorption in the frequency range from 30 MHz to 1 GHz. In this paper, we discussed the characteristics of conventional ferrite absorber which is used for a 3 m or a CAC from 2 MHz to 30 MHz utilized for PLC system. Site attenuation characteristics of the conventional 3 m anechoic chamber were investigated.

Figure 1: Semi anechoic chamber lined ferrite tiles. (Ferrite tiles are installed back of the white interior finishing panel. Pyramidal ferrite absorbers are installed back of the black color rea).

2. Characteristics of Ferrite Absorber

2.1. Measurement Method

The Reflection characteristics, relative permittivity and relative permeability of ferrite absorbers were measured using the coaxial line with a diameter of 39 mm (The 39 D Coax.) in Figure 2, and the square coaxial line with a section of 300 mm × 300 mm (The Square Coax.) in Figure 3. The 39 D Coax is used for measurement complex permittivity and permeability. In this paper, it was used to measure characteristics of ferrite material without small gaps. It is well known that minute air gaps between ferrite tiles reduce absorption of ferrite absorber, and the Square Coax is able to evaluate the reflection of ferrite tiles including the air gaps. This measurement procedure of the Square Coax is same way as the $1.8\,\mathrm{m} \times 1.8\,\mathrm{m}$ Large Square Coax which had been developed and presented [1]. The Square Coax is an outer conducting line with a section of $302\,\mathrm{mm} \times 302\,\mathrm{mm}$ and an inner conducting line with a section of $98\,\mathrm{mm} \times 98\,\mathrm{mm}$, and eight pieces of ferrite tiles were arranged. A special feature is to set two ports in order to measure full complex S parameter (S11, S22 and S21) of a test sample, and it is possible to calculate complex permittivity and permeability from the measured S parameter of the test sample. As it is well known, it is very important to know the complex permittivity and permeability. Because the characteristics impedance of the Square Coax was about $60\,\Omega$, there was impedance mismatching between a $50\,\Omega$ coaxial cable and a port of the Coax. To solve this mismatching problem, a serial resistance was inserted at the end of inner conducting line, and it could reduce inner reflection. On the other hand, the mismatching at the port of viewpoint from outside increased by the inserted serial resistance. The complex S parameters which removed the redundant reflections are driven by quotation (1), (2), and (3).

$$S11_{cor} = \frac{S11_{sample} - S11_{air}}{1 - S11_{air}} \quad \mathrm{RPR}_{\mathrm{S11}} \tag{1}$$

$$S22_{cor} = \frac{S22_{sample} - S22_{air}}{1 - S22_{air}} \quad \mathrm{RPR}_{\mathrm{S22}} \tag{2}$$

$$S21_{cor} = \frac{S21_{sample}}{S21_{air}} \tag{3}$$

Where

$$\mathrm{RPR}_{\mathrm{S11}} = e^{J \cdot \frac{2\pi \cdot 2(EL_{s11} - d)}{\lambda}} \tag{4}$$

$$\mathrm{RPR}_{\mathrm{S22}} = e^{J \cdot \frac{2\pi \cdot 2 \cdot EL_{s22}}{\lambda}} \tag{5}$$

$$\mathrm{RPR}_{\mathrm{S21}} = e^{J \cdot \frac{2\pi \cdot d}{\lambda}} \tag{6}$$

Where
d: Thickness of test sample
λ: Wave length
$\mathrm{EL}_{\mathrm{S11}}$: Electric Length between the calibration point of port 1 and the sample set point
$\mathrm{EL}_{\mathrm{S22}}$: Electric Length between the calibration point of port 2 and the sample set point

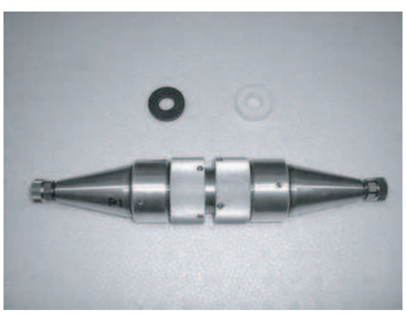


Figure 2: The 39D Coax and test sample.

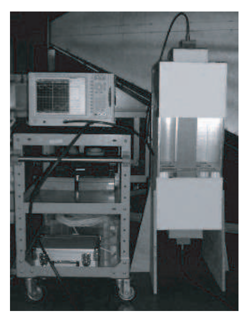


Figure 3: The 300 Square Coax.

2.2. Fundamental Characteristics of Ferrite Absorber

At first the fundamental characteristics of the Ni–Zn–Cu ferrite absorber with 6.3 mm thick was investigated below 30 MHz, in order to confirm the characteristics which is influenced by minute air gaps between ferrite tiles. The 39 D Coax and the Square Coax were each used for obtaining the fundamental characteristics of without or with the influence of minute air gaps. Figure 4 shows the shape of test sample for 39 D Coax, and Figure 5 shows the eight piece of ferrite tiles are inserted in the Square Coax.

Figure 6 shows chart of the reflectivity of conventional ferrite absorber which was measured using the 39 D Coax. In this chart, this ferrite absorber does not have sufficient absorbing characteristics in the frequency range from 3 MHz to 30 MHz used for PLC system. The absorbing characteristics of eight piece of ferrite tile including minute air gaps were reduced compared from the measured data of ferrite absorber with no air gap.

These air gaps were not artificially given between ferrite tiles, ferrite tiles were arranged to keep minimum air gaps. The complex permittivity and permeability are shown in Figures 7 and 8, and the value of the imaginary permeability which is loss paragraph is reduced by minute air gaps.

Figure 4: Test sample for 39D Coax.

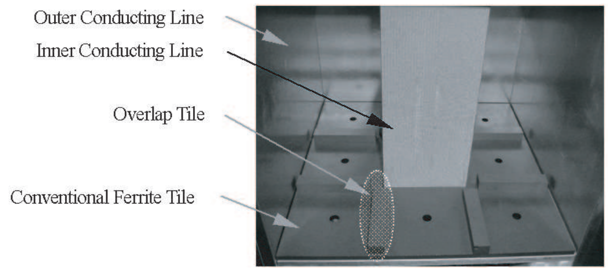


Figure 5: Arrangement of Ferrite Tiles in the 300 Square Coax.

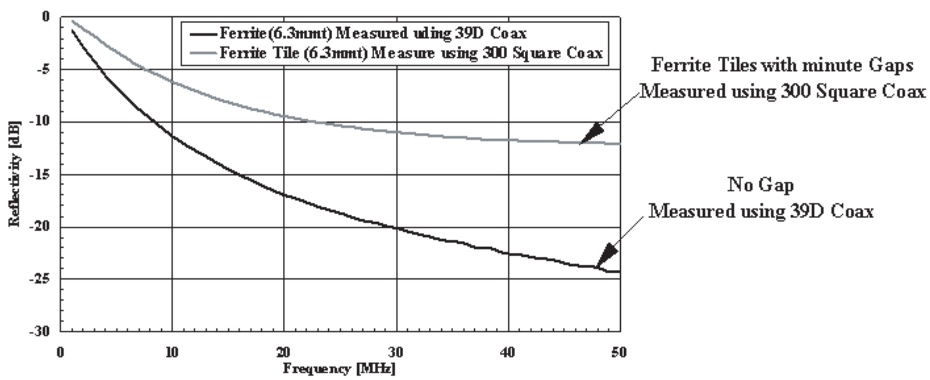
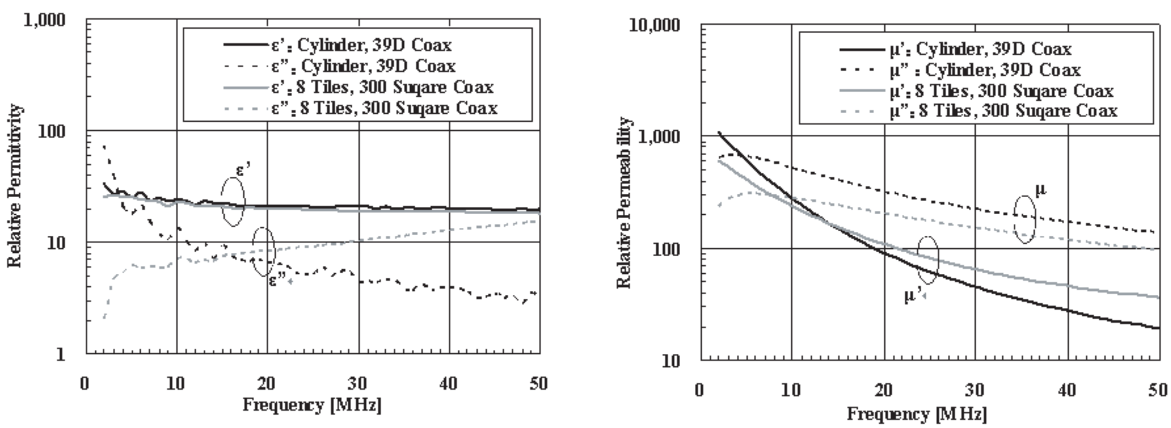


Figure 6: Measured permittivity and permeability of ferrite absorber with short end.



(a) Measured relative complex permittivity (b) Measured relative complex permeability

Figure 7: Measured permittivity and permeability of ferrite absorber. (Compare of 39 D and 300 Square Coax.)

2.3. Various Measurement Results

The following methods were investigated in order to improve the absorption of the ferrite tiles with minute air gaps.

(1) Change the thickness of the ferrite.

(2) Put overlap tile onto the joint between ferrite tiles as shown in Figure 5.

(3) Combine a carbon material board on the ferrite absorber.

Figure 8 shows the reflectivity of the ferrite tiles with a thickness of 6.3, 8, 10 and 12 mm thick. The reflectivity became to reduce with to thicken the ferrite below 15 MHz, and it became larger over 10 mm thick in the frequency range above 15 MHz. To put overlap tile onto the ferrite tile reduced the reflectivity of the ferrite in Figure 9.

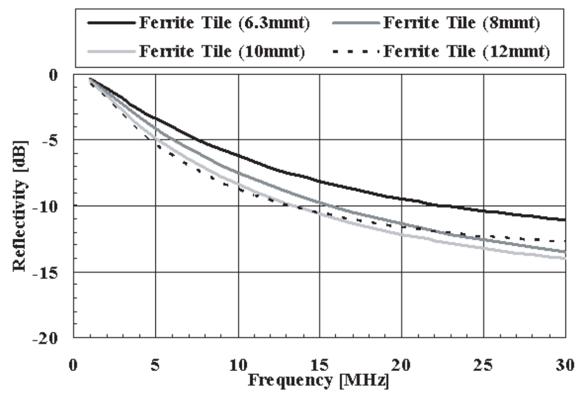


Figure 8: Relation reflectivity and thickness of ferrite.

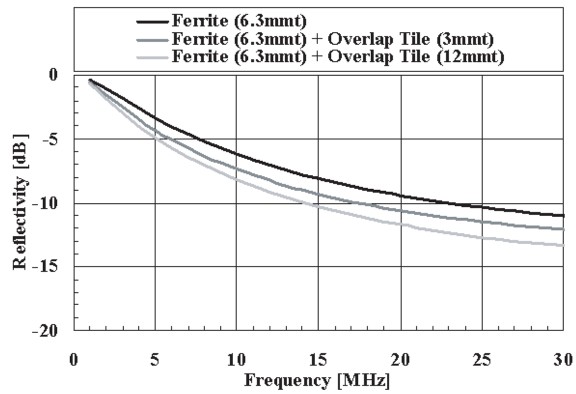


Figure 9: Reflectivity of using overlap tile .

It was studied that combining carbon material was reduced the reflectivity of the conventional ferrite from 3 MHz to 30 MHz used PLC system. Figure 10 shows the relative complex permittivity of the carbon material (Polypropylene dispersed carbon powder) for combining to the ferrite absorber. Figure 11 shows the measured reflectivity of the double layer absorber composed the ferrite with 12 mm thick and carbon material. The resonance frequency was lower with to thicken the carbon material.

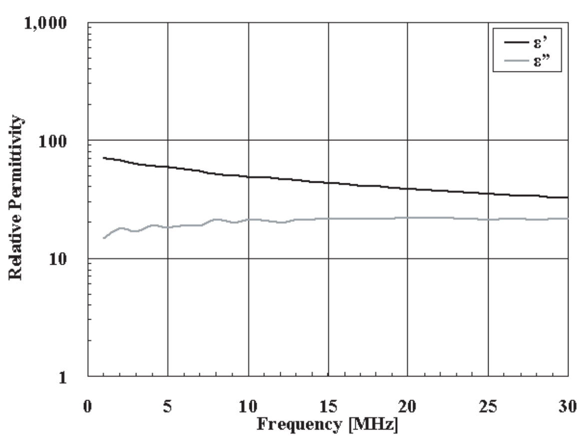


Figure 10: Relative permittivity of carbon material

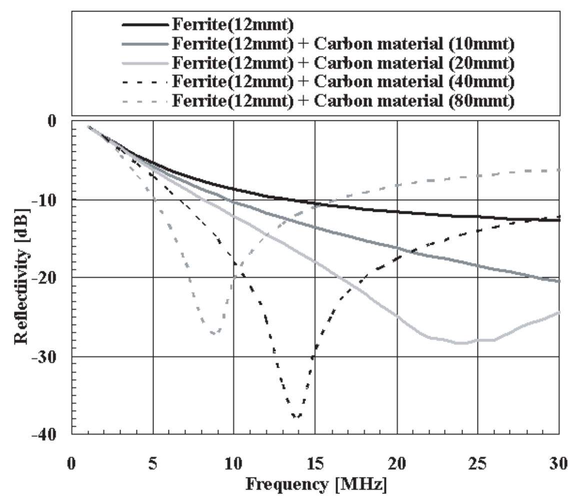


Figure 11: Reflectivity of combining carbon material.

3. Calculated Results of Site Attenuation of Semi Anechoic Chamber

Measurement layout for testing leaked E-field from PLC system is shown Figures 12 [2]. Figures 13 shows a layout of two 80 MHz tuned dipole antennas in order to calculate classical site attenuation (CSA) of a typical 3 m semi anechoic chamber lined ferrite tiles with 6.0 m wide × 9.0 m length × 5.5 m high. Test distance was 3 m, and the transmitting and the receiving antenna were each 1.5 m and 1.0 m high. The CSA of the SAC was calculated by ray tracing method, and the electro motive force (EMF) method was utilized for analysis of antenna [3]. The characteristics of the ferrite absorber which measured by the Square Coax was adopted for calculation.

Figure 14 shows the calculated of CSA of the SAC lined the ferrite tiles. To take notice of the CSA deviation of the 6.3 mm thick conventional ferrite without overlap tile, there were two large peak points at about 21 MHz and 48 MHz at horizontal polarization, and there was one large peak point at about 16 MHz at

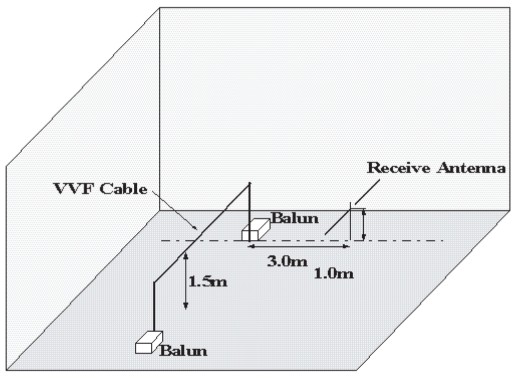


Figure 12: Layout for leaked E-field from PLC.

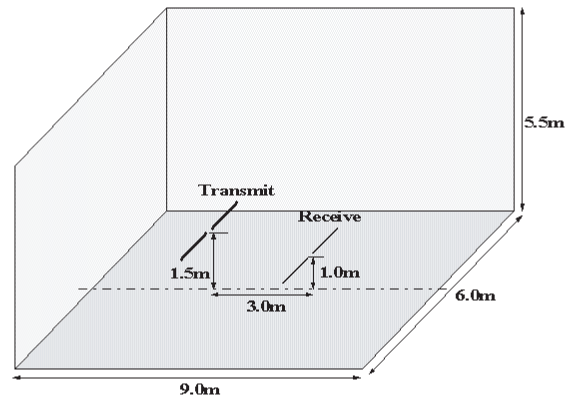


Figure 13: Model for CSA calculation of anechoic chamber.

vertical polarization. These peak points were caused by the resonance of the chamber and insufficient absorbing characteristics of the conventional ferrite absorber. The CSA deviation was reduced to put the overlap tile onto air gap between ferrite tiles. Furthermore CSA deviation was improved to about ±4 dB by adopting the double layers absorber composed the 12 mm thick ferrite tile and the 80 mm thick carbon material. The results showed that there was a possibility to evaluate PLC system in the SAC lined conventional ferrite absorber without long pyramidal absorber.

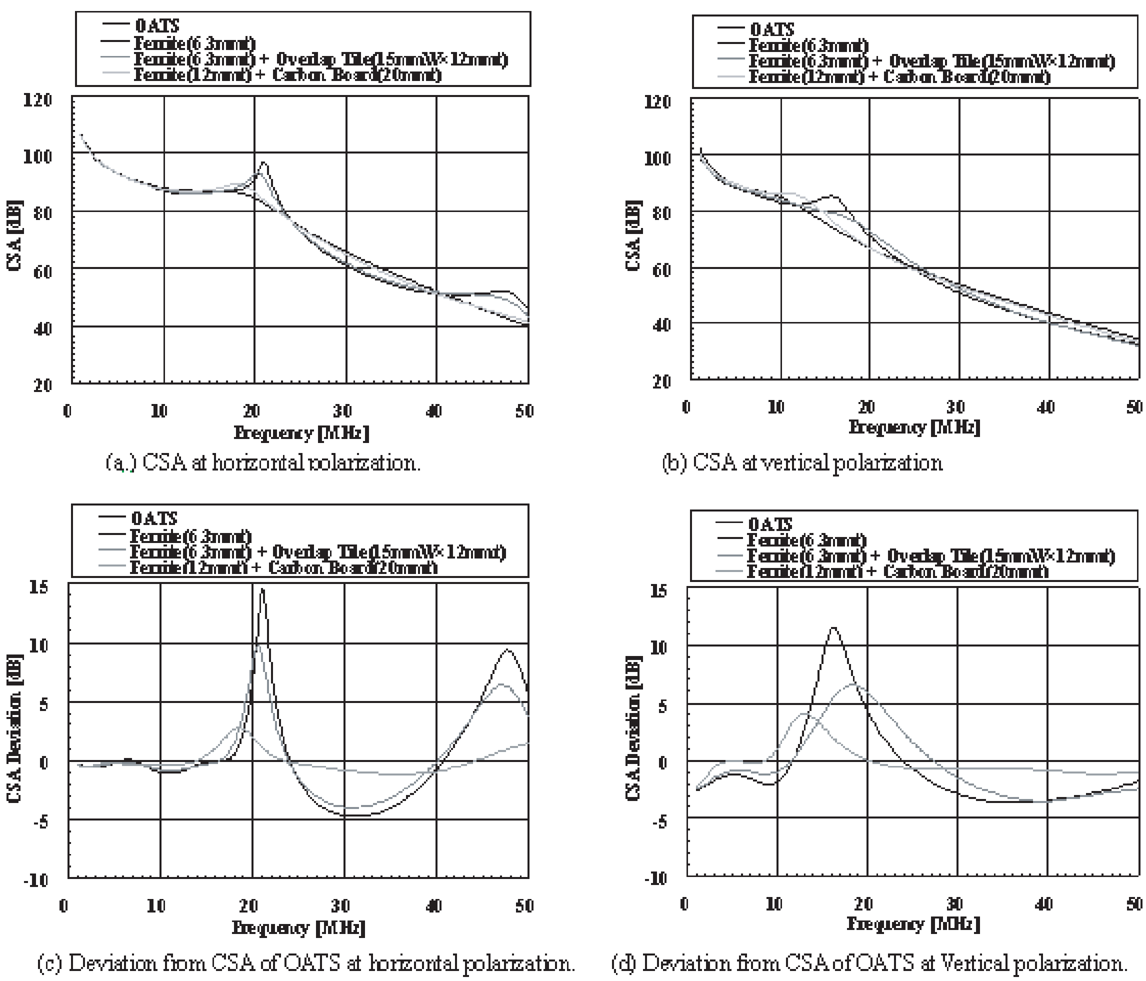


Figure 14: Calculated CSA of semi-anechoic chamber lined conventional ferrite tiles.

4. Conclusion

The conventional ferrite absorber had not excellent absorption below 30 MHz, and it was able to improve by changing thickness of ferrite tile, adding overlap tile onto air gap or combining the carbon material with the ferrite tile. The calculated CSA deviation was improved to about ±4 dB by adopting the double layers absorber composed the 12 mm thick ferrite tile and the 80 mm thick carbon material, it showed that there was a possibility to evaluate PLC system in the SAC lined conventional ferrite absorber without long pyramidal absorber. However the ray tracing method does not have sufficient accuracy below 100 MHz [4]. We will calculate the site attenuation by FDTD method, and will measure the actual site attenuation of the SAC which lined the conventional ferrite tiles.

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