A Study on Development of the EM Wave Absorber for ETC System

Soo Hoon Park[1] · Dong Il Kim[1] · Young Man Song[2] · Sang Gil Yoon[1]

Abstract

In this paper, the EM wave absorber was designed and fabricated for countermeasure against EMI from a ceiling of a tollgate in ETC system. We fabricated several samples in different composition ratios of MnZn-ferrite, Carbon, and CPE(Chlorinated Polyethylene). Absorption abilities were simulated in accordance with different thicknesses of the prepared absorbers and changed complex relative permittivity and permeability according to composition ratio. The optimized mixing ratio of MnZn-ferrite, Carbon, and CPE was found as 40:15:45 wt.% by experiments and simulation. Then the EM wave absorber was fabricated and tested using the simulated data. As a result, the developed EM wave absorber has the thickness of 3.3 mm and absorption ability was more than 20 dB in the case of normal incidence and more than 11 dB for the incident angle from 15 to 45 degrees at 5.8 GHz. Therefore, it was confirmed that the newly developed absorber can be used for ETC system.

Key words : ETC, EM Wave Absorber, MnZn-ferrite, Carbon, Permittivity, Permeability.

Ⅰ. Introduction

Metropolis is faced with serious traffic jam as the advancement of society and development of economy. The government has introduced intelligent transport system (ITS) for the solution of these problems. ITS offers the service of various form combining hardware such as road building, traffic, communication technology, and software. Especially, electric toll collection(ETC) system is possible to realize ITS. ETC system is non-stop auto collection system through an application of dedicated short range wireless communication(DSRC), which uses microwave of the 5.8 GHz. ETC is a communication system between a roadside antenna at the toll gate and a vehicular antenna inside the car[1]. When the operation of ETC system was started, communication error was caused in ETC Environment due to undesired electromagnetic (EM) waves from walls, ETC gates, or other possible nearby objects. The optimal use of EM wave absorber is a possible way to mitigate this problem, and several kinds of absorbers are used in various places, such as plate type used for a ceiling of a tollgate[2] or sheet type used for nearby objects as shown in Fig. 1[3],[4].

In this paper, we attempt to fabricate EM wave absorbers, the thickness of which is less than 3.5 mm, absorption ability is over 20 dB at 5.8 GHz for a ceiling of a tollgate in ETC system. The EM wave absorber samples were made of MnZn-ferrite(magnetically lossy material) and carbon(conductively lossy material) with CPE. Then their reflection coefficients were measured.

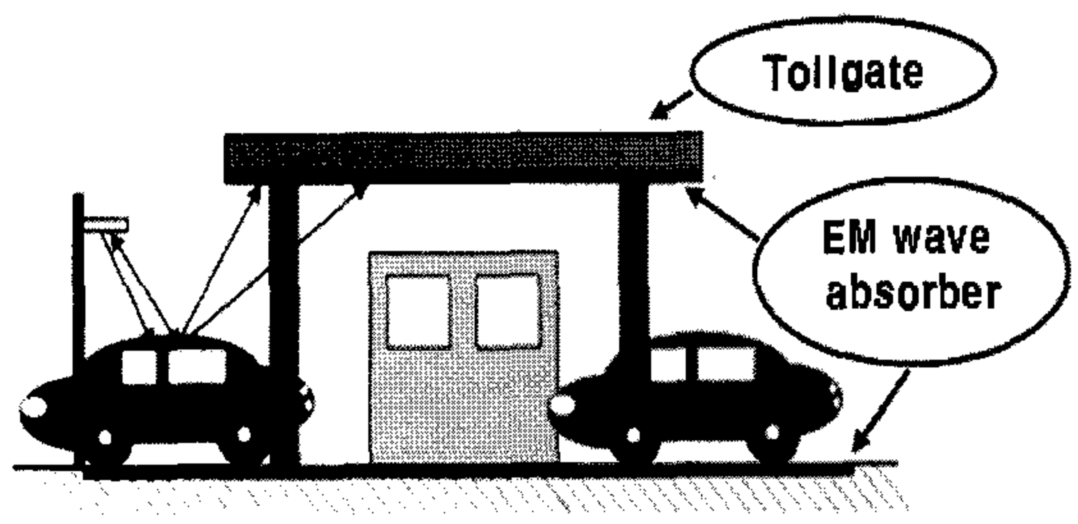

Fig. 1. EM wave absorber used ETC system.

The complex relative permittivity($\varepsilon_r = \varepsilon'_r - j\varepsilon''_r$) and complex relative permeability($\mu_r = \mu'_r - j\mu''_r$) are calculated by the measured data. The EM wave absorber for ETC system is simulated and fabricated based on the simulated design.

Ⅱ. Design of EM Wave Absorber

For an EM wave absorber made of a conductor-backed single layer as shown in Fig. 2, the return loss (RL) can be obtained from the equivalent circuit as follows

$$RL = -20\log\left|\frac{z_{in}-1}{z_{in}+1}\right| \quad [dB] \tag{1}$$

Here, z_{in} is the normalized input impedance from the surface of absorber.

The normalized input impedance is expressed as equation (2)[5].

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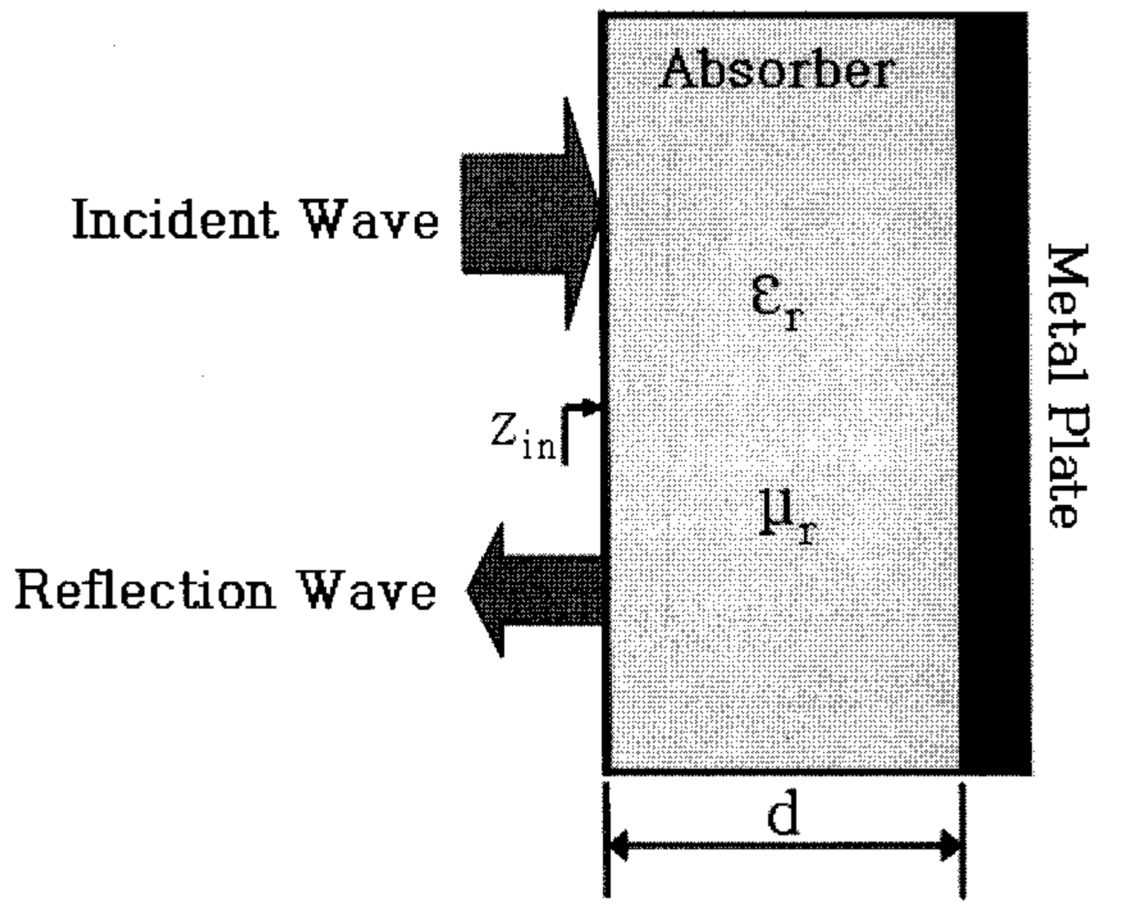


Fig. 2. EM wave absorber.

$$z_{in} = \sqrt{\frac{\mu_r}{\varepsilon_r}} \tanh\left(j\frac{2\pi}{\lambda}\sqrt{\varepsilon_r \mu_r}\, d \right) \quad (2)$$

Here, λ is the wavelength, d is the thickness of the sample, ε_r is the complex relative permittivity, and μ_r is the complex relative permeability. The situation in *RL* more than 20 dB("matching situation") for incidence of an electromagnetic wave is given by [5],[6]

In case of normal incidence wave :

$$\sqrt{\frac{\mu_r}{\varepsilon_r}} \tanh\left(j\frac{2\pi}{\lambda}\sqrt{\varepsilon_r \mu_r}\, d \right) = 1 \quad (3)$$

In case of oblique incidence wave :

For the TE wave

$$\frac{\mu_r \cos\theta}{\sqrt{\varepsilon_r \mu_r - \sin^2\theta}} \tanh\left(j\frac{2\pi d}{\lambda}\sqrt{\varepsilon_r \mu_r - \sin^2\theta} \right) = 1 \quad (4)$$

and for the TM wave

$$\frac{\sqrt{\varepsilon_r \mu_r - \sin^2\theta}}{\varepsilon_r \cos\theta} \tanh\left(j\frac{2\pi d}{\lambda}\sqrt{\varepsilon_r \mu_r - \sin^2\theta} \right) = 1 \quad (5)$$

Ideal EM wave absorber can be designed using equation (3), (4), and (5) and it was recognized that the important parameter is the complex relative permittivity, the complex relative permeability, and thickness of EM wave absorber[6].

Ⅲ. Preparation and Measurements of Samples

3-1 Preparation of Samples

We used Carbon and MnZn-ferrite(Carbon-Ferrite absorber) as the raw material in order to prepare sheet-type EM wave absorbers. Carbon-Ferrite absorber is cheaper than pre-existing absorber and can be purchased easily in the market. Also Carbon is very light weight so that the developed EM wave absorber is to be suitable for ceiling of a tollgate in ETC system. Each material was mixed with CPE as a binder, and a sheet type absorber was fabricated by using an open roller. The open roller's surface temperature was controlled uniform by 70℃ during sample preparation because the surface temperature affects the EM wave properties of sheet- type absorbers[7]. In order to investigate the characteristics(material property and Absorption ability etc.) of samples which have a difference composition ratios of materials, EM wave absorber samples were fabricated by the composition ratios of Table 1. The fabricating process of an EM wave absorber is shown in Fig. 3.

Table 1. Composition ratio of sample.

Composition ratio of sample(wt.%)		
MnZn Ferrite	Carbon	CPE
35	5	60
	10	55
	15	50
40	5	55
	10	51
	15	45
45	5	50
	10	45
	15	40

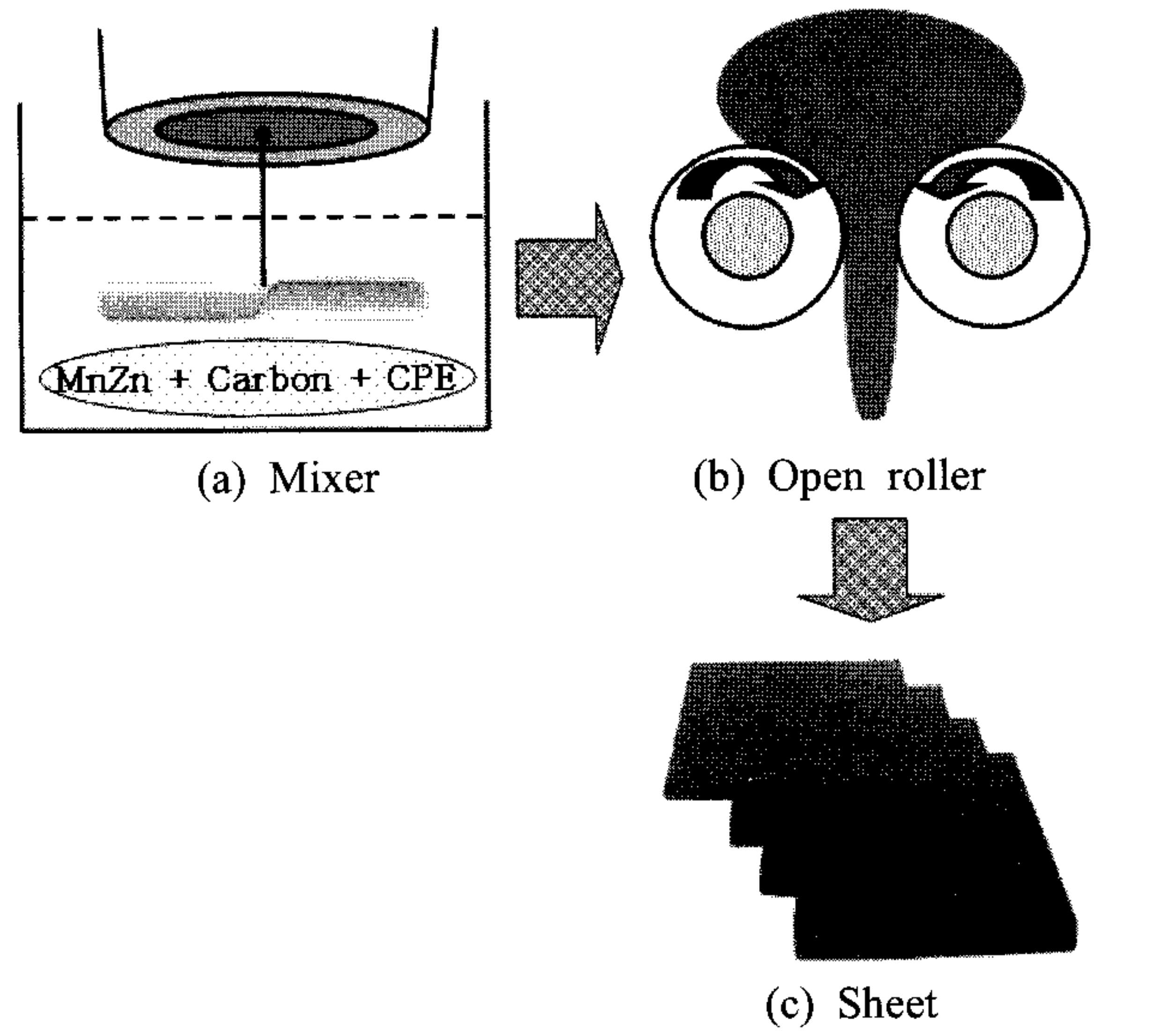


Fig. 3. Fabricating process of an EM wave absorber.

3-2 Measurements of Samples

For investigating of the EM wave absorption abilities of the samples, the prepared sheet-type absorbers were punched into a toroidal shape with an inner diameter of 3.05 mm and an outer diameter of 6.95 mm(GPC7 type). The absorption abilities of the samples were investigated by using WILTRON-MODEL 360B network analyzer and gauged by measurement system as shown in Fig. 4. and Fig. 5 presents a photo of the sample holder and sheet-type sample and toroidal shape sample. and the material properties of these samples are calculated from S-parameter of samples through 1-21 method[8].

Ⅳ. Simulation and Results

We measured reflection coefficient of the EM wave absorber samples containing MnZn-ferrite and Carbon with CPE. Fig. 6 shows reflection coefficient of EM wave absorber samples containing difference composition ratio of materials in case of vertical incidence wave. The thickness of the samples shown in Fig. 5 is 4 mm. A sample

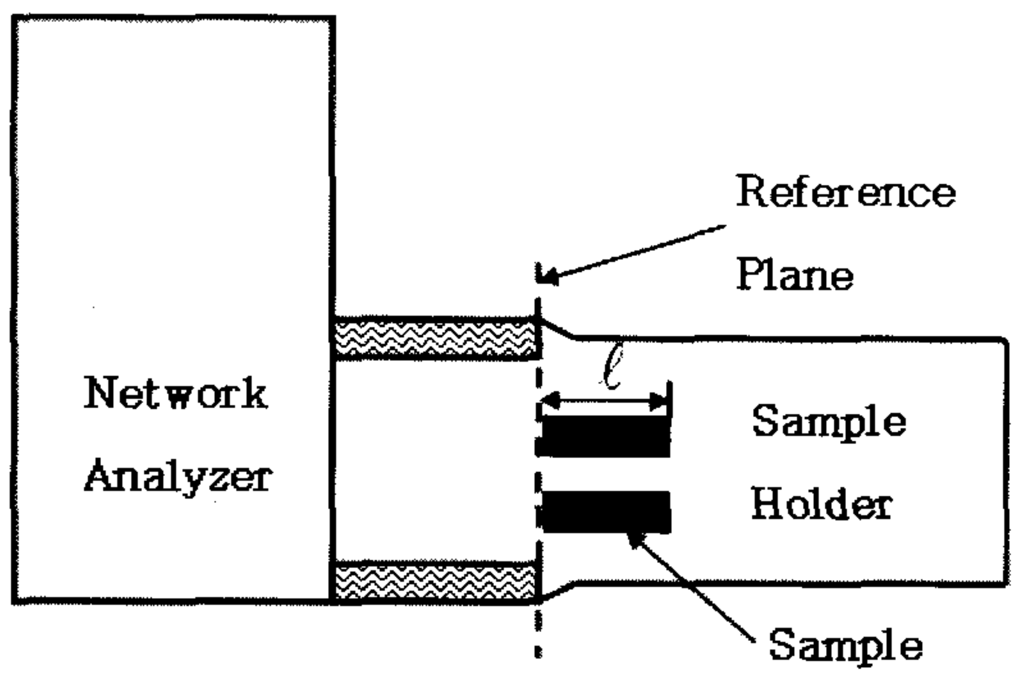


Fig. 4. Measurement system for reflection coefficient(Transmission line method).

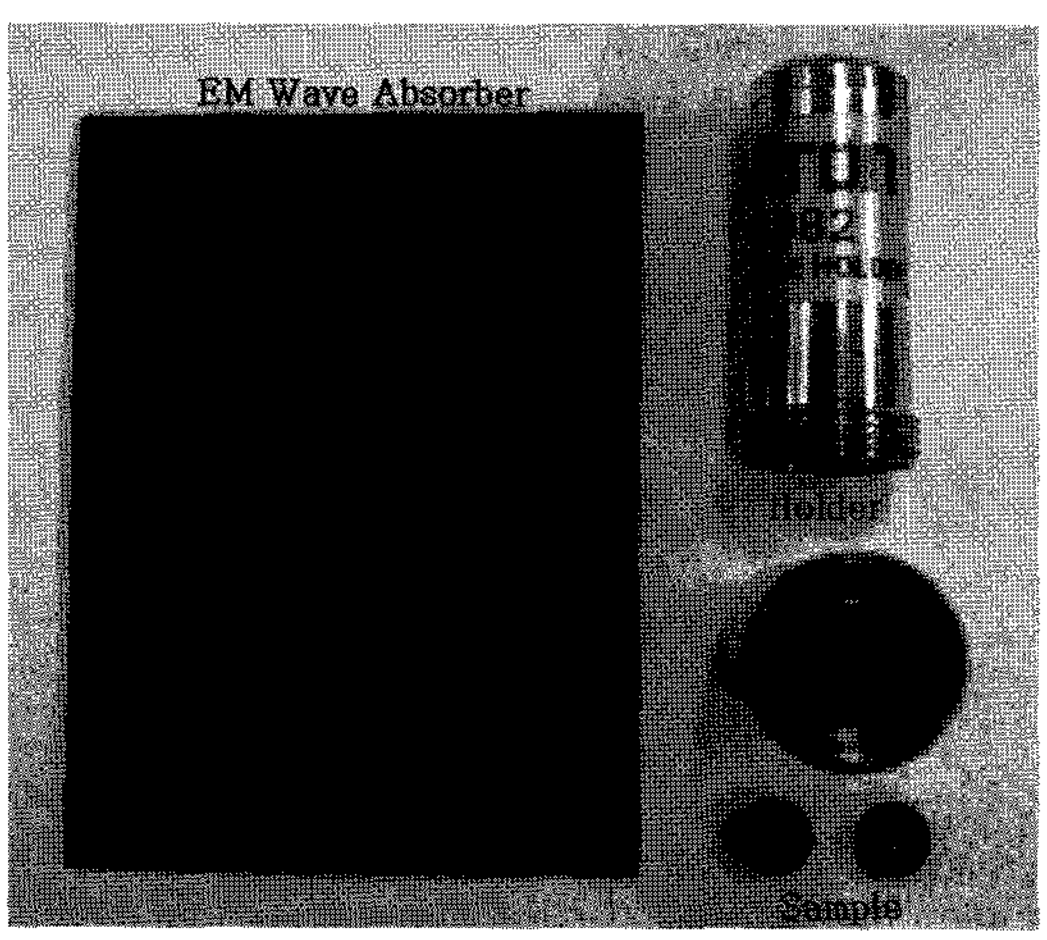
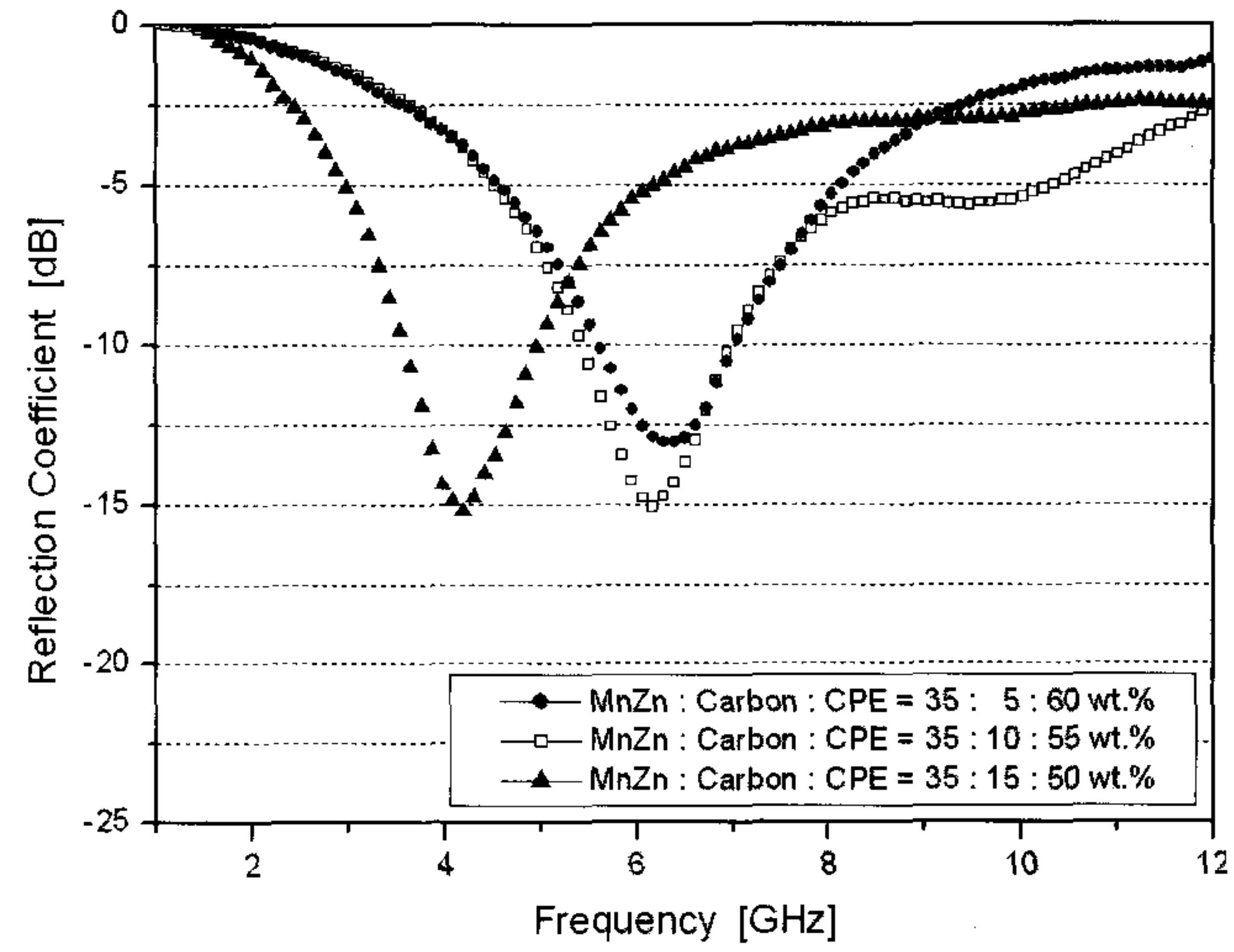
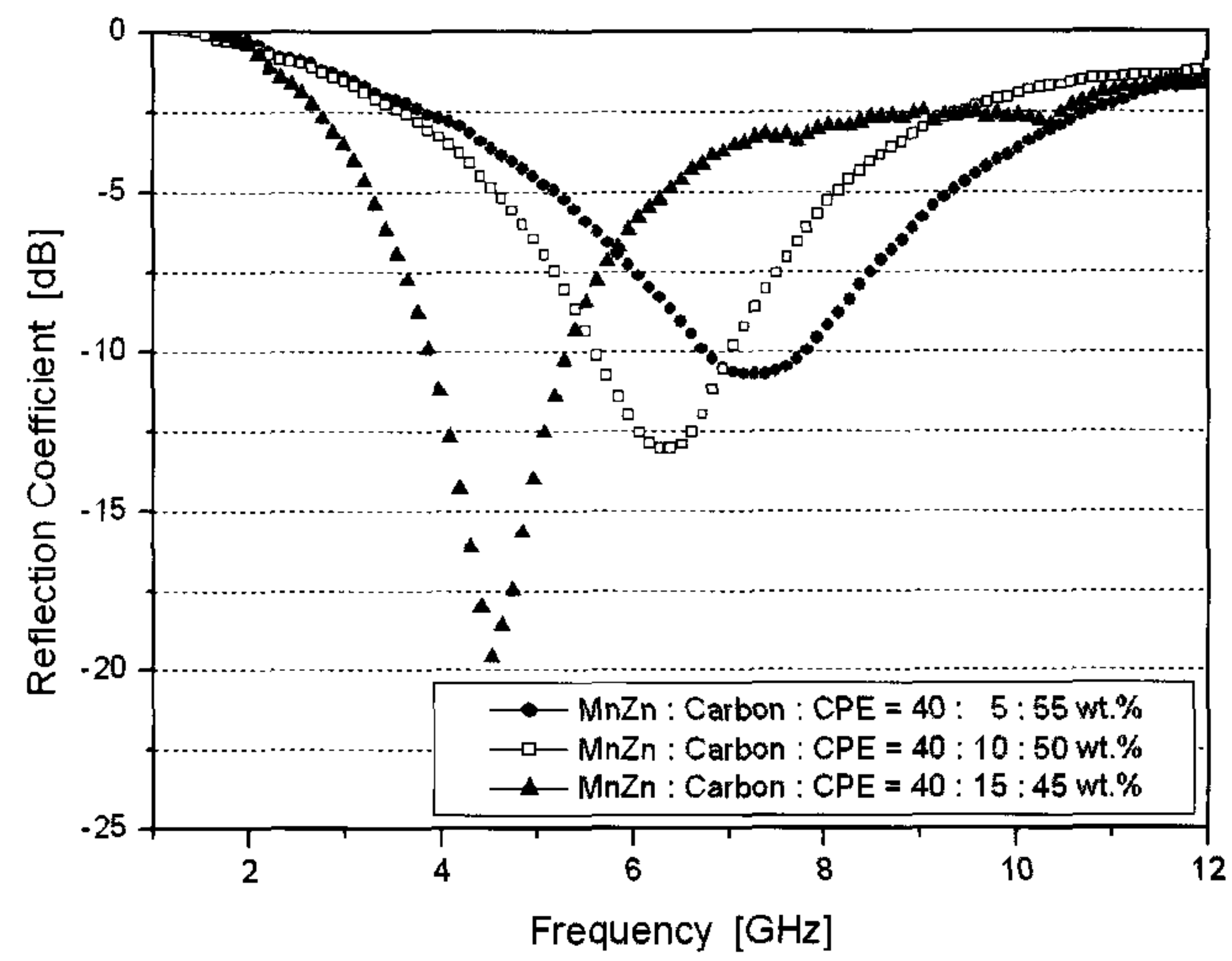


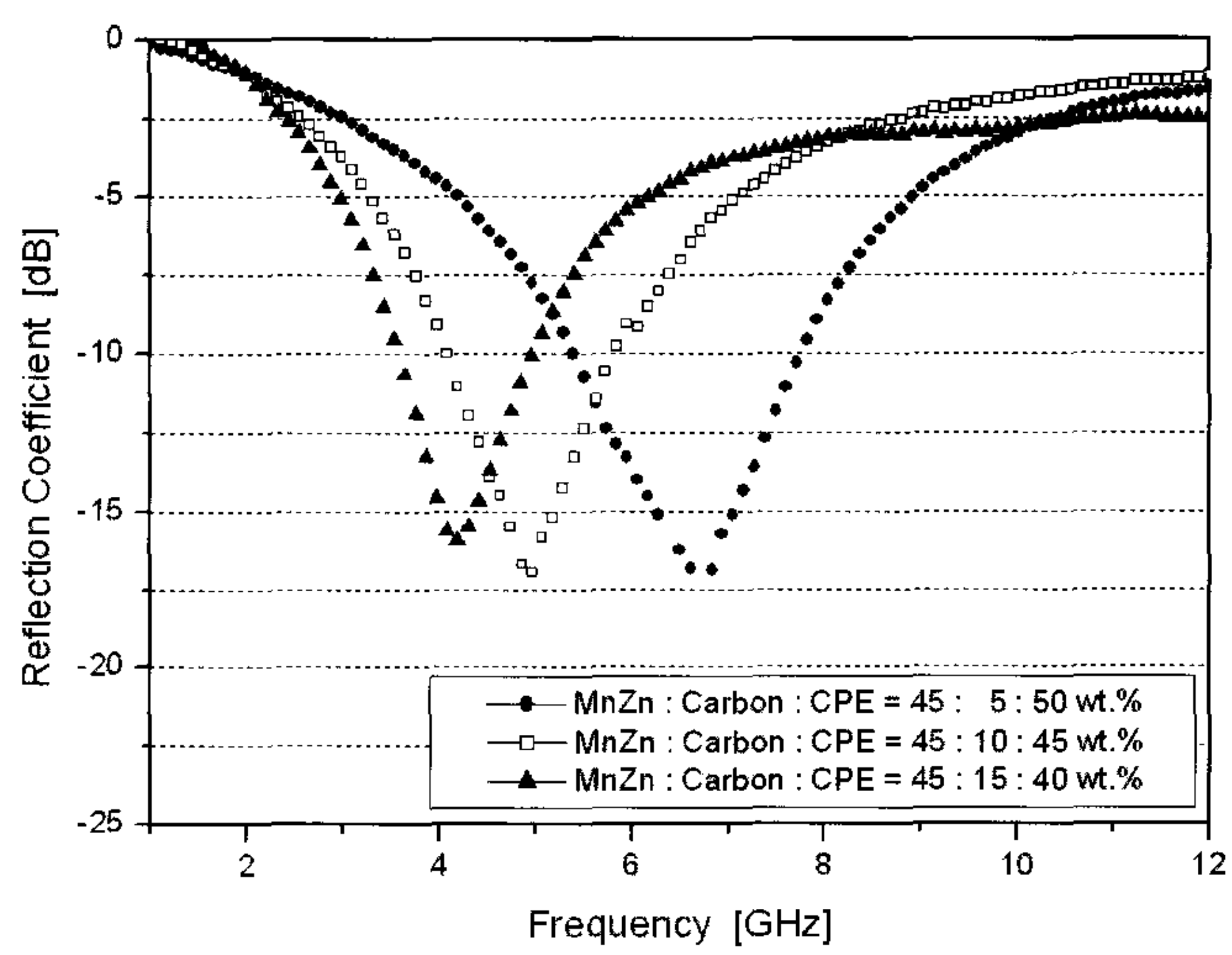
Fig. 5. A photo of EM wave absorber, sample holder and sample.



(a) Reflection coefficients of samples fixed ratio of MnZn-Ferrite(MnZn-Ferrite=35 wt.%)



(b) Reflection coefficients of samples fixed ratio of MnZn-Ferrite(MnZn-Ferrite=40 wt.%)



(c) Reflection coefficients of samples fixed ratio of MnZn-Ferrite(MnZn-Ferrite=45 wt.%)

Fig. 6. Reflection coefficients of samples with different composition ratio (Thickness: 4 mm).

consist of MnZn-ferrite:Carbon:CPE=40:15:45 wt.% showed the best absorption ability. This sample can be used for designing the EM wave absorber of ETC system. The optimum absorption ability of MnZn-ferrite and Carbon with CPE is simulated by using the measured material properties(relative permittivity and relative permeability) of samples and controlling the thickness of absorber based on equation 3. Fig. 7 shows design and manufacture course of EM wave absorber.

The optimized EM wave absorber with thickness of 3.3 mm was absorption ability more than 22.5 dB at 5.8 GHz as shown in Fig. 8. And we fabricated EM wave

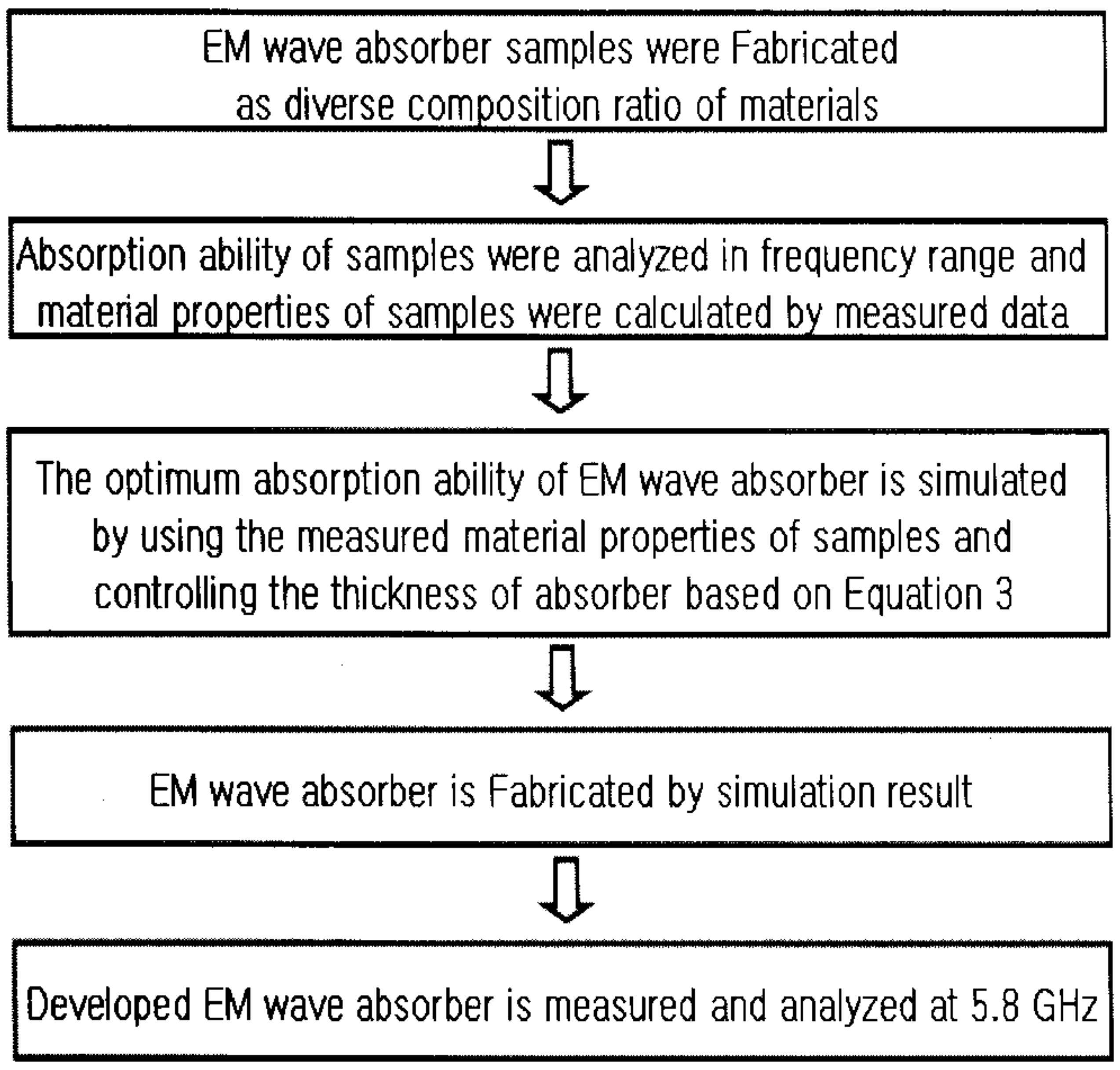


Fig. 7. Design and manufacture course of EM wave absorber.

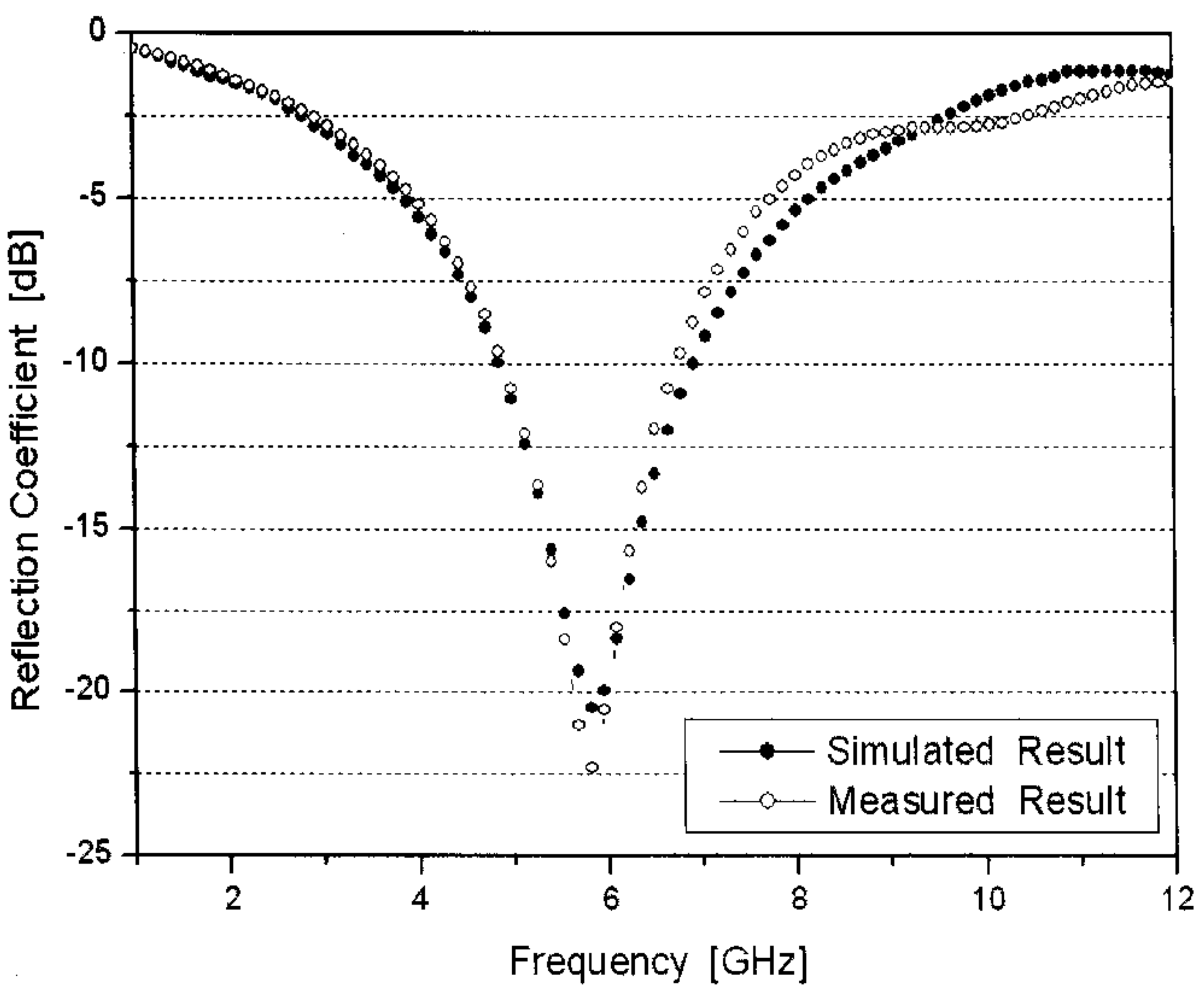
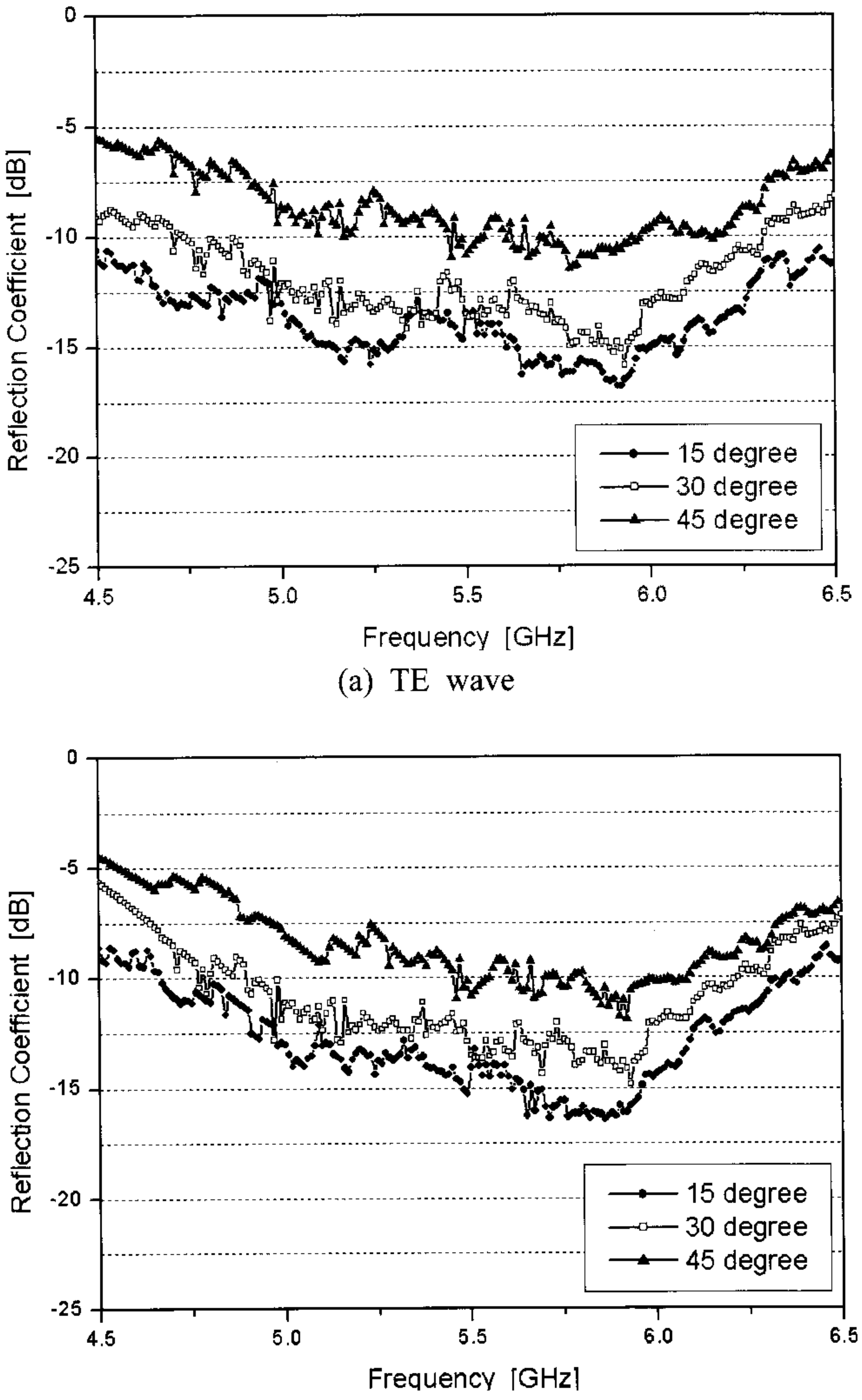


Fig. 8. Comparisons of simulated and measured results in case of vertical incidence wave.



(a) TE wave

(b) TM wave

Fig. 9. Reflection coefficient in case of oblique incidence wave(Thickness: 3.3 mm).

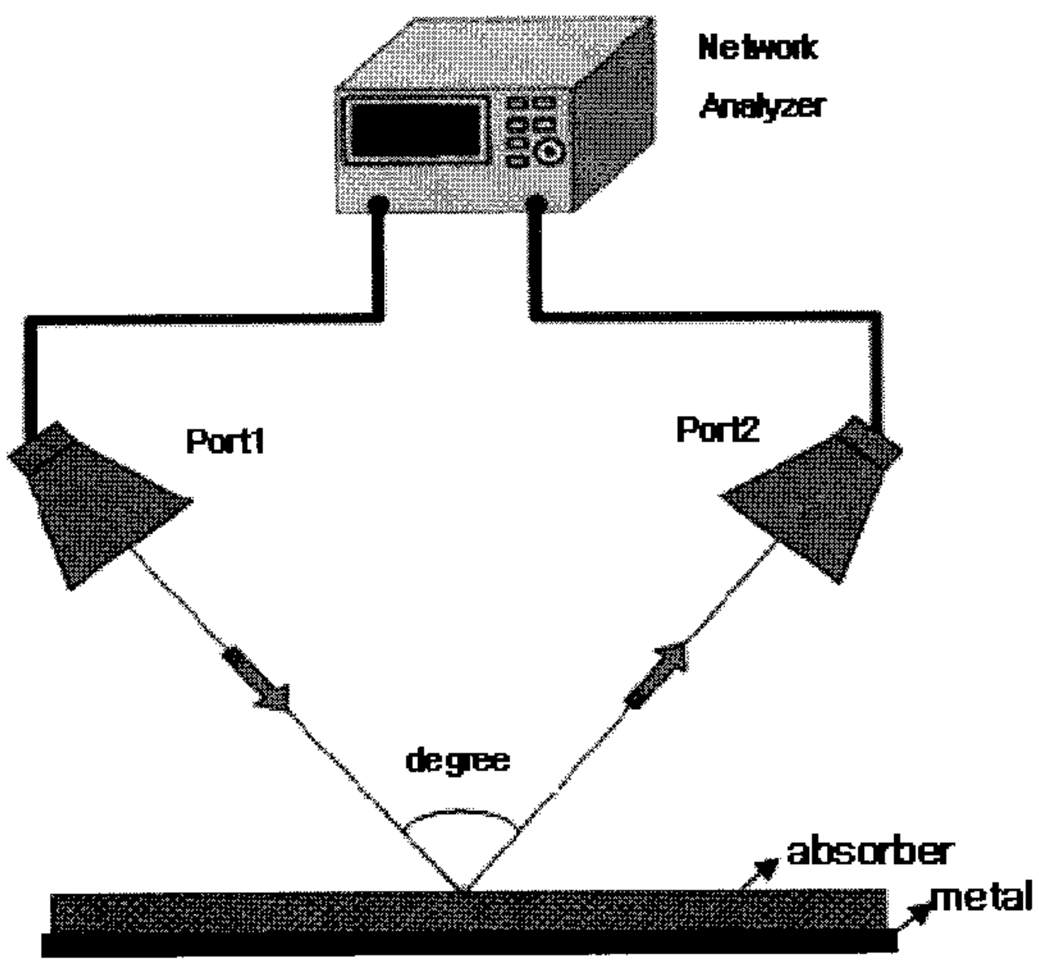


Fig. 10. Measurement system for reflection coefficient in case of oblique incidence wave(Free Space Method).

absorbers based on simulation results, thickness is 3.3 mm, absorption ability is more than 20 dB at 5.8 GHz as shown in Fig. 8. The simulated data agree very well with the measured ones.

When EM wave is oblique incidence wave, Fig. 9 shows the absorption ability of a fabricated EM wave absorber. Fig. 10 shows a measurement system for oblique incidence wave.

We confirmed the developed EM wave absorber have good absorption properties of more than 11 dB over incident angle ranging from 15 to 45 degree at 5.8 GHz by Free Space Measurements Method[9].

V. Conclusion

In this paper, we investigated EM wave absorber for a ceiling of a tollgate in ETC system. The EM wave absorber samples were made of MnZn-ferrite of a magnetic material and Carbon of a dielectric material with CPE. The absorption ability of the samples were measured by vector network analyzer. We compared the absorption abilities of each sample. These material properties were calculated from the S-parameter. EM wave absorber is designed by using material property and variation of thickness at 5.8 GHz. The optimized composition ratio of absorbing materials was MnZn-ferrite:Carbon:CPE=40:15:45 wt.%, and absorption ability of the EM wave absorber with thickness of 3.3 mm showed more than 20 dB in the case of normal incidence wave and more than 11 dB in the case of oblique wave incidence from 15° to 45° at 5.8 GHz. Therefore, it was confirmed that the newly developed absorber can be used for countermeasure against EMI from a ceiling of a tollgate in ETC system.

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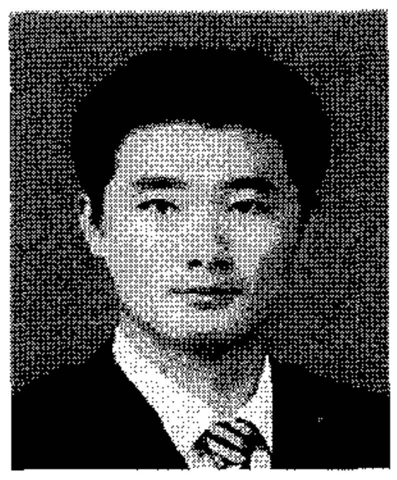

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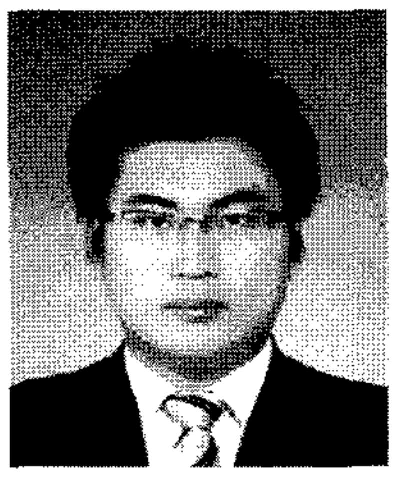

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