A Study on a Shape of Ferrite Electromagnetic Wave Absorber For an Anechoic chamber

Dong Il Kim[1) · June Young Son[1) · Dong Woo Ku[1) · Jae Young Bae[1)

Abstract

According to the progress of electronic industry and radio communication technologies, mankind might enjoy its abundant life On the other hand, serious social problems such as electromagnetic Interference(EMI) by unnecessary electromagnetic(EM) waves occur due to the increased use of electromagnetic waves. Therefore, the organizations such as Comite Internationale Special des Perturbations Radioelectrique(CISPR), Federal Communications Commissions(FCC), American National Standards Institute(ANSI), etc., have provided the standard of EM wave environment for the countermeasure of the electromagnetic compatibility (EMC). The absorption ability of EM wave absorber has required more than 20 dB, and the bandwidth has been required through 30 MHz to 1,000 MHz for satisfying the international standards about an anechoic chamber for EMI/EMS(electromagnetic susceptibility) measurement. From November of 1998, however, the CISPR has accepted the extended frequency band from 1 GHz to 18 GHz additionally in the bandwidth of EMI measurement[1] In this paper, we proposed the hemisphere shape-added absorber on the cutting cone-shape in order to satisfy the above requirements and carried out broadband design using the equivalent material constants method. Furthermore, the experiments were carried out over the frequency band from 30 MHz to 3 GHz, and the validity of the proposed design theory was confirmed.

I. Introduction

The EM wave absorber is used to construct an anechoic chamber to test and measure the EMI and EMS, To satisfy, however, the international standards such as IEC(International Electrotechnical Commission) 61000-4-3, CISPR A SEC 109, and ANSI C63.4-1991, more than 20 dB in absorption ability of EM wave absorber for anechoic chamber is needed and the bandwidth is required through 30 MHz to 18 GHz by the CISPR11[1].

However, a conventional single-layered ferrite absorber composed of the sintered ferrite tiles covers only 30 MHz to 400 MHz under the tolerance limits of 20 dB in absorption In addition, the grid ferrite EM wave absorber covers through 30 MHz to 800 MHz

Recently, we have proposed a ferrite absorber with the cutting cone-shape on a ferrite tile[2] In this paper, we propose a new type absorber in hemisphere type on cutting cone-shape The proposed EM absorber was designed by using the equivalent material constants method (EMCM)[3]-[5]

1) Dept of Radio Sciences & Engineering, Korea Maritime University

II. Design of New EM Wave Absorber

The proposed EM wave absorber is shown in Fig. 1 Figure 2 exhibits a side view and a floor plan of the proposed EM wave absorber

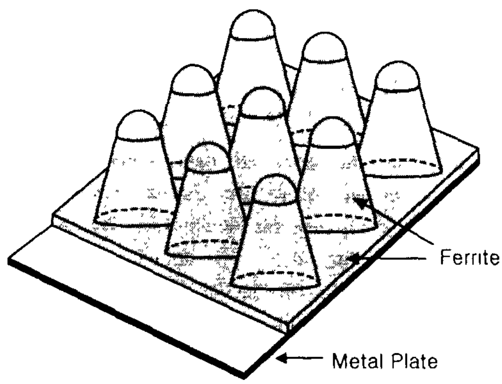


Fig. 1. Bird's eye of the proposed wave absorber.

As shown in Figs. 1 and 2, it consists of the ferrite tile, the cutting cone-shaped, and hemisphere -typed ferrite parts on metal plate

When the period of an absorbing structure is small compared to wavelength, then the periodic structure can be replaced by an effective medium as indicated by homogenization. Then the EMCM is available only when the period of an absorbing structure is small compared to the wavelength. In high frequency, however, the period of the absorbing structure becomes relatively large compared to the wavelength.

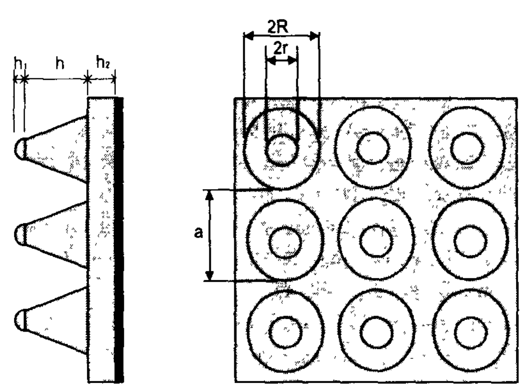


Fig. 2 Side view and floor plan of the propos- ed wave absorber

As the cutting cone-shaped part and the hemisphere-shaped part are together with ferrite and air parts, we can obtain the effective permittivity and permeability by using homogenization models[3]-[5], respectively

Thus, the equivalent permittivity and permeability of the cutting cone-shaped part can be calculated by using the equivalent circuits as shown in Fig 3 and 4, respectively For the cutting cone-shaped part, the equivalent permittivity ε_{eff} and the equivalent permeability μ_{eff} are obtained by eqs (1) and (2), using Figs 3 and 4, respectively[6]-[7]

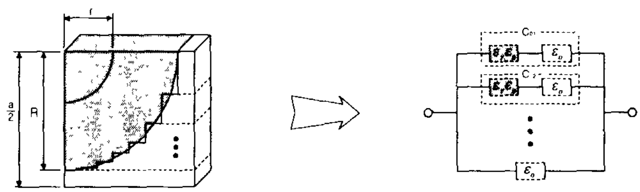


Fig 3. Equivalent Capacitance model of cutting cone-shaped part

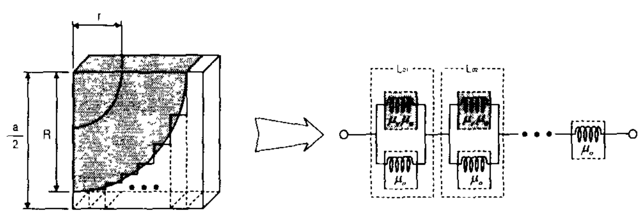


Fig. 4 Equivalent Inductance model of cutting cone-shaped part.

$$\varepsilon_{eff} = \frac{a[(a-\Delta t)\varepsilon_r+\Delta t]}{a(x_{n+1}-x_n)\varepsilon_r} + \frac{[(a-x_n+n\Delta t)(x_{n+1}-x_n)]\varepsilon_r}{a(x_{n+1}-x_n)\varepsilon_r} \tag{1}$$

$$\mu_{eff} = \frac{a[(a-x_n)\mu_r+(x_n-n\Delta t)]}{a\Delta t\mu_r} + \frac{(a-x_n+n\Delta t)\mu_r}{a\mu_r} \tag{2}$$

where, a is a period of the cones, x_n is a radius of a n-region and Δt is a thickness of a divided cutting-cone for analysis.

In the hemisphere type part, the analysis principle is similar to the cutting cone-shaped part's It only differs the hemisphere type part from the cutting cone-shaped part in the reduction of a radius of a n-region. Therefore, the equivalent permittivity and permeability is equal to eqs (1), (2), but the only value of a radius of a n-region must be changed

III. Frequency Dispersion Characteristics of Ferrite material

When the ferrite wave absorber is used in microwave band, the relative permittivity ε_r of ferrite is almost constant. In this paper, we put $\varepsilon_r = 14$.

However, the relative permeability μ_r of ferrite heavily depends on the frequency In this paper, to fit the experimental results to the simulated ones, we proposed a corrected frequency dispersion formula.

3.1 Naito's Dispersion formula

It has been reported that the actual frequency dispersion characteristics for the relative permeability or complex permeability of ferrite, comparatively correspond to that of the formula proposed by Y Naito[8] However, as shown in Fig 5, the serious errors occur between the calculated values and the measured ones of the relative permeability near 100 ㎒ Equation (3) shows the Naito's frequency dispersion formula for permeability.

$$\mu_r = 1 + \frac{\mu_i}{1 + jf/f_m} \tag{3}$$

where μ_i is the initial permeability, f is the frequency, and f_m is the relaxation frequency

3.2 Corrected Dispersion Formula

In this section, to obtain simulated result with accuracy, we have proposed the corrected frequency dispersion formula as eq (4).

$$\mu_r = \mu' - j\mu'' \tag{4}$$

where,

$$\mu' = 1 + \frac{(\mu_i - 1)}{1 + k_1 \mid f_1^2 - f_p^2 \mid^{k_0} \mid f^2 - f_p^2 \mid^{k_0} \mid f^2 - f_1^2 \mid^{k_0} f^{k_0}}$$

$$\mu'' = \frac{(\mu_m - 1)[(f - f_s)/f]^6}{1 + k_2 (f - f_m)^2 / (f f_m)}$$

and μ' depends on μ_i, f_1, f_p, and k_0, as well as μ'' depends on μ_m, f_m, f_s, and k_2 Then all of parameters must be determined by experimental values.

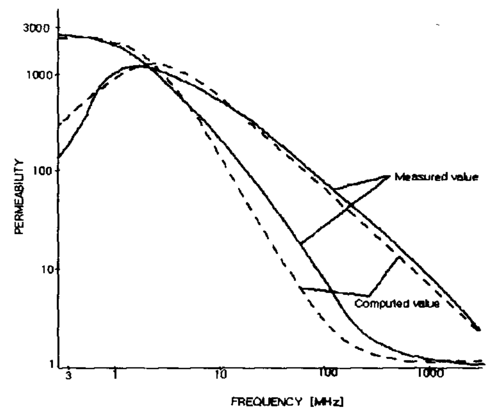


Fig. 5. Comparison of complex permeability between the simulated values by Naito's formula and the measured ones.

Figure 6 shows comparison between the calculated values of the corrected frequency dispersion formula compared to the measured ones. As shown in Fig. 6, the calculated values agree well with the measured ones.

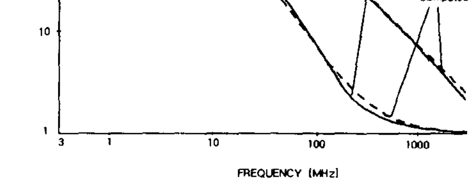


Fig. 6. Comparison of complex permeability between the simulated values of the corrected dispersion formula and the measured ones.

Ⅳ. Fabrication, Measured and Simulated Results

Figure 7 shows the simulation result for the fabricated wave absorber. Table 1 exhibits the dimensions of the designed EM wave absorber in the cutting cone-shape.

Table 1. Dimensions of the designed EM wave absorber in the cutting cone-shape.

Dimension	2R	2r	h	h_1	a
Size (mm)	18	10	18	6.5	20

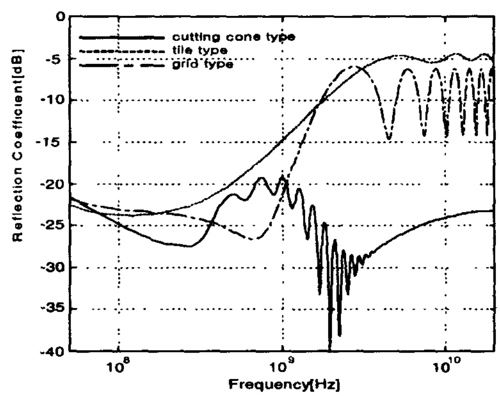
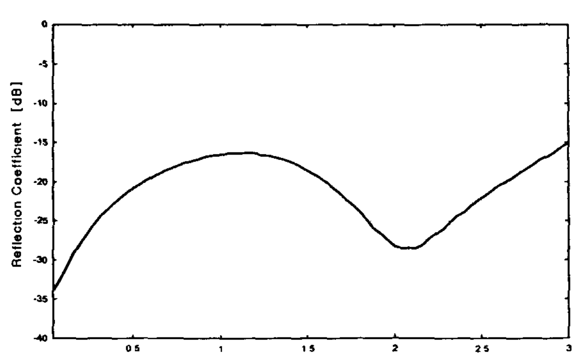
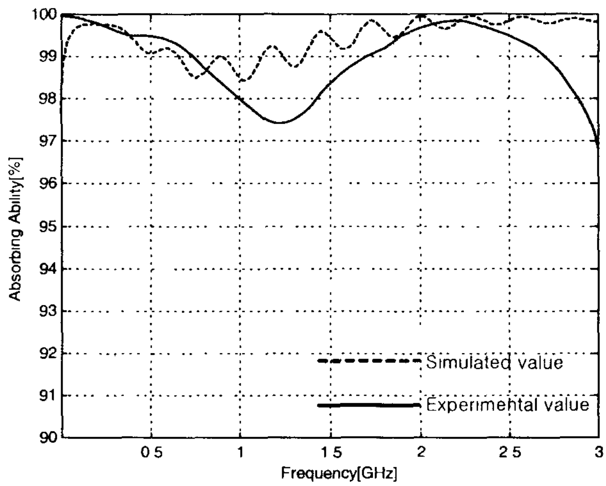


Fig. 7. The frequency characteristics of the cutting cone-shaped EM wave absorber.

As shown in the simulation result, it was shown clearly that the wave absorber has over 20 dB EM wave absorption ability in 30 ㎒ to 20 ㎓. Since the total height of the absorber is very small, it is recognized that it has the advantage of expanding effective space in an anechoic chamber when the absorbers used.



(a)



(b)

Fig. 8. (a) Measured frequency characteristics of the fabricated wave absorber in the cutting cone shape (Dimensions are shown in Table 1). (b) Comparison with the theoretical ones

Figure 8 (a) shows the actually measured results for the EM wave absorber in the cutting cone- shape. The experimental system is shown in Fig. 9. As shown in Fig 8 (b), the measured results agree well with the simulated ones in the frequency range

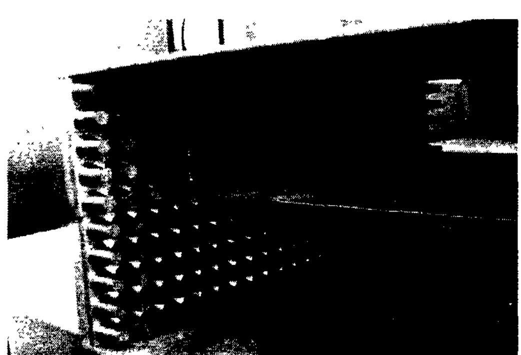


Fig 9. Experimental set-up.

Figure 10 shows the simulated results of new type EM wave absorber which is newly proposed in this paper Table 2 exhibits the dimensions of the designed new wave absorber in hemisphere added type

Table 2 Dimensions of the new wave absorber used in simulation

Dimension	2R	2r	h	h_1	h_2	a
Size (mm)	18	7	18	3.5	6.5	20

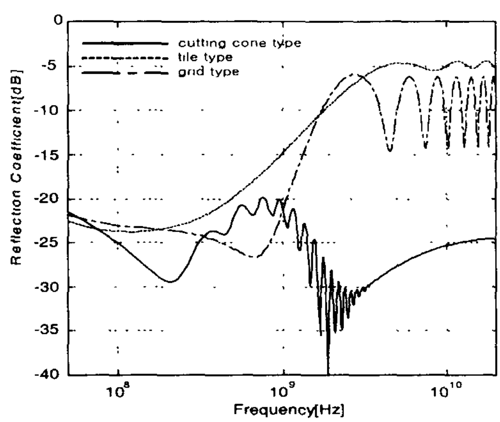


Fig. 10 The frequency characteristics of the new wave absorber shown in Table 2.

As shown in the simulation result, it was shown clearly not only the wave absorber has over 20 dB EM wave absorption ability in 30 MHz to 20 GHz but only it is better than the conventional absorber in absorption ability.

Ⅵ. Conclusion

In this paper, we have designed a new-type absorber with the broad-band frequency characteristics. The results of simulation for the proposed absorber showed better characteristics than those of conventional one. It was shown that the experiments for the cutting cone shape absorber agreed with the theoretical ones as a tendency. In the near future, the proposed absorber in hemisphere-added type is to be fabricated and examined.

Reference

[1] CISPR/B/220/RVC, CISPR11, Nov. 8, 1998.

[2] Dong Il Kim, J. Y. Son, J. Y. Bae, Y. S. Won, and J. M. Song, "A Study on Fabrication and Evaluation of Electromagnetic Wave Absorber," Journal of The Korea Electromagnetic

Engineering Society, vol. 1, no. 1, pp. 95-99, May 2001.
[3] Dong Il Kim, M. Takashashi, H. Anzai, and S. Y. Jun, "Electromagnetic Wave Absorber with Wide-Band Frequency Characteristics Using Exponentially Tapered Ferrite," IEEE Trans. EMC, vol. 38, no. 2, pp. 173-177, Feb. 1996.
[4] Dong Il Kim, S Y. Jun, "Design of Improved Grid Type Electromagnetic Wave absorber Using Exponentially Tapered Ferrite," Proceedings of the 1996 KJJC-EMCT, pp. 627-630, Sept. 1996.
[5] Dong Il Kim, S. Y. Jun, Se Mo Chung, "The Development of 2nd-layer Broadband Electromagnetic Wave Absorber with Cross-Shaped at 2nd-layer," Proceedings of Korea Electromagnetic Engineering Society, pp. 8-13, 1995.
[6] Dong Il Kim, Ch. G. Park, Y. S. Won, "Broad-Band Design of Ferrite Absorbers in Cross-Shaped Projection Type," Proceedings of Korea Electromagnetic Engineering Society, vol. 11, no. 3, pp. 372-378, Apr. 2000.
[7] Dong Il Kim, Ch. G. Park, Y. S. Won, Y. G. Lee, "A Study on Development of Ferrite Wave Absorber with Cutting Cone-Shaped Type," Proceedings of Korea Electromagnetic Engineering Society, vol. 4, no. 2, pp. 153-156, Aug. 27, 2000.
[8] Y. Naito et al., "Formulation of frequency dispersion of ferrite permeability," IEICE Japan, vol. J59-C, no. 5, pp. 297-304, May 1976.