A Study on Broadband Design of EM Wave Absorber for Anechoic Chamber

Dong Il Kim[1] · June Young Son[1] · Young Su Weon[2] ·
Dong Woo Ku[1] · Ki Man Kim[1] · Jae Man Song[3] · Byeong-Deok Yea[4]

Abstract

On the contrary to the progress of the electronic industry and radio communication technologies, many social problems such as EMI, due to unnecessary electromagnetic(EM) wave are serious with the increased use of EM wave. It is required that the absorbing capability of an EM wave absorber is more than 20 dB, the bandwidth of which is required from 30 MHz to 18 GHz to satisfy the international standard about an anechoic chamber for EMI/EMS measurement[1]. However, the absorbing frequency band of the conventional EM wave absorbers satisfying more than 20 dB is very narrow, for examples, from 30 MHz to 400 MHz in ferrite tile type and from 30 MHz to 870 MHz in ferrite grid type, respectively. In this paper, we proposed and designed a new type absorber with broadband characteristics covering the frequency band from 30 MHz to 10 GHz by use of the equivalent material constants method (EMCM)[2]~[4].

Key words : EMI/EMS, EMC, anechoic chamber, equivalent material constants method.

Ⅰ. Introduction

Recently, the microwave technology has advanced rapidly for wireless and mobile communications. On the other hand, the EM wave environment has been deteriorating more than ever before. Therefore, the international organizations such as CISPR (Comite Internationale Special des Perturbations Radioelectrique), FCC(Federal Communications Commissions), ANSI (American National Standards Institute), etc. have intensified the regulation of EM wave environment for the countermeasure of the EMC for diverse equipments.

The EM wave absorber is used to construct an anechoic chamber for test and measurement the EMI/EMS. To satisfy, however, the international standard such as ANSI C63.4-1991, CISPR A SEC.

109, or IEC 801-3, the absorption capability of EM wave absorber for an anechoic chamber is required more than 20 dB, and broad bandwidth as well from 30 MHz to 18 GHz by CISPR11[1].

However, a conventional single-layered ferrite absorber composed of the sintered ferrite tiles covers only from 30 MHz to 400 MHz under the tolerance limit of 20 dB in absorption and the grid ferrite EM wave absorber from 30 MHz to 800 MHz.

Recently, we have proposed a ferrite absorber with the cutting cone-shaped and circular cylinder ferrites on a ferrite tile[5]. In this paper, we proposed a new type ferrite absorber with the circular cylinder shape and cutting cone-shaped, and ellipse-shaped ferrites on the ferrite tile. The proposed EM absorber was designed by using the equivalent material constants method (EMCM)[2]~[4]. The proposed broadband EM wave absorber could satisfy the international standard.

Ⅱ. Design of New EM Wave Absorber

The EM wave absorber that was proposed by our laboratory before is shown in Fig. 1. Fig. 2 exhibits a side and plan view of the EM wave absorber.

As shown in Figs. 1 and 2, it consists of ferrite tile, ferrite post of the cutting cone-shape, and cylinder-type ferrite layer on metal plate. Since the first-layer is tile-typed ferrite filled with ferrite fully, the permittivity and the permeability of the

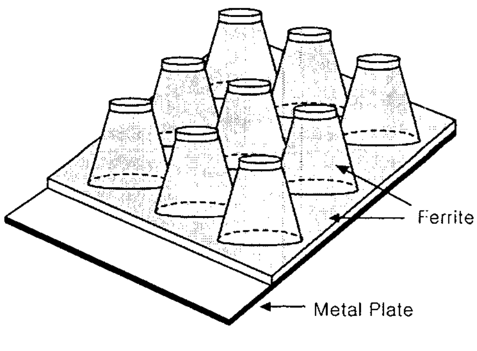

Fig. 1. Bird's eye of the proposed absorber.

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[1] Dept. of Radio Sciences & Engineering, Korea Maritime Univ., Busan, Korea.
[2] Dept. of Electronics & Comm. Engineering, Korea Maritime Univ., Busan, Korea.
[3] Research Institute of Industrial Technology, Korea Maritime Univ., Busan, Korea.
[4] Division of Maritime Transportation Science of Korea Maritime Univ., Busan, Korea.

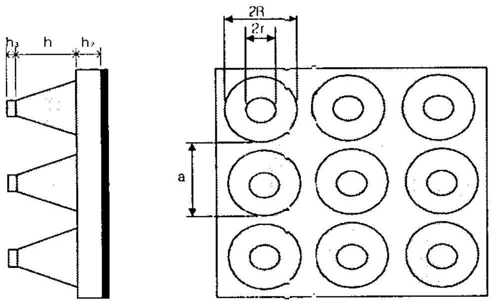

Fig. 2. Side view and floor plan of the proposed absorber.

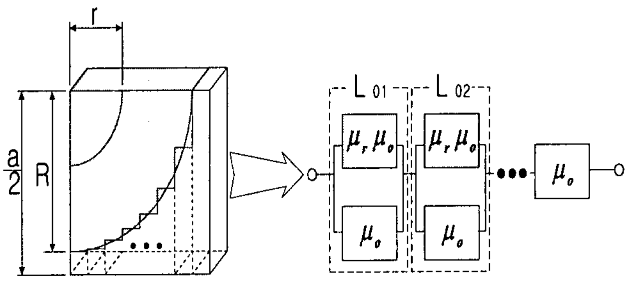

Fig. 4. Equivalent inductance model of the 2nd layer.

first-layer are the same as those of bulk ferrite material.

As the cutting cone-shaped layer and the circularly cylindrical layer are composed of ferrite and air, we can obtain the effective permittivity and permeability by using the synthesized capacitance and the synthesized inductance models, respectively.

Thus, the equivalent permittivity and permeability of the second layer can be calculated by using the equivalent circuits as shown in Figs. 3 and 4, respectively. For the second layer, the equivalent permittivity ε_{eff} and the equivalent permeability μ_{eff} are given by eqs. (1) and (2), respectively[6],[7].

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

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

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

For the third layer, the equivalent permittivity and the equivalent permeability can be obtained by eqs. (3) and (4), respectively.

$$\varepsilon_{eff} = \frac{h_3\,\varepsilon_r}{(a - r)\varepsilon_r + r} \tag{3}$$

$$\mu_{eff} = \frac{h_3\,\mu_r}{(a - r)\mu_r + r} \tag{4}$$

where, h_3 is the height of cylinder and r is the radius of cylinder.

The new proposed EM wave absorber in this paper is shown in Fig. 5. Fig. 6 shows a side and plan view of the EM wave absorber.

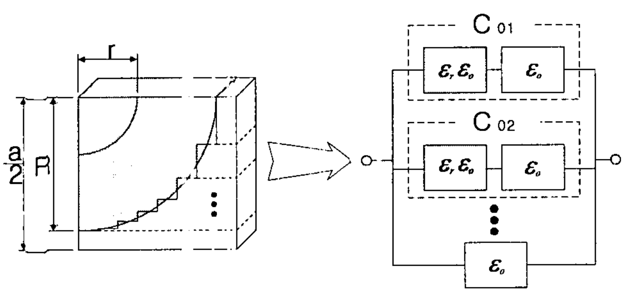

Fig. 3. Equivalent capacitance model of the 2nd layer.

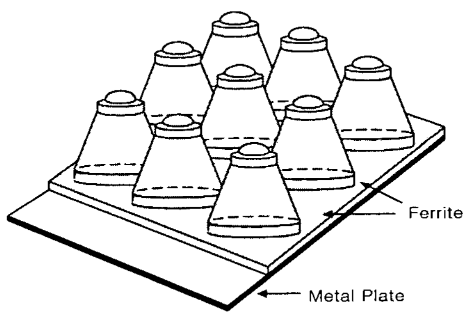

Fig. 5. Bird's eye of new proposed EM wave absorber.

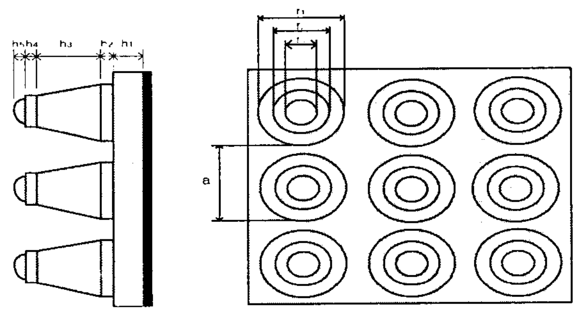

Fig. 6. Side view and floor plan of the new proposed EM wave absorber.

As shown in Figs. 5 and 6, it consists of ferrite tile, ferrite post in the cutting cone-shaped type, ellipse type, and cylinder-typed ferrite layer on metal plate. The calculating method is equal to the method used for conventional EM wave absorber except for the ellipse shaped part.

For the ellipse type part, the analysis principle is similar to that for the cutting cone-shaped part's. The only difference between the ellipse type part and the cutting cone-shaped part is the reduction of a radius of an nth region. Therefore, the equivalent permittivity and permeability is equal to eqs. (1), (2), but the value of the radius of the nth region should changed.

Ⅲ. Frequency Dispersion Characteristics of Ferrite Material

When the ferrite absorber is used in microwave band, the relative permittivity ε_r of ferrite is almost constant as ε_r=14. However, the relative permeability μ_r of ferrite heavily depends on the frequency[9]. In this paper, to fit the experimental results to the simulated ones, we proposed a corrected frequency dispersion formula. Eq. (5) shows the proposed experimentally corrected dispersion formula.

$$\mu_r = \mu' - j\mu'' \tag{5}$$

where,

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

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

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 the parameters was determined by experimental values, which were shown in Table 1.

Figure 7 shows comparison between the calculated values of the corrected frequency dispersion formula and the measured ones. As shown in Fig. 7, the calculated values agree well with the measured ones.

Ⅳ. Fabrication and Measured Results

Figure 8 shows the simulation results for the fabricated absorber that was proposed by our laboratory before. Table 2 shows the dimensions of the absorber.

As shown in Fig. 8, it was shown clearly that the EM wave absorber has absorption capability better than 16 dB in 30 MHz to 10 GHz.

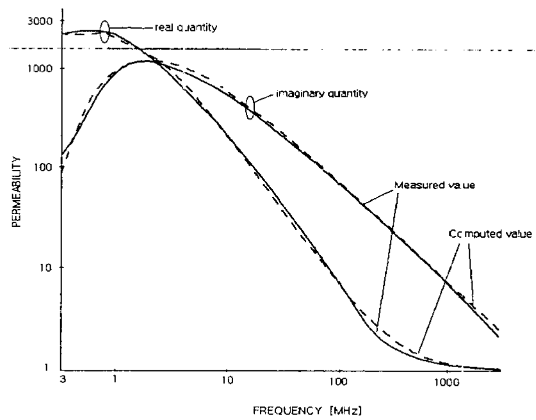

Fig. 7. Comparison of complex permeability between the simulated values of the corrected dispersion formula and the measured ones.

Table 1. Values of the parameters.

μ_i	k_0	f_1	f_p	μ_m	k_2	f_s	f_m
2500	0.31	0.2	0.7	2500	0.18	0.13	0.5

Table 2. Dimensions of the EM wave absorber.

Dimension	2R	2r	h	h_1	h_2	a
Size (mm)	13	10.2	18	2	6.6	20

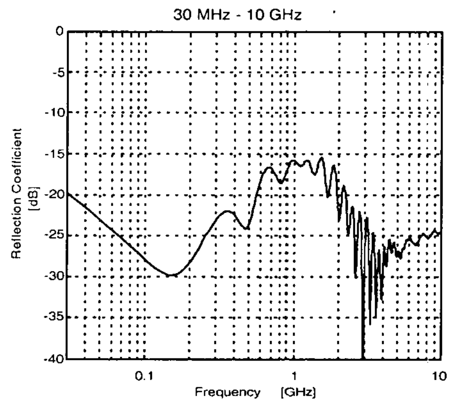

Fig. 8. The frequency characteristics of the simulated wave absorber.

Figure 9 shows the actual fabricated EM wave absorber, and Fig. 10 shows the measuring set-up. The system was made by our laboratory and it was used for measurement of fabricated EM wave absorber up to 6 GHz. Figure 11(a) shows the perspective drawing of the system. As shown in Fig. 11(b), eight pieces of absorber were attached to the metal plate, and the absorption capability was measured using the Network

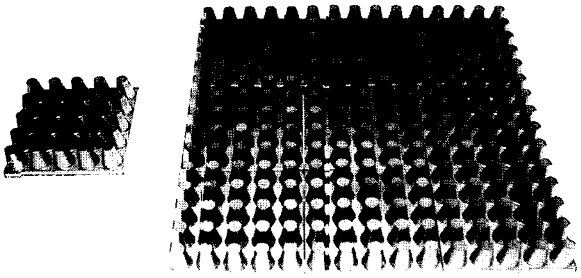

Fig. 9. Fabricated EM wave absorber.

Fig. 10. Rectangular coaxial waveguide system.

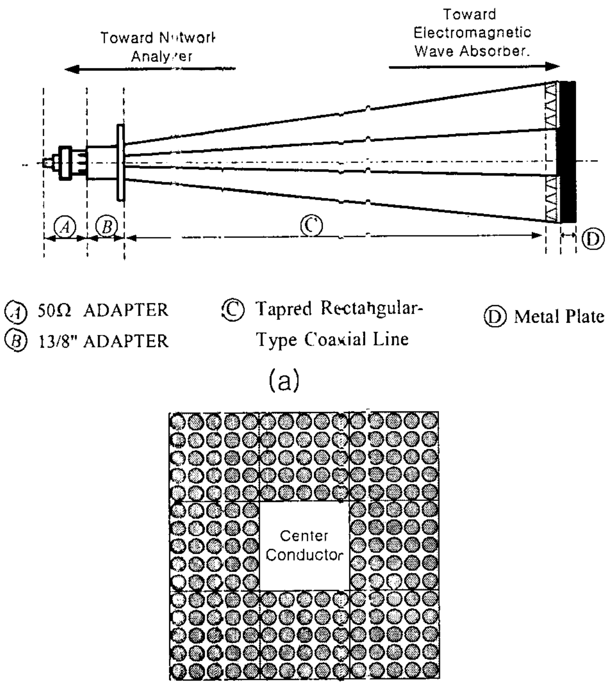

Fig. 11. The perspective drawing of the system.

Analyzer (Model HP8753D).

Figure 12 shows the comparison between the simulated absorption capability and the measured one. The solid line shows the actually measured results for the fabricated absorber

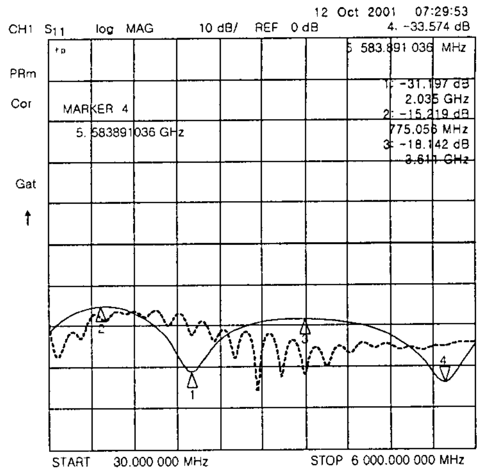

Fig. 12. Comparison between the simulated and the measured absorption capabilities.

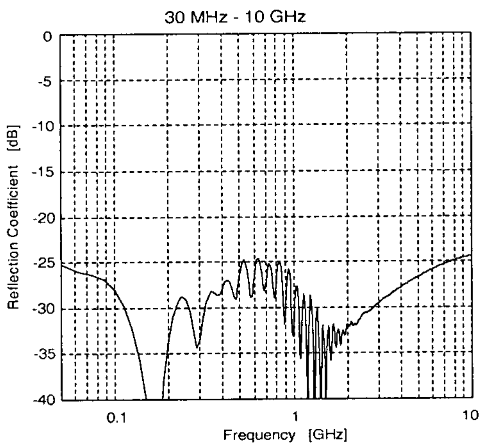

Fig. 13. The simulated frequency characteristics of the new EM wave absorber.

Table 3. Dimensions of new proposed EM wave absorber.

Dimension	h_1	h_2	h_3	h_4	h_5	r_1	r_2	r_3	a
Size (mm)	6.2	2	16	0.5	2.3	18	10	6.8	20

and the dotted line shows the simulated results.

The measured results are in good agreement with the designed ones in the frequency range from 30 MHz to 6 GHz. However, as shown in Fig. 12, the 20 dB absorption capability of EM wave absorber was not satisfied. To solve this problem we proposed new type EM wave absorber as shown in Fig. 5.

Figure 13 shows the simulation results for the new proposed EM wave absorber, and Table 3 shows the dimensions of the proposed absorber.

In order to obtain the optimized structure, a try and error method was applied by changing the dimensions for the various structures, repeatedly.

As shown in Fig. 13, it is respected that the proposed EM wave absorber has more EM wave absorption capability than those of the formerly proposed one shown in Fig.1. In the near future the newly proposed absorber will be fabricated, measured, and applied for an anechoic chamber.

V. Conclusion

In this paper, we have designed a new-type absorber with broad-band frequency characteristics. From the simulation and the experimental results, it is respected that the proposed EM wave absorber has more EM wave absorption capability than those of the formerly proposed one. In addition, we can conclude that the designed EM wave absorber has superior absorption capability compared with the conventional EM wave absorbers. Since the designed EM wave absorber has, furthermore, the thickness of 27 mm, more effective space efficiency can be obtained in a volume within an anechoic chamber.

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Dong Il Kim

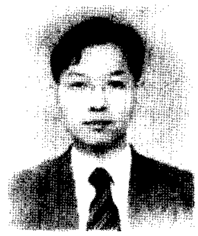
was born in Nonsan, Korea. He received the B.E. and M.E. degrees in nautical science and electronic communications from the Korea Maritime University, in 1975 and 1977, respectively. He received the Ph.D. degree in electronics from the Tokyo Institute of Technology in 1984. Currently, he is professor of the Dept. of Radio Sciences & Engineering at the Korea Maritime University. His research interests include the design of microwave circuits and CATV transmission circuits, development of EM absorber, and EMI/EMC countermeasures.

He received the Academy-Industry Cooperation (A-I-C) Award from Korea A-I-C. Foundation in 1990, Treatise Awards from the Korea Electromagnetic Engineering Society and the Korea Institute of Navigation in 1993 and 1998, and the Korea President's Award from the Promotion of Science and Technology in 1995, respectively. He is the president of KEES and member of IEEE, the Institute of Electronics, Information and Communications of Japan, the IEEC of Korea, the KICS, and the Kore Electromagnetic Engineering Society.

June Young Son

was born in Pusan, Korea in 1969. He received the B.S. and M.S. degree in Dongeui University, Pusan, Korea, in 1995, and 1997, respectively. He is currently pursuing the Ph.D. degree under the supervision of Prof. D. I. Kim at Korea Maritime University, Pusan, Korea. His research interests include the design of Electromagnetic Wave Absorber, EMI/EMC analysis, and bluetooth.

Ki Man Kim



received his B.S. in 1988, M.S. in 1990, and Ph.D. in 1995 from Yonsei University, Seoul, Korea, all in electronics engineering.

From 1995 to 1996, he worked for Yonsei Medical Center as a fellow, where he was involved in developing medical diagnosis equipments. In 1996, he joined the Department of Radio Science and Engineering, Korea Maritime University, Pusan, Korea, where he is currently an assistant professor. Since 1997 he has also research interests include passive ranging, synthetic aperture sonar, smart antenna for mobile communication, virtual sound, and hardware implementation by using digital signal processor/CPLD.

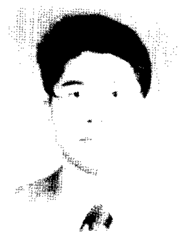
Young Su Weon

received the M.S. and Ph. D. degrees from Korea Maritime University, Pusan, Korea in 1997 and 2002, respectively.

He was employed as an engineer at KBS, where he worked in the area of RF system for broadcast from 1976 to 2000. He has been a chief researcher at the PSB Broadcast & Telecommunication Reserch Institute since 2001.

[Interest Field] Microwave RF-devices, Electro-magnetic Wave Absorbers, RF System in Broadcast.

Jae Man Song

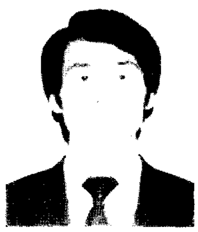


was born in Buyoe Korea March 21st, 1962. He received the B. S., M. S., and Ph. D. degrees in department of physics from Soong Sil University in Feb. 1985, Feb. 1987, and Aug. 1995, respectively. He made a special study magnetic materials at Nagasake University in the period of 1986-1987 as a visiting researcher, at Isu Ceramics Co., LTD in the period of 1987-1988 as a senior research engineer, and at Nagasaki University in the period of 1988-2000 as a special researcher. Now, he is a research professor at Research Institute of Industrial Technology in Korea Maritime University from Sep. 1st, 2000. His research interests include the development of electro-magnetic wave absorber, soft magnetic material, soft magnetic thin films, hard magnetic thin films, and nano-composite magnets. He is a member of Korea Physical Society, Korea Magnetic Society, IEEE transaction on Magnetic Society, and American Institute of Physics.

Dong Woo Ku

was born in Pusan in 1975. He received B.E. degree from Dongeui University, Pusan, Korea, in 2001. He is currently pursuing the M.E. degree under the supervision of Prof. D. I. Kim at Korea Maritime University, Pusan, Korea. His research interests include the design of E/M circuits, EMI/EMC analysis, and countermeasures.

Byeong-Deok Yea



was born in the Republic of Korea in 1961. He received the B.E. and M.E. degrees from Korea Maritime University in 1983 and 1985, respectively. He received Doctor of Engineering from the Department of Electrical and Electronic Engineering of Tottori University, Japan in 1999. In 1989, he joined the Division of Maritime Transportation Science of Korea Maritime University and is now an associate professor there. His research interests include the development of high performance thin-film semiconductor sensors and signal processing algorithms from the sensors. He is also interested in neural networks and fuzzy systems.