DEVELOPMENTS OF NEW EM WAVE ABSORBERS

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ABSTRACT

This paper presents some recently developed EM wave absorbers. The research on the development of new materials and binders for EM wave absorbers has been carried out, where sheet-type absorbers for mobile phone, ship's radar, and the complex type absorber for an anechoic chamber designed. Soft ferrite and hard ferrite are well-known as the materials for EM wave absorbers. Soft ferrite such as MnZn ferrite and NiZn ferrite, are useful materials for EM wave absorbers, but the magnetic loss of them decreases quickly in the GHz range. Since, however, hard ferrites such as Ba ferrite and Sr ferrite, show high magnetic loss in the GHz range, they are useful materials for EM wave absorbers in the GHz range. Thus the sheet type EM wave absorbers were fabricated with Ba ferrites, Sr ferrites, Sendust, and Alnico magnet. The sheet-type absorber using Sendust is useful for mobile phone the frequency of which is from 1.2 GHz to 2 GHz, and they are useful for preventing unwanted EM waves in the C-band and X-band radar. Especially, the effects of EM wave absorption ability have been shown by field test. On the other hand, the complex type absorber for an anechoic chamber has been designed which has the thickness of 178.3 mm and showed absorption ability over 20 dB in the frequency band from 30 MHz to more than 20 GHz.

1. INTRODUCTION

With the rapid advancements in electronics industry and radio communication technology, mankind might enjoy its abundant life. On the other hand, serious social problems such as electromagnetic interference (EMI) and electromagnetic susceptibility (EMS) have arisen due to the increased use of electromagnetic waves[1]. Therefore, countermeasure against electromagnetic waves obstacle was embossed to important subject.

Unnecessary electro-magnetic waves leak from the circuits of communication equipment and electronic equipment or such electromagnetic waves cause the equipment to malfunction. Problems regarding electromagnetic compatibility (EMC) are more likely to occur, as smaller, lighter, and more sophisticated electronic equipment is made and the packaging density of electronic components increases drastically.

In addition, as recent communication and digital technologies advance, the applied frequency becomes higher, so that a point of view that is different from conventional one is necessary to address EMC. Further, in mobile phones that have recently been spread rapidly, the possibility of the adverse effect of radiated EM waves on the human body is also pointed out.

To measure the generation and leakage of unnecessary EM waves and the malfunction caused by EMI, anechoic chamber is useful which is composed of EM wave absorbers.

In this paper, the development of new materials and binders for EM wave absorbers has been carried out, where sheet-type absorbers for mobile phone and ship's radar, and complex type absorber for an anechoic chamber has been designed. The EM wave absorption abilities have been demonstrated by simulated and measured results.

2. DEVELOPMENT OF MATERIALS FOR EM WAVE ABSORBERS

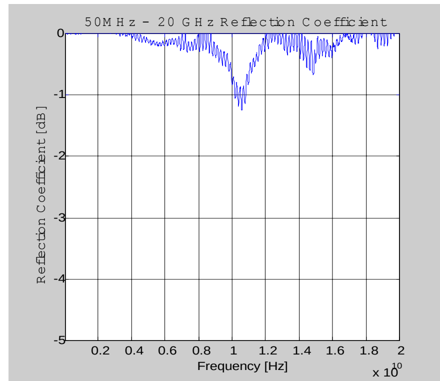
2.1 New Materials

Soft ferrites, such as Mn-Zn ferrite and Ni-Zn ferrite are useful materials for EM wave absorbers, but the magnetic loss of them decreases quickly in the GHz range. Hard ferrites, such as Ba ferrites and Sr ferrites show high magnetic loss in the GHz range, so they are useful materials for EM wave absorbers in the GHz range. In addition to developing advanced EM wave absorbers with well-known soft and hard magnetic materials, it is important to develop new materials for EM wave absorbers.

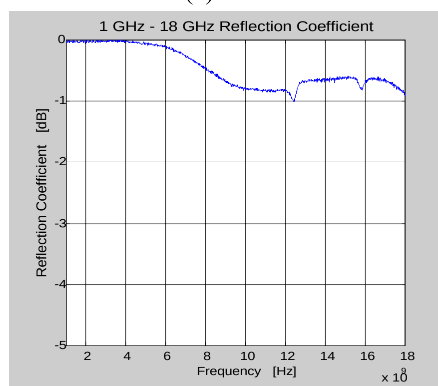
Therefore, Alnico magnet and sendust were newly suggested as a EM wave absorber material for GHz frequency band. The newly suggested Alnico magnet EM wave absorber has been useful for preventing unwanted EM waves in the C-band and X-band[2], and the sendust EM wave absorber has been suitable for mobile phones.

2.2 New Binders

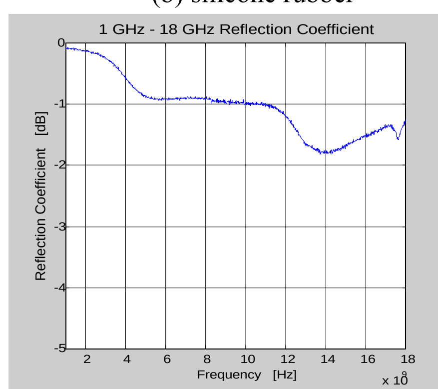
Binders are used to support composite EM wave absorbers. So far, CPE(Chlorinated Poly ethylene), silicone, and rubber have been used as a binder for EM wave absorbers. Many studies have been carried out to investigate the effect of ferrites and their volume percentages in composite on the absorption of EM waves to make absorbers with broad absorption bands. But our group have studied the effect of binders with broad band absorption properties of EM wave absorbers. We suggested natural lacquer as a new binder for EM wave absorbers. We found the natural lacquer is to have a high quality in absorption broadness[1]. Fig. 1 shows the reflectivity from CPE, silicon rubber, and natural lacquer sheets.



(a) CPE



(b) silicone rubber



(c) Natural lacquer

Fig. 1. Reflection coefficients for binders vs. frequency.

2.3 The Effects of Temperature and Particle Size

Many researches on EM wave absorbers have been carried out to investigate the effects of their volume percentages in composite and sintering conditions. However the effects of particle size and preparation temperature on the absorption of EM wave absorbers have not been reported. Recently, the effects of particle size and preparation temperature of Sr, Ba, and Mn-Zn ferrites on EM wave absorption properties were investigated[3,4]. The study shows that the particle size of magnetic materials and preparation temperature in manufacturing process are important factors for preparing superior EM wave absorbers. Fig. 2 shows their reflectivity at the matching frequency as a function of the milling time for Mn-Zn ferrite absorbers and Sr ferrite absorbers.

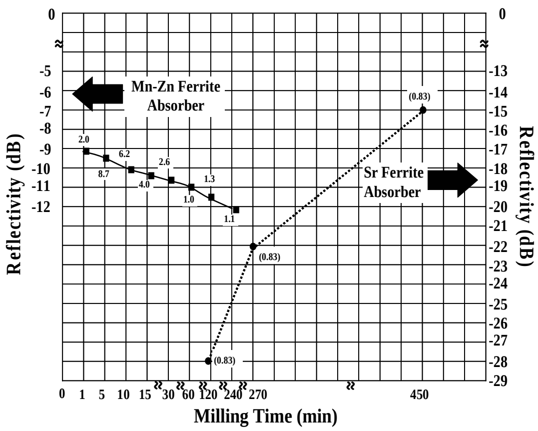


Fig. 2. Reflectivity at the matching frequency as a function of the milling time for Mn-Zn ferrite absorbers and Sr ferrite absorbers.

3. DEVELOPMENT OF EM WAVE ABSORBERS FOR MOBILE PHONE

With recent communication and digital technologies advance, mobile phones have recently been spread rapidly, the possibility of the adverse effect of radiated EM waves on the human body is also pointed out.

Today, researchers have studied to protect human body and EM machines from the unwanted EM waves caused by mobile phones. Our researches are also studying for them[3]. We fabricated sheet-type EM wave absorbers using sendust and investigated their EM wave absorption. They are useful for mobile phones because tanδ=1 of them comes in the region of 1.2 – 2 GHz which is frequency for mobile phones. Fig. 3 presents reflection coefficient of EM wave absorber with Sendust. It has absorption ability over 5 dB in 1.8 GHz with thickness of 0.8 mm.

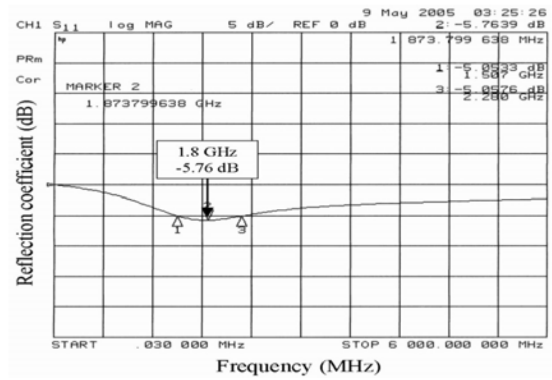


Fig. 3. Reflection coefficients as a function of frequency for the Sendust EM wave absorber.

4. DEVELOPMENT OF EM WAVE ABSORBERS FOR RADAR

Today's modern warship has a wide variety of electronic systems on board. Navigational and target acquisitions radars, countermeasures systems, and a wide variety of communications equipment are all mounted on a large metal superstructure. This arrangement creates two major problems : false images from self-reflections, and system-to-system interference. False images or ghosts are indirect radar returns resulting from specular reflections of radar energy off the ship's own superstructure. False echoes cause navigation hazards, and, if severe enough, can make radar navigation impossible. False returns to target acquisition and fire control systems can cause the system to "lock on" to the false images. These problems can be eliminated through the use of EM wave absorber.

The materials showed high magnetic loss in the GHz range are hard ferrites such as Ba ferrite and Sr ferrite. Fig. 4 and Fig. 5 present reflection coefficient as a function of frequency for Sr ferrite absorber of coated Alumina with different compositions and thicknesses.

Alnico magnets as a EM wave absorber material are effective for GHz range[2], which encompass many fire control and weapon-guidance radars. Fig. 6 shows reflection coefficient of Alnico magnet absorber with different thicknesses.

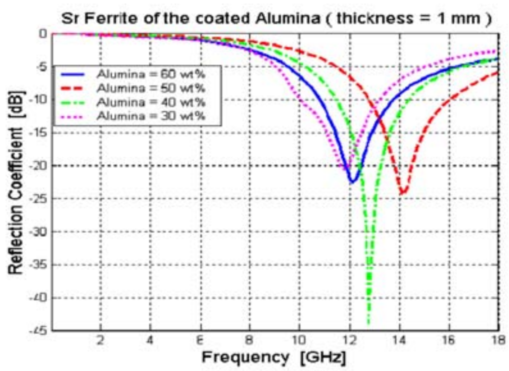


Fig. 4. Reflection coefficient for Sr ferrite of coated Alumina with different compositions in thickness of 1 mm.

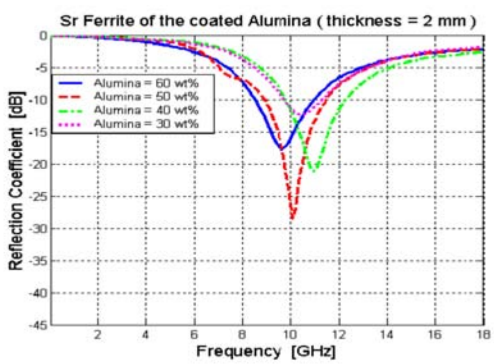


Fig. 5. Reflection coefficient for Sr ferrite of coated Alumina with different compositions in thickness of 2 mm.

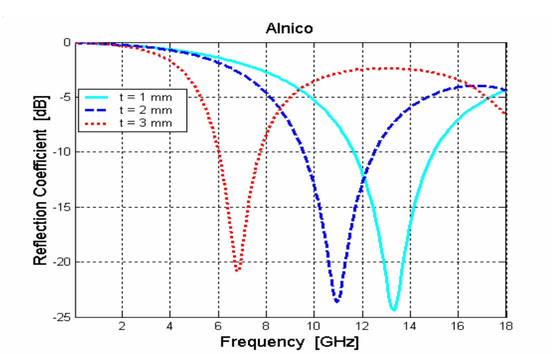


Fig. 6. Reflection coefficient for Alnico magnet absorber with different thicknesses.

The sheet-type absorber using Alnico magnet is useful for preventing unwanted EM wave in the C-band and X-band radar. We fabricated sheet-type absorber using ferrite, which has absorption ability over 20 dB in the frequency band from 9.6 to 10.7 GHz as shown in Fig. 7.

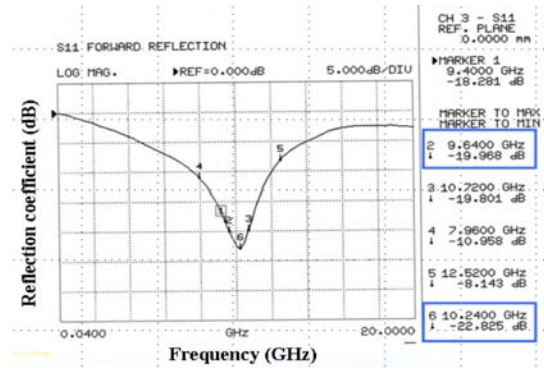
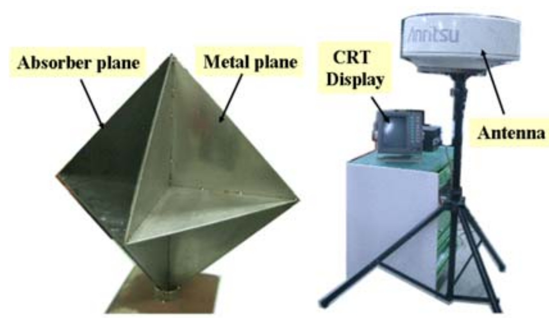
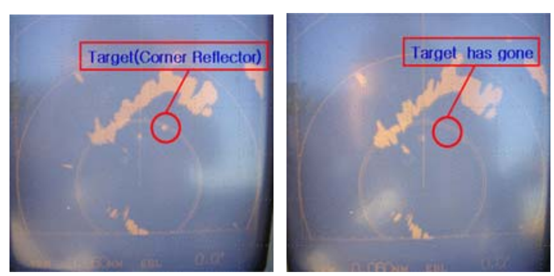


Fig. 7. Reflection coefficient of the fabricated sheet-type absorber using ferrite



(a) Target (Corner Reflector) (b) Radar system

Fig. 8. The target and radar system.



(a) Metal plate (b) absorber plate

Fig. 9. The effects of EM wave absorber by radar in outdoor range.

We tested the effects of EM absorber in outdoor field using the equipments as shown in Fig. 8. The corner reflector is used as target, and the sheet-type absorber is attached one plate in target, then one plate is metal and the other plate is absorber. The effects of EM wave absorption by outdoor field test have been shown in Fig. 9.

5. DEVELOPMENT OF EM WAVE ABSORBERS FOR ANECHOIC CHAMBER

An important application of absorbers is in construction of anechoic chambers. Using today's state-of-the-art absorbers and chamber designs, "free-space" with regard to amplitude and phase uniformity can be simulated to a very high degree. EM wave absorbers for anechoic chambers need broad band absorption properties. The lower frequency limit requires pyramidal absorbers, having thickness as great as 15 feet.

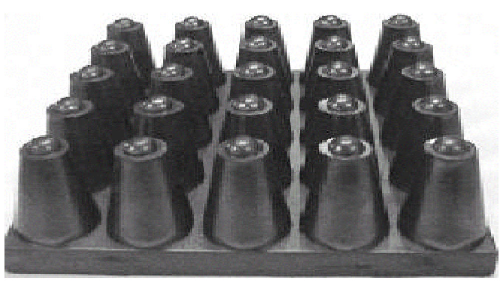


Fig 10. Bird's eye of the hemisphere type on a cutting cone-shaped absorber.

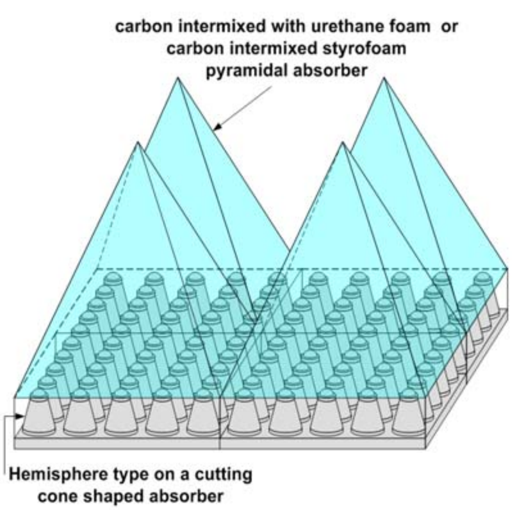


Fig. 11. Bird's eye of the complex type absorber

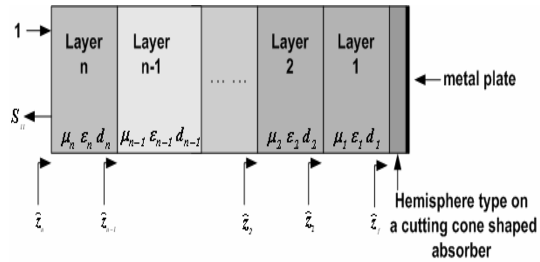


Fig. 12. Multi-layered Model of the EM wave absorber.

Our group has studied to develop EM wave absorbers with broad band properties for anechoic chambers. We designed the multi-layered absorbers in Fig. 10 and Fig. 11. The multi-layered model of the designing EM wave absorber is illustrated in Fig. 12. Where, ε_r, μ_r, d are the equivalent permittivity of each layer, the equivalent permeability, and the thickness, respectively.

The normalized input impedance from the last layer of a hemisphere type absorber on a cutting cone-shaped ferrite is $\hat{z}_f$ in Fig. 12.

The normalized input impedance of the first layer of pyramidal absorber is calculated by eq. (1).

$$\hat{z}_1 = \sqrt{\frac{1}{\varepsilon_{r1}}}\,\frac{\hat{z}_f + \sqrt{\frac{1}{\varepsilon_{r1}}}\tanh\left(j\frac{2\pi}{\lambda}\sqrt{\varepsilon_{r1}}d_1\right)}{\sqrt{\frac{1}{\varepsilon_{r1}}} + \hat{z}_1\tanh\left(j\frac{2\pi}{\lambda}\sqrt{\varepsilon_{r1}}d_1\right)} \quad (1)$$

By calculating repeatedly, the normalized input impedance from the last layer of pyramidal absorber is calculated by eq. (2).

$$\hat{z}_n = \sqrt{\frac{1}{\varepsilon_{rn}}}\,\frac{\hat{z}_n + \sqrt{\frac{1}{\varepsilon_{rn}}}\tanh\left(j\frac{2\pi}{\lambda}\sqrt{\varepsilon_{rn}}d_n\right)}{\sqrt{\frac{1}{\varepsilon_{rn}}} + \hat{z}_n\tanh\left(j\frac{2\pi}{\lambda}\sqrt{\varepsilon_{rn}}d_n\right)} \quad (2)$$

The final Reflection coefficient s_{11} is obtained by eq. (3) using the normalized impedance $\hat{z}_n$.

$$s_{11} = \frac{\hat{z}_n - 1}{\hat{z}_n + 1} \quad (3)$$

The designed hemisphere type EM wave absorber has a height of 28.6 mm and absorption ability over 20 dB from 30 MHz to more than 6 GHz[1,4]. Moreover, the complex type EM wave absorber has a height of 178.3 mm and has better absorption ability from 30 MHz to more than 20 GHz.

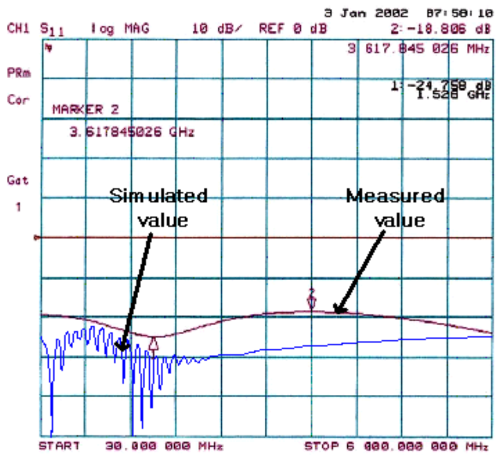


Fig. 13. The comparison of EMCM simulation and measurement of the Hemisphere type absorber.

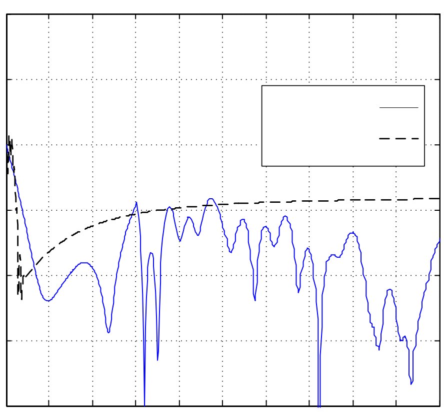


Fig. 14. The comparison of EMCM simulation and measurement of the complex type absorber.

Simulated and measured results of the hemisphere type absorber are shown in Fig. 13. In Fig. 14, the results of EMCM simulation and measurement of the complex type absorber were shown.

6. CONCLUSIONS

To measure the generation and leakage of unnecessary EM waves and the malfunction caused by EMI, EM wave absorbers are useful.

In this paper, the development of new materials and binders for EM wave absorbers has been carried out, where sheet-type absorbers for mobile phone and ship's radar, and complex type absorber for anechoic chamber has been designed.

Thus the sheet type EM wave absorbers were fabricated by Ba ferrite, Sr ferrite, Sendust, and Alnico magnet, respectively. The sheet-type absorber using Sendust is useful for mobile phone the frequency of which is from 1.2 GHz to 2 GHz, and sheet-type absorber using Alnico magnet is useful for preventing unwanted EM waves in the C-band and X-band radar. Especially, it has been verified that the effects of EM wave absorber has excellent characteristics by the outdoor field test.

On the other hand, complex type absorber for an anechoic chamber has been designed which has a height of 178.3 mm and the frequency band with absorption ability over 20 dB was from 30 MHz to more than 20 GHz.

ACKNOWLEDGEMENT

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