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Design and Fabrication of Wide-band Ferrite Absorber Used in Anechoic Chamber

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Ferrite tile absorber is of great concern for the application to anechoic chambers due to the growing demand of EMI or EMC measurements. This paper investigates the magnetic, dielectric and microwave absorbing properties of a Ni-Zn ferrite for the purpose. A design chart was constructed with the solutions of impedance-matching equation in the radio frequencies (30 MHz - 1 GHz). The material parameters for zero-reflection are predicted from the chart. The magnetic and dielectric properties of sintered Ni-Zn ferrite is found to be well suited for this requirements. A superior microwave absorbing properties (frequency band and absorber thickness) of the samples are demonstrated.

1. Introduction

Widespread use of electric and electronic circuits for various purposes requires for circuit designers to control the EMI (electromagnetic interference) problems. For the precise measurements of EMI signal or spectrum, ferrite tile absorber is widely used in indoor shielded semi-anechoic or anechoic chambers [1]. Ferrite tile absorbers are made of highly condensed lossy magnetic materials utilizing the sintered ceramic technology. Since the magnetic absorber primary interacts with magnetic field energy near the metallic surface (shield wall), ferrite tile absorber can achieve very good absorbing performance with a few millimeters in thickness for frequencies as low as 30 MHz. The primary advantage of the ferrite tile absorber is this low-frequency absorbence in comparison with the dielectric foam absorber which is conventionally used at high frequencies above 1 GHz [2].

The purpose of this study is to investigate the magnetic and dielectric properties of Ni-Zn ferrites and successful design of absorber for the application to anechoic chambers. Using the impedance-matching solution maps proposed by Natio [3] and Musal [4], the microwave absorbing properties are analyzed in the ferrite tile absorber.

2. Design of Absorber

For the ferrite tile terminated by a metal plate, the zero-reflection can be obtained by satisfying the following equation [3],

$$\sqrt{\frac{\mu_\gamma}{\varepsilon_\gamma}}\tanh[j\frac{2\pi d}{\lambda}\sqrt{\mu_\gamma\varepsilon_\gamma}] = 1 \tag{1}$$

where d is abosrber thickness, λ is wavelength. Since the frequency range of operation is 30 MHz - 1 GHz and the allowed thickness limit is about 10 mm, the solutions of equation (1) are made in the range of frequency and thickness ($f \cdot d$) of 300 - 10,000 MHz · mm.

Fig. 1 is the solution maps showing the combinations of μ_γ, and ε_γ, in the given range of $f \cdot d$. Similar results were given by Natio [3], Musal and Hahn [4]. In the region where $\mu_\gamma'' > \mu_\gamma'$, the parameters for zero-reflection are well approximated by the simple relationships:

$$\frac{d}{\lambda} = \frac{1}{2\pi\mu_\gamma''} \tag{2}$$

$$\varepsilon_\gamma' = 3\mu_\gamma' \tag{3}$$

Equation (2) determines the layer thickness in terms of wavelength and imaginary part of magnetic permeability at that wavelength. The absorber thickness can be reduced by increasing the magnetic loss. Equation (3), which involves the real part of the dielectric constant and magnetic permeability, must be satisfied in order to approach the zero reflection. Wave- impedance matching at the surface of absorber can be obtained at a frequency satisfying the

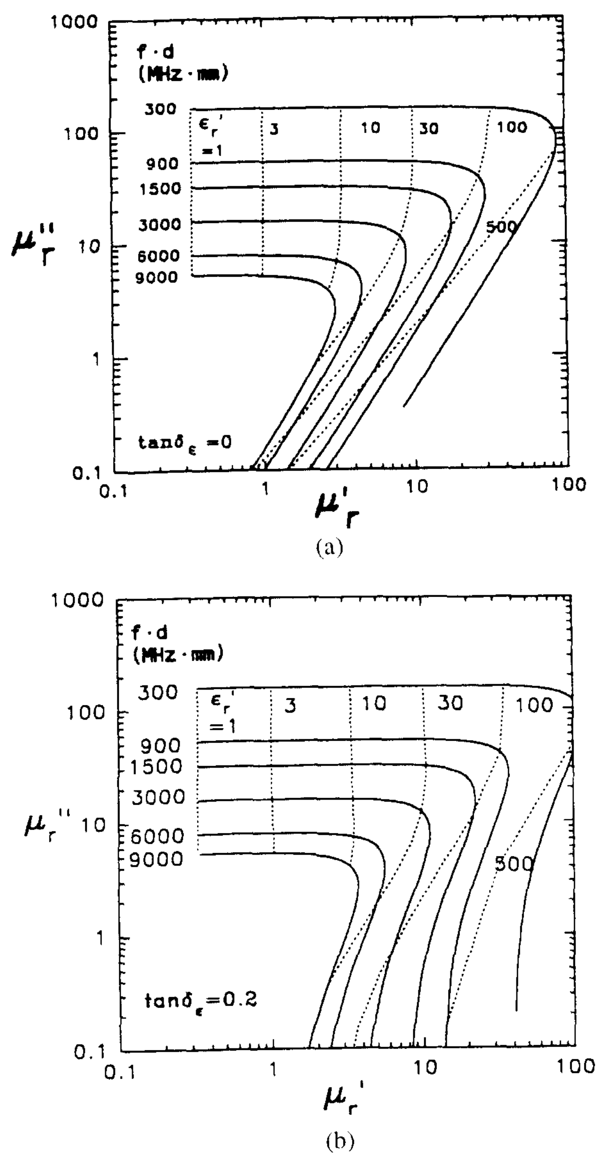

Fig. 1. Impcndance-matching solution maps for zero reflection; (a) tan δ_ϵ=0 and (b) tan δ_ϵ=0.2.

equation (3).

In the lower right region of μ_{γ}' - μ_{γ}'' plane (Fig. 1) where $\mu_{\gamma}'' < \mu_{\gamma}'$, a relationship between the parameter groups that constitute zero-reflection absorber is complicated. This region includes the quarter-wavelength-thick absorber, which is dependent on not only magnetic permeability but dielectric loss tangent (tan δ_ϵ) as well.

In the case of ferrite materials, since the dielectric constant (ϵ_{γ}') does not exceed 30, the selection of a ferrite material with high magnetic loss ($\mu_{\gamma}'' > \mu_{\gamma}'$) is most important in the frequency range of 30 MHz - 1 GHz. For instance, for the zero-reflection absorber about 10 mm in thickness operated at 30 MHz, μ_{γ}'', should be at least 200 and μ_{γ}' must not exceed 10.

3. Experimentals and Discussion

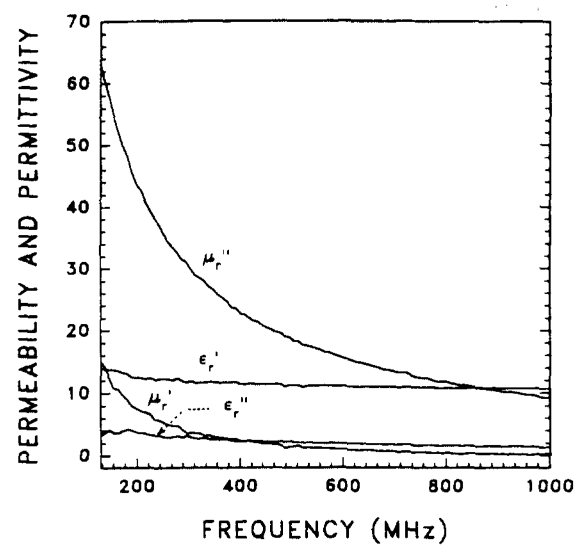

Fig. 2. Complex permeability and permittivity of sintered $Ni_{0.36}Zn_{0.64}Fe_2O_4$ specimen.

A sample of $Ni_{0.36}Zn_{0.64}Fe_2O_4$ composition was prepared by conventional ceramic processing technique. The toroidal compacts were sintered at 1250°C for 2 hrs in air. The complex permeability and dielectric constant were determined by the reflection/transmission technique described in the earlier paper [5].

Fig. 2 shows the complex permeability (μ_{γ}' - $j\mu_{\gamma}''$) and dielectric constant (ϵ_{γ}' - $j\epsilon_{\gamma}''$) measured in the frequencies 130 MHz - 1 GHz. The permeability spectrum (both μ_{γ}' and μ_{γ}'') is a decreasing function of frequency. Imaginary part of permeability is much higher than the real part over the

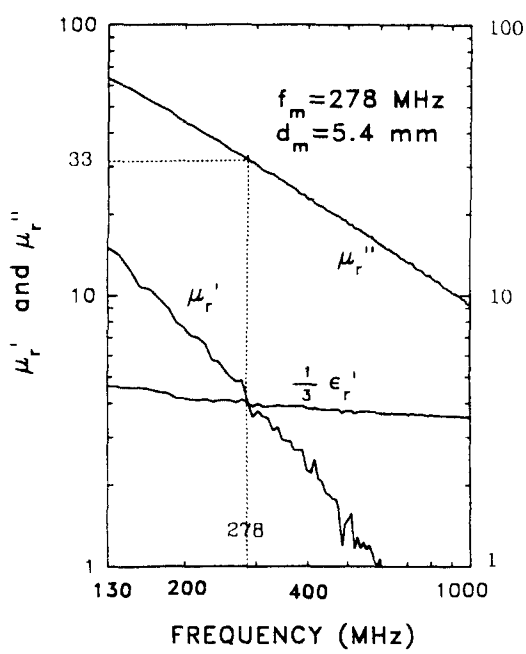

Fig. 3. Prediction of zero-reflection frequency and absorbed thickness in $Ni_{0.36}Zn_{0.64}Fe_2O_4$ specimen.

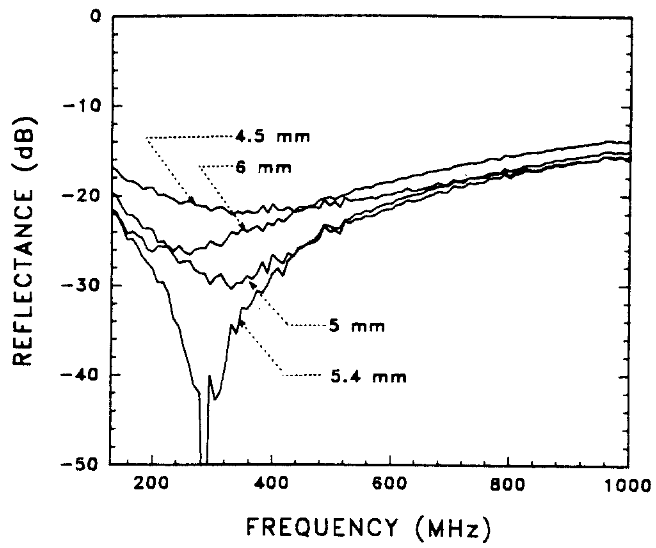

Fig. 4. Thickness dependence of radiowave reflectance of $Ni_{0.36}Zn_{0.64}Fe_2O_4$ specimen.

whole range. The real part of dielectric constant is about 10 and almost constant, while the dielectric loss (ε_{γ}'') is negligibly small. The material parameters are well suited for the absorber of an anechoic chamber.

The material properties satisfy equation (3) at 278 GHz, where zero-reflection should be obtained with an appropriate thickness. Using equation (2), the thickness is calculated to be 5.4 mm. This approach is illustrated with Fig. 3.

Fig. 4 shows thickness dependence of the microwave reflectance. The maximum attenuation is found to be at a thickness d=5.4mm. This value is in good agreement with the prediction shown in Fig. 3. The attenuation is greatly reduced when the thickness deviates from the value. The absorbing band is relatively wide. The reflection loss is lower than -16 dB in the whole frequencies. The ferrite plate with controlled composition and thickness can be effectively used for the absorber in shielded semi-anechoic or anechoic chambers because of its superior absorbing performance in radio frequencies.

4. Conclusion

Based on the design chart for radio-frequency absorber, the material parameters of magnetic permeability and dielectric constant of Ni-Zn ferrite tile was investigated for the application to anechoic chambers. The design chart satisfying the impedance-matching equation shows the area of complex plane of magnetic permeability. High magnetic lossy material is required in order to obtain the superior absorbing properties in the radio frequency range (30 MHz - 1 GHz). Sintered body of $Ni_{0.36}Zn_{0.64}Fe_2O_4$ spinel satisfies this magnetic properties and has superior microwave absorbing properties (frequency band and plate thickness) required in anechoic chambers.

Acknowledgements

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