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# THE MICROWAVE ABSORBING CHARACTERISTICS OF FERRITE GRID ABSORBER

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**Abstract**--In order to widen the band-width of ferrite absorber, compositional effect on the complex permeability of Ni-Zn ferrite and the structure of grid absorber were studied. From the experimental results, we could determine the optimum composition of Ni-Zn ferrite and the structure of grid absorber. Also, we manufactured grid absorber and investigated its microwave absorbing characteristics. Calculation shows that the ferrite grid absorber suppresses reflection ≤-20dB from 30 MHz to 700 MHz and the conventional ferrite tile absorber suppresses reflection ≤-20dB in the frequency range of 30 MHz-400 MHz. It was found that the microwave absorbing performance of the ferrite grid absorber was superior to the ferrite tile absorber.

## I. INTRODUCTION

The microwave absorber has been developed for broad band-width and light weight [1]. Especially, the widening of band-width is very important, because the band-width determines the operation frequency range. The regulations of microwave leakage in information technology equipments were decided from 30 MHz to 1000 MHz by C.I.S.P.R. Publ.22. To measure the radiated emission, nowadays, the RF anechoic chambers are used in many places.

At present, if only ferrite is used, the F.C.C standard is not satisfied. The reason is that the single layered ferrite absorber(ferrite tile absorber) can absorb microwaves from 30 MHz to 400 MHz in case of reflection ≤-20dB. So, not only the ferrite tile absorber but also lossy pyramid has been used.

In this study, in order to widen the band-width of ferrite absorber, two methods were applied. First, the variations of complex permeability with ferrite compositions were investigated. Second, variations of the microwave absorbing characteristics with grid structure were also examined. Based on the experimental, we manufactured the ferrite grid absorber and investigated the microwave absorbing characteristics.

## II. EXPERIMENTAL

Ni-Zn ferrites were prepared by conventional ceramic process. Raw materials(NiO,ZnO and $\alpha$-$Fe_2O_3$) were mixed, calcined, milled, axially pressed then sintered at 1150℃ for 2 hours in air.

The initial permeability and other magnetic properties of toroidally shaped specimens were measured by an impedance analyzer (Hewlett-Packard, HP-4194) and a B-H analyzer(Iwatsu, SY-8232), respectively. The scattering parameters($S_{11}$,$S_{21}$) of toroidally shaped ferrite(out dia.=7.0 mm, inner dia=3.0 mm) were measured by a network analyzer (Hewlett-Packard, HP-8753) in the frequency range 300 kHz~1 GHz. The complex permeability and permittivity were determined from the scattering parameters [2].

## III. RESULTS AND DISCUSSION

### *A) Effect of ferrite composition*

The microwave absorbing characteristics are influenced by the complex permeability and permittivity. Since the complex permittivity of the ferrite absorber is constant in the MHz range, the microwave absorbing characteristics strongly depend on the complex permeability. Fig.1 shows the variation of initial permeability($\mu_i$) with $Fe_2O_3$ and NiO content. As can be seen in Fig.1, the $\mu_i$ shows maximum at 49 mol %-$Fe_2O_3$.

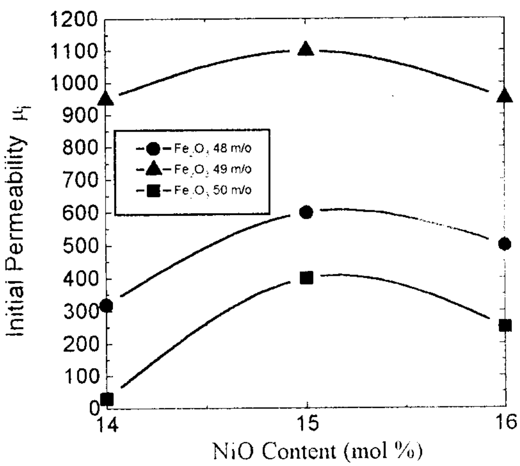


Fig.1 Variation of initial permeability of ferrite absorber with NiO content.

However, $\mu_i$ decreases upon increasing $Fe_2O_3$ content. This is believed to be due to the increase of anisotropy by addition of excess $Fe_2O_3$ [4]. The initial permeability also increased according to the decrease of NiO content (increasing ZnO content). For smaller NiO concentrations, however, the initial permeability remarkably decreased. The reason is probably that, for inverse spinel ferrite, the substitution of magnetic ions in a ferrimagnetic substance by non-magnetic ions(Zn ion) can lead to an increase in the saturation magnetization. However, in the case of lager concentration of non-magnetic ion, the magnetic moments of the few remaining $Fe^{3+}$ ions on the A sites are no longer able to align all the moments of the B ions antiparallel to themselves [5].

In order to optimize the composition for the wide band-width material of ferrite absorber, we constructed the initial permeability contour of NiO-ZnO-$Fe_2O_3$ system, and the results are shown in Fig.2.

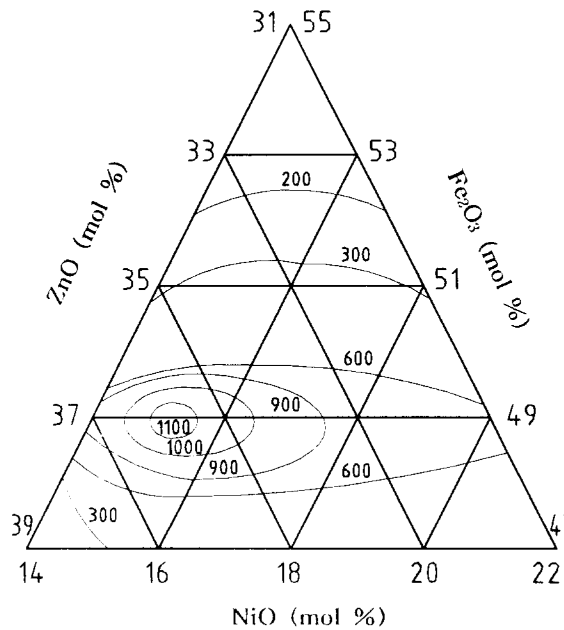


Fig.2 Initial permeability contour of Ni-Zn ferrite.

With decreasing the NiO content, the initial permeability increased. However, it has been known that the Curie temperature($T_c$) decreases according to the decrease of NiO content [5]. Therefore, the optimum composition must be designed under the consideration of initial permeability and other magnetic properties. From the results of Fig.2, we could develop two high permeability Ni-Zn ferrites (A-material : $\mu_i$=2000, B-material : $\mu_i$=1000). The magnetic properties of two materials are summarized in Table I.

Table I Magnetic properties of Ni-Zn ferrite developed in this study. ( freq. : 100 kHz, H : 800 A/m)

| | A material | B material |
|---|---|---|
| $\mu_{iac}$ | 2000 | 1000 |
| $B_{ms}$ | 260 mT | 280 mT |
| $H_c$ | 12 A/m | 24 A/m |
| $\tan\delta / \mu_{iac}$ | $25\times10^{-6}$ | $30\times10^{-6}$ |
| $T_c$ | 〉100℃ | 〉120℃ |
| $\rho$ | 1.0 MΩm | 1.0 MΩm |

Fig.3 and Fig.4 shows the complex permeability of A and B material, respectively. As shown in Fig.3 and Fig.4, the resonance phenomenon was observed. It was found that the $\mu'$ and $\mu''$ of A-material were higher than those of B-material.

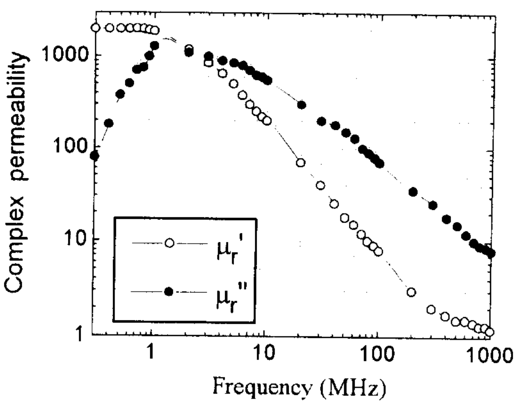


Fig.3 Frequency dependence of the complex permeability of Ni-Zn ferrite (A-material).

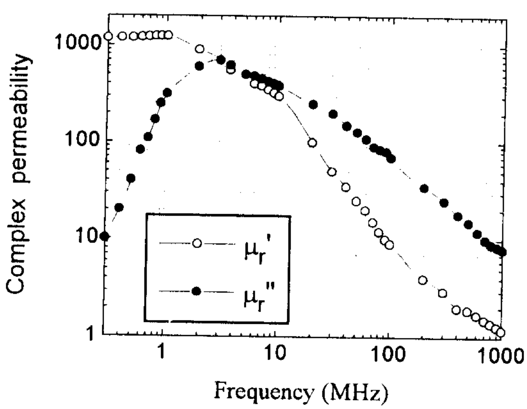


Fig.4 Frequency dependence of the complex permeability of Ni-Zn ferrite (B-material).

But the resonance frequency($f_r$ : frequency which $\mu''$ is maximum) of A-material was lower than that of B-material. Snoek [6] has suggested that the relation between $f_r$ and $\mu_i$ is

$$f_r\ (\mu_i - 1) = (4/3)\gamma M_s \quad (1)$$

where, $M_s$ is saturation magnetization and $\gamma$ is gyro-magnetic ratio.

From equation(1), $f_r$ and $\mu_i$ has inverse proportional relations. As can be seen in Fig.3, $\mu_i$ of B-material is smaller than that of A-material. Therefore, the resonance frequency of B-material is higher than that of A-material.

### *B) The microwave absorbing characteristics of ferrite grid absorber*

Fig.5 represents the structure of the ferrite grid absorber manufactured (SGA : Samwha Grid Absorber) in this study. In order to realize the polarization, i.e. low reflection for both vertical and horizontal polarization, the period and thickness of ferrite grid was set to be identical in both vertical and horizontal directions. Using the spatial network method [7], the reflectivity characteristics of grid structure were calculated for normal incidence of plane wave.

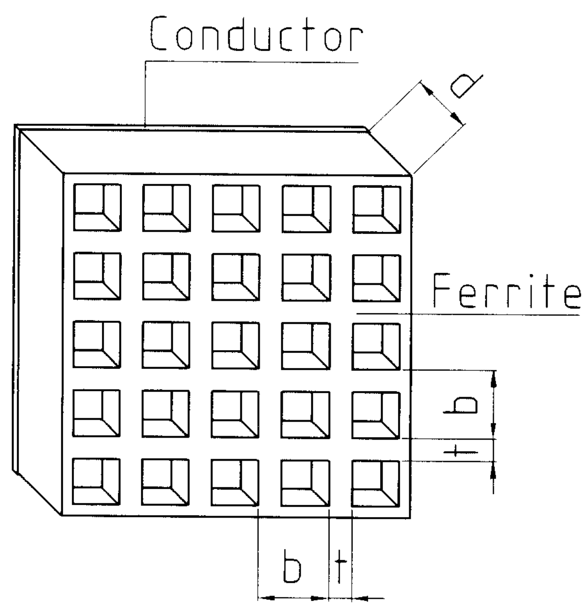


Fig.5 Structure of ferrite grid absorber(SGA).

In the calculation, the electromagnetic field was expressed in the equivalent circuit of the three-dimensional lattice network [8]. When a distance between adjacent nodes in the lattice network is taken sufficiently small comparing to the wavelength of interest, this method gives accurate results in the analysis of electromagnetic field even for complicated three-dimensional structures.

In order to determine the optimum structure which provides the highest band-width for reflection ≤-20dB, the reflection loss was investigated with variation of structure parameter in Fig.5. The sintered Ni-Zn ferrite used for calculation had the properties of K=1071, $f_r$=6.3 MHz and ε′ =12.5. The relative permeability of magnetic material is described by the dispersion equation [6].

$$\mu r=1+\frac{K}{1+j\ (f/f_r)} \tag{2}$$

where, K corresponds to the DC permeability and f is operating frequency. It is shown that the equation gives a good approximation in the frequency range which the permittivity ε′ is constant [9]. For examples, the results of calculation for the depth of ferrite grid taken as a parameter are shown in Fig.6 and Fig.7.

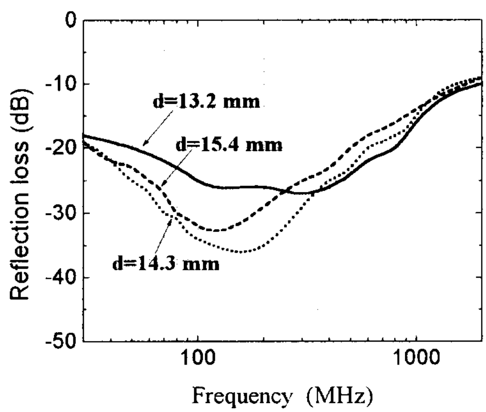


Fig.6 Characteristics of the grid absorbers with b=15.4 mm and t=6.6 mm. Grid depth d is taken as a parameter.

After the calculation of absorption characteristics, we concluded that the grid structure of b=19.8 mm, d=18.7 mm and t=6.6 mm provides the widest frequency range of 30 MHz～700 MHz for reflection ≤-20dB under the condition of -20dB reflectivity at 30MHz.

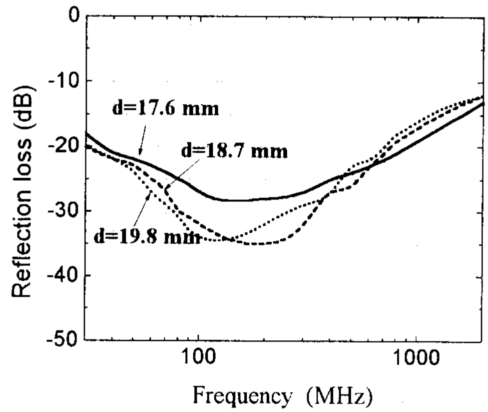


Fig.7 Characteristics of the grid absorbers with b=19.8 mm and t=6.6 mm. Grid depth d is taken as a parameter.

We compared the microwave absorbing performance of ferrite tile absorber with the grid absorber made of A-material, and the results are shown in Fig.8. It can be found that the ferrite tile absorber absorbs microwaves from 30 MHz to only 400 MHz in case of reflection ≤-20dB. However, the reflection of grid absorber is suppressed ≤-20dB in the frequency range from 30 MHz to 700 MHz and ≤-15dB up to 1000 MHz.

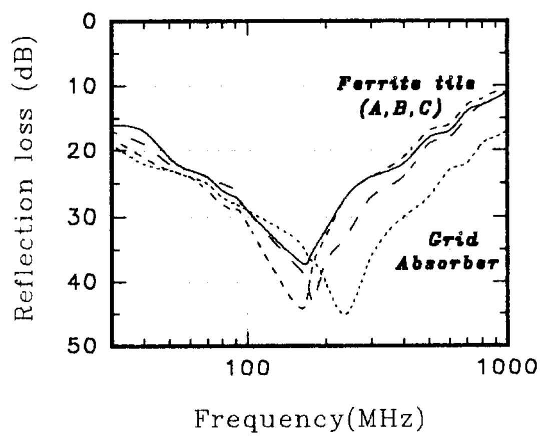


Fig.8 Normal incidence reflectivity of grid absorber performance (SGA).

Also, by constructing an electromagnetic darkroom with grid absorber, its superior absorption characteristic has been verified [10].

## Ⅳ.CONCLUSION

In this study, we focused on the broad-band absorption of ferrite absorber. From the experimental results, we could design the optimum ferrite composition and structure of grid absorber for wide band-width.

The optimized grid absorber provided the wide frequency range of 30 MHz～700 MHz for reflection ≤-20dB.

Based on these results, it can be concluded that the ferrite grid absorber provides wide frequency range of low reflection compare to the ferrite tile absorber.

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