The Reflectivity of the Ni-Zn Ferrite Tiles in the Microwave Frequency Range

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Abstract— In the paper, the investigation of the reflection coefficient of commercially available ferrite tiles at microwaves is presented. This material is typically used as an absorber in anechoic chambers but rather in low frequency range, mainly below 1 GHz where absorptive properties of sintered Ni-Zn ferrite are good enough. In the work it has been demonstrated that such ferrite absorber can also be used in higher frequencies up to 7 GHz. Proposed investigation of ferrite material allows to deeply reveal the reflection as well as the absorption properties of this material.

1. INTRODUCTION

The main advantage of testing in a chamber environment is having a clean ambient environment to work within. An anechoic chamber is the most common shield facility in use [8, 9, 11, 13, 14]. Such chamber contains ferrite tiles, carbon-filled absorber cones or mainly both of them. Generally there are two types of anechoic chambers. A full anechoic chamber is equipped with shielding material on the floor to antenna investigation while a semi-anechoic chamber has a metal ground plane on the floor [12, 16, 18–21, 23, 24].

To obtain high shielding performance for suppressing the radio frequency reflections inside the anechoic chamber the broadband absorptive materials with low level of reflection coefficient is necessary [2, 3, 6, 9]. In the frequency range below 1 GHz ferrites are the most commonly used materials as a kind of electromagnetic wave absorber. Many studies have been carried out to investigate the electromagnetic absorption properties of ferrite however, the application has been restricted by the narrow band characteristics of ferrite-absorbers [4, 5, 10, 15, 17, 21]. For the purpose of preparing a low-reflecting ferrite-absorber in the desired wide frequency range, two fundamental conditions must be satisfied, the first is that the energy of incident wave can enter the absorber (low reflectivity which can be guaranteed with suitable impedance matching characteristic of the material), and the second is that the electromagnetic wave entering into the materials can be attenuated (absorbed in the material) within the finite thickness of the material.

In this study the electromagnetic properties of commercially available Ni-Zn ferrite plates, were investigated. Typically this material is used as a metal-backed absorber. The principle of the metal-backed microwave absorber is to make use of the reflection reduction by impedance matching. According to the technical documentations the ferrite tiles can be used below 1 GHz due to their good shielding effectiveness in this frequency range. The electrical properties of commercially available Ni-Zn ferrite absorber above 1 GHz were not presented in the literature but very often such absorbers are used as the cover of the metal-floor hopefully that the reflectivity is almost low. In this work the investigation of reflection as well as absorption coefficients of commercially available Ni-Zn ferrite tiles at microwaves is studied. For this investigation the constitutive properties of material — permittivity and permeability have to be measured.

2. MEASUREMENT SYSTEM

Permittivity and permeability measurements of solid materials are commonly performed using coaxial fixtures. At microwaves, the coaxial line technique is especially recommended for broadband frequency measurements. The method of measurements of ε and μ based on determining the scattering parameters (S_{ik}) of the measured sample is the most popular [1]. In this work, the method of permittivity and permeability determination has been adopted for measurement of the slab materials in the coaxial lines. In this case, the measured material completely fills the cross section of the holder.

The single-slab plane-wave model was adapted to measure and compute the relative permittivity $\varepsilon = \varepsilon' - j\varepsilon''$ and permeability $\mu = \mu' - j\mu''$ of the measured material. The reflection and transmission S-parameters in coaxial line when the incident electromagnetic field is treated as plane wave can be interpreted as the infinite series of rays as a multiple reflections between the two surfaces of the sample. Scattering parameters of the sample S_{11} and S_{21} have been measured using the vector network analyzer (VNA) and they are the functions of unknown parameters ε and μ of the specimen.

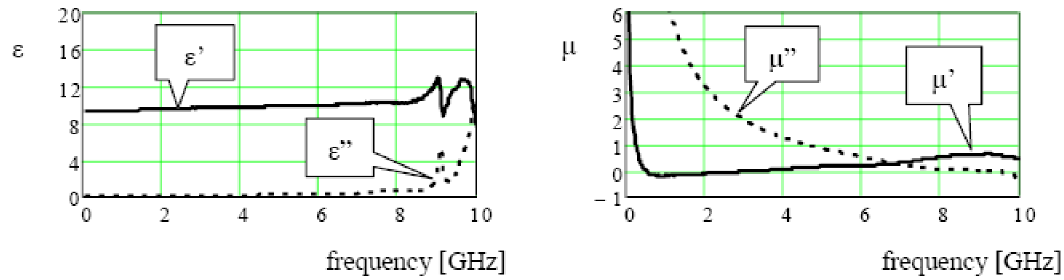

Figure 1: Real and imaginary parts of the relative permittivity and permeability of Ni-Zn sintered ferrite.

Having the scattering parameters of the sample, it is possible to calculate the permittivity and permeability using the NRW method [7, 22]. Measured values of permittivity and permeability of Ni-Zn ferrite in the frequency range from 100 MHz to 10 GHz are presented in Fig. 1.

Complex values of permittivity and permeability of Ni-Zn sintered ferrite allow to determine the reflection and absorption properties of this absorber.

3. REFLECTION COEFFICIENT

For a ferrite backed by a perfect conductor only the reflectivity can be characterized, but such information is not sufficient to recognize the absorption properties of the material. Additional analysis will be done with the S scattering parameters of a slab of the material in the free space. Two geometrical configurations of the material are taken into account:

a) the material is backed by a perfect conductor,

b) the material in the free space.

For the above geometry schematic presentations of the reflection coefficient Γ as well as reflection S_{11} and transmission S_{21} parameters of the slab of ferrite material for the case of normal incident of electromagnetic field are depicted in Fig. 2.

Figure 2(a) shows the case when analyzed ferrite absorber is backed by a perfect conductor, while Fig. 2(b) is done for investigation of such slab of material in free-space condition. The reflection coefficient Γ (Fig. 2(a)) of the slab of ferrite absorber backed by a perfect conductor can be compute using the transmission line analysis for normal incidence. For such field condition the incident electric and magnetic fields are parallel to the surface of the absorber slab. The reflection coefficient can be given as:

$$\Gamma = \frac{\sqrt{\mu}\tanh(\gamma d) - \sqrt{\varepsilon}}{\sqrt{\mu}\tanh(\gamma d) + \sqrt{\varepsilon}} \tag{1}$$

where: γ and d are the propagation constant and the thickness of the ferrite tile respectively.

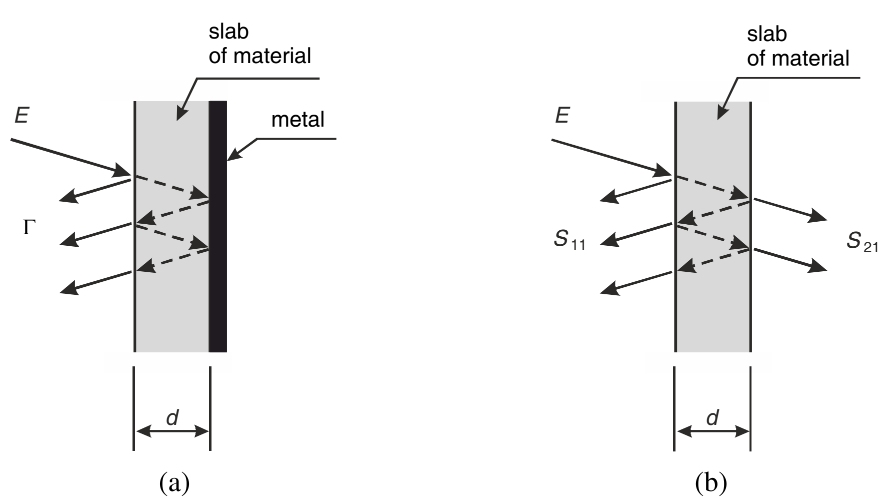

Figure 2: Schematic view of the reflection and transmission of the slab of material for the case of normal incident; (a) the material is backed by a perfect conductor, (b) the material in the free space.

Alternatively, the reflection loss expressed in dB can be used and is given by:

$$LR = 20 \log(|\Gamma|) \tag{2}$$

The thickness of the ferrite tile has been taken as $d = 5.4$ mm and this is typical thickness of commercially available ferrite absorber. Reflection loss (LR) of this ferrite absorber backed by metal was shown in Fig. 3.

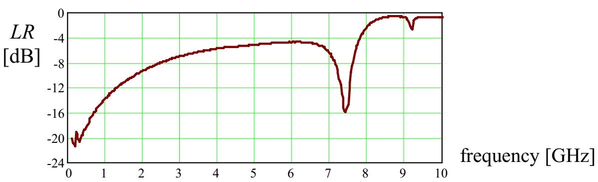

Figure 3: Reflection loss of ferrite tile backed by a perfect conductor.

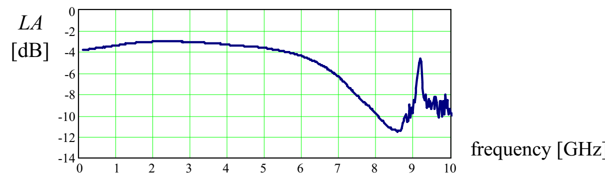

Figure 4: Absorption loss of ferrite tile.

As presented in Fig. 3, the reflection loss of 5.4 mm thick ferrite material backed by a metal shows good absorbing properties in the low frequency, i.e., below 1 GHz. In this case, the value of the reflection loss is low, lower than −15 dB. Thus, the reflected energy from the ferrite backed by metal can be negligible. In the frequency range from 1 to 7 GHz, the reflection loss increases with frequency and the level of reflected energy is higher, reaching value of −4 dB. At frequency 7.5 GHz, the ferrite backed by metal has good absorption properties. This good impedance matching was achieved by a quarter wavelength distance which works as a $\lambda_d/4$ transformer; where: λ_d is the wavelength in the material. For frequencies higher than 8 GHz the reflection loss is close to zero and this is why whole energy is reflected from such composite. Nevertheless, such investigation does not provide the information about the nature of such high reflection loss. To answer this question the additional investigation of absorbing properties of this material in free space condition are analyzed in the next section.

4. ABSORPTION COEFFICIENT

To obtain broader information about absorption properties of ferrite, the S-scattering parameters are necessary, Fig. 2(b). The S parameters can be acquired by the Vector Network Analyzer. According to the transmission line theory for a slab sample of material in free space, the following relationship can be formulated:

$$1 = |S_{11}|^2 + |S_{21}|^2 + |A|^2 \tag{3}$$

where: S_{11}, S_{21} — S-scattering parameters, A — absorption coefficient.

Alternatively, the absorption loss is expressed in decibels as:

$$LA = 20 \log(A) \, [\text{dB}] \tag{4}$$

The absorption loss can be used as a measure of the microwave absorption efficiency of the material. The higher the value of A is, the stronger the microwave absorbing ability of the composites would be. The value of absorption loss for Ni-Zn ferrite tile is presented in Fig. 4.

Figure 4 shows the absorption loss of ferrite tile in the free space condition. In frequencies lower than 6 GHz, the absorption loss is higher than −4 dB, which means that significant part of incident energy is absorbed by the material. In this frequency range, ferrite tiles are good absorbers and significantly reduce reflected rays. On the other hand, in frequency higher than 7 GHz the absorption loss has low value and the material does not absorb electromagnetic energy. In this case, the high value of the reflection loss mentioned in Fig. 3 is due to reflection from conducting surface on the back of ferrite because ferrite should be treated as transparent dielectric.

5. CONCLUSIONS

In this paper the investigation of the reflection coefficient of commercially available ferrite tiles used in anechoic chambers has been presented. This material is typically used as an absorber but his use in it is rather suggested for low frequency range, mainly below 1 GHz. In this work using additional investigation, it has been proved that such ferrite absorber can also be used in higher frequencies up to 7 GHz. Proposed investigation of ferrite material allows to deeply reveal the reflection as well as the absorption properties of this material.

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