Accurate Determination of Magnetic Loss of Ferrite Material, far from Gyroresonance, ΔH_{eff}, in a Wide Frequency Range

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***Abstract*—The purpose of the presented work is an accurate determination of magnetic loss far from gyromagnetic resonance (ΔH_{eff}), in a wide frequency range using resonant cavities completely or partially filled with magnetic material. The rigorous analytic field expressions are given for any mode of each device. The importance of the relative metallic loss is pointed out and the accuracy of the determination of the conductivity of metallic walls is discussed. The accuracy of the ΔH_{eff} determination is studied for each structure.**

I. Introduction

Microwave magnetic loss far from the ferrimagnetic resonance is characterized by the parameter ΔH_{eff} which is difficult to obtain in a wide frequency range. Measurements are often made by perturbation method in a cavity where a small magnetic sample is centered [1]. The main problem of this method is that magnetic loss is just calculated at one frequency for one size of cavity and furthermore large cavities are needed at low frequencies. Another method of determination of magnetic loss far from gyroresonance has already been presented by Ogasawara and Al [2]. The authors used a metallic cavity completely filled with a ferrite. The ferrite is considered as a nearly isotropic material and quasi $TE_{\pm 111}$ mode is used. Metallic loss is assumed constant when the static internal magnetic field varies.

In this paper three resonant structures are used to determine ΔH_{eff} more rigorously:

- the metallized ferrite coaxial resonator,
- the metallized ferrite resonator,
- a ferrite disk centered in a metallic cavity.

Accuracy of obtained results are compared:

The analytical field expressions and resonant frequencies of the three devices are calculated by mode matching method taking into account the anisotropy of the medium. The theoretical principle of determination of magnetic loss (ΔH_{eff}) is presented. Every kind of loss (dielectric, magnetic, and metallic) is calculated for each static magnetic field. The conductivity of metallic walls σ_M is determined for each device and the effect of the accuracy obtained on this parameter on the accuracy of the ΔH_{eff} determination is shown. At last, examples of characterisation are given for each structure.

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II. Fields and Resonant Frequencies in the Three Studied Structures

Field components and resonant frequencies of these structures have been already studied and published [3], [7], [8], so the main results are just recalled in this paper.

The 3 devices are on Fig. 1.

The ferrite sample is magnetised by a static magnetic field H_0 applied along the z axis. In this case the permeability tensor is [4]:

$$(\mu) = \mu_0 \begin{pmatrix} \mu & -jK & 0 \\ jK & \mu & 0 \\ 0 & 0 & \mu_z \end{pmatrix}$$

with:

$$\mu = 1 + \frac{\omega_0 \mu_M}{\omega_0^2 - \omega^2} \quad \text{(losses are neglected and material is supposed to be saturated)}$$

$$K = -\frac{\omega \omega_M}{\omega_0^2 - \omega^2}$$

$\omega_0 = 2\pi\gamma H_0$

$\omega_M = 2\pi\gamma 4\pi M_S$

H_0 = internal magnetic field (Oe) related to the applied field by the demagnetizing factors for each structure

γ = gyromagnetic ratio (2.8 MHz/Oe)

$4\pi M_S$ = saturation magnetisation

ω = microwave radian frequency.

In the ferrite material the longitudinal components of fields are solutions of coupled differential equations derived from Maxwell equations which are coupled [5], [6]:

$$\begin{cases} \Delta_t E_z + \dfrac{\delta^2 E_z}{\delta z^2} + \omega^2 \epsilon_0 \epsilon_f \mu_{\text{eff}} E_z - \omega K \dfrac{\mu_z}{\mu} \dfrac{\delta H_z}{\delta z} = 0 \\ \Delta_t H_z + \dfrac{\mu_z}{\mu} \dfrac{\delta^2 H_z}{\delta z^2} + \omega^2 \epsilon_0 \epsilon_f \mu_z H_z + \omega \epsilon_0 \epsilon_f \dfrac{K}{\mu} \dfrac{\delta E_z}{\delta z} = 0 \end{cases} \tag{1}$$

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