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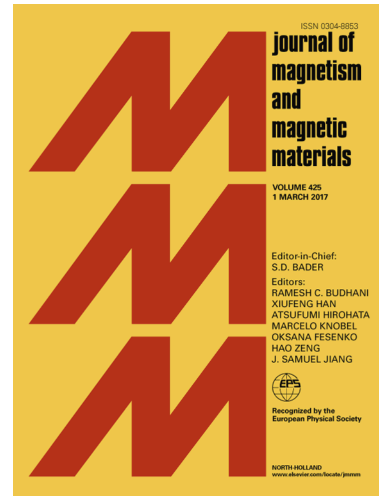

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Magnetic and dielectric properties in the UHF frequency band of half-dense Ni-Zn-Co ferrites ceramics with Fe-excess and Fe-deficiency

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This work investigates electromagnetic properties of half-dense ceramics with compositions $Ni_{0.5}Zn_{0.3}Co_{0.2}Fe_yO_{4-\delta}$ where y=1.98 (Iron deficient, noted ID) or y=2.3 (Iron in excess, noted IE). IE and ID materials are obtained by chemical coprecipitation route. The obtained nano-sized powders are pressed and annealed at two temperatures (800 °C, 900 °C), so has to obtain half-massive ceramics. Ferrous and ferric ions coexist in the crystalline structures, but the former in a less extend for ID ferrite. The concomitant influences of Fe^{2+} and Fe^{3+} on the dielectric and magnetic losses (ε''/ε' and μ''/μ', respectively) are considered at frequency up to 6 GHz. The permeability dispersion changes from relaxation-like to resonance-like with the decrease in ferrous ions. In reason of the relaxing-like behavior of Fe^{2+}, and because of a relatively high amount in Fe^{2+}, IE sample shows lower total losses (magnetic and dielectric) than ID sample. These conclusions applied for T_A=900 °C. At frequencies above 700 MHz, the total loss values (IE and ID samples) are prohibitive for antenna downsizing whatever is the firing temperature value (800 °C and 900 °C). Whereas at frequencies below 700 MHz $Ni_{0.5}Zn_{0.3}Co_{0.2}Fe_{2.3}O_{4+\delta}$ may leads to better antenna performances than $Ni_{0.5}Zn_{0.3}Co_{0.2}Fe_{1.98}O_{4-\delta}$.

Index Terms— **Iron-excess ferrites, magnetic permeability, Microwave frequencies.**

1. Introduction

There is an increasing demand of antenna downsizing, which especially concerns the electronic devices for mobile communication and aerospace areas [1]. In this topic, size reduction is frequently reached using high-permittivity substrates. However a drawback is a considerable decrease in antenna efficiency and bandwidth [2,3]. It has been shown that the use of magneto-dielectric substrates for applications in the low-UHF frequency band (300-900 MHz) may get over these limitations. Actually, using such materials (with permeability $\mu^*=\mu'+j\mu''$ and permittivity $\varepsilon^*=\varepsilon'+j\varepsilon''$, where μ'>1 and ε'>1) led to larger bandwidths and improved efficiency for the antenna [4,5]. Indeed, the permeability (μ') decreases the detrimental effects of losses, whereas the permittivity (ε') -while increasing the stored energy- has the opposite effect. Then the permeability presents a positive impact on antennas' performances, which counterbalance the negative impact of permittivity. An example is provided by the antenna efficiency η. An ideal transmitting antenna accepts power (P_{input}) from a source and radiates the power ($P_{radiated}$) into space. The ratio of $P_{radiated}$ to P_{input} is the antenna efficiency η (Eq.1) [6], which affects the ability of an antenna to generate far field electromagnetic radiation. Let us consider a patch antenna of width W over a magneto-dielectric substrate (μ, ε) of thickness d. Eq.(1), illustrates the opposite roles taken by μ' and ε' on the antenna efficiency. Actually in this equation, where G_r is the radiation conductance of the antenna [7], L represents the sum of magnetic and dielectric losses (defined as μ''/μ' and ε''/ε', respectively). It is clear from Eq.(1) that to use a substrate with μ>1 would lead to compensate –at least partly- the undesirable effects coming from L.

$$\eta = \left(1 + \frac{L}{240G_r}\frac{W}{d}\sqrt{\frac{\varepsilon}{\mu}}\right)^{-1} \qquad (1)$$

The materials intended to be used for antenna miniaturization should show ε'>1 and μ'>1, together with low loss tangents (both dielectric and magnetic) [8,9]. Bulk spinel ferrites meet these requirements up to frequency values about 300 MHz, but show detrimental magnetic losses at higher frequencies. Elevated sintering temperatures are usually required (1100 °C-1200 °C) in order to obtain such dense ferrite substrates [9,10]. Actually this allows a large grain growth, and therefore a multi-domain magnetic grain structure by which high permeability values are ensured. As a counterpart, domain-wall bulging results in magnetic losses. These losses remain high from the quasistatic frequencies until several 100 MHz. There is an upper limit of frequency above which ferro-ferrimagnetic materials cannot be used for low-loss electromagnetic devices applications. This limit is fixed by the ferromagnetic resonance frequency f_R (The observed maximum of μ" in the μ"-f curve obtained on polycrystalline materials, accords with the resonance frequency; this feature defined the ferro-ferrimagnetic resonance f_R [11]). Above this cut-off value of frequency there is a large increase in magnetic losses, which runs along with a decrease in permeability. This was recognized by Snoek [12], who stated first the following relationship that exists between the static permeability μ_S and the spin resonance frequency f_R: $(\mu_S-1).f_R=2/3\bar{\gamma}\, M_S$, where M_S is the magnetization at saturation and $\bar{\gamma}$ is the gyromagnetic ratio ($\bar{\gamma}$ =35.185 MHz/kA.m^{-1}). For most bulk materials, Snoek's law applies [13]. More recently, the following