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Determination of Electric and Magnetic Properties of Commercial LTCC Soft Ferrite Material

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Abstract—**This paper offers an effective, accurate, and simple method for permittivity and permeability determination of an LTCC (low temperature cofired ceramic) ferrite sample. The presented research can be of importance in the fields of ferrite component design and application, as well as for RF and microwave engineering.**

The characterization sample is a stack of LTCC tapes forming a toroid. Commercially available ferrite tape ESL 40012 was used and standard LTCC processing was applied for the sample fabrication. For the first time, the electrical properties of a ferrite toroid sample of ESL 40012 LTCC ferrite tape is presented at various frequencies. The electrical properties of LTCC ferrite materials, permittivity and specific resistivity, are shown in a frequency range from 10 kHz to 1 MHz using the capacitive method. The hysteresis properties of this material are also determined. B-H hysteresis loops were measured applying a maximum excitation of 2 kA/m and frequencies of 50 Hz, 500 Hz, and 1000 Hz.

Permeability is determined in the frequency range from 10 kHz to 1 GHz and a characterization procedure is divided in two segments, for low and high frequencies. Low frequency measurements (from 10 kHz to 1 MHz) are performed using LCZ meter and discrete turns of wire, while a short coaxial sample holder and vector network analyzer were used for the higher frequency range (from 300 kHz to 1 GHz).

In addition, another important factor required for the practical design of devices is presented, the temperature variation of the permeability dispersion parameters.

Keywords—**LTCC ferrite tape, permeability, permittivity, specific resistivity—**

Introduction

Low temperature cofired ceramic (LTCC) technology has become one of the key technologies for the fabrication of integrated passive devices. Multilayer chip LC filters, multilayer hybrid circuit devices, and chip beads have been introduced in recent years, expanding the family of inductive multilayer devices [1].

As a result of the expansion of devices, the characterization of the electric and magnetic properties of LTCC ferrite material is very important for component design. Knowledge of these parameters can be crucial in circuit design and wave transmission calculations. These materials have many important properties and require different measurement methods for their characterization.

In addition, ferrite materials have extremely nonlinear properties, and a great deal of information can be learned about the magnetic properties of a material by studying its hysteresis loop. There are various methods to determine the hysteresis loop, for example, as shown in Nakmahachalasint et al. [2] and in Tellini et al. [3].

Ferrite's permeability measurements are necessary for engineers to design and choose ferrite properly. The inductance of ferrite core inductors depends not only on the number and geometry of the winding wires, but also on the permeability of the ferrite core. However, at high frequencies, direct measurement of permeability is difficult. The commonly used methods for magnetic material determination are the transmission/reflection method [3-10], the equivalent circuit model method [11, 12], and the resonant method [13]. In Naishadham [11], the frequency dependent RLC equivalent circuit parameters (impedance, resonant frequency, resonant impedance, and quality factor), as well as the effective permeability of the ferrite core, are extracted from the measured values. It is assumed that the capacitance of the equivalent circuit does not vary with frequency. The impedance measurement is accomplished using an impedance analyzer.

Another extraction method, presented in Yu et al. [12], requires the assumption that the inductance of the equivalent circuit does not change significantly with frequency when the frequency is lower than the roll off frequency of core permeability. The equivalent circuit parameters of the inductor are derived by measuring the resonant frequencies of two different inductor circuits where the resonant frequencies are close to each other. Due to the assumptions mentioned above, the upper frequency limitation of this method is the inductor's self-resonant frequency. The measurements must be accomplished using both a network analyzer and an RF LCZ meter. When the relative permeability in the high frequency range extended to 1 GHz or even higher has to be determined, a vector network analyzer (VNA) and an appropriate coaxial sample holder is used acting as a measurement setup [14, 15]. A simple experimental method to determine the initial complex permeability of the toroidal ferrite core using custome designed fixtures is introduced. With the ferrite core installed

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