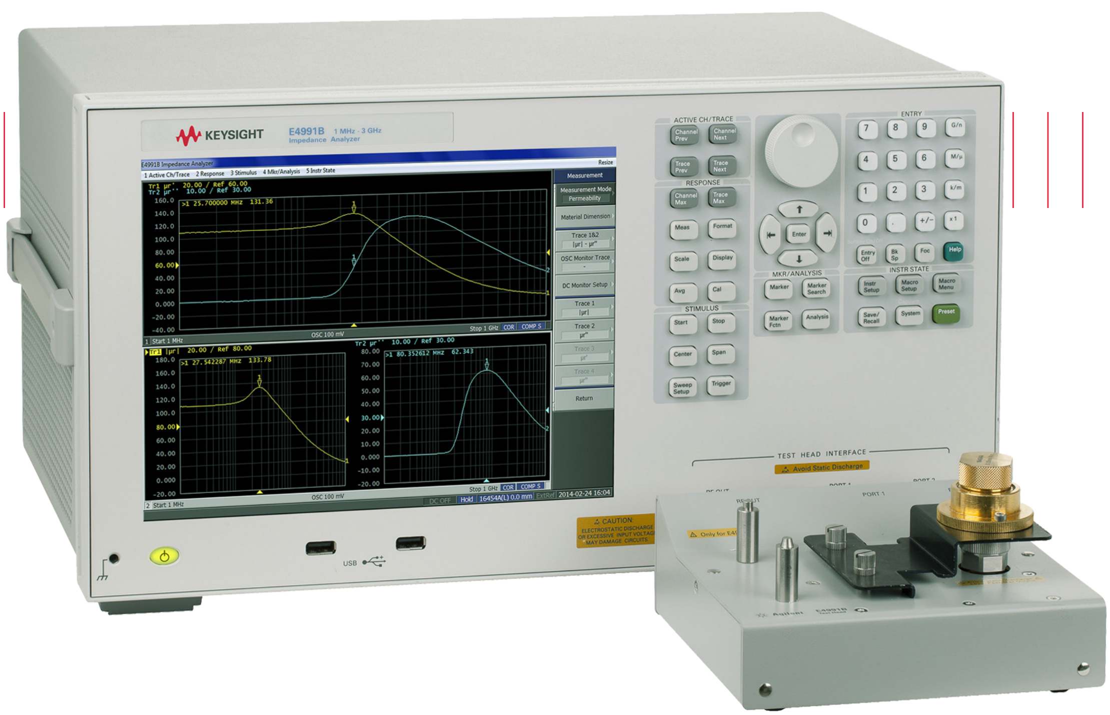
Keysight Technologies
Materials Measurement: Magnetic Materials

Application Brief



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Overview

Ferrite materials are widely used in electronic equipment such as computers, communication devices, power management systems, etc. They serve as inductive components, transformers, magnets, magnetic field absorbers and suppressors.

Continual exploration of new materials helps not only to improve performance, but to reduce size and power consumption. Recent progress in the material science and nanotechnology area has created new types of ferrite materials and components.

Evaluation of magnetic characteristics of those materials is important in predicting performance of the components. Performance includes permeability and loss of the material at various frequencies where the devices are used.

Impedance analyzers used with magnetic material fixtures provides precise, repeatable, cost-effective and an easy-to-operate measurement system over a wide frequency range.

Problem

Complex permeability is a magnetic property of a material. Its real and imaginary part represents the ability of a material to conduct magnetic flux and the losses dissipated in the material respectively. Material with large permeability is desired to reduce size and weight. Losses should be minimized for maximum efficiency while large loss is required for magnetic shield.

Complex permeability is determined by the impedance of the inductor formed with the material. In most cases, it is not a constant over the frequency and must be characterized at the frequency where the device is used. At higher frequencies, accurate measurements are difficult due to the parasitic impedance of the fixture. For low loss material, phase angle of the impedance is critical however the phase accuracy is not sufficient in many cases.

Permeability also varies with temperature. The desired measurement system is one that can evaluate temperature characteristics with sufficient accuracy over a wide frequency range using a simple operation.

Solution

The complex permeability is derived by measuring the impedance of the magnetic material. It is done by winding some wire around the material and measuring the impedance with respect to the ends of the wire. The result may change depending on how the wire is wound and how the magnetic field interacts with its surroundings.

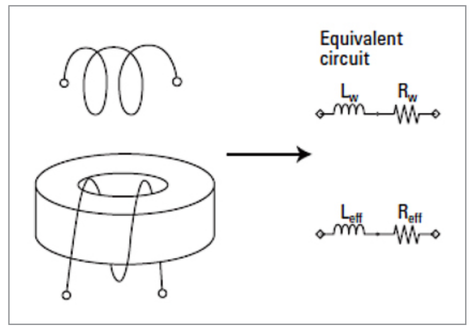

Figure 1. Method of measuring effective permeability

The Keysight 16454A magnetic material test fixture provides an ideal structure, configuring a single-turn inductor with the material molded into a toroidal shape. There is no leakage flux in the single-turn inductor and the magnetic field in the fixture is strictly calculated from the electromagnetic theory.

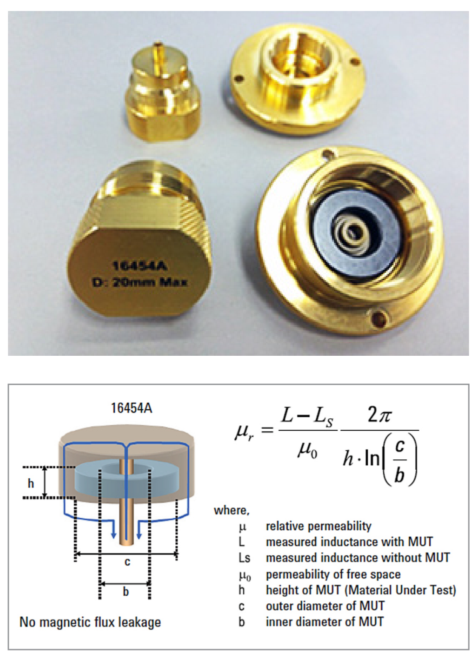

Figure 2. Structure of the 16454A

The simple shape of the coaxial fixture and the toroidal material under test allows not only the precise evaluation but the wide frequency coverage. The 16454A magnetic material fixture covers 1 kHz to 1 GHz when combined with the Keysight E4991B impedance/material analyzer or the Keysight E4990A impedance analyzer.

Errors due to the measurement system should be removed prior to the measurement. The error due to the impedance analyzer can be calibrated by three term error correction. At higher frequencies, phase angle accuracy is enhanced by the low-loss capacitor calibration built into the E4991B.

Another source of error is due to the fixture. Residual inductance included in the fixture can be removed by a short calibration, which compensates the residual inductance by measuring the fixture without toroidal core.

$$\mu^* = \mu' - j\mu'' = 1 + \frac{2\pi(Z_m - Z_s)}{j\omega\mu_0 h \ln\frac{c}{b}}$$

where μ^* : complex permeability

μ_0 : permeability of free space

Zm : measured impedance

Zs: short impedance

ω: angular frequency

h, c, b: dimension of the troidal core

$$\tan\delta = \frac{\mu''}{\mu'}$$

These systems allow users who have no specific expertise to evaluate the magnetic property of the material without knowledge of electromagnetic theory or calibration techniques. All the necessary calibrations, corrections, and calculations are done within the analyzer and the result is directly obtained.

The graph below shows a permeability example of three different ferrite cores measured by the E4990A and the E4991B with the 16454A fixture.

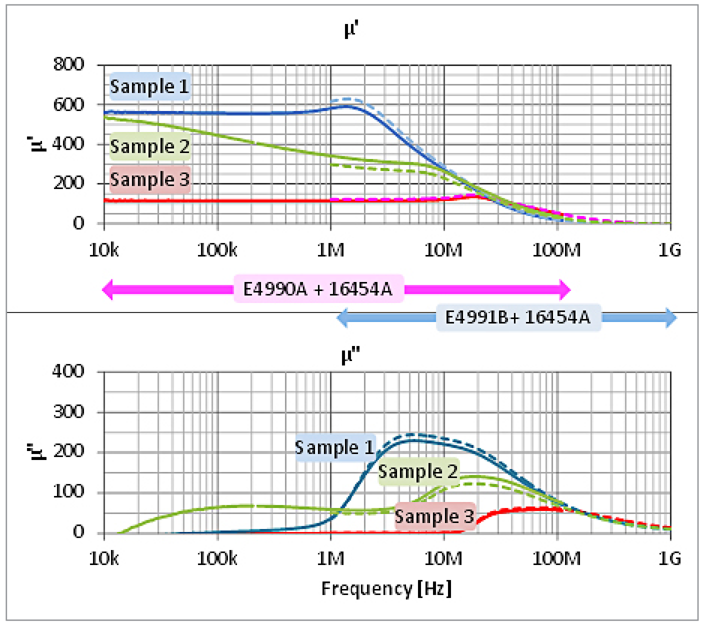

Figure 3. Measurement result example

For the evaluation of temperature characteristics of the magnetic material, a temperature chamber and heat resistant cables are required. Keysight supplies a program for chamber control and data analysis along with the heat resistant cable kit as an option of the E4991B.

Conclusion

Advances in technology are demanding newer devices. Recent progress in material science has allowed for the development of new materials. A measurement system with accuracy and stability is desired for time and cost effective evaluation.

A combination of a fixture and an impedance analyzer is a standard solution for the evaluation of magnetic material. Single-turn inductor formed with toroidal core and test fixture enables a simple and repeatable method over a wide frequency range.

Keysight Technologies provides impedance analyzers, fixtures, calibration technique and software for data analysis and temperature characteristic evaluation.

For more information, application notes and papers are available under references.

References

1. Bai, Yang, et al. “The static and hyper-frequency magnetic properties of a ferromagnetic–ferroelectric composite.” Journal of Magnetism and Magnetic Materials 321.3 (2009): 148-151.

2. Xu, Fang, et al. “The magnetic and dielectric properties of multiferroic Sr substituted Zn2-Y hexagonal ferrites.” (2008).

3. Ji, Jeong Keun, et al. “Miniaturized T-DMB Antenna With a Low–Loss Ni–Mn–Co Ferrite for Mobile Handset Applications.” Magnetics Letters, IEEE 1 (2010): 5000104-5000104.

4. Kračunovska, S., and J. Töpfer. “Preparation, thermal stability and permeability behavior of substituted Z-type hexagonal ferrites for multilayer inductors.” Journal of electroceramics 22.1-3 (2009): 227-232.

5. Mallick, Kajal K., Philip Shepherd, and Roger J. Green. “Magnetic properties of cobalt substituted M-type barium hexaferrite prepared by co-precipitation.” Journal of Magnetism and Magnetic Materials 312.2 (2007): 418-429.

6. Park, Sang Hoon, Won Ki Ahn, and Ki Ho Kim. “Complex Permittivity and Permeability of Magnesium-Copper Spinel Ferrite under Heat-treatment Conditions.” ELECTRONIC MATERIALS LETTERS 4.4 (2008): 175-179.

7. Pervaiz, Erum, and I. H. Gul. “Magneto-Dielectric and Electromagnetic Absorbing studies of Antimony Doped Nickel Ferrites.” (2013).

8. *Solutions for Measuring Permittivity and Permeability with LCR Meters and Impedance Analyzers*, Application Note 1369-1 Literature number 5980-2862EN

9. *Basics of Measuring the Dielectric Properties of Materials*, Application note, Literature number 5989-2589EN

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Published in USA, July 17, 2014
5991-4714EN
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