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Agilent AN 1300-4

Permeability Measurements Using the 4291B and 16454A

Application Note

The Agilent 4291B RF impedance and material test system

New solutions for material measurements at RF range

Introduction

Magnetic materials are commonly used in electronic products as cores of inductors and transformers and as EMI suppressers. With many digital applications operating with increased clock speeds and with the multitude of new products operating in the RF range for wireless communication, evaluating magnetic material over RF frequencies has become more important.

This application note discusses magnetic material relative permeability measurements and introduces the Agilent Technologies 4291B RF Impedance/Material Analyzer. This application combines the measurement accuracy of the 4291B RF Impedance Analyzer with special material measurement firmware (Option 002) and the 16454A magnetic material test fixture. The result is an easy-to-use measurement system that simplifies the characterization of magnetic materials from 1 MHz to 1 GHz.

Background

Magnetic material relative complex permeability (permeability and loss factor) affects many parameters of inductive circuit components. Inductance, loss, Q, and usable frequency are just a few. Relative permeability is therefore often measured over a variety of conditions to characterize permeability parameters as a function of:

- Frequency
- Current dependence (AC signal and DC bias)
- Temperature

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The conventional method to measure relative permeability of a toroidal core is shown in Figure 1. A handmade inductor is wound on the core and the inductance is then measured using an impedance analyzer or LCR meter. Calculations are then performed to derive the relative permeability parameters.

This procedure has some major disadvantages. First, since the measurement is based on a handmade inductor, measurement results are affected by how an inductor is made. If many core samples are measured, repeatability can be a problem due to variation coil winding. Second, as the frequency of interest increases, physical dimensions get small, making winding and quality control of the test turns even more difficult. Third, calculations are required to derive permeability from the impedance results.

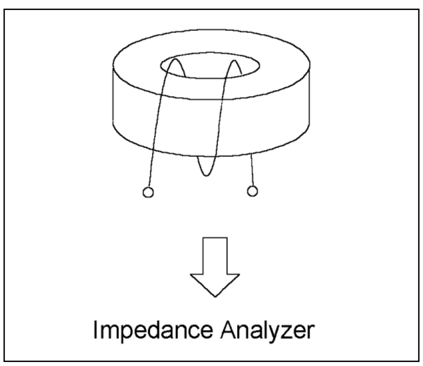

Figure 1. Hand-wound inductor method for permeability measurement

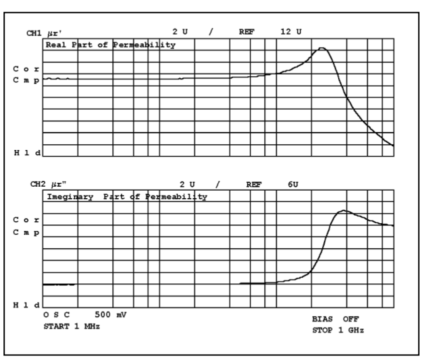

Figure 2. Relative permeability test results shown in magnitude and loss tangent

Another challenge confronting the person characterizing these materials is how to measure permeability parameters as a function of temperature. Traditionally, extending the measurements to a temperature chamber created additional errors and setting up the temperature test system was not trivial.

New RF measurement solution provides ease of use and high accuracy

The 4291B magnetic material measurement system consists of the 4291B RF Impedance/Material Analyzer, Option 002 material analysis firmware, Option 012 low impedance test head, and the 16454A magnetic material test fixture. The combination offers an easy-to-use and highly accurate solution for permeability analysis.

Simplified testing saves time: The 4291B system is a complete solution for relative permeability measurement that doesn't rewire any inductor winding or calculations. Option 002 material measurement firmware provides direct relative complex permeability readouts, eliminating the need for an external controller. Results may be displayed in a variety of formats. Figure 2 shows permeability magnitude and loss tangent test results as a function of frequency. The firmware also includes a 16454A fixture compensation function for improved accuracy.

Testing is simplified with the 16454A magnetic material test fixture. See Figure 3. Consisting of a large and a small fixture assembly, the 16454A allows a wide range of toroid sizes and requires no special core preparation. See Figure 4 for core dimensions.

High accuracy measurement method: The system uses the inductor method to measure relative permeability. The measurement basics are shown in Figure 5. When a toroidal core is inserted into the fixture, the fixture halves from an ideal one-turn inductor (no magnetic flux leakage). The 4291B measures the impedance of the inductor and calculates relative complex permeability with the equation shown.

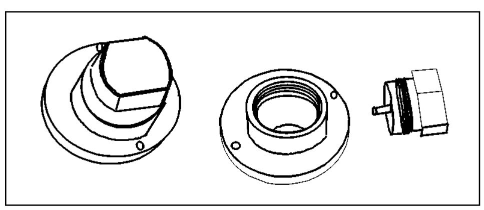

Figure 3. The Agilent 16454A magnetic material test fixture assemblies

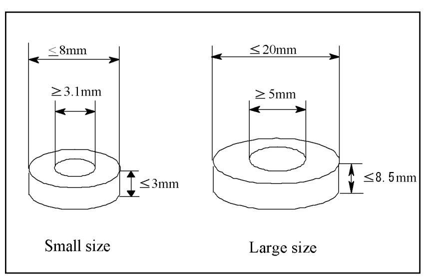

Figure 4. Toroid dimensions for the 16454A fixtures

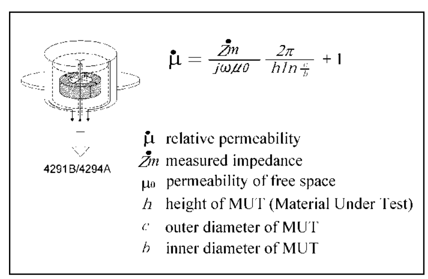

Figure 5. Inductor method permeability measurement

Its high accuracy (typically ±4% for permeability and ±0.002 for loss tangent at 100 MHz and ε_r=100) is achieved by the near ideal characteristics of the 16454A fixture and the analyzer's high accuracy impedance measurement capability.

Measure voltage and current dependence: The 4291B is also capable of making measurements while changing the AC test signal applied to the fixture's effective one-turn winding. The test signal can be swept from 0.2mV to 1V (up to 0.5V for 1 GHz and higher). Test signal current sweep is available using IBASIC and an application program furnished with the standard 4291B. Figure 6 shows an example of an AC current dependence measurement using IBASIC and the current sweep application program.

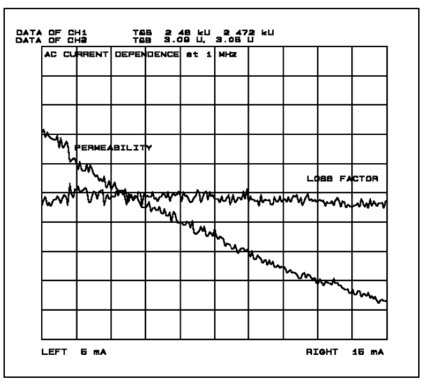

Figure 6. Relative permeability as a function of test current

A DC bias of up to 100 mA can also be applied or swept by adding Option 001. See Figure 7. The system's ability to vary the test conditions to simulate actual operating conditions provides important information for magnetic material research and evaluation.

Simplified temperature characteristic measurement

The 4291B is designed to be an instrument controller using IBASIC. As such, it can control other test equipment and/or a GPIB controllable environmental chamber. The system provides the following features and options to simplify evaluating the curie temperature (maximum usable temperature) or other permeability temperature characteristics.

1.8 m cable to the measurement head: Convenient for system configuration. Does not affect the accuracy of the measurement.

High temperature low impedance test head option (Option 014): A heat-resistant cable (–55°C to 200°C) to extend the 7 mm calibration plane while at the same time maintaining high accuracy.

Wide operating temperature range of the fixture: The 16454A fixture can be used from –55°C to 200°C without loss of accuracy.

GPIB and built-in IBASIC controller function: Provides an interface and controller function for automatic measurement and chamber control. A third party temperature chamber is required. Tabai Espec Corporation offers a temperature chamber (SU-240-Y) compatible with the 4291B. It is pictured in Figure 8.

Application program: This IBASIC program for temperature characteristics evaluation and chamber control is compatible with the Tabai Espec temperature chamber. It is included with the optional high temperature low impedance test head (Option 014).

Graphic display: Displays measured parameters as a function of chamber temperature. See Figure 9.

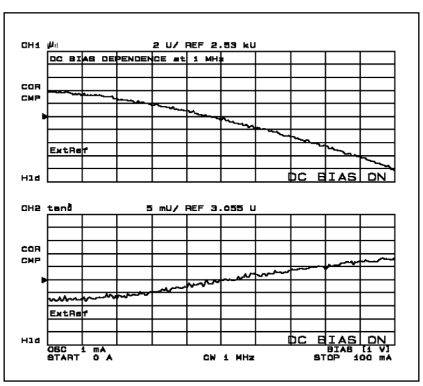

Figure 7. Permeability as a function of DC bias

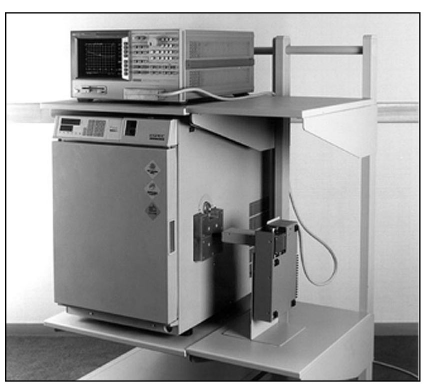

Figure 8. Using the Tabai Espec SU-240-Y temperature chamber with the 4291B

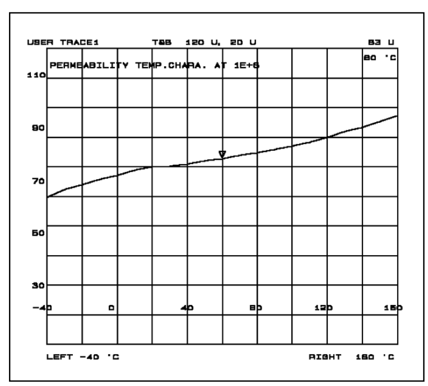

Figure 9. Direct display of temperature characteristics

Basic measurement procedure
Figure 10 shows the basic measurement steps for magnetic material measurements.

System configuration information

Basic permeability measurement system configuration:

- 4291B RF Impedance/Material Analyzer
  Options:
  002: Material measurement firmware
  012: Low impedance test head*
- 16454A Magnetic material test fixture

*The low impedance test head is required for permeability. Option 011 is available to delete standard high impedance test head.

Temperature characteristics evaluation system configuration:

- 4291B RF Impedance/Material Analyzer
  Options:
  002: Material measurement firmware
  014: High temperature low impedance test head*
- 16454A Magnetic material test fixture
- Temperature chamber (third party)**

* 4291B Option 011 is available to delete standard high impedance test head.

**Tabai Espec Corporation offers a temperature chamber (SU-240-Y) compatible with the 4291B system.

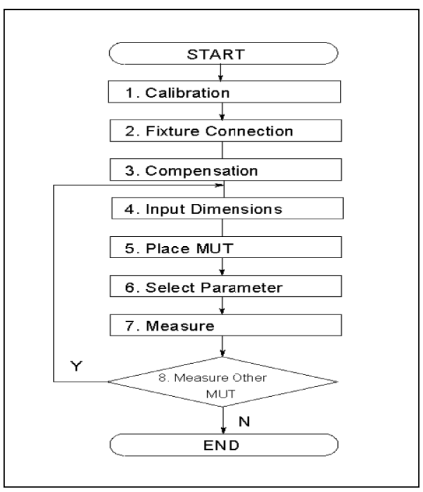

Figure 10. Magnetic material measurement process

Conclusion

The Agilent 4291B RF Impedance/Material Analyzer (with Option 002 material measurement firmware) and 16454A dielectric material fixture system is an ideal solution for toroidal magnetic material permeability measurements up to 1 GHz. The system provides accurate results and is easy to use. It also has the capability to automatically control a compatible temperature chamber and provide direct display of permeability temperature characteristics.

For more information

For more information, request the following literature from your local Agilent representative:

Agilent 4291B 1.8 GHz Impedance/Material Analyzer, Product Overview, 5966-1501E

Agilent 4291B 1.8 GHz Impedance/Material Analyzer, Data Sheet, 5966-1543E

Evaluating Temperature Characteristics using a Temperature Chamber and the 4291B, Product Note, 5966-1927E

Solutions for Measuring Permittivity and Permeability, Catalog, 5965-9430E

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