Agilent AN 1300-6

Impedance Characterization of Magneto-Resistive Disk Heads

Application Note

Using the Agilent 4291B Impedance/Material Analyzer

Introduction

In the computer data storage business, there is an endless demand for hard disk drives with higher density and faster data transfer. This demand has given rise to a constant stream of new technologies in recent years. Disk drive heads using the magneto resistive (MR) effect are now of prime importance among such technologies. Deliveries of MR heads have shown a steady growth for the last few years through expanded production volume. In addition, MR head technology has experienced growing interest because it is now seen as the first viable candidate for replacing conventional inductive heads.

For the MR technology, the manufacturing processes are far more precise and complex than those for conventional inductive heads. This calls for immediate improvement in production yields. One important improvement factor is to identify defective heads at early stages of the manufacturing processes.

Agilent 4291B Impedance/Material Analyzer and Fixtures

This application note is intended for engineers involved in research, development, and production technology management, and shows how to efficiently evaluate LCR (inductance, capacitance, resistance) characteristics of MR heads using the Agilent Technologies 4291B.

Brief Description of MR Head

The MR head, a current target for the most intensive research and development, is called a composite MR head. It writes data by using a thin film inductor, and reads data by using an MR element. Figure 1 shows the conceptual drawing of an MR head. To evaluate the MR head performance, an impedance analyzer (e.g., Agilent 4294A) is generally used to measure the inductance of the recording section, and a multimeter is used to measure the direct current resistance (DCR) of the reading MR section.

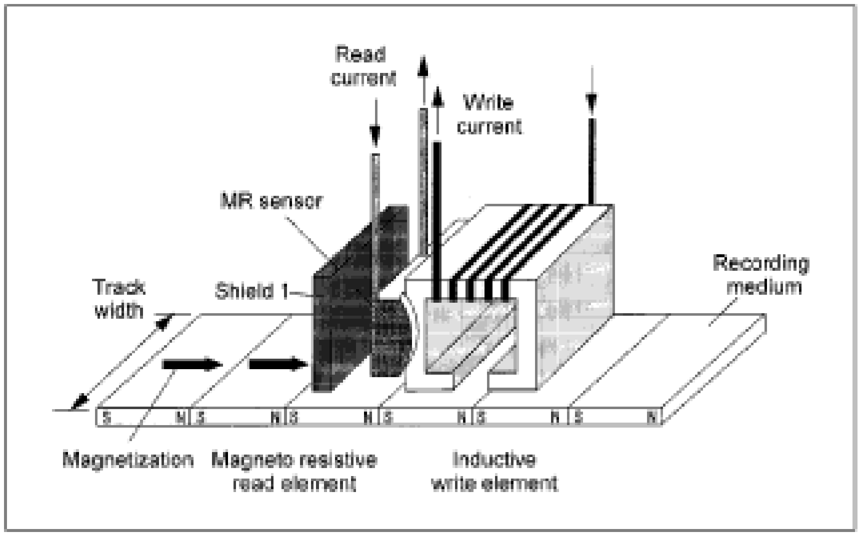

Figure 1. Conceptual Diagram of an MR Head

Manufacturing Processes and Measurements

Figure 2 outlines the MR head manufacturing processes. A read/write analyzer is used to test at final stage, writing and reading data. However, rejecting defective heads at the final stage can only result in higher labor cost and wasted man-hours. Therefore, there is a demand for a type of analyzer that can conduct Pass/Fail judgments of individual components at earlier stages. Naturally, there is also a demand for a type of analyzer that can test the MR head performance before it is mounted to the hard disk drive.

Figure 3 shows the schematic drawing of the MR head manufacturing processes. During the course of these processes, products must be checked electrically three times: the first time in Process b, before the wafer is cut; the second time in Process c, during which the MR head surface is lapped; and the third time after Process d, in which the head is assembled to form an assembly called an HGA (Head Gimbal Assembly). We describe each measurement in detail on the pages that follow.

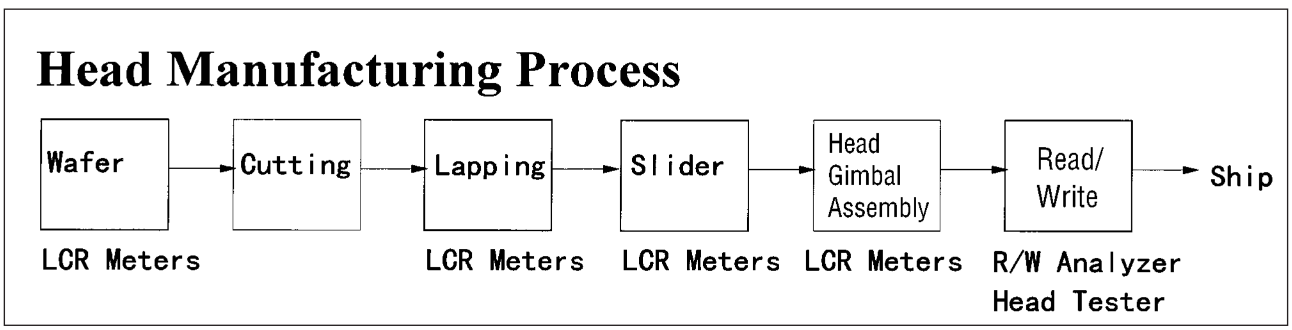

Figure 2. MR Head Manufacturing Processes

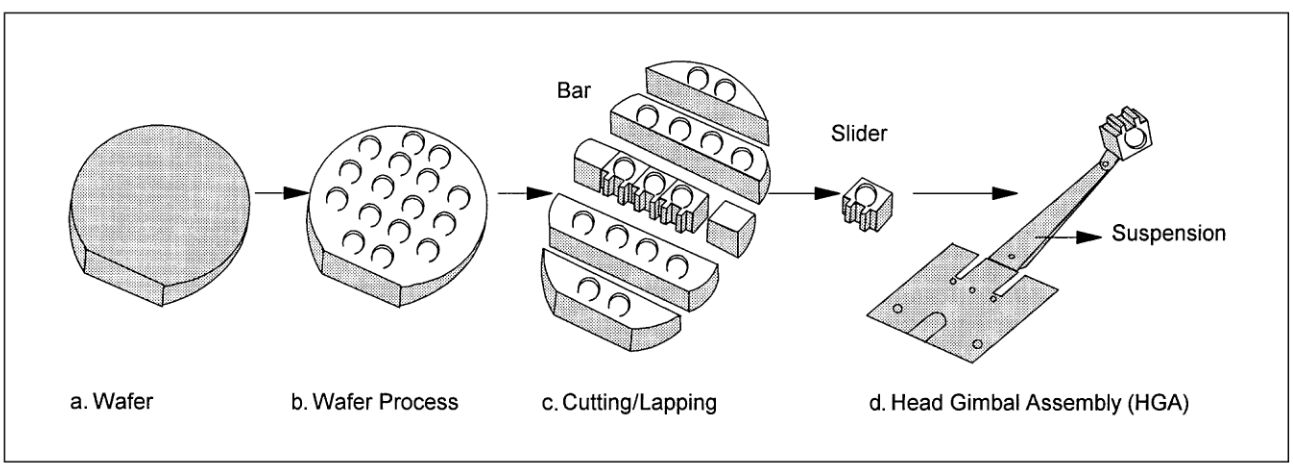

Figure 3. Conceptual Diagram of MR Head Manufacturing Processes

Measurements of chip characteristics before cutting
Connecting a test probe to the measuring instrument allows measurements of the chip characteristics on the wafer. In the research and development phase of a product, it is extremely important to determine the basic LCR characteristics of chips and to define proper measurement items for detecting early process failures. In this case, the user must understand how to extend the measurement point from the instrument and conduct calibration at that position on the target surface. The technique can substantially affect the accuracy of measurement results.

For more information on this probe and calibration process, see the Agilent Product Note 4291-3 which shows examples of characterizing wafers using the Agilent 4291B Impedance Analyzer together with probing equipment that is manufactured by Cascade Inc.

Process management during lapping
Lapping is done on plural heads lined up in each bar. The lapping provides a desired gap of the recording section and the resistance of the MR section of each head. Using this crucial mechanical lapping process, a monitoring technique is required to control the lapping progress. You can conduct this monitoring optically or electrically. Electrical monitoring can be conducted by measuring the DC resistance or AC impedance of the MR head. But, you can obtain the most detailed information from the AC impedance measurement.

AC impedance measurement sweeps not only the test frequency, but also DC bias, and indicates, for example, whether the magnetic material is saturated or not. Because the chip sizes are becoming increasingly smaller, finer adjustments will be required in the lapping process. Therefore, the process monitoring must be conducted with improved accuracy.

Measurements of HGA characteristics
When you test the HGA performance, you need to evaluate the characteristics of the entire HGA, including the MR head and lead wires extending from the HGA. (See Figure 4.) This evaluation is extremely important for research and development of MR heads so that you can understand the overall characteristics of the head. For example, an MR component in a head essentially has only a DC resistance (DCR). However, when it is a part of an HGA that has lead wires, this HGA assembly has frequency response characteristics. Therefore, you should evaluate it using AC signals.

You must also test the thin film inductance of the recording section in the same manner as is done with a conventional inductive head. That is, you should evaluate its characteristics with changing frequency and AC current level. Practically, a thin film inductor is evaluated under the actual operating conditions (frequency band, AC current level, and DC bias level) that the MR head will undergo during actual operation. Of course, when you conduct research on a next generation head, you need to take measurements at even higher frequencies.

This HGA testing will probably prove effective on the production line as well. We recommend that you measure the HGA impedance before mounting it to the hard disk drive assembly to intercept rejects at that stage. We also recommend it for acceptance inspection when you purchase MR heads from vendors.

Measurements of suspension characteristics
Today, research and development is also focused on eliminating lead wires from heads by forming an electric pattern on head suspensions. We call this a wireless suspension. The FPC (Flexible Printed Circuit) pattern put on a suspension also has frequency response characteristics. In the research and development phase, its inductance must be evaluated as a function of frequency with an accuracy down to nH.

Parasitic capacitance between lines in FPC is also of measurement interest, because an unwanted resonance caused by the inductance and capacitance within an FPC and head may degrade the performances.

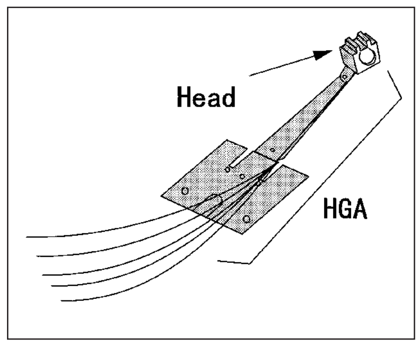

Figure 4. Schematic Diagram of HGA with MR Head

Measurement items and functions required in the analyzer

You need to make the measurements listed below to evaluate the overall characteristics of MR head.

Recording section:

L (inductance) measurement sweeping frequency, DC current bias, and AC current:

- Frequency characteristic evaluation
- Failure analysis of magnetic head material
- Analysis of improper head shape including head gap
- Evaluation of magnetic material saturation (hysteresis)

Q (reactance quality) evaluation:

- Core loss evaluation

|Z|-Θ (impedance) measurement sweeping frequency:

- Failure analysis of magnetic head material
- Detection of shorted/opened patterns
- Resonance frequency evaluation
- Detection of defective assemblies (disconnected circuitry)

Equivalent circuit analysis

MR section:

DCR (DC resistance) measurement:

- Failure analysis of MR section material
- Detection of shorted/opened patterns
- Detection of defective assemblies (disconnected circuitry)

|Z|-Θ (impedance) measurement sweeping frequency, DC current bias, and AC current:

- Frequency characteristic evaluation
- Failure analysis of MR section material/shape
- Resonance frequency evaluation
- Detection of defective assemblies (disconnected circuitry)
- Understanding of skin effect at high frequencies

L (inductance) measurement sweeping frequency or DC current bias:

- Frequency characteristic evaluation
- Evaluation of magnetic material saturation(hysteresis)

Equivalent circuit analysis:

What deserves special attention in the recent trend is that MR heads are used at increasingly higher frequencies. Therefore, your analyzer must be able to cover such high frequencies. Needless to say, it must be able to cover required signal levels and DC bias levels. In addition, MR elements, in general, are very susceptible to high voltages. In particular, allowing a specific bias current to flow through an unstable element, for example, during failure analysis, can eventually damage the element. Therefore, it is important that test equipment has the voltage-limit capability to prevent such accidental damage.

Example of Measurement Using the Agilent 4291B

The 4291B Impedance/Material Analyzer, with its powerful test functions, can be configured with the 34401A Digital Multimeter to make DC resistance (DCR) measurement or with a magnetic field generator to meet almost all measurement needs for MR heads. Therefore, the 4291B is an indispensable item for research and development of MR heads.

The instrument calibration and open/short/load compensation functions of the 4291B can remove errors from the test system, including test fixtures, and assure the quality and accuracy of measurements. In addition, you can specify the voltage limits for DC bias level to prevent damage of heads due to excessive voltages. The 4291B also monitors the current actually produced by applied voltage, and also monitors DC bias current during constant current measurement. Thus, you are assured of improved accuracy in the test current produced by applied voltage.

This section shows you actual examples of measurements that characterize the performance of an HGA with an MR head.

Figure 5 shows a photograph of the HGA with a fixture used for measurements.

Agilent 4291B basic specifications

- Measurement frequency range: 1MHz to 1.8 GHz
- Measurement accuracy: Basic impedance accuracy: 0.8%
- Measurement parameters: Z, Θ, R, L, C, G, B, X, etc.

- Measurement signal level:
  Voltage:
  0.2 mV to 1 V (1 MHz to 1 GHz)
  0.2 mV to 0.5 V (1 GHz to 1.8 GHz)

  Current:
  4 µA to 20 mA (1 MHz to 1 GHz)
  4 µA to 10 mA (1 GHz to 1.8 GHz)

- DC bias (option):
  Voltage: ±40V (1 mV resolution)

  Current: ± 100 mA (20 µA resolution)

Thin film inductor (recording section) L measurement sweeping frequency

Figure 6 shows the measurement results of the inductance of a thin film inductor on the recording section, obtained when the frequency sweeps from 1 MHz to 200 MHz. It shows that the inductance drops at higher frequencies due to increased core loss. This measurement provides a very useful piece of information regarding the limit of frequency at which the head can correctly record data. As you can see, with the higher data transfer rate available with hard disk drives, it will become increasingly important to understand the performance characteristics of MR heads at high frequencies.

The Agilent 4291B offers a signal monitoring function that permits monitoring of signals applied to the device under test. When an inductive element in a head is tested, its inductance varies depending on the current flowing through it. Therefore, it is extremely important to monitor the current by using this function. The annotated value shown as "mon AC-I" on Figure 6 represents the measured current actually flowing through the head.

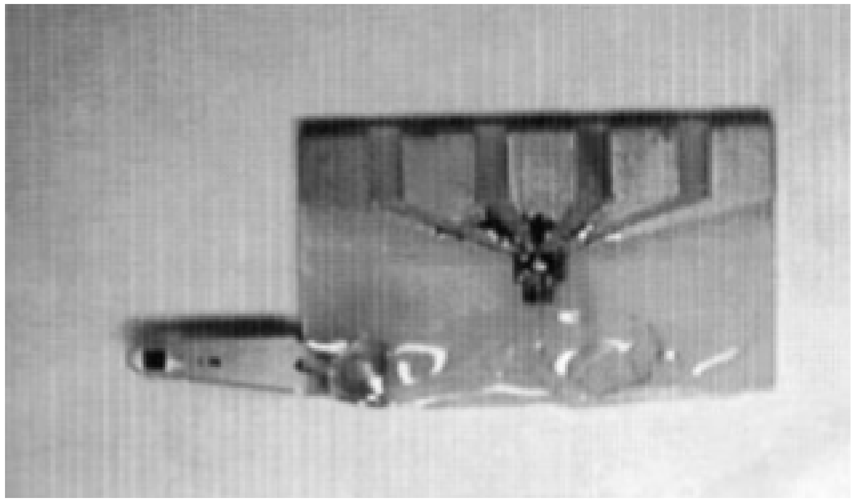

Figure 5. MR Head and Fixture Used for Measurement

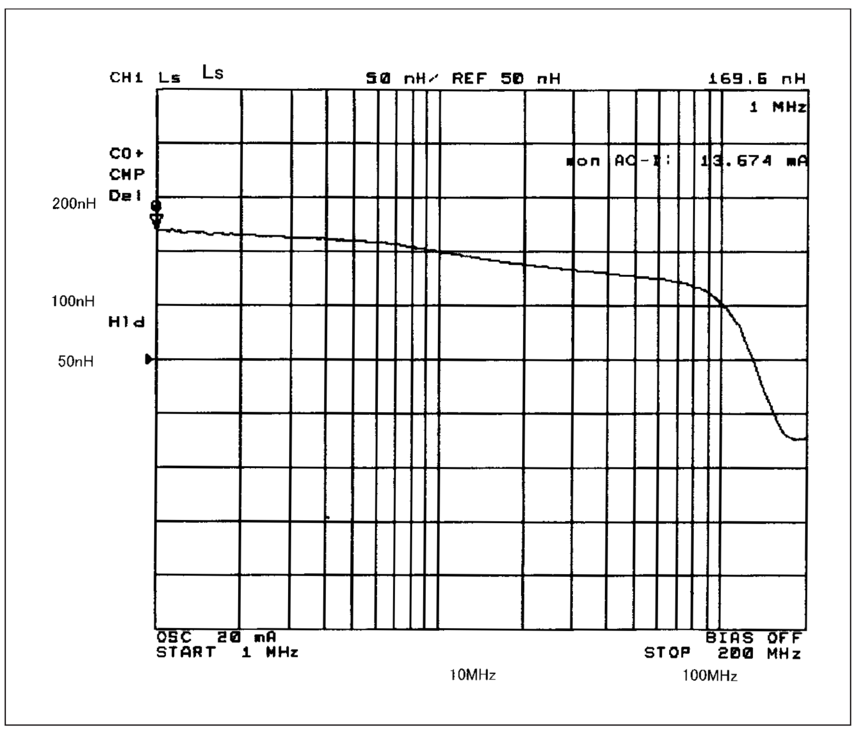

Figure 6. Ls (Inductance) of the Recording Section vs. Frequency

Thin film inductor (recording section)
L measurement sweeping DC bias current
Figure 7 shows the measurement results of the inductance of the same inductor obtained when the frequency was maintained constant at 60 MHz with the DC bias current sweeping from 0 A to 100 mA. This shows that the magnetic material saturates when the DC bias current is beyond a specific level.

MR component (reading section)
R measurement sweeping frequency
Figure 8 shows the measurement results of the resistance of an MR component (the reading section of a head) obtained when the bias was applied to the chip with the frequency sweeping from 1MHz to 400 MHz. The resonant frequency is apparent.

MR component (reading section)
R measurement sweeping DC bias current
Figure 9 shows the measurement results of the resistance of the MR component obtained when the frequency was maintained constant at 60 MHz as the DC current bias swept from 0 mA to 100 mA. This shows that the resistance is saturated due to the bias current.

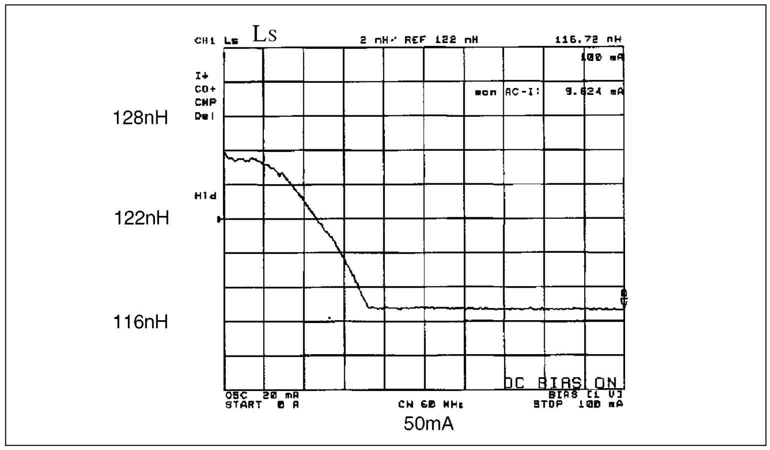

Figure 7. L (Inductance) of the Recording Section vs. DC Bias Current

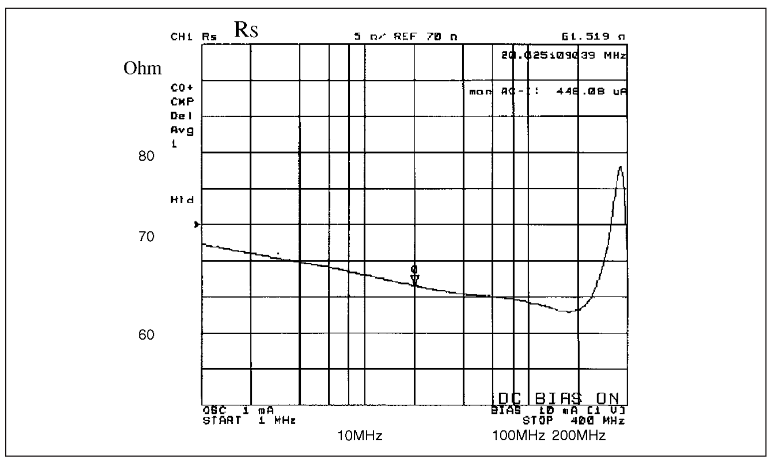

Figure 8. MR Resistance of the Reading Section vs. Frequency

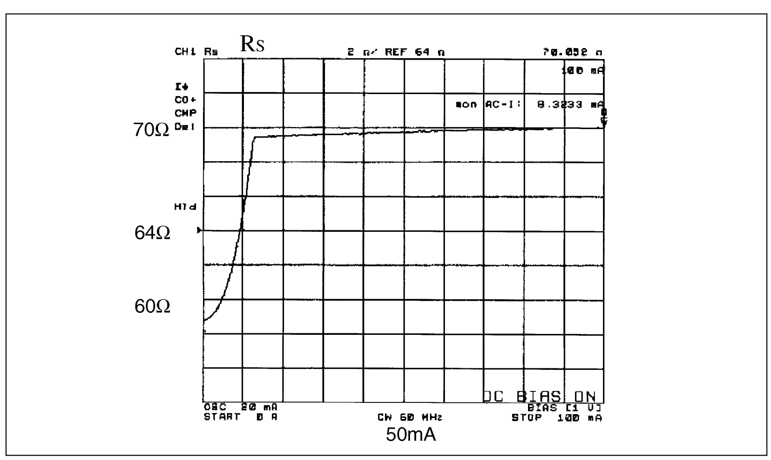

Figure 9. MR Resistance of the Reading Section vs. DC Current Bias

Equivalent circuit analysis of MR component (reading section)

The equivalent circuit analysis function, available with the Agilent 4291B, is very convenient when you wish to determine the L, C, and R components of an MR chip and lead wires. This function is designed to separately provide the L, C, and R components that are otherwise combined to represent impedance of HGA at the measurement point. This function has been made available through an innovative algorithm and calculations based on actual measurements.

Figure 10 shows the impedance (|Z|-Θ) characteristics of an MR head superimposed on the simulation results by the equivalent circuit analysis function. You can assume that HGA has an impedance configuration, as in model B in Figure 11, that is composed of resis-tance of the MR element inductance of lead wires, and wire-to-wire capacitance. Therefore, you apply model B in Figure 11 to the measurements to separate it into L, C, and R.

As a result, the resistances of MR element, lead wire inductance, and stray capacitance between lead wires are 52.7 Ω , 35.0 nH, and 1.34 pF, respectively. The results of simulation, based on these values, are shown in Figure 10. By comparing the measurements and simulation results, you can see that the simulation model was appropriate for this measurement. As shown above, the equivalent circuit analysis function allows easy analysis of impedance components. This innovative function of the 4291B was not readily available with conventional analyzers.

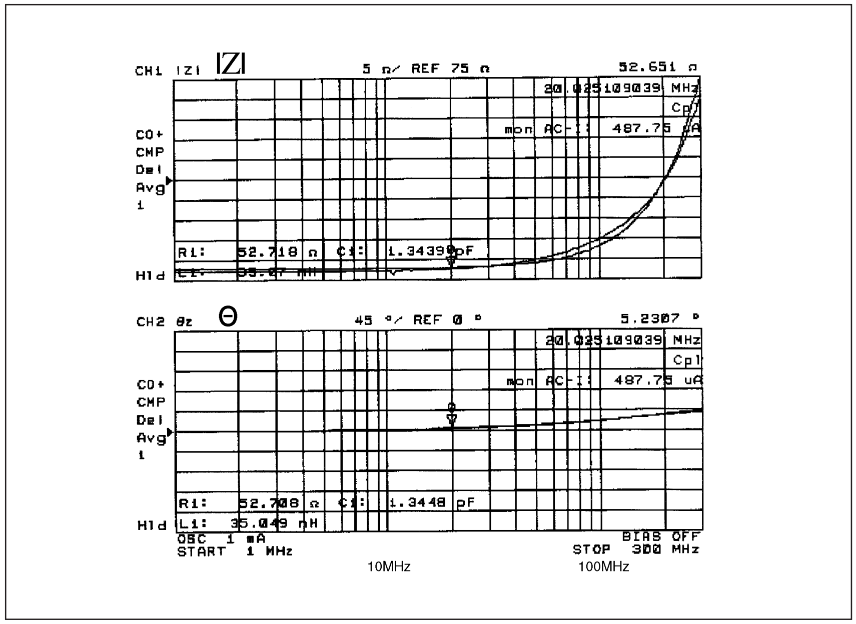

Figure 10. Comparison of |Z|-Θ Measurement and Simulation Result Based on the Equivalent Circuit Analysis

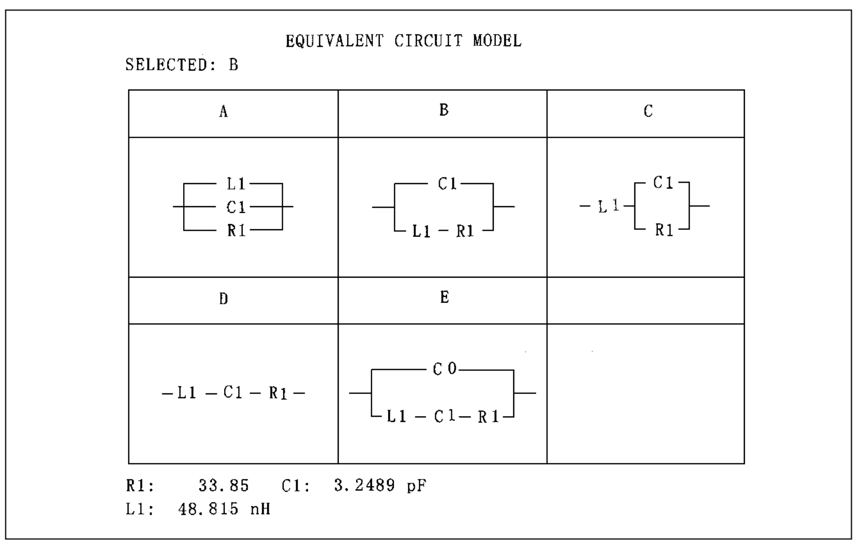

Figure 11. Equivalent Circuit Models Built in the Agilent 4291B

Summary

The 4291B, with various LCR measurement capabilities and simulation functions available, is a powerful and indispensable tool for performing detailed evaluation of MR heads and HGA characteristics. With the development of new products such as the Giant-MR (GMR) head, the size of components to be handled will be even smaller, and the frequencies used even higher, thus leading to an increasingly strong demand for accurate measurement at high frequencies.

The Agilent 4291B with its capability to meet future measurement needs, is a worthy candidate for your equipment investment. Its built-in IBASIC function permits software control of repetitive test sequences. For example, it allows control of an external magnetic field generator and multimeter for DCR measurement, thus making the 4291B an ideal tool for overall evaluation of MR heads. In addition, you can use Agilent LCR meters (e.g., Agilent 4284A, 4285A, 4287A) to efficiently perform Pass/Fail judgments at multiple measurement points on the production line.

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