

APPLICATION NOTE

# Test for Hysteresis Loop Properties

## Introduction

An intensive study of the hysteresis loop properties of ferrimagnets used in logic and memory core applications concludes that a regular hysteresis loop provides two stable oppositely directed remanent magnetization states, and is the major engineering feature.

The microwave device engineer uses the rectangular loop property that is exhibited by certain microwave ferrimagnetics in the design of a number of digital or latching ferrite phase shifters. This property is being used in high-power, electronically scanned radar antenna arrays.

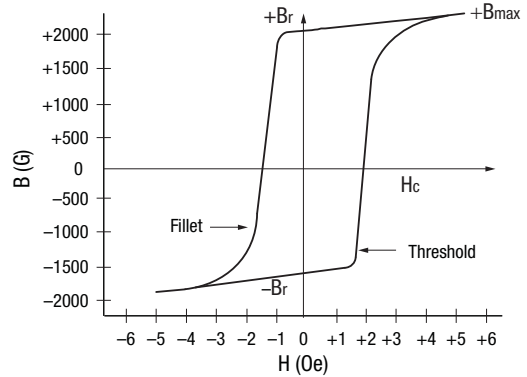
Measurement of the dynamic hysteresis loop characteristics of microwave ferrimagnets can be used for design and quality control purposes.

Figure 1 shows a convenient method of making these measurements by means of an oscilloscope loop tracer.

## Oscilloscope Method

Figure 2 shows a typical measuring circuit, and includes a means for impressing upon the:

- Vertical input of the Cathode Ray Oscilloscope (CRO) by a signal that is proportional to the flux density (B) in the test specimen.
- Horizontal input of the CRO by a signal that is proportional to the magnetizing force (H) acting on the specimen under test.



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**Figure 1. Typical Hysteresis Loop of a Microwave Ferrimagnetic Used in Digital Phase Shifters**

The primary circuit consists of a signal source, the winding of  $N_p$  turns on the test specimen, and an  $R_p$  resistor.

The instantaneous voltage drop ( $e_r$ ) across  $R_p$  is applied to the horizontal deflection terminals of the CRO. The  $e_r$  is related to the magnetizing force (H) by the following equation:

$$e_r = \frac{R_p I_m}{0.4\pi N_p} \times H \quad (1)$$

Where:

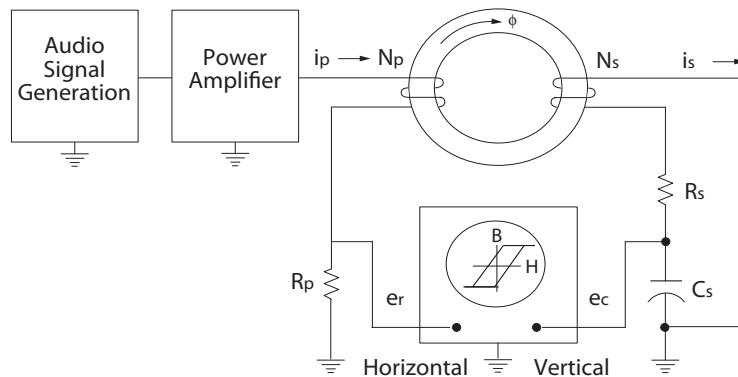
$e_r$  = Instantaneous voltage drop.

$R_p, N_p$  = Impedance.

$I_m$  = Mean length of the test specimen magnetic path.

H = Magnetizing force.

**Figure 2. Dynamic Hysteresis Loop Equipment Diagram**



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The secondary circuit contains a winding of  $N_s$  turns on the test specimen, and a Resistor–Capacitor (RC) integrating network. The instantaneous voltage ( $e_c$ ) developed across the capacitor is applied to the vertical deflection terminals of the CRO.

If  $R_s \gg 1/\omega C_s$  (approximately 250:1), the voltage drop across  $C_s$  is related to the magnetic flux density ( $B$ ) in the test specimen by the following equation:

$$e_c = \frac{N_s A}{10^8 R_s C_s} \times B \quad (2)$$

Where:

$e_c$  = Instantaneous voltage.

$N_s$  = Secondary circuit number of windings.

$R_s$  = Impedance.

$C_s$  = Capacitor (pF).

$A$  = Active cross-sectional area of the test specimen.

$B$  = Flux density.

### Measurement

Equations 1 and 2 indicate that the pattern displayed on the CRO represents the dynamic hysteresis loop of the test specimen if the CRO amplifier bandwidths are adequate. For

rectangular loop ferrimagnets, the amplifiers should be capable of handling up to the twentieth harmonic of the test frequency.

The hysteresis loop properties of interest may be read directly from the CRO screen and a photograph made for permanent records, which includes:

- Data on the coercive force ( $H_c$ ).
- Remanent flux density ( $B_r$ ).
- Squareness ratio defined as  $B_r/B_{max}$ , where  $B_{max}$  is the maximum flux density obtained at the highest value of the magnetizing force being used.

Figure 1 shows a typical dynamic hysteresis loop obtained by the oscilloscope method. A sharp and well-defined threshold gives rise to a distinct value of  $H$  that produces the onset of magnetic flux switching.

A small fillet is instrumental in minimizing the amount of energy required for switching. The time required for the magnetic flux to switch from  $-B_r$  to  $+B_r$  is inversely proportional to the magnetizing force (for  $H \geq 2H_c$ ). Pulse techniques are generally used when switching time data is required.

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