APPLICATION NOTE

No. 664: Test for Hysteresis Loop Properties

Introduction

The hysteresis loop of ferrimagnets employed in logic and memory core applications has been intensively studied during the past fifteen years. A rectangular hysteresis loop, providing two stable oppositely directed remanent magnetization states, is the major engineering feature of these materials.

Recently, the microwave device engineer has utilized the rectangular loop property exhibited by certain microwave ferrimagnets in the design of a number of digital or "latching" ferrite phase shifters. These are currently finding use 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. A convenient method of making these measurements by means of an oscilloscope loop tracer is described below.

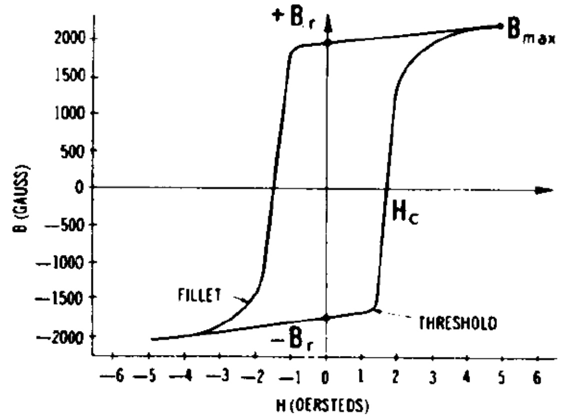

Figure 1
Typical Hysteresis Loop of a Microwave Ferrimagnet Used in Digital Phase Shifters

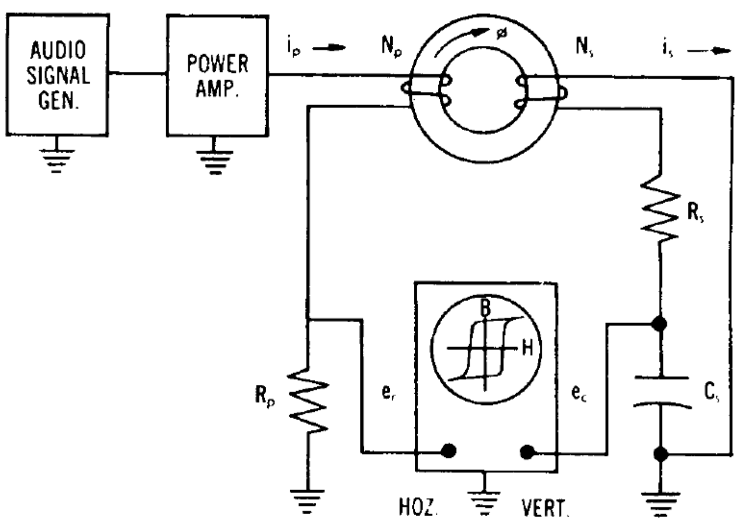

Figure 2. Diagram Of Dynamic Hysteresis Loop Equipment

Oscilloscope Method

Figure 2 shows a typical measuring circuit. It includes a means for impressing upon the vertical input of the CRO a signal which is proportional to the flux density (B) in the test specimen; and upon the horizontal input of the CRO a signal which is proportional to the magnetizing force (H) acting on the specimen under test.

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

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

$$e_r = \frac{R_p \, 1m}{0.4\pi \, N_p} \cdot H \qquad (1)$$

where 1m is the mean length of the test specimen magnetic path.

The secondary circuit contains a winding of N_s turns on the test specimen, and an RC integrating network. The instantaneous voltage (e_r) developed across the capacitor is applied to the vertical deflection terminals of the CRO. If $R_s >> I/\omega C_s$ (app. 250:1), the voltage drop across C_s is related to the magnetic flux density (B) in the test specimen by the equation:

$$e_r = \frac{N_s \, A}{10^8 \, R_s \, C_s} \cdot B \qquad (2)$$

where A is the active cross sectional area of the specimen.

Measurement

Equations (1) and (2) indicate that the pattern displayed on the CRO will represent 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 20th 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. These include data on the coercive force (H_e), remanent flux density (B_r), and squareness ratio defined as B_r/B_{max} where B_{max} is the maximum flux density obtained at the highest value of magnetizing force employed. A typical dynamic hysteresis loop obtained by the oscilloscope method is shown in Figure 1. A sharp and well defined threshold gives rise to a distinct value of H that will produce 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 $H \geq 2H_e$).

When switching time data is required, pulse techniques are generally employed.

Reference

H. F. Storm, “Magnetic Amplifiers”, J. Wiley, New York 1955, pp. 53-58.