Dielectric/Magnetic Probe

A Unique NDT Sensor for Magnetic Material Quality Assurance

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General Applied Physics *Solutions*

GAPS

Approach

- **Simple, cost effective measurement techniques**

  - **Measure parameters directly related to performance**

- **Ability to measure local variations (spatial mapping)**

- **Adaptable to automation (if needed)**

APS

NDT for Measuring Electromagnetic Properties

- **Eddy Current and Interdigital Patterned Sensors**

  Can be sensitive to dielectric and magnetic properties but limited to frequencies less than HF (<30 MHz)

- **Open-Ended Transmission Line**

  Determine $\mathbf{e}$ by the interaction of a material with the fringing field at the end of an open transmission line

- **Free-space (NRL Arch; Radar Range*)**

  Measure the reflection and/or transmission of a plane wave in free space using a flat panel (NRL arch or range),   fabricated component (range) or final assembled part

  *including non-anechoic impulse imaging radar

APS

Open-Ended Coaxial Dielectric Probe

Material (e, μ)
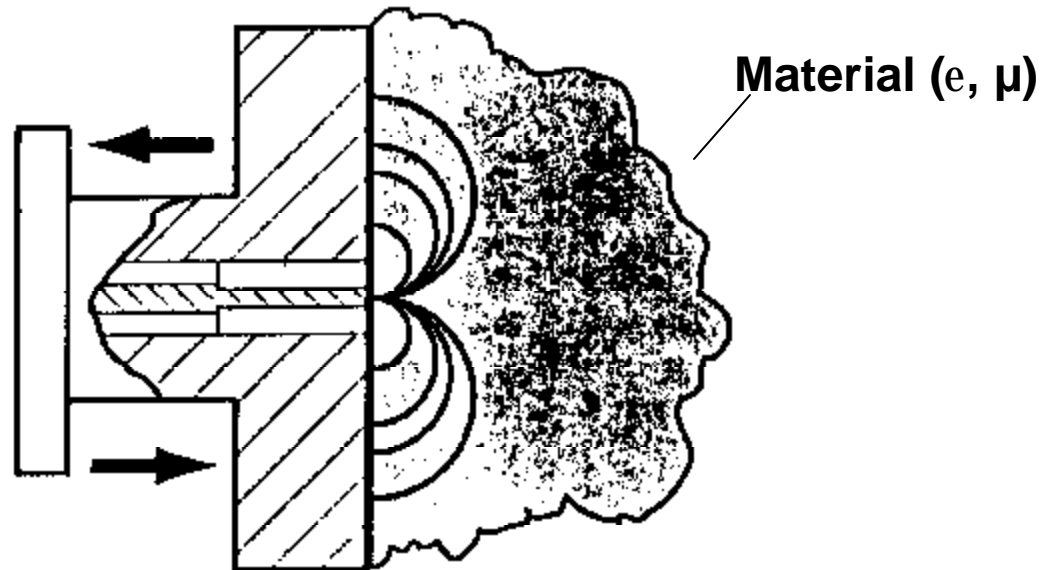
- **Both the electric and magnetic field components interact with the sample and affect the magnitude and phase of the reflected wave**

- **Altering the magnetic character (μ) in a controlled way can change the reflected wave's amplitude and phase**
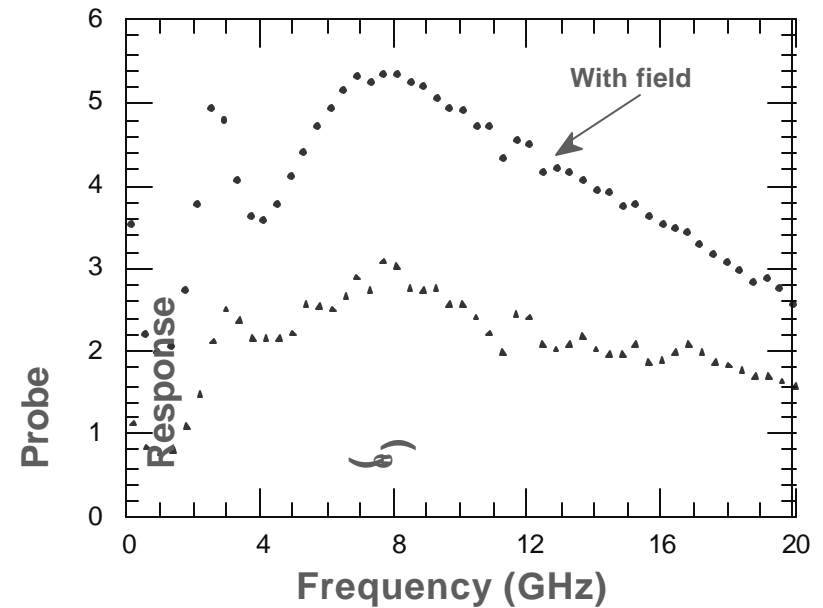
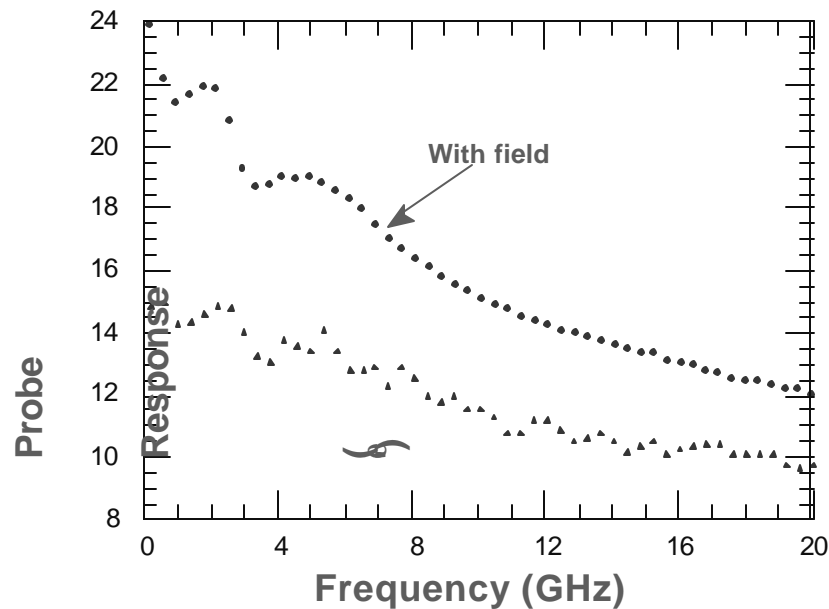# Effect of Applied Magnetic Field on Permeability

$$Y_3Al_{0.66}Fe_{4.34}O_{12}$$
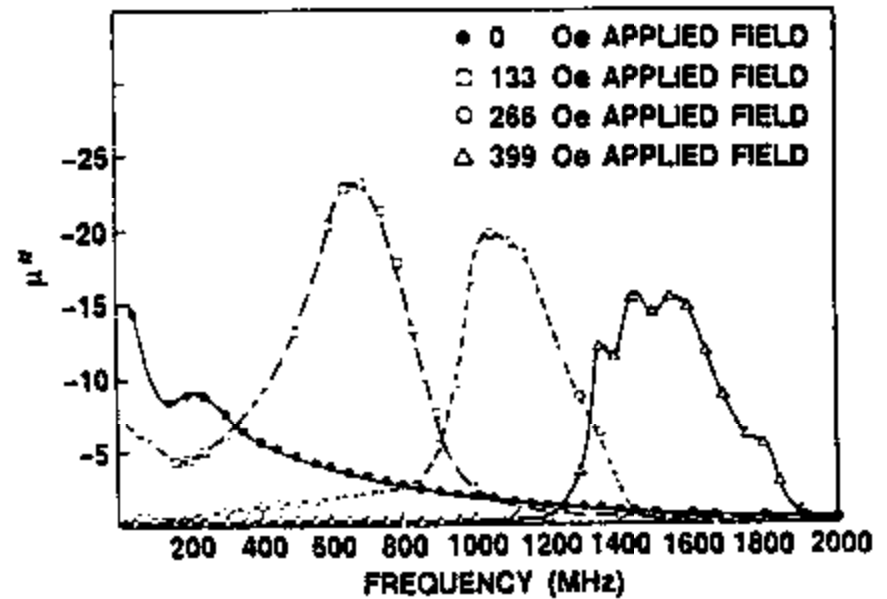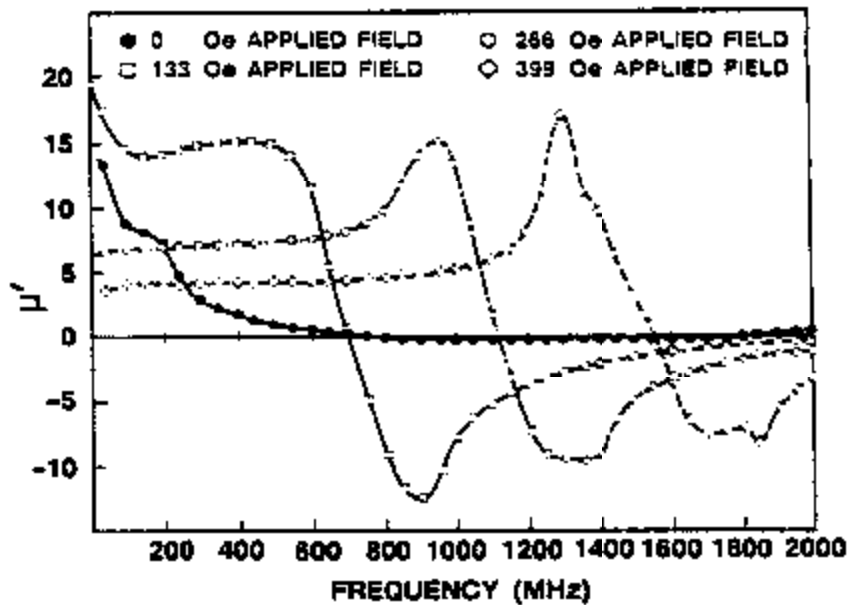
From: G. G. Bush, J. Appl. Phys. **64** (1988), 5653

Effect of Applied Magnetic Field on Probe Response
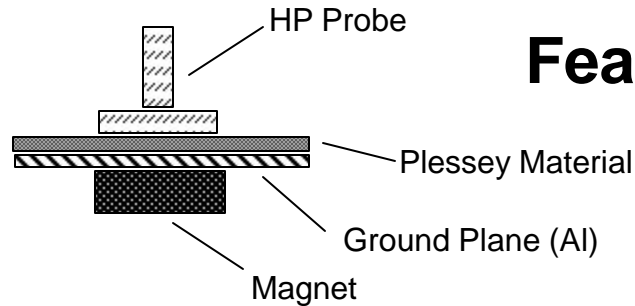
Feasibility Test of Concept

HP Probe

Plessey Material

Ground Plane (Al)

Magnet
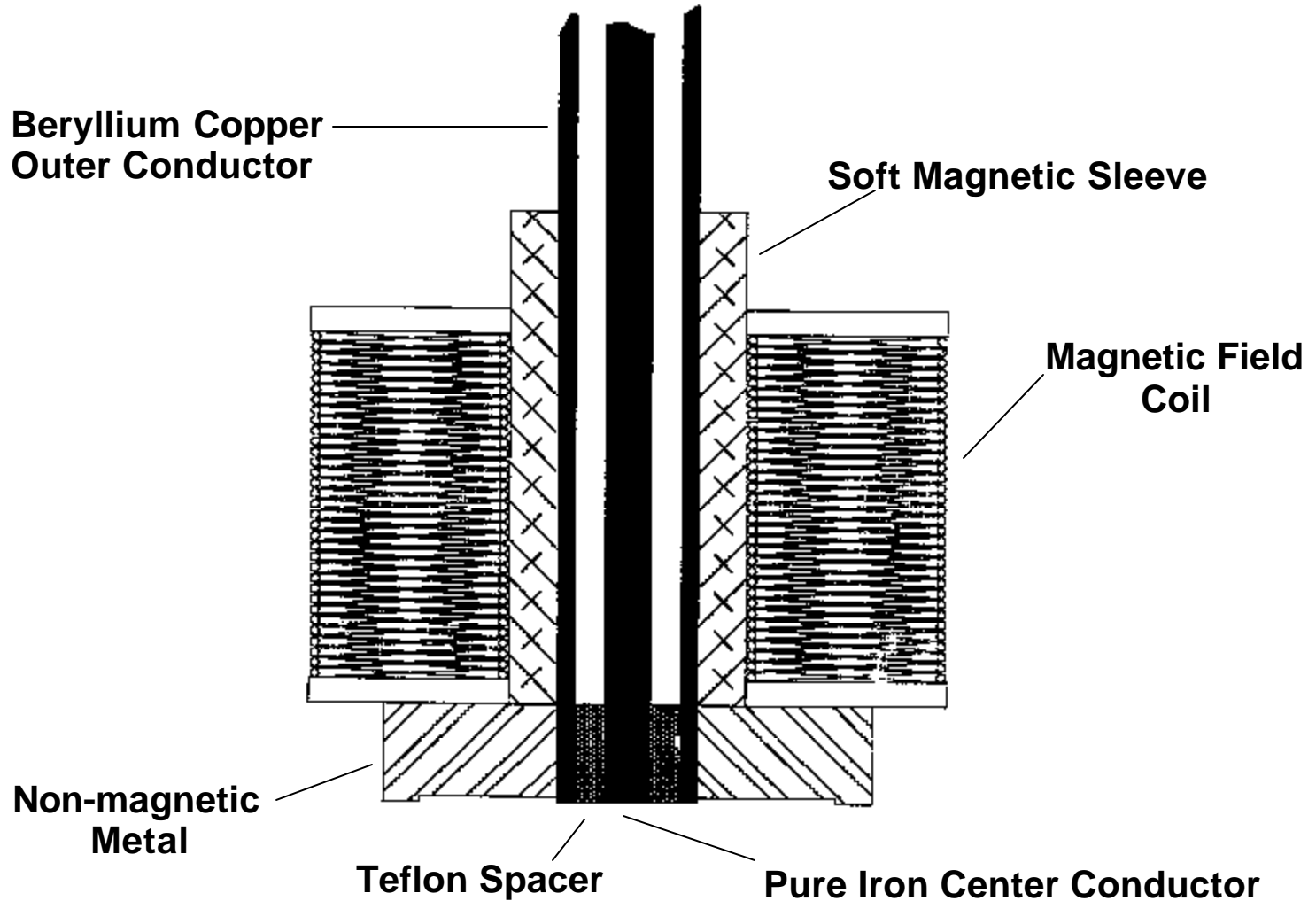
Plessey 1634 MagRAM
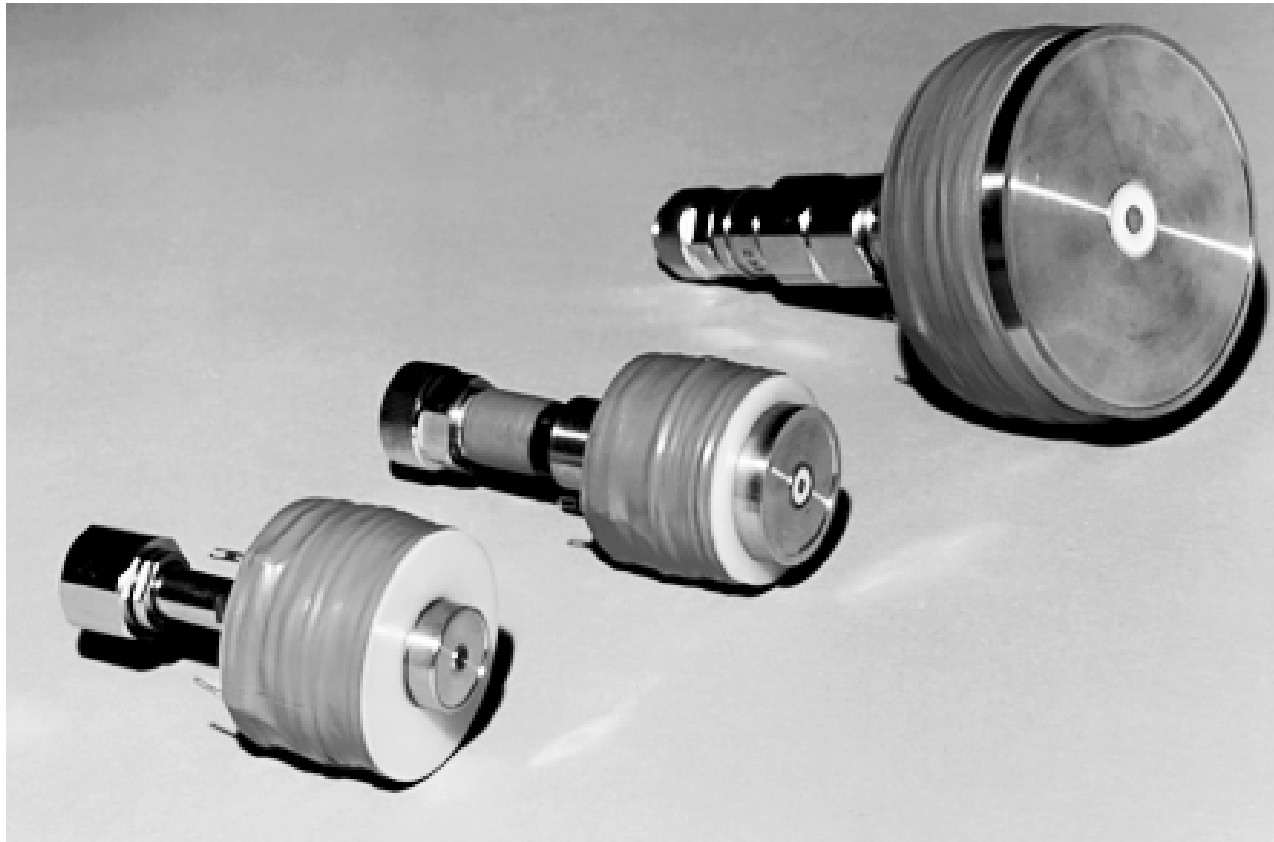**36 mils**

Dielectric/Magnetic Probe

Modified Open-Ended Coaxial Probe

- Addition of an axial coil for applying an external magnetic field

- External field can alter the contribution of the material's magnetic spins (dipoles)

- Difference in the probe response with and without the field is related to μ of the material

- Patented

APS

Dielectric/Magnetic Probe Design

Beryllium Copper
Outer Conductor

Soft Magnetic Sleeve

Magnetic Field
Coil

Non-magnetic
Metal

Teflon Spacer

Pure Iron Center Conductor

Prototype Probes

Measurement Problem

Lack of reproducible measurement due to contact variations with the sample:

- operator dependent

- sample surface dependent (not flat and/or rough)

Conformal Tip

- **Use of custom designed spring loaded test pins**

- **Pins adjust to surface imperfections (roughness and/or curvature)**

- **Pins allow wave to propagate to surface so that fringing field interacts with sample (eliminates air gap effect)**

- **Patented**
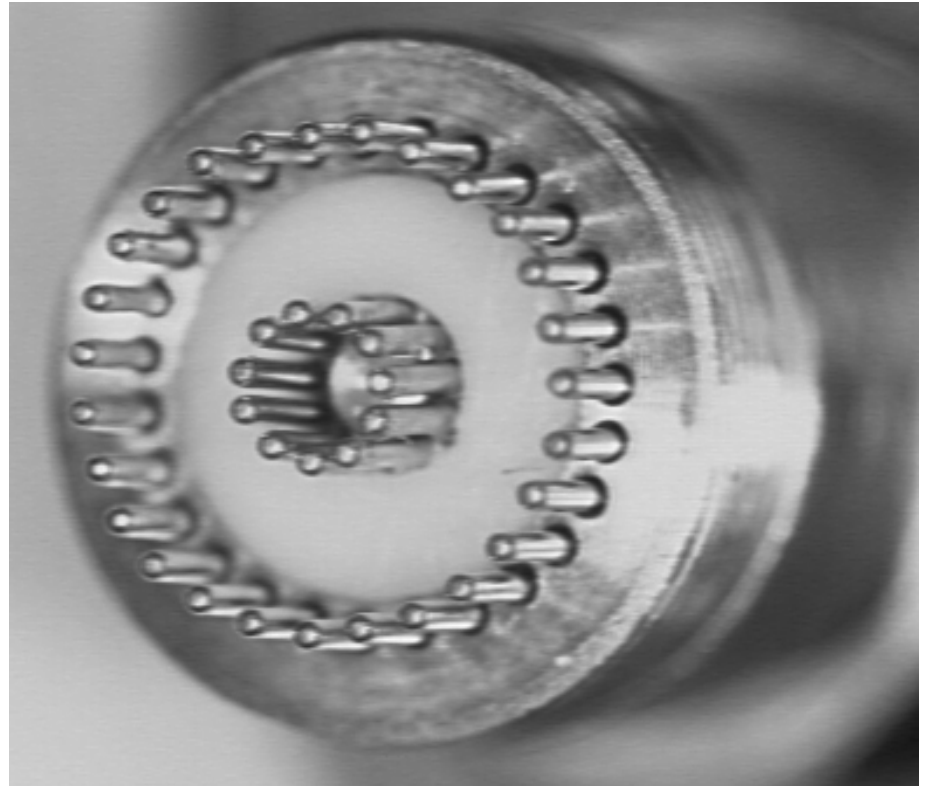
First Prototype (7mm Probe)

Dielectric/Magnetic Probe Modeling Tools

High Frequency Structure Simulator (HFSS)

Source: Hewlett-Packard Company

Computes S-parameters for passive 3D structures by finite element solution of Maxwell's equations

Powerful tool for modeling the response of our probe (S11, reflected wave amplitude and phase)
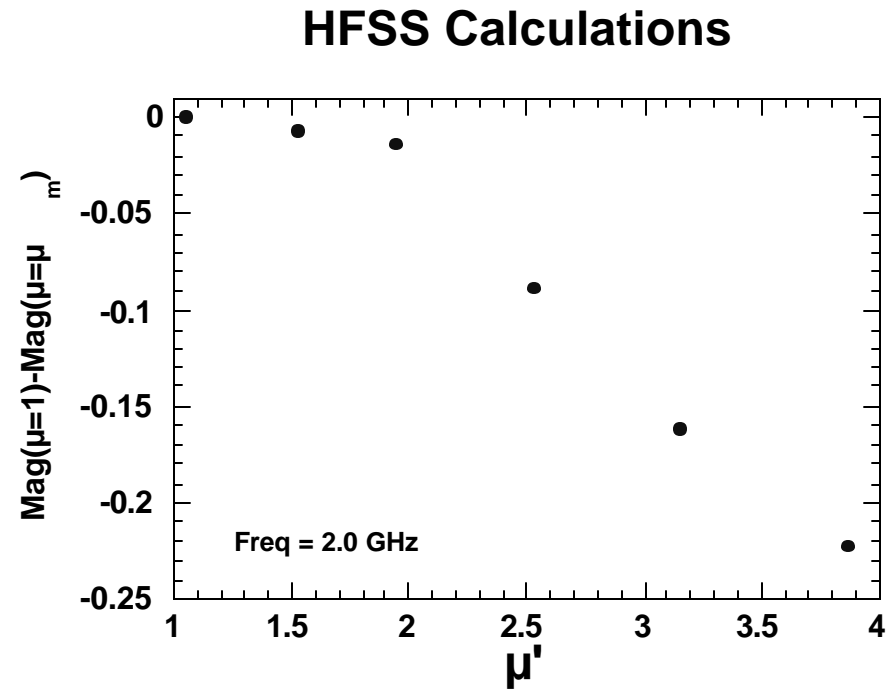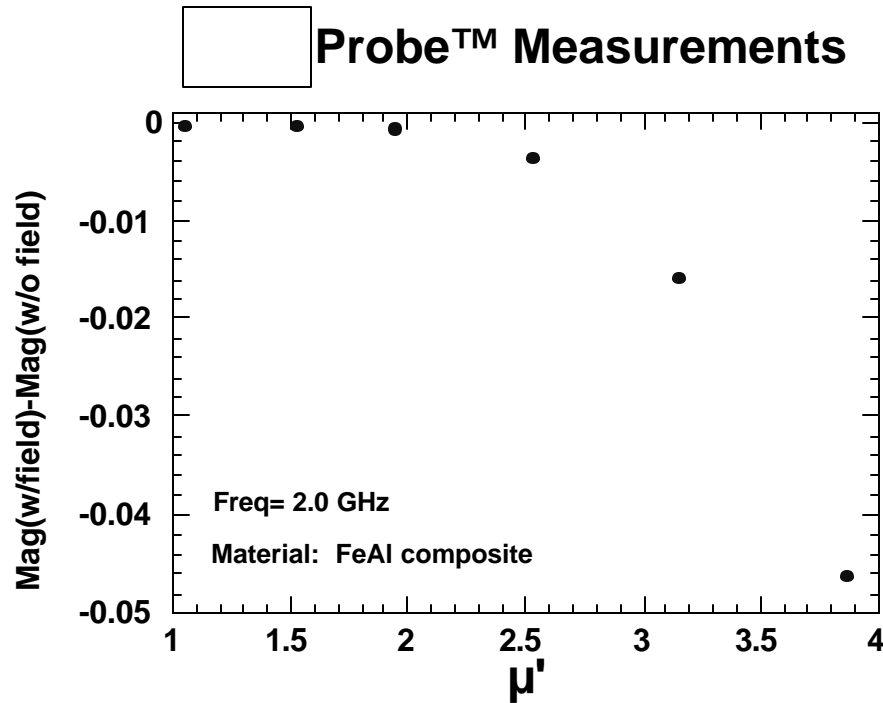
Magneto

Source: Integrated Engineering Software, Inc.

Software for solving magnetostatic problems using boundary element method

Used to optimize magnetic field coupling to sample volume sensed by probe

Comparison Between Measurement and Modeling

Probe™ Measurements

HFSS Calculations

Difference indicates that the applied magnetic field was not able to completely turn off the magnetic permeability (μ)
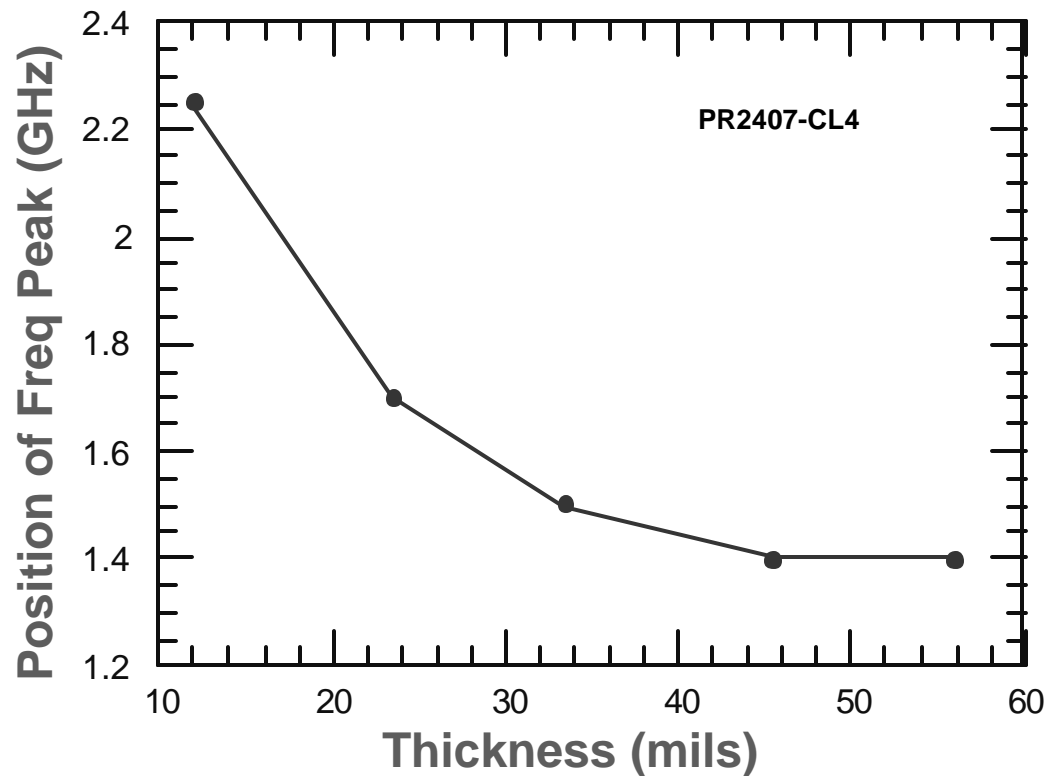
Probe Frequency Response (Signature)
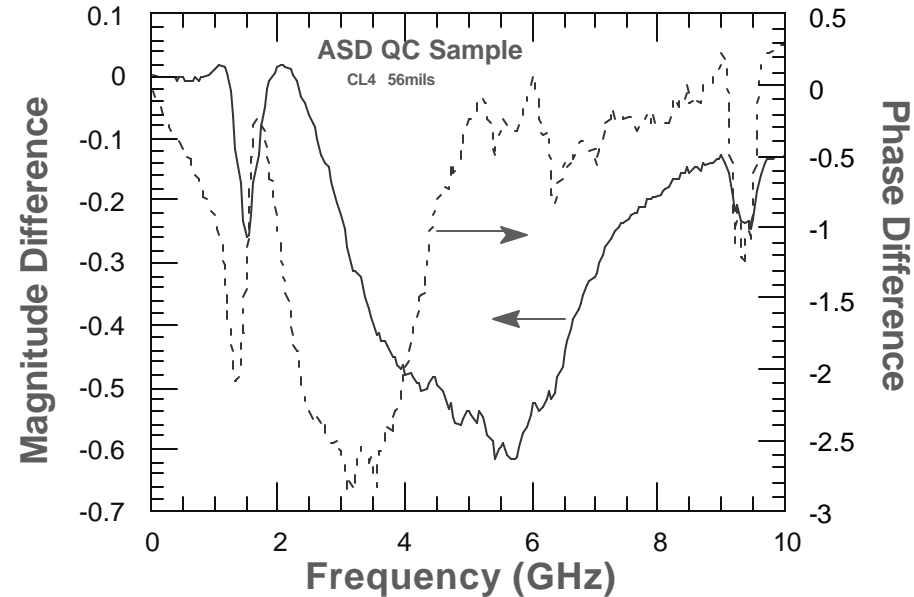
Signature is influenced by:

(1) ε & μ
(2) Structure
(3) Physical defects

Effect of Thickness on 7mm Probe Response

Probe is sensitive to the thickness as well as to the electromagnetic properties

Dielectric/Magnetic Probe

A New Unique NDT Sensor for
Magnetic Material Quality Assurance

- **Sensor is sensitive to both e & µ**
- **Very Broadband**
- **Easily Addresses the very difficult to measure frequency range below 4 GHz**
- **Can provide**
  - **Spatial Mapping**
  - **Depth Profile of Structures**
- **Provides Processing Control**