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Plane Wave Scattering from Infinite Microstrip Arrays on Ferrite Substrates

Frances J. Harackiewicz
Southern Illinois University Carbondale, fran@engr.siu.edu

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Frances J. Harackiewicz

Department of Electrical Engineering
Southern Illinois University
Carbondale, IL 62901

INTRODUCTION

A full-wave analysis of plane-wave scattering from an infinite, periodic array of microstrip patches on a ferrite slab under different bias conditions is presented. The magnetic bias field is applied in a direction parallel to the slab. Similarly to what was found for a single patch on a ferrite slab biased in a direction perpendicular to the slab [1], the scattering coefficient which is directly related to the monostatic radar cross section is seen to move around in frequency as the bias field strength changes. This effect indicates that microstrip antennas could be made "invisible" or hide in frequency when not in transmitting or receiving mode. The bias field could be applied when the antenna is not transmitting but is wished to be hidden.

Figure 1 shows the geometry of the array and substrate. The given inputs to the analysis are the substrate parameters including the bias field strength, the array grid geometry, the patch dimensions, and the incident angle. The substrate's permeability is given by the tensor:

$$\bar{\bar{\mu}} = \begin{vmatrix} \mu & 0 & -j\kappa \\ 0 & 1 & 0 \\ j\kappa & 0 & \mu \end{vmatrix} \mu_o$$

where

$$\mu = (1 + \bar{\omega}_o\omega_m/(\bar{\omega}_o^2 - \omega^2)), \quad \kappa = \omega\omega_m/(\bar{\omega}_o^2 - \omega^2)$$

and

$$\omega = 2\pi f, \; \omega_m = \gamma 4\pi M_s, \quad \omega_o = \gamma H_o, \; \bar{\omega}_o = \omega_o + j/T,$$

and

$$T=2/(\psi\Omega H)$$

and γ is the gyromagnetic ratio, and T is the relaxation time, and ΔH is the 3dB line width. Note that the imaginary parts of the off-diagonal elements do not correspond to loss in the medium. Notice that

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the tensor elements vary with bias field strength H_o and with frequency f.

THEORY

The analysis is based on the spectral domain Green's function Galerkin method [2] and [3] for arrays printed on isotropic and biaxial slabs. The theory of [2] and [3] has been extended using the spectral-domain dyadic Green's function as derived in [4]. This Green's function has been extended to the case of an infinite, phased array of sources so that only one unit cell need be considered. In this unit cell, the patch surface currents are expanded in entire-domain trigonometric basis functions. The given exitation is a unit amplitude plane wave that is incident and reflected from the grounded ferrite slab when no patches are present. A Galerkin method is used to solve the boundary condition

$$E_{tan}^{inc} = - E_{tan}^{scat}$$

on the patches for the induced currents on the patch in a unit cell. Then the scattering coefficients $S_{\theta\theta}$, $S_{\phi\phi}$, $S_{\theta\phi}$, and $S_{\phi\theta}$ are found. These scattering coefficients can range in amplitude from 0 to 2 and are directly related to the monostatic return from a finite array.

Surface wave effects are accounted for with the Green's function Galerkin method. Also the method can be extended to include other patch shapes, finite arrays, or single patches.

RESULTS

Figures 2 and 3 show the magnitudes of $S_{\theta\theta}$ and $S_{\phi\phi}$ in dB versus frequency for a near normal incident plane wave and for three different bias conditions [5]. In the first case, the incident field does not couple strongly with the ferrite magnetic moments, and the response does not change much with bias field. In the second case, the incident field is polarized as to couple with the ferrite magnetic moments and the response does change with the y-directed bias field. In the second case, notice that the resonant peaks shift with bias field. Also, in the second case, the section from first peak to first deep null in the magnetized cases corresponds to the frequency range where a magnetostatic surface wave may exist.

These results indicate some promise for the use of controlled-biased ferrites as substrates for stealth antennas.

REFERENCES

[1] David M. Pozar. "Radar Cross Section of a Microstrip Antenna on a Normally Biased Ferrite Substrate," Electronics Letters. June 1989.

[2] David M. Pozar and Daniel H. Schaubert. "Analysis of an Infinite Array of Rectangular Microstrip Patches with Idealized Probe Feeds," IEEE Trans. on Antennas and Propagation. Vol. AP-32, No. 10, pp. 1101-1107, October 1984.

[3] Frances J. Harackiewicz and David M. Pozar. "Radiation and Scattering by Infinite Microstrip Patch Arrays on Anisotropic Substrates," 1988 IEEE AP-S International Symposium Digest. June 1988.

[4] El-Badawy El-Sharawy. Full Wave Analysis of Printed Lines on Magnetic Substrates. A Ph.D. dissertation, University of Massachusetts, September 1989.

[5] Frances J. Harackiewicz. Electromagnetic Radiation and Scattering from Microstrip Antennas on Anisotropic Substrates. A Ph.D. dissertation, University of Massachusetts, February 1990.

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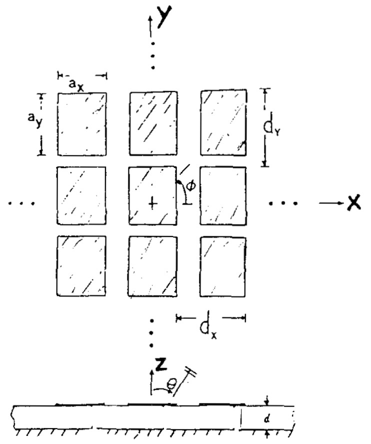

Figure 1 Geometry of the infinite array problem.

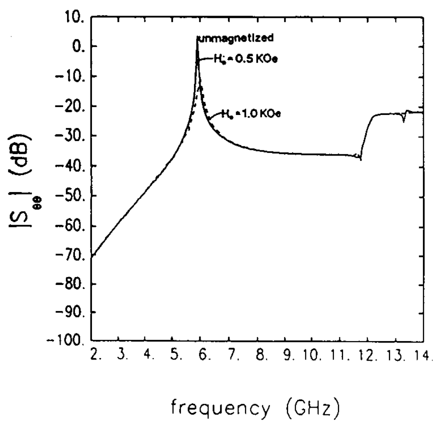

Figure 2 Magnitude of $S_{\theta\theta}$ versus frequency (GHz) for $H_o = M_s \approx 0$ (unmagnetized) and $H_o = 0.5, 1.0$ (KOe) with $M_s = 0.137$ (KOe).

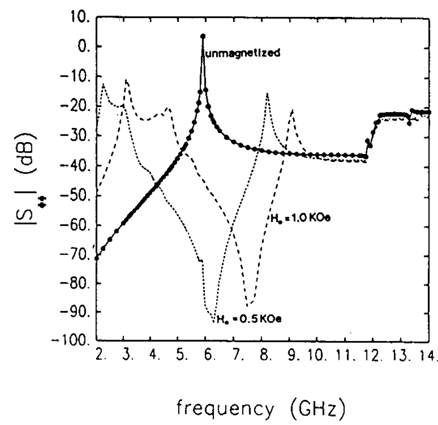

Figure 3 Magnitude of $S_{\phi\phi}$ versus frequency (GHz) for three different ferrite bias conditions.