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I. Introduction

This paper presents an analysis of an infinite array of printed patches on a grounded anisotropic–dielectric slab. The array is considered as both a transmitter fed by idealized probes and as a scatterer of plane waves. For the transmit case, the input reflection coefficient versus scan angle is presented for various substrates. For the scattering case, the plane wave reflection coefficient versus incident angle is computed for various loads and substrates. The theory in both cases is confirmed by comparing its limit to isotropic cases with previous analyses.

The inputs to the analysis are 1) the substrate parameters, 2) the array grid geometry, 3) the patch dimensions including probe position, and 4) the probe load impedance which is assumed conjugate matched at broadside for the transmit case. See Figure 1. The substrate's permittivity is given by a diagonal tensor $\bar{\bar{\epsilon}}$ with complex elements as

$$\bar{\bar{\epsilon}} = \epsilon_0 \begin{bmatrix} \epsilon_{x_r}(1 + j\tan\delta_x) & 0 & 0 \\ 0 & \epsilon_{y_r}(1 + j\tan\delta_y) & 0 \\ 0 & 0 & \epsilon_{z_r}(1 + j\tan\delta_z) \end{bmatrix} .$$

This assumes the substrate is biaxial with optic axes aligned with the geometrical axes of the array. It is shown that, for the transmit case $\epsilon_{z_r}(1+j\tan\delta_z)$, the component of $\bar{\bar{\epsilon}}$ in the direction perpendicular to the slab, is the most dominant. This is expected for the thin substrates for which the idealized probe model is valid, because the E field is mostly $\hat{z}$-directed in the substrate.

II. Theory

The analysis is based on the moment method solution for arrays of printed patches on isotropic substrates [1] and on the moment method solution for the RCS of a single patch on a uniaxial substrate [2]. The theory of [1] and [2] has been extended by first finding the exact spectral domain

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dyadic Green's function for a grounded biaxial dielectric slab. This Green's function is then extended to the case of an infinite phased array of sources, so that only one unit cell of the infinite array need be considered. In the unit cell, the patch surface currents are expanded in entire–domain trigonometric (cavity mode) basis functions, and the probe is idealized as an infinitesimally thick line with uniform amplitude current running on it. The excitation is the phased probe currents for the transmit case and is an incident and reflected plane wave (that exists when no patches or probes are present) for the scattering case. A Galerkin method is then used to solve the boundary condition $E_{\text{TAN}}^{\text{incident}} = -E_{\text{TAN}}^{\text{scattered}}$ on the patch in the unit cell for the patch surface current expansion coefficients.

As in [1] and [2], surface wave effects are rigorously accounted for by using an exact spectral domain Green's function. The analysis may be used for any canonical shape patch for which the current can be expressed by a small number of known basis functions. As in [2], the Green's function could also be used to analyze the single patch or small array. As in the previous theories, the idealized probe model limits the theory's usefulness to cases with thin substrates and thin probes.

III. Examples

Figure 2 shows the reflection coefficient magnitude versus scan angle for the transmit case for four different substrates. The two isotropic cases were checked against the results from [2]'s analysis, and found to be exactly the same. The anisotropic cases were found to behave like an isotropic case with some effective relative permittivity. Since the $\overline{E}$–field is mainly $\hat{z}$–directed for thin substrates, the scan characteristics depend most strongly on ϵ_{z_r}. And, since the patches are fed along the x–axis, the resonant length P_ℓ does not depend on ϵ_{y_r}.

Figure 3 shows the plane wave reflection coefficient's phase versus frequency for the scattering case. Here, the incident angle is varied with frequency as in a waveguide simulator experiment to compare with the results in [3]. The theory and experiment in [3] are for the open–circuited patch case (probe load impedance of infinity). Theoretical results presented here are for the probe load impedance $Z_L = \infty$ and $Z_L = 50\Omega$. Also presented here is the theoretical results for a uniaxial case with $\epsilon_{z_r} = \epsilon_r$ of the isotropic case and with $\epsilon_{x_r} = \epsilon_{y_r} = 3.5$. For the uniaxial case $Z_L = \infty$ (no probe) was chosen.

If available at the time of presentation, results will be shown for cases with biaxial permeability.

IV. References

[1] D. M. Pozar and D. H. Schaubert, "Analysis of an Infinite Array of Rectangular Microstrip Patches with Idealized Probe Feeds," IEEE Trans. Antennas and Prop., Vol. AP-32, pp. 1101–1107, October 1984.

[2] D. M. Pozar, "Radiation and Scattering from a Microstrip Patch on a Uniaxial Substrate," IEEE Trans. Antennas and Prop., Vol. AP-35, pp. 613–621, June 1987.

[3] C. C. Liu, J. Shmoys, A. Hessel, J. D. Hanfling, and J. M. Usoff, "Plane Wave Reflection from Microstrip-Patch Arrays — Theory and Experiment," IEEE Trans. Antennas and Prop., Vol. AP-33, pp. 426–435, April 1985.

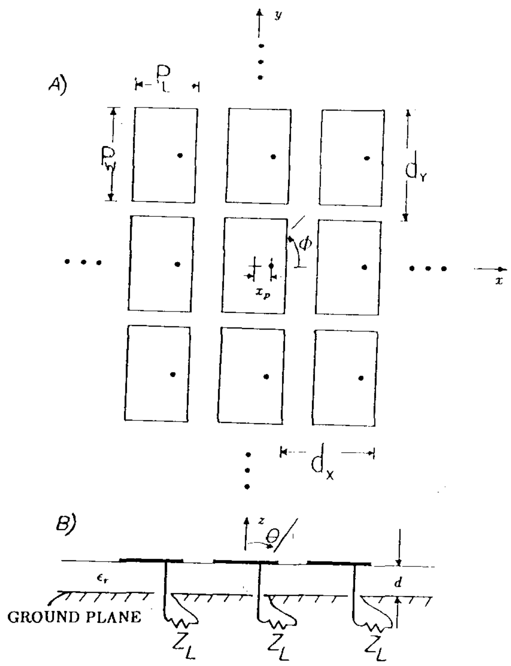

Figure 1. Geometry of Array.
a) top view of array,
b) side view of array.

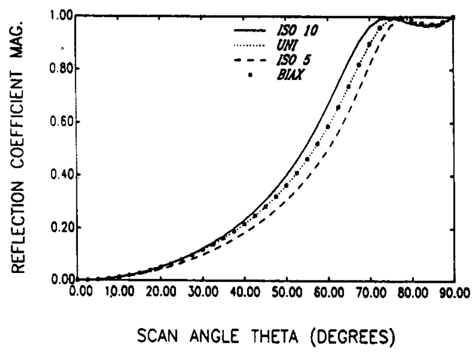

Figure 2. Computed reflection coefficient magnitude of an infinite array of one–probe–fed rectangular patches for an E–plane scan ($\phi = 0°$, θ varies from 0° to 90°) for four different dielectric cases ($d = 0.04\lambda_0$, $P_w = 0.3\lambda_0$, P_ℓ = resonant length, $x_p = -P_\ell/3.5$, $d_x = d_y = .5\lambda_0$.

Case	ϵ_{x_r}	ϵ_{y_r}	ϵ_{z_r}	$P_\ell(\lambda_0)$
ISO 10	10.	10.	10.	0.13
UNI	2.	2.	10.	0.15
BIAX	2.	5.	10.	0.15
ISO 5	5.	5.	5.	0.20

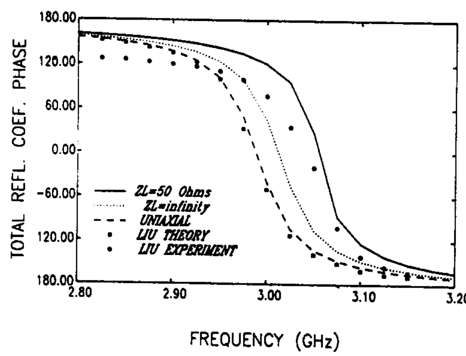

Figure 3. Resonance curves for microstrip patch array in a waveguide simulator. (Waveguide 3.6×2.87 in., $P_\ell = P_w$ = 1.2 in., d = 0.062 in., $\phi = 90°$, $\sin\theta = \lambda/(4d_y)$, d_x = 2.87 in., $2d_y$ = 3.6 in., $\hat{z}$–polarization of incident field $x_p = -P_\ell/4$).

Case	$\epsilon_{x_r} = \epsilon_{y_r}$	ϵ_{z_r}	Z_L (Ω)
$Z_L = 50\Omega$	2.47	2.47	50
$Z_L = \infty$	2.47	2.47	∞
UNI	3.5	2.47	∞
LIU THY. [3]	2.47	2.47	∞
LIU EXP. [3]	2.47	2.47	∞