Southern Illinois University Carbondale [OpenSIUC](http://opensiuc.lib.siu.edu?utm_source=opensiuc.lib.siu.edu%2Fece_confs%2F15&utm_medium=PDF&utm_campaign=PDFCoverPages)

[Conference Proceedings](http://opensiuc.lib.siu.edu/ece_confs?utm_source=opensiuc.lib.siu.edu%2Fece_confs%2F15&utm_medium=PDF&utm_campaign=PDFCoverPages)

[Department of Electrical and Computer](http://opensiuc.lib.siu.edu/ece?utm_source=opensiuc.lib.siu.edu%2Fece_confs%2F15&utm_medium=PDF&utm_campaign=PDFCoverPages) [Engineering](http://opensiuc.lib.siu.edu/ece?utm_source=opensiuc.lib.siu.edu%2Fece_confs%2F15&utm_medium=PDF&utm_campaign=PDFCoverPages)

6-1988

Radiation and Scattering by Infinite Microstrip Patch Arrays on Anisotropic Substrates

Frances J. Harackiewicz *University of Massachusetts - Amherst*, fran@engr.siu.edu

David M. Pozar *University of Massachusetts - Amherst*

Follow this and additional works at: [http://opensiuc.lib.siu.edu/ece_confs](http://opensiuc.lib.siu.edu/ece_confs?utm_source=opensiuc.lib.siu.edu%2Fece_confs%2F15&utm_medium=PDF&utm_campaign=PDFCoverPages)

Published in Harackiewicz, F.J., & Pozar, D.M. (1988). Radiation and scattering by infinite microstrip patch arrays on anisotropic substrates. *Antennas and Propagation Society International Symposium, 1988. AP-S. Digest 6-10 June 1988, vol. 1*, 10 - 13. doi: 10.1109/APS.1988.93976 ©1988 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE. This material is presented to ensure timely dissemination of scholarly and technical work. Copyright and all rights therein are retained by authors or by other copyright holders. All persons copying this information are expected to adhere to the terms and constraints invoked by each author's copyright. In most cases, these works may not be reposted without the explicit permission of the copyright holder.

Recommended Citation

Harackiewicz, Frances J. and Pozar, David M., "Radiation and Scattering by Infinite Microstrip Patch Arrays on Anisotropic Substrates" (1988). *Conference Proceedings.* Paper 15. [http://opensiuc.lib.siu.edu/ece_confs/15](http://opensiuc.lib.siu.edu/ece_confs/15?utm_source=opensiuc.lib.siu.edu%2Fece_confs%2F15&utm_medium=PDF&utm_campaign=PDFCoverPages)

This Article is brought to you for free and open access by the Department of Electrical and Computer Engineering at OpenSIUC. It has been accepted for inclusion in Conference Proceedings by an authorized administrator of OpenSIUC. For more information, please contact [opensiuc@lib.siu.edu.](mailto:opensiuc@lib.siu.edu)

Radiation and Scattering by Infinite Microstrip Patch Arrays on Anisotropic Substrates

Frances J. Harackiewicz* David M. Pozar

Department of Electrical and Computer Engineering University of Massachusetts Amherst, MA 01003

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](#page-3-0) 1. The substrate's permittivity is given by a diagonal tensor $\bar{\epsilon}$ with complex elements as

.

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

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.

11. Theory

The analysis is based on the moment method solution for arrays of printed patches on isotropic substrates [I] and on the moment method solution for the RCS of a single patch on a uniaxial substrate **(21.** The theory of $|1|$ and $|2|$ has been extended by first finding the exact spectral domain

 I

 $112563.5/88/0000.0010$ \$1.00 $^{\circ}$ 1988 IEEE

10

2-3

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 **(11** and **(21,** 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 **(21,** 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.

111. 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 **(21'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_{x_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 fre quency **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 $\epsilon_{z_r} = \epsilon_{y_r} = 3.5$. 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.

11

Authorized licensed use limited to: Southern Illinois University Carbondale. Downloaded on March 11, 2009 at 16:44 from IEEE Xplore. Restrictions apply.

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.
- 121 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.
- **131 C. C. Liu, J. Shmoys, A. Hessel, J. D. Hanfling, and J. M. Usoff, "Plane Wave Reflection from Microstrip-Patch Arrays Theory and Exper**iment," 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

12

1

SCAN ANGLE THETA (DEGREES)

180.00

Figure 2. Computed reflection coefficient magnitude of an infinite
array of one-probe-fed rectangular patches for an E-
plane scan ($\phi = 0^{\circ}$, θ varies from 0° to 90°) for four
different dielectric cases (

| Case | ε. | ε, | ٤. | $P_{\ell}(\lambda_0)$ |
|-------------|-----|-----|-----|-----------------------|
| 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 |

 $\ddot{}$

Figure 3. Resonance curves for microstrip patch array in a waveguide simulator. (Waveguide 3.6×2.87 in., $P_{\ell} = P_{\omega} =$ 1.2 in., $d = 0.062$ in., $\phi = 90^{\circ}$, $\sin \theta = \lambda/(4d_{\nu})$, $d_{z} =$ 2.87 in., $2d_{\nu} = 3.6$ in., \hat{x} -

| Case | $\epsilon_{x_r} = \epsilon_{y_r}$ | t., | $Z_L(\Omega)$ | |
|------------------|-----------------------------------|------|---------------|--|
| $Z_L = 50\Omega$ | 2.47 | 2.47 | 50 | |
| $Z_L = \infty$ | 2.47 | 2.47 | œ | |
| UNI | 3.5 | 2.47 | ∞ | |
| LIU THY. [3] | 2.47 | 2.47 | ∞ | |
| LIU EXP. [3] | 2.47 | 2.47 | ∞ | |