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# JOINT SERVICES ELECTRONICS PROGRAM Final Report

The Ohio State University

## ElectroScience Laboratory

Department of Electrical Engineering  
Columbus, Ohio 43212

Final Report 721563-4  
Contract No. N00014-89-J-1007  
January 1992

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SELECTED  
FEB 05 1992  
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Department of the Navy  
Office of Naval Research  
800 North Quincy Street  
Arlington, Virginia 22217

92-02740



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## OVERVIEW

The JSEP studies at the ElectroScience Laboratory continue to focus on Electromagnetics and Electromagnetics related subjects. The emphasis of this program was highlighted during our Major Review when all JSEP schools with an Electromagnetic component also presented their own activities in this discipline. In addition there were presentations by A. Jordan (Navy), F. Schwering (Army) and R. Mallioux (Air Force). The meeting was attended by 44 DoD personnel and was considered to be successful by all attendees. It is expected that this format for the Major Review will continue in the future.

During the third year of our program we have added Prof. R. Lee who replaced Prof. J.H. Richmond (deceased). Prof. Lee is the second young researcher who has been added to our JSEP unit in recent years, the first being Prof. R-C. Chou. Prof. Lee's expertise lies in the general area of Finite Difference/Finite Element Solutions.

Research this past three years has involved Diffraction Studies, Integral Equation Studies, Hybrid Studies and Adaptive Array/Packet Radio.

R.G. Rojas received the 1990 Browder J. Thompson Memorial Prize Award, for the best paper in any IEEE publication for an author under the age of thirty, for the paper, "Wiener-Hopf Analysis of the EM Diffraction by an Impedance Discontinuity in a Planar Surface and by an Impedance Half-Plane," *IEEE Transactions on Antennas and Propagation*, Vol. AP-36, January 1988, pp. 71-83.

The Diffraction and Hybrid Studies work units have been recognized in yet another manner in that Prof. Pathak has given 10 invited papers/lectures during this past contract period. He is also a Distinguished Lecturer for the Antenna and Propagation Society of the Institute of Electronics and Electrical Engineers for the 1990-1993 term and has presented seven lectures under this program.

There have been 42 archival journal papers published in this contract period. An additional 13 such papers have been accepted, 10 such papers have been submitted and another 9 papers are in preparation. Also a substantial number of oral papers have been presented at national/international symposia.

## LISTING OF PRINCIPAL INVESTIGATORS

1988 - 1991

1. Professor R-C. Chou
2. Dr. C.W. Chuang
3. Professor R.T. Compton
4. Professor R.G. Kouyoumjian
5. Professor R. Lee
6. Professor E.H. Newman
7. Professor P.H. Pathak
8. Professor J.H. Richmond
9. Dr. R.G. Rojas

## **DEGREES AWARDED**

Over the past 3 years with the support of JSEP, 5 students have been granted the M.Sc. degree and 6 students have been granted the Ph.D. degree in Electrical Engineering. The following list tabulates these students and gives the date of their graduation.

### **Master of Science Degrees**

|           |        |      |
|-----------|--------|------|
| F. Vook   | Autumn | 1988 |
| H.C. Ly   | Winter | 1989 |
| C. Olen   | Summer | 1989 |
| M. Peters | Winter | 1990 |
| P. Munk   | Winter | 1991 |

### **Doctor of Philosophy Degrees**

|                 |        |      |
|-----------------|--------|------|
| R.J. Burkholder | Spring | 1989 |
| J. Choi         | Summer | 1989 |
| J. Ward         | Summer | 1990 |
| K.C. Hill       | Summer | 1990 |
| M. Kluskens     | Spring | 1991 |
| J. Blanchard    | Autumn | 1991 |

**JSEP REFEREED JOURNAL PAPERS  
PUBLISHED  
OCTOBER 1988 TO SEPTEMBER 1991**

1. L. Ersoy and P.H. Pathak, "An Asymptotic High Frequency Analysis of the Radiation by a Source on a Perfectly Conducting Convex Cylinder with an Impedance Surface Patch," *IEEE Transactions on Antennas and Propagation*, Vol. 36, No. 10, pp. 1407-1417, October 1988.
2. C.W. Chuang and M.C. Liang, "A Uniform Asymptotic Analysis of the Diffraction by an Edge in a Curved Screen," *J. Radio Science*, Vol. 23, pp. 781-790, September-October 1988.
3. A.K. Dominek and L. Peters, Jr., "RCS Measurements of Small Circular Holes," *IEEE Transactions on Antennas and Propagation*, Vol. 36, No. 10, October 1988.
4. J.H. Richmond, "Scattering by a Conducting Elliptic Cylinder with Dielectric Coating," *J. Radio Science*, Vol. 23, pp. 1061-1066, November 1988.
5. P.H. Pathak and A. Altintas, "An Efficient High Frequency Analysis of Modal Reflection and Transmission Coefficients for a Class of Waveguide Discontinuities," *J. Radio Science*, Vol. 23, No. 6, pp. 1107-1119, November-December 1988.
6. E.H. Newman, "Generation of Wideband Data from the Method of Moments by Interpolating the Impedance Matrix," *IEEE Transaction on Antennas and Propagation*, Vol. 36, No. 12, pp. 1820-1824, December 1988.
7. R.G. Rojas and Z. Al-hekail, "Generalized Impedance/Resistive Boundary Conditions for Electromagnetic Scattering Problems," *J. Radio Science*, Vol. 24, pp. 1-12, January-February 1989.
8. R. Tiberio, G. Pelosi, G. Manara and P.H. Pathak, "High-Frequency Scattering from a Wedge with Impedance Faces Illuminated by a Live Source, Part I: Diffraction," *IEEE Transactions on Antennas and Propagation*, Vol. 37, No. 2, February 1989.
9. C.W. Chuang and P.H. Pathak, "Ray Analysis of Modal Reflection for Three-Dimensional Open-Ended Waveguides," *IEEE Transactions on Antennas and Propagation*, Vol. 37, No. 3, pp. 339-346, March 1989.
10. M. Marin, S. Barkeshli and P.H. Pathak, "Efficient Analysis of Planar Microstrip Geometries Using a Closed Form Asymptotic Representation of the Grounded-Dielectric Slab Green's Function," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 37, pp. 669-679, April 1989.

11. J.L. Blanchard and E.H. Newman, "Numerical Evaluation of Parabolic Cylinder Functions," *IEEE Transactions on Antennas and Propagation*, Vol. 37, No. 4, pp. 519-523, April 1989.
12. E.H. Newman and R.J. Marhefka, "Overview of MM and UTD methods at The Ohio State University," *Proceedings of the IEEE*, Vol 77, No. 5, May 1989.
13. P.H. Pathak and R.J. Burkholder, "Modal, Ray and Beam Techniques for Analyzing the EM Scattering by Open End Waveguide Cavities," *IEEE Transactions on Antennas and Propagation*, Vol. 37, No. 5, pp. 635-647, May 1989.
14. R.G. Rojas and P.H. Pathak, "Diffractions of EM Waves by a Dielectric/Ferrite Half-Plane and Related Configurations," *IEEE Transactions on Antennas and Propagation*, Vol. 37, No. 6, pp. 751-763, June 1989.
15. M.W. Ganz and R.T. Compton, Jr., "A Data-Derived Reference Signal Technique for Adaptive Arrays," *IEEE Transactions on Communications*, Vol. 37, No. 9, pp. 975-983, September 1989.
16. G. Turhan and D.L. Moffatt, "K-Pulse Estimation and Target Identification of Low-Q Radar Targets," *Wave Motion*, Vol. 11(5), September 1989.
17. G. Turhan-Sayan and D.L. Moffatt, "K-Pulse Estimation Using Legendre Polynomial Expansions and Target Discrimination," *Journal of Electromagnetic Waves and Applications*, Vol. 1989.
18. J.H. Richmond, "Axial Slot Antenna on Dielectric-Coated Elliptic Cylinder," *IEEE Transactions on Antennas and Propagation*, Vol. 37, No. 10, pp. 1235-1241, October 1989.
19. H.T. Kim and N. Wang, "UTD Solution for the Electromagnetic Scattering by a Circular Cylinder with Thin Lossy Coatings," *IEEE Transactions on Antennas and Propagation*, Vol. 37, No. 11, pp. 1463-1472, November 1989.
20. E.H. Newman, "Polygonal Plate Modeling," *Electromagnetics*, Vol. 10, pp. 65-83, January-June 1990, (invited paper).
21. S. Barkeshli and P.H. Pathak, "Radial Propagation and Steepest Descent Path Integral Representations of the Planar Microstrip Dyadic Green's Function," *Radio Science*, Vol. 25, No. 2, pp. 161-174, March-April 1990.
22. R.G. Rojas and L.M. Chou, "Diffraction by a Partially Coated Perfect Dielectric Conducting Half-Plane," *Radio Science*, Vol. 25, No. 2, pp. 175-188, March-April 1990.
23. E.H. Newman, "Plane Wave Scattering from a Material Coated Parabolic Cylinder," *IEEE Transactions on Antennas and Propagation*, Vol. 38, No. 4, pp. 541-550, April 1990.

24. M. Marin, S. Barkeshli and P.H. Pathak, "On the Location of Proper and Improper Surface Wave Poles for the Grounded Dielectric Slab," *IEEE Transactions on Antennas and Propagation*, Vol. 38, No. 4, pp. 570-572, April 1990.
25. J. Choi, N. Wang, L. Peters, Jr. and P. Levy, "Near Axial Back Scattering from Finite Cones," *IEEE Transactions on Antennas and Propagation*, Vol. 38, No. 8, pp. 1264-1272, August 1990.
26. P.H. Pathak and M.C. Liang, "On a Uniform Asymptotic Solution Valid Across Smooth Caustics of Rays Reflected by Smoothly Indented Boundaries," *IEEE Transactions on Antennas and Propagation*, Vol. 38, No. 8, pp. 1192-1203, August 1990.
27. K.D. Trott, P.H. Pathak and F. Molinet, "A UTD Type Analysis of the Plane Wave Scattering by a Fully Illuminated Perfectly-Conducting Cone," *IEEE Transactions on Antennas and Propagation*, Vol. 38, No. 8, pp. 1150-1160, August 1990.
28. J. Choi, N. Wang, L. Peters, Jr. and P. Levy, "Near Axial Backscattering from a Cone Sphere," *Radio Science*, Vol. 25, No. 4, pp. 427-434, July-August 1990.
29. M.S. Kluskens and E.H. Newman, "Scattering by a Chiral Cylinder of Arbitrary Cross Section," *IEEE Transactions on Antennas and Propagation*, Vol. AP-38, pp. 1448-1455, September 1990.
30. S. Barkeshli, P.H. Pathak and M. Marin, "An Asymptotic Closed-Form Microstrip Surface Green's Function for the Efficient Moment Method Analysis of Mutual Coupling in Microstrip Antennas," *IEEE Transactions on Antennas and Propagation*, Vol. 38, No. 9, pp. 1374-1383, September 1990.
31. C.A. Olen and R.T. Compton, Jr., "A Numerical Pattern Synthesis Algorithm for Arrays," *IEEE Transactions on Antennas and Propagation*, Vol. AP-38, No. 10, pp. 1666-1676, October 1990.
32. J.W. Ward and R.T. Compton, Jr., "Sidelobe Level Performance of Adaptive Sidelobe Canceller Arrays with Element Reuse," *IEEE Transactions on Antennas and Propagation*, Vol. AP-38, No. 10, pp. 1684-1693, October 1990.
33. A. Nagamune and P.H. Pathak, "An Efficient Plane Wave Spectral Analysis to Predict the Focal Region of Parabolic Reflector Antennas for Small and Wide Angle Scanning," *IEEE Transactions on Antennas and Propagation*, Vol. AP-38, No. 11, pp. 1746-1756, November 1990.
34. M.S. Kluskens and E.H. Newman, "Scattering by a Multilayer Chiral Cylinder," *IEEE Transactions on Antennas and Propagation*, Vol. AP-39, No. 1, pp. 91-96, January 1991.
35. P. H. Pathak and R.J. Burkholder, "High Frequency EM Scattering by Open-Ended Waveguide Cavities," *Journal Radio Science*, Vol.26, No.1, pp. 211-218, January-February 1991.

36. M.E. Peters and E.H. Newman, "TM Scattering by a General Sheet Impedance Discontinuity," *IEEE Transactions on Antennas and Propagation*, Vol. AP-39, No. 3, pp. 359-366, March 1991.
37. J.H. Richmond, "On Variational Aspects of the Moment Method," *IEEE Transactions on Antennas and Propagation* Vol. AP-39, No. 4, pp. 473-480, April 1991.
38. M.S. Kluskens and E.H. Newman, "Image Theory for Chiral Bodies," *IEEE Transactions on Antennas and Propagation*, Vol. AP-39, No. 5, pp. 676-677, May 1991.
39. R.G. Rojas, H.C. Ly, P.H. Pathak, "EM Plane Wave Diffraction by a Planar Junction of Two Thin Dielectric/Ferrite Half-Planes," *Journal Radio Science*, pp. 641-660, May-June 1991.
40. S. Barkeshli and P.H. Pathak, "Reciprocal Properties of the Dyadic Green's Function for Planar Multilayered Dielectric/Magnetic Media," *Microwave and Optical Technology Letters*, Vol. 4, No. 8, pp. 333-335, August 1991.
41. J. Li and R. T. Compton, Jr., "Angle and Polarization Estimation using ESPRIT with a Polarization Sensitive Array," *IEEE Transactions on Antennas and Propagation*, Vol. AP-39, No. 9, pp. 1376-1383, September 1991.
42. R.G. Rojas, H.C. Ly, P.H. Pathak, R. Tiberio, "EM Plane Wave Diffraction by a Three-part Thin, Planar Dielectric/Ferrite Slab," *Journal Radio Science*, Vol. 26, No. 5, pp. 1267-1280, September-October 1991.

## JSEP RELATED PAPERS ACCEPTED FOR PUBLICATION

1. R.J. Burkholder and P.H. Pathak, "An Analysis of the EM Scattering from an Open-Ended Waveguide Cavity Using Gaussian Beam Shooting," *Proc. IEEE*, October 1991.
2. E.H. Newman and K. Kingsley, "An Introduction to the Method of Moments," *Computer Physics Communications*, (invited paper).
3. M.S. Kluskens and E.H. Newman, "Scattering by a Chiral Cylinder of Arbitrary Cross Section in the Presence of a Half-Plane," *Journal Electromagnetic Waves and Applications*.
4. M.S. Kluskens and E.H. Newman, "A Microstrip Line on a Chiral Substrate," *IEEE Transactions on Microwave Theory and Techniques*.
5. R.J. Burkholder, R-C. Chou and P.H. Pathak, "Two Ray Shooting Methods for Computing the EM Scattering by Large Open-Ended Cavities," for publication in *Computer Physics Communications*. (invited).
6. M. Marin and P.H. Pathak, "An Asymptotic Closed-Form Representation for the Grounded Double Layer Surface Green's Function," *IEEE Transactions on Antennas and Propagation*.
7. G. Pelosi, R. Tiberio and R.G. Rojas, "Electromagnetic Field Excited by a Line Source Placed at the Edge of an Impedance Wedge," *Journal Electromagnetic Waves and Applications*.
8. R.G. Rojas, "Integral Equations for the Scattering by Three Dimensional Inhomogeneous Chiral Bodies," submitted for publication to *Journal of Electromagnetic Waves and Applications*.
9. P.H. Pathak, "High Frequency Methods for Antenna Analysis," for IEEE Proceedings (invited).
10. J. Li and R.T. Compton, Jr., "Angle Estimation using a Polarization Sensitive Array," *IEEE Transactions on Antennas and Propagation*, vol. AP-39, October 1991.
11. J. Ward and R.T. Compton, Jr., "Improving the Performance of a Slotted ALOHA Packet Radio Network with an Adaptive Array," *IEEE Transactions on Communications*.

12. J. Ward and R.T. Compton, Jr., "High Throughput Slotted ALOHA Packet Radio Networks with Adaptive Arrays," *IEEE Transactions on Communications*.
13. S. Barkeshli and P.H. Pathak, "On the Dyadic Green's Function for a Planar Multi-Layered Dielectric/Magnetic Media," *IEEE Transactions on Microwave Theory and Techniques*.

## JSEP RELATED PAPERS SUBMITTED FOR PUBLICATION

1. M.C. Liang, P.H. Pathak and C.W. Chuang, "A Generalized Uniform Ray Solution for Diffraction by a Perfectly-Conducting Wedge with Convex Faces," submitted to *J. Radio Science*.
2. R.G. Rojas, "Integral Equation for EM Scattering by Two Dimensional Chiral Bodies," submitted to *IEEE Transactions on Antennas and Propagation*.
3. K.C. Hill and P.H. Pathak, "On the Nature and Evaluation of the Transition Function for a UTD Corner Diffraction Coefficient," submitted to ACES journal.
4. R. Lee and A.C. Cangellaris "A Study of Discretization Error in the Finite Element Approximation of Wave Solutions," submitted to *IEEE Trans. Antennas Propagation*.
5. P.H. Pathak and R.J. Burkholder, "A Reciprocity Formulation for Calculating the EM Scattering by an Obstacle within an Open-Ended Waveguide Cavity," submitted to *IEEE Transactions on Microwave Theory and Techniques*.
6. J. Li and R. T. Compton, Jr. "Maximum Likelihood Estimation of the Arrival Direction of a Signal with Known Waveform," Submitted to *IEEE Transactions on Signal Processing*.
7. J. Li and R. T. Compton, Jr., " Maximum Likelihood Angle Estimation for a Signal with known Waveform in the Presence of Interfering Signals," Submitted to *IEEE Transactions on Signal Processing*.
8. J. Li and R. T. Compton, Jr., " Maximum Likelihood Angle Estimation for Signals with known Waveforms," Submitted to *IEEE Transactions on Signal Processing*.
9. J. Li and R. T. Compton, Jr., " Angle and Polarization Estimation in a Coherent Signal Environment," submitted to *IEEE Transactions on Aerospace and Electronic Systems*.
10. J. Li and R. T. Compton, Jr., " Two-Dimensional Angle and Polarization Estimation using the ESPRIT Algorithm," submitted to *IEEE Transactions on Antennas and Propagation*.

## JSEP RELATED PAPERS IN PREPARATION

1. P.H. Pathak, A. Nagamune and R.G. Kouyoumjian, "An Analysis of Compact Range Measurements."
2. P.H. Pathak, P. Law, and R. J. Burkholder, "High Frequency Electromagnetic Scattering by a Large Obstacle/Termination within an Open Cavity Structure."
3. M. Hsu, R-C. Chou, P. Pathak and C.W. Chuang, " Analysis of the Asymptotic HF EM Coupling Between Sources Anywhere in the Vicinity of a Circular Cylinder."
4. P. Munk and P. Pathak, "Analysis of EM Scattering by an Array of Waveguide Fed Slots in a Dielectric Filled Rectangular Cavity Opening into a Ground of a Plane."
5. J. Ward and R. T. Compton, Jr., " High Throughput Unslotted ALOHA Packet Radio with an Adaptive Array," In preparation.
6. J.L. Blanchard and E.H. Newman, "Integral Equation Analysis of Artificial Media,"
7. R.G. Rojas and L.M. Chou, "Generalized Impedance/Resistive Boundary Conditions for a Planar Chiral Slab."
8. K.C. Hill and P.H. Pathak, "A Uniform Stationary Phase Evaluation of a Double integral with Algebraic ."
9. K.C. Hill and P.H. Pathak, "An Approximate UTD Corner Diffraction Coefficient."

## **JSEP RELATED M.SC. THESES AND PH.D. DISSERTATIONS**

1. F. Vook, "The Bandwidth Performance of Multi-Element Adaptive Arrays with Tapped Delay-Line Processing," M.Sc. Thesis, Fall 1988.
2. H.C. Ly, "A UTD Analysis of the Diffraction by Planar Two and Three Part Configurations Consisting of Thin Dielectric/Ferrite Materials," M.Sc. Thesis, Winter 1989.
3. R.J. Burkholder, "High-Frequency Asymptotic Methods for Analyzing the EM Scattering by Open-Ended Waveguide Cavities," Ph.D. Dissertation, Spring 1989.
4. J. Choi, "EM Scattering from Perfectly Conducting Finite Cones and Cone-Spheres," Ph.D. Dissertation, Summer 1989.
5. C.A. Olen, "A Sidelobe Control Algorithm Using Adaptive Array Techniques," M.Sc. Thesis, Summer 1989.
6. M. Peters, "TM Scattering by a Variable Sheet Impedance in a Multilayered Slab," M.Sc. Thesis, Winter 1990.
7. J. Ward, "High Throughput Packet Radio Networks with Adaptive Antenna Arrays," Ph.D. Dissertation, Summer 1990.
8. K.C. Hill, "A UTD Solution to the EM Scattering by the Vertex of a Perfectly Conducting Plane Angular Sector," Ph.D. Dissertation, Summer 1990.
9. J.L. Blanchard, "Integral Equation Analysis of Artificial Dielectrics," Ph.D. Dissertation, Autumn 1990.
10. P. Munk, "EM Scattering by a Dielectric Filled Rectangular Antenna Cavity Recessed in a Ground Plane and Backed with an Array of Rectangular Waveguide Fed Slots," M.Sc. Thesis, Winter 1991.
11. M.S. Kluskens, "Method of Moments Analysis of Scattering by Chiral Media," Ph.D. Dissertation, Spring 1991.