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13. ABSTRACT *(Maximum 200 words)*

1) A hybird method has been developed which efficiently models a large cavity constructed of a waveguide with a flanged opening at one end that couples it to free space. This method uses adiabatic mode theory to describe the electromagnetic fields in the waveguide (single mode) which is slowly changing and shorted at the far end. A finite difference scheme is used to describe the scattered electromagnetic fields in the exterior. This infinite region is truncated using a non-absorbing boundary condition. 2) A methodology has been developed to extend the above results to more realistic applications. Specifically S-Matrix theory is used to take into account discontinuities in the guide, such as an iris or another flanged outlet. This methodology holds for multi-mode waveguides. 3) Analysis of numerical errors for the FDTD method for pulse propagation in a dispersive media have been substantially refined and extended to the appended integral equation approach. 4) A substantially more efficient alternative to the FDTD method for dispersive media has been developed in one spatial dimension for homogeneous materials. Preliminary exploration of extensions to inhomogeneous materials (including material interfaces) and higher dimensions has begun.

14. SUBJECT TERMS
electromagnetic fields, dispersive media, waveguide

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Applied Mathematical Problems in Modern Electromagnetics
AFOSR Grant/Contract #F-49620-94-1-0338

Final Report
1 July 94 - 30 June 97

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OBJECTIVES

. Our program was involved with the investigation of three classes of electromagnetic problems, which require a blend of asymptotic and numerical methods. The problems we considered arise in

* Microwave Heating of Dispersive Materials; e.g., ceramics and biological tissues,

* Pulse Propagation in Highly Dispersive Media, e.g., biological tissue,

* Scattering by electrically large structures with local fine structure, e.g., periodic coatings and slowly changing ducts,

* Pulse propagation in long distance optical fiber communication systems,

RESULTS OF EFFORT

. A hybrid method has been developed which efficiently models a large cavity constructed of a waveguide with a flanged opening at one end that couples it to free space. This method uses adiabatic mode theory to describe the electromagnetic fields in the waveguide (single mode) which is slowly changing and shorted at the far end. A finite difference scheme is used to describe the scattered electromagnetic fields in the exterior. This infinite region is truncated using a non-absorbing boundary condition.

. A methodology has been developed to extend the above results to more realistic applications. Specifically S-Matrix theory is used to take into account discontinuities in the guide, such as an iris or another flanged outlet. This methodology holds for multi-mode waveguides.

. A new theory for the development of hot spots in microwave heated ceramic fibers has been developed. It incorporates the effects of cavity detuning and higher mode generation. A non-local reaction-diffusion equation governs the temperature along the rod and predicts localized thermal structures.

. Analysis of numerical errors for the FDTD method for pulse propagation in a dispersive media have been substantially refined and extended to the appended integral equation approach.

. A substantially more efficient alternative to the FDTD method for

dispersive media has been developed in one spatial dimension for homogeneous materials. Preliminary exploration of extensions to inhomogeneous materials (including material interfaces) and higher dimensions has begun.

ACCOMPLISHMENTS/NEW FINDINGS
see above

PERSONNEL SUPPORTED
* Faculty
G.A. Kriegsmann, J.H.C. Luke, C.V. Hile

* Post-Docs
S. Booker

* Graduate Students

* Other (please list role)

PUBLICATIONS
* SUBMITTED
* Journals

"A Hybrid Numerical Method for Modeling Microwave Sintering Experiments ,"
C.V. Hile and G.A. Kriegsmann, Journal of Computational Physics, under revision.

"Numerical Error Analysis of FDTD Methods for Pulse Propagation in Deby e
Dispersive Materials," E.G. Gordon, C.V. Hile and J.H.C. Luke, IEEE Antennas and Propagation, submitted.

"A Filtered Pseudo-Spectral Method for Solving NLS and Extended NLS Equ ations,"
C.V. Hile, in preparation.

"A Finite Difference Method for Dispersive Linear with Applications to Simulating Electromagnetic Pulses in Water", Jonathan H. C.Luke, Journa l of
Computational Physics, submitted.

"The Flanged Waveguide Antenna: Discrete Reciprocity and Conservation, Wave Motion, submitted.

* ACCEPTED
* Journals

"Numerical Solutions of Maxwell's Equations for Nonlinear Optical Pulse Propagation," C.V. Hile and W.L. Kath, J. Opt. Soc. Am. B. Vol. 13, No. 6,
June 1996.

"Comparisons Between Maxwell's Equations and an Extended NLS Equation, C.V. Hile, Wave Motion, VOl. 24, 1996.

"Microwave Heating of Carbon Coated Ceramic Fibers", G. A. Kriegsmann and B. A. Wagner, IMA Journal Applied Mathematics, Vol. 55, 1995.

"Control Region Approximation of Scattering by Two-Dimensional Periodic Structures", G.A. Kriegsmann and B.J. McCartin, Journal of Electromagne tic
Waves and Applications, Vol. 9, No. 5, 1995.

"Microwave Heating of Ceramics: Bistability and Thermal Runaway", Transactions of the American Ceramic Society, Vol. 59, 1995.

"Scattering by Large Structures with Periodic Surface: A Prototype Prob lem",
G. A. Kriegsmann and C. L .Scandrett, Journal of the Society for Applie d
Computational Electromagnetics, Vol. 11, No. 1, 1996.

"Scattering by a Rectangularly Corrugated Surface: An Approximate Theor y",
G. A. Kriegsmann and B. J. McCartin, IEEE Transactions on Antennas and Propagation", Vol. 44, No. 8, August, 1996.

"Cavity Effects in Microwave Heating of Ceramics", G. A. Kriegsmann, SIAM Journal of Applied Mathematics, Vol. 57, No. 2, 1997.

"The Galerkin Approximation of the Iris Problem: Conservation of Power ",
G. A. Kriegsmann, Applied Mathematics Letters, Vol. 10, No. 1, 1997.

" Microwave Heating of Ceramic Laminates", J. A. Pelesko and
G. A. Kriegsmann,Journal of Engineering Mathematics, Vol. 32, 1997.

* Conferences

"A Hybrid Numerical Method for Modeling Microwave Sintering Experiments ,"
C.V. Hile and G.A. Kriegsmann, Microwave Processing of Materials V Symposium, Volume 430, Material Research Society Symposium Proceedings Series, 1996.

"Cavity Effects and Hot Spot Formulation in Microwave Heated Ceramic Fibers", G.A. Kriegsmann, Microwave Processing of Materials V Symposium, Volume 430, Material Research Society Symposium Proceedings

Series, 1996.

INTERACTIONS/TRANSITIONS
* Participation/Presentations At Meetings, Conferences, Seminars, Etc

AFOSR Nonlinear Optics Workshop, Tuscon, AZ, October 1995,
"Comparisons Between Maxwell's Equations and an Extended NLS Equation."

AFOSR Electromagnetics Workshop, San Antonio, TX, January, 1996,
J. H. C. Luke.

Department of Mathematics, University of Delaware, Newark, DE, April, 1 996
"Cavity Effects and Hot Spot Formulation in Microwave Heated Ceramic Fibers", G. A. Kriegsmann.

Materials Research Society Spring Meeting, San Francisco, CA, April 199 6,
"A Hybrid Numerical Method for Modeling Microwave Sintering Experiments ",
C. V. Hile.

Materials Research Society Spring Meeting, San Francisco, CA, April 199 6,
"Cavity Effects and Hot Spot Formulation in Microwave Heated Ceramic Fibers", G. A. Kriegsmann.

Grantees' and Contractors' Meeting: Computational and Physical Mathema tics,
WPAFB, Dayton, June 24-26, 1996, "A Finite Difference Method for Highly

Dispersive Linear Wave Equations".

Conference on Ordinary Differential Equations, Dundee, Scotland, June 1 996,
"A Hybrid Numerical Method for Modeling Microwave Sintering Experiments ",
C. V. Hile.

Conference on Ordinary Differential Equations, Dundee, Scotland, June 1 996,
"Cavity Effects and Hot Spot Formulation in Microwave Heated Ceramic Fibers", G. A. Kriegsmann.

SIAM Annual Meeting, Kansas City, MO, July 1996, "A Hybrid Numerical Me thod
for Modeling Microwave Sintering Experiments" C. V. Hile.

SIAM Annual Meeting, Kansas City, MO, July 1996, "Hybrid Methods in E&M Scattering and Propagation: Cavity Problems", G. A. Kriegsmann.

AFOSR Electromagnetics Workshop, San Antonio, TX, January, 1997,
J. H. C. Luke.

* Consultative And Advisory Functions To Other Laboratories And Agencie
s

* Transitions

NEW DISCOVERIES, INVENTIONS, OR PATENT DISCLOSURES
None

HONORS/AWARDS
G. A. Kriegsmann, Fellow of the Acoustical Society of America, 1991.
G. A. Kriegsmann, Fellow of the Institute for Mathematics and Its
Applications (U.K.), 1992.