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NEWSLETTER

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TABLE OF CONTENTS

ACES NEWSLETTER STAFF

EDITOR-IN-CHIEF, NEWSLETTER
Ray Perez
Martin Marietta Astronautics
MS 58700, PO Box 179
Denver, CO 80201, U.S.A.
Phone: 303-977-5845
Fax: 303-971-4306
email:ray.j.perez@lmco.com

ASSOCIATE EDITOR-IN-CHIEF
David B. Davidson
Dept. Electrical and Electronic Engineering
University of Stellenbosch
Stellenbosch 7600, SOUTH AFRICA
Phone: +27 2231 77 4458 Work
Phone: +27 2231 77 6577 Home
Fax: +27 21 808 4981
email:davidson@firga.sun.ac.za

EDITOR-IN-CHIEF, PUBLICATIONS
W. Perry Wheless, Jr.
University of Alabama
P.O. Box 11134
Tuscaloosa, AL 35486-3008, U.S.A.
Phone: (205) 348-1757
Fax: (205) 348-6959
email:wwheless@ua1vm.ua.edu

MANAGING EDITOR
Richard W. Adler
Pat Adler, Production Assistant
Naval Postgraduate School/ECE Department
Code ECAB, 833 Dyer Road, Room 437
Monterey, CA 93943-5121, U.S.A.
Phone: 831-646-1111
Fax: 831-649-0300
email:rwa@ibm.net

EDITORS

CEM NEWS FROM EUROPE
Pat R. Foster
Microwaves and Antenna Systems
16 Peachfield Road
Great Malvern, Worc, UK WR14 4AP
Phone: +44 1684 5744057
Fax: +44 1684 573509
email:prf@maasas1.demon.co.uk

MODELER'S NOTES
Gerald Burke
Lawrence Livermore National Labs.
Box 5504/L-156
Livermore, CA 94550, U.S.A.
Phone: (510) 422-8414
Fax: (510) 422-3013
email:burke2@llnl.gov

TECHNICAL FEATURE ARTICLE
Andy Drozd
ANDRO Consulting Services
PO Box 543
Rome, NY 13442-0543 U.S.A.
Phone: (315) 337-4396
Fax: (314) 337-4396
email:andro1@aol.com

PERSPECTIVES IN CEM
Melinda Piket-May
University of Colorado at Boulder
ECE Dept., CB425
Boulder, CO 80309-0425
Phone: (303) 492-7448
Fax: (303) 492-2758
email:mjp@boulder.colorado.edu

THE PRACTICAL CEMIST
W. Perry Wheless, Jr.
University of Alabama
P.O. Box 11134
Tuscaloosa, AL 35486-3008, U.S.A.
Phone: (205) 348-1757
Fax: (205) 348-6959
email:wwheless@ua1vm.ua.edu

TUTORIAL
Bruce Archambeault
IBM
Dept. 18DA, Bldg. 306
PO Box 12195, 3039 Cornwallis Road
Research Triangle Park, NC 27709
Phone: (919) 486-0120
Fax: (919) 543-8324
email:barch@us.ibm.com

ACES JOURNAL

EDITOR-IN-CHIEF
Ahmed Kishk
EE Department
University of Mississippi
University, MS 38677 U.S.A.
Phone: (662) 232-5385
Fax: (662) 232-7231
email:ahmed@olemiss.edu

ASSOCIATE EDITOR-IN-CHIEF
Allen Glisson
EE Department
University of Mississippi
University, MS 38677 U.S.A.
Phone: (662) 232-5353
Phone: (662) 232-7231
email:aglisson@olemiss.edu

NEWSLETTER ARTICLES AND VOLUNTEERS WELCOME

The ACES Newsletter is always looking for articles, letters, and short communications of interest to ACES members. All individuals are encouraged to write, suggest, or solicit articles either on a one-time or continuing basis. Please contact a Newsletter Editor.

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NEEDED: ADVERTISING AND REPORTS EDITOR

If interested, please contact :

Ray Perez
Martin Marietta Astronautics
MS 58700, PO Box 179
Denver, CO 80201
Phone: 303-977-5845
Fax: 303-971-4306
email:ray.j.perez@ast.lmco.com

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OFFICER'S REPORTS

President's Message

If this Newsletter reaches you during the month of October, please be reminded that paper submissions for the 16th Annual Review of Progress in Applied Computational Electromagnetics (a.k.a. ACES 2000) are due November 1! You will find considerable information about the conference elsewhere in this Newsletter, and I certainly hope you will plan to join us in Monterey for the traditional "third week in March" pilgrimage. If you are interested in submitting a paper, but November 1 is now imminent, you probably can obtain a few days grace from Doug Werner with only minimal begging and groveling.

The major annual ACES Board of Directors meeting always takes place at the March conference. Thinking ahead to that meeting, it appears that a review of ACES structure and priorities is in order. Our volunteer labor pool is small, and has been slowly shrinking in recent years. It seems that all working scientists and engineers everywhere are being squeezed more and more for increased productivity. The net effect is more time spent at work, and less time for family, hobbies, and service activities.

At ACES, our bedrock activity has always been the annual conference. On that front, I am pleased to report that we continue to enjoy excellent volunteer teams and adequate peoplepower to keep the conference thriving. I think most ACES members would agree that the conference is our pride-and-joy centerpiece.

After the conference, second priority has gone to ACES Publications – both the ACES Newsletter and ACES Journal. With very small and all-volunteer staffs, both publications have served us well. At this time, we are looking at ways to begin electronic distribution of the Newsletter, and probably ACES will move more in that direction over the next few years. On the Journal side of the coin, more Special Issue topics and volunteer S.I. Guest Editors are needed. The ACES Journal has published some timely and excellent Special Issues over the years, but the pipeline is light now and it is time to prime the pump again. If you have topic suggestions or are interested in serving as Editor (or co-Editor) for a Special Issue, please contact Ahmed Kishk or Allen Glisson.

Next on the priority totem pole would seem to be ACES workshops and short courses. This appears to be where we are running out of volunteer gas. John Brauer was very instrumental in arranging the ACES short courses in Japan which began on October 14, and John deserves our public thanks for his successful efforts. Our attempts to offer short courses on the east coast, specifically on the Penn State University campus, have been less successful. Still, as an educational society, I think we should "endeavor to persevere" and keep trying. This gets us back to the matter of available volunteer time, and the need for someone with a passion for expanding the educational mission of ACES. If your special interests and/or expertise match up with this need, I hope you will contact me.

Finally, as you know, ACES has several standing committees. Tony Brown has suggested that we should review the committee infrastructure, and he has a point. If you have favorable experience with alternative organizations in other societies, we would welcome your insights and suggestions.

If you would like to see a "Town Hall" type meeting at ACES 2000 for the purpose of gathering member sentiment with regard to the ACES organizational structure and priorities going forward, please email me and we will reserve a time slot during the conference.

Submitted with best wishes for good health and prosperity to good ACESians all,

Perry Wheless, ACES President
wwheless@coe.eng.ua.edu

PERMANENT STANDING COMMITTEES OF ACES INC.

COMMITTEE	CHAIRMAN	ADDRESS
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ELECTIONS	Pingjuan Werner	Penn State University 321 Oakley Drive State College, PA 16803
FINANCE	Andrew Peterson	Georgia Institute of Technology School of ECE Atlanta, GA 30332-0250
WAYS & MEANS	Ray Perez	Lockheed Martin Astronautics MS: S8800, PO Box 179 Denver, Colorado 80201
PUBLICATIONS	Perry Wheless	University of Alabama P.O. Box 11134 Tuscaloosa, AL 35486-3008
CONFERENCE	Robert Bevensee	BOMA Enterprises 128 Irongate Court Alamo, CA 94507-0812
AWARDS	John Brauer	Ansoft Corporation 9000 N. Deerbrook Tr., Suite 100 Milwaukee, WI 53223-2465

MEMBERSHIP ACTIVITY COMMITTEES OF ACES INC.

COMMITTEE	CHAIRMAN	ADDRESS
SOFTWARE EXCHANGE	Atef Elsherbeni	Univ of Mississippi Anderson Hall, Box #13 University, MS 38677
SOFTWARE PERFORMANCE STANDARDS	Donald Pflug	Rome Laboratory/ERST 525 Brooks Rd. Griffiss AFB, NY 13441-4505
HISTORICAL	Robert Bevensee	BOMA Enterprises PO Box 812 Alamo, CA 94507-0812

COMMITTEE REPORTS

NOMINATIONS COMMITTEE

In the coming months, ACES members will be asked to vote for three board members. For uniformity, each candidate will be asked to provide a short statement that addresses:

(1) GENERAL BACKGROUND (e.g., professional experience, degrees, employment, etc.).

(2) PAST SERVICE TO ACES (e.g., service on ACES committees, or other contributions).

(3) CANDIDATES' STATEMENTS (e.g., short statement of the candidates views of major issues relevant to ACES). Candidates' statements will be no more than 500 words, unless otherwise directed by the board.

(4) OTHER UNIQUE QUALIFICATIONS (An additional but optional statement).

It is hoped that these areas will provide data on each candidate that might otherwise be obscured in a general, unstructured statement. When the time comes, please take a few minutes to study the candidates' statements and vote.

DIRECTORS-AT-LARGE

Andreas Cangellaris	2000	Bruce Archambeault	2001	Allen W. Glisson	2002
Ray Perez	2000	Anthony Brown	2001	Guiseppe Pelosi	2002
Norio Takahashi	2000	Eric Michielssen	2001	Perry Wheless, Jr.	2002

MODELER'S NOTES

Gerald J. Burke

There are no new bugs in NEC to report, but some comments at the end of this column may be of interest if you get a blank screen when you start up NEC–4. Tom Wallace at Advanced Power Technologies sent some interesting information on the increase in speed in matrix factoring when using the LAPACK routines rather than the standard NEC routines FACTR and SOLVE. His results are consistent with those reported by J. v. Hagen, R. Mittra and D. Werner in their paper "MMSNEC – Multiple Matrix Solver NEC" at the 1999 ACES Conference in Monterey. I have heard from other people over the years suggesting that we should update the matrix solution routines in NEC, and apologize for not crediting them also. Some of Tom's information follows:

From Tom Wallace, Advanced Power Technologies, Inc., 1250 24th St. NW, Suite 850, Washington, DC 20037, email: twallace@apti.com

I have implemented drop-in replacements for FACTR and SOLVE using the LAPACK library (optimized routines), and the updated matrix routines have several advantages:

- Factoring is 3 to 6 times faster for large problems on most PCs and workstations (see examples below). The modifications speed up the factoring and solving operations that dominate the runtime on large problems, but do not affect the fill or I/O times significantly.
- The results are virtually identical to those obtained using the standard NEC routines.
- The LAPACK routines are freely distributed, very well tested and supported by a NSF/DoE funded research group at the University of Tennessee.
- Many manufacturers have optimized LAPACK libraries available for their machines (Intel, for example, has a free library which also supports multiple processors.)
- LAPACK includes the capability to estimate the condition of the matrix being factored and warn the user if it is close to singular (this would also help users choose between single and double precision.)

There is only one disadvantage that I am aware of:

- NGF files computed with the old routines cannot be read in and used by the new routines, but must be recomputed.

As an example of the speed improvements, I've done some comparisons using NEC4D on a problem with increasing numbers of segments (and with no symmetry.) On a single processor 266 MHz Pentium II, using Intel's optimized LAPACK, I get the following total run times (in seconds) for the original and LAPACK versions (the same compiler and optimization settings were used in both cases):

No. segments	Original	LAPACK	Speedup
200	1.00	0.681	1.5x
400	7.41	3.22	2.3x
800	47.2	16.1	2.9x
1600	434.	96.9	4.5x
3200	3330	624.	5.3x

The speed increase with LAPACK is the result of a reorganization of the matrix factorization algorithm, so that it works on small submatrices rather than on individual entries. Although the number of floating-point operations is the same, the "block" algorithms that LAPACK employs are optimized for machines that have a fast cache between the processor and the slower main memory.

Using a dual processor machine speeds up the 3200 segment case by an additional 1.7x, reducing the run time to 370 seconds. In all of these cases, there was no difference at all between the output files (including segment currents) produced by the original and the LAPACK versions, except for the lines showing the fill, factor and total run times. Experiments on other machines, including Sun Ultras, show similar improvements.

Tom said that he would be happy to donate the interface that he has written between NEC and LAPACK (about 75 lines), and the necessary LAPACK routines are freely available. He also sent the LAPACK source code and NEC interface using the routine ZGETRF and also computing the condition number. I tried this on an old DEC Alpha running VMS, and the factor time for 1200 segments was 199.18 s with the standard NEC routines and 94.18 s with the LAPACK routines. On a SGI R-12000 (300 MHz, 3 processors) the factor time was 27.851 s with the standard routines and 16.01 s with LAPACK. The minimum set of LAPACK code that Tom sent to do the LU decomposition and compute the condition number was 6114 lines. So it adds a bit to the bulk of the code, but is worthwhile for doing large problems.

I have not been able to test the Intel optimized routines on my old (2 years?) Pentium MMX. Intel includes libraries labeled default, P-II and P-III for DEC Visual Fortran. I tried the default library, but it crashed with "illegal instruction." Guess Intel would like us all to go out and buy new P-III systems.

There are no new bugs to report in NEC. However, the codes that we send out for Windows, compiled with DEC/Compaq Visual Fortran Version 5 (DVF), seem to suffer from a compiler bug that causes the writes to the screen, write(*,...), to not appear on some Windows NT systems. We first encountered this at the NEC workshop at last year's ACES Conference. A whole room full of Windows NT systems showed no output on the screen. However, the codes worked correctly on a laptop running Windows NT. I recently talked to someone who had this problem with the NEC-4 codes that we sent. He had DVF version 6 installed, so that seems to rule out some DVF library that we need to send with the NEC code. He said that when he recompiled the code the writes to the screen worked OK, so apparently the problem has been fixed in version 6.

With that information, I shelled out the money to buy DVF version 6 for my home PC and updated it with the latest set of patches. However, it seems to have a new problem. When I type input on the screen and then use the delete key to correct it the right half of each character deleted is left on the screen. This is usable, since it really does delete the input, but it leaves a mess on the screen that is not good when you try to type the new input. I reported this problem to Compaq Support, and got a response "Thank you very much for pointing out this problem..." and included a "workaround". I did not check the archives to see if had been reported before, but it is hard to see how it could slip by testing unless it occurs only on a limited number of systems. I compile codes as "Standard Graphics Application" so that the file dialog box can be used, so maybe the problem is confined to that mode.

The "workaround" had a read statement to demonstrate the problem, then opened a new maximum sized window and had more read statements to demonstrate that the problem was fixed. However, when the initial read to demonstrate the problem was deleted, the workaround did not work, so I am waiting for more advice from Compaq Support. Until then, I will continue to send out the codes compiled with version 5. I have not compared the execution speeds of the version 5 and 6 codes, but version 6 seems to take longer to compile than version 5 did, so maybe it is working harder.

If anyone can contribute modeling-related material for future newsletters, they are encouraged to contact our editor Ray Perez or Jerry Burke, Lawrence Livermore National Lab., P.O. Box 808, L-154, Livermore, CA 94550, phone: 925-422-8414, FAX: 925-423-3144, e-mail: burke2@llnl.gov.

TECHNICAL FEATURES ARTICLE

A Brief Summary of Thick-Layer Surface Impedance Boundary Condition Implementations for FDTD

by

John H. Beggs
NASA/GSFC
Microwave Systems Branch
Code 567
Greenbelt, MD 20771

Abstract

This paper briefly summarizes the basic theory and implementations of various forms of the thick-layer surface impedance boundary condition (SIBC) for the Finite-Difference Time-Domain (FDTD) method. For each implementation, a summary of the basic theory is given along with a brief discussion of the numerical results presented in the original referenced papers. The methods are compared with respect to computational requirements and range of applicability. The overall goal of this paper is to provide a quick reference guide to those individuals that may need to implement a thick-layer SIBC for the FDTD method. A previously published companion paper summarized thin-layer SIBC implementations for FDTD [1].

1 Introduction

The surface impedance boundary condition (SIBC) is a frequency-domain concept that was first used by Leontovich during the 1940's [2]-[3] in analyzing propagation over the earth by attempting to account for the properties of real ground materials by specifying an impedance boundary condition at the surface of the earth. Since that time, the SIBC has been used to formulate frequency-domain integral equations for a wide variety of scattering and propagation problems [4]–[19].

The computation of scattered fields from an imperfectly conducting body requires a discretization of the entire volume of the body. If the complex refractive index of the body is large, this can result in an excessive amount of memory required and can render a problem intractable given a fixed amount of computational resources. The SIBC is an approximate boundary condition which relates the tangential electric and magnetic fields at the surface of the body. This results only in a discretization of the surface of the body and the exterior region; thereby eliminating computation of fields inside the body. Thus a larger grid size can be used in the exterior region of the body which reduces the amount of computational resources required for a given problem. This type of simplification is ideal for a memory and CPU intensive method such as the Finite-Difference Time-Domain (FDTD) method. However, the FDTD method is a time-domain method, and the surface impedance boundary condition was originally developed as a frequency domain concept.

Tesche [20] recently reformulated the frequency-domain SIBC in terms of a time-domain integral equation involving a convolution integral between a time-domain impedance function and the tangential magnetic field at the surface of the body. In that paper, Tesche pointed out that the computation of the convolution integral was not practical due to the large storage requirements and computation time. Many different researchers have overcome this difficulty in developing implementations of the thick-layer SIBC for the FDTD method [21]–[24]. Each implementation has certain advantages and disadvantages but all strive to obtain the most efficient and accurate method. In this paper, the theory for several different dispersive and non-dispersive thick-layer FDTD surface impedance boundary conditions is reviewed, and since they cover several application areas, a rigorous quantitative comparison is beyond the scope of this paper. Instead, this paper provides a more tutorial-like discussion and a qualitative comparison on such topics as the basic theory of each implementation, the intended application area and any difficulties or special circumstances. The example problems from each original FDTD SIBC paper are discussed, but no additional results are presented. The interested reader is referred to each original paper for the relevant numerical results. Many of the referenced papers have reproduced results from earlier SIBC papers, which provides for a good comparison. The goal of this paper is to provide a quick reference guide to those individuals that may have a need to implement a thick-layer SIBC for the FDTD method.

Section 2 provides the basic theory of the SIBC along with the basic tenets of each thick-layer FDTD SIBC implementation and a brief discussion of the computational requirements of some of the methods. Section 3 discusses some of the general applicability issues of the SIBC and Section 4 provides concluding remarks.

2 Theory and Implementations

The first order (or Leontovich) impedance boundary condition relates tangential total field components and is given in the frequency domain as [5]

$$\vec{E}(\omega) - \hat{n}\left[\hat{n}\cdot\vec{E}(\omega)\right] = Z_s(\omega)\left[\hat{n}\times\vec{H}(\omega)\right] \quad (1)$$

where ω is the radian frequency, $\hat{n}$ is the unit outward normal from the surface and $Z_s(\omega)$ is the frequency-domain surface impedance of the material. An $e^{j\omega t}$ time dependence is assumed and suppressed. This frequency-domain SIBC is for a planar material interface and does not account for surface curvature of an object. Since all FDTD formulations use the planar SIBC, they are limited to those geometries where the smallest radius of curvature is relatively large compared to the wavelength. The frequency-domain surface impedance is given by

$$Z_s(\omega) = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}} \quad (2)$$

This can be rewritten using the complex frequency variable $s = j\omega$ as

$$Z_s(s) = Z_i\sqrt{\frac{s}{s+a}} \quad (3)$$

where $a = \sigma/\epsilon$ and Z_i is the intrinsic wave impedance of the material given by $Z_i = \sqrt{\mu/\epsilon}$. The time-domain surface impedance boundary condition is obtained by applying the Convolution Theorem to (1) which gives

$$\vec{E}_{tan}(t) = Z_s(t) \otimes \left[\hat{n}\times\vec{h}(t)\right] \quad (4)$$

where the $\otimes$ is the convolution operator. Each FDTD implementation deals with obtaining the time-domain surface impedance impulse response, $Z_s(t)$, or some approximation thereof to obtain an accurate and efficient SIBC implementation. The thick-layer SIBCs can be divided into nondispersive and dispersive implementations. The nondispersive implementations treat the frequency domain surface impedance as a constant which is evaluated at a specific frequency. The dispersive implementations are more general as they preserve the continuous frequency variation of the surface impedance. In the following sections, each of the thick-layer FDTD SIBC implementations will be briefly described and reviewed.

2.1 Nondispersive

Kashiwa *et al.*

Kashiwa *et al.* [25] presented a FDTD SIBC formulation that represented the frequency-domain surface impedance function of (2) either as a parallel or series RLC circuit connected to ground. For a one-dimensional FDTD grid with field components E_x and H_y and impedance boundary located at cell k, the FDTD update equations were then derived for the parallel and series case as

$$E_x^{n+1}(k) = \frac{1}{\alpha}\left\{2\left(\alpha - \frac{\Delta t\mu}{2L}\right)E_x^n(k) - \left(\alpha - \frac{\mu}{R}\right)E_x^{n-1}(k) + \frac{\Delta t}{\Delta z}E_x^n(k-1)\right\} \quad (5)$$

for the parallel case and

$$E_x^{n+1}(k) = \frac{1}{\beta_2}\left\{\gamma_1 E_x^n(k) + \gamma_2 E_x^{n-1}(k) + \gamma_3 E_{xC}^n(k) + \gamma_4 E_{xC}^{n-1}(k) + \gamma_5 E_{xL}^n(k) + \gamma_6 E_x^n(k-1)\right\} \quad (6)$$

for the series case. The α, β_2 and $\gamma_1 \rightarrow \gamma_6$ terms are all constants that depend on the cell size, time step, material properties and equivalent R, L and C values. The terms E_{xc} and E_{xL} are additional electric field terms and they are defined by equations (13) and (15) of [25]. An example problem was used to calculate reflections from an impedance wall for both the parallel and series cases and the results agreed very well with measurements. However, this approach has limited applicability because it is a non-dispersive method and treats the dispersive surface impedance at only one frequency. Consequently, it is similar in principle to Yee's SIBC method [26], but instead represents the surface impedance as a series or parallel RLC transient circuit, rather than as a capacitive or inductive impedance as in Yee's method (described in the following section).

Yee *et al.*

Yee's FDTD SIBC implementation [26] treats the frequency-domain surface impedance function of (2) as a constant by evaluating it at a specified frequency ω_0. The algorithm used depends upon the surface impedance being inductive or capacitive. For the inductive case, the frequency-domain surface impedance is expressed as

$$Z_s = R + j\omega L \tag{7}$$

where $R = Re\{Z_s(\omega_0)\}$ and $L = Im\{Z_s(\omega_0)\}/\omega_0$. Substituting (7) into (1) and taking the inverse Fourier transform gives a time-domain SIBC of the form

$$\vec{E}_{tan}(t) = \hat{n} \times \left[R\,\vec{H}(t) + L\,\frac{\partial \vec{H}(t)}{\partial t} \right] \tag{8}$$

This equation is then discretized according to the FDTD algorithm and is used to advance the magnetic fields for bordering faces at the surface of the object. The electric fields for exterior edges on the object surface are then updated with the regular FDTD algorithm. For the capacitive case, the frequency-domain surface admittance is used and is given by

$$Y_s = \frac{1}{Z_s} = G + j\omega B \tag{9}$$

where $G = Re\{Y_s(\omega_0)\}$ and $B = Im\{Y_s(\omega_0)\}/\omega_0$. Substituting (9) into (1) and taking the inverse Fourier transform gives a time-domain SIBC of the form

$$G\,\vec{E}_{tan}(t) + B\,\frac{\partial \vec{E}_{tan}(t)}{\partial t} = \hat{n} \times \vec{H}(t) \tag{10}$$

The magnetic fields on exterior faces and boundary faces are first updated with the regular FDTD algorithm, then a discretized version of (10) is used to advance the electric fields for exterior edges on the object surface. Results were presented for Radar Cross Section (RCS) calculations from an ellipsoid with both inductive and capacitive surface impedances and they agreed well with Method of Moments (MoM) calculations. Although these approaches are very straightforward and intuitive, they are non-dispersive implementations and are therefore strictly valid at one frequency. Due to the non-dispersive nature of these SIBC methods, the additional computational cost is almost nothing over a standard FDTD code. However, to obtain a more accurate and general SIBC implementation, a dispersive approach needs to be considered. The following SIBC implementations are all dispersive methods.

2.2 Dispersive

Riley and Turner

Riley and Turner's FDTD SIBC implementation [27] begins with a high conductivity approximation for the frequency-domain of

$$\sigma/\omega\epsilon \gg 1 \tag{11}$$

Substituting this in (2) gives

$$Z_s(\omega) = \sqrt{\frac{j\omega\mu}{\sigma}} \tag{12}$$

where ϵ, μ and σ are the permittivity, permeability and conductivity, respectively, of the lossy dielectric material. Using (12), the time-domain SIBC of (4) can be rewritten in the form

$$\vec{E}_{tan}(t) = Z_s'(t) \otimes \left[\hat{n} \times \frac{\partial \vec{H}(t)}{\partial t} \right] \tag{13}$$

where

$$Z_s'(t) = \sqrt{\frac{\mu}{\pi\sigma t}}, \quad t > 0 \tag{14}$$

The final FDTD update equation for the SIBC involves a discretized version of the convolution in (13). This involves storing a complete time history of the magnetic field adjacent to the impedance boundary. However, since Riley and Turner's SIBC was implemented to include wall loss in thin-slot algorithms, the full discrete convolution sum usually only applied to very few magnetic field components. As a result, any overhead penalty associated with evaluating the full convolution was not particularly severe. The example problem showed electromagnetic coupling into a cavity having a thin slot with lossy walls and with a 50 Ω terminated wire inside. Excellent results were shown for slot electric field and wire current using various slot widths and wall losses. This paper illustrated the first successful application of an impedance boundary condition in a thin-slot FDTD algorithm.

Maloney and Smith

Maloney and Smith's SIBC [28] involves obtaining the time-domain surface impedance impulse response directly from (3) as

$$Z_s(t) = \frac{\eta_0}{\sqrt{\epsilon_r}} \left\{ a e^{at} \left[I_1(at) + I_0(at) \right] u(t) + \delta(t) \right\} \tag{15}$$

where $a = -\sigma/2\epsilon$, σ is the conductivity and ϵ_r is the relative permittivity for the lossy material and η_0 is the free space wave impedance. In this case, I_0 and I_1 are the modified Bessel functions of the first kind of order 0 and 1, respectively, $u(t)$ is the unit step function and $\delta(t)$ is the unit impulse function. The surface impedance impulse response of (15) exhibits the behavior of a decaying exponential, which permits the convolution integral in (4) to be approximated by a weighted summation of decaying exponentials with different characteristic time constants. This approximation is given by

$$Z_s(t) \otimes \left[\hat{n} \times \vec{h}(t)\right] \approx \sum_{j=1}^{N_x} a_j \, e^{b_j t} \quad (16)$$

and it allows the time-domain SIBC to be updated recursively and efficiently, thereby avoiding storage of the complete time history of tangential magnetic fields at the surface of the body. Prony's method [29] was used to obtain the weights and characteristic time constants for each exponential term and the final FDTD update equation for this time-domain SIBC is

$$\vec{E}_{tan}(N) = \frac{\eta_0}{\sqrt{\epsilon_r}} \left\{ \left[\hat{n} \times \vec{H}(N)\right] + \sum_{K=1}^{Q} \vec{G}_K(N) \right\} \quad (17)$$

where N is the FDTD time step index, Q is the total number of terms in the exponential approximation and $\vec{G}_K(N)$ is the recursive updating variable given by

$$\vec{G}_K(N) = C_K \left[\hat{n} \times \vec{H}(N)\right] + \mu_K \vec{G}_K(N-1) \quad (18)$$

The terms C_K and μ_K are constants obtained during the Prony approximation process. Examples presented in the paper [28] were reflection from a lossy dielectric half-space, a line current over a lossy dielectric half-space, and a two-dimensional example showing normalized attenuation and phase constants for a lossy parallel-plate waveguide. The results for these examples were in excellent agreement with analytical calculations. This SIBC implementation is the best approach for practical applications as it provides a surface impedance that is independent of incidence angle and it accounts for the displacement current whereas the high conductivity approximations do not. The surface impedance impulse response of (15) is dependent upon the conductivity, which means the Prony approximation must be recalculated when the conductivity is changed. However, this approximation can be done as part of the FDTD preprocessing and the overall time compared to total solution time is minimal. One must also be careful in evaluating the modified Bessel functions of the first kind, I_0 and I_1, in (15) for large arguments as they become unbounded. For Q terms in the exponential approximation, this method requires Q real variables for storage of the recursive updating variable and it requires $2Q$ adds and $2Q+1$ multiplies to update the SIBC. These values are specified on a per-cell, per-dimension basis.

Kellali *et al.*

The FDTD SIBC approach proposed by Kellali *et al.* [30] is a general method similar to Maloney and Smith's [28], but it accounts for the incidence angle in the formulation. In this paper [30], the time-domain SIBC of (4) is rewritten in the form

$$\vec{E}_{tan}(t) = Z_s(t) \otimes \vec{J}_s(t) \quad (19)$$

where $\vec{J}_s(t)$ is the surface current density. Since this SIBC approach accounts for the incidence angle, the time-domain surface impedance impulse response will have two cases because the wave impedance differs for horizontal or vertical polarization. For vertical polarization and incidence angle θ, the time-domain impulse response is

$$\begin{aligned} Z_{sv}(t) = Z_{v0}\delta(t) + Z_{v0} \Bigg[\frac{B'}{2} \left(I_1\left(\frac{B't}{2}\right) - \right. & \\ \left. I_0\left(\frac{B't}{2}\right)\right) e^{-B't/2} + (B' - B) \Bigg[e^{-Bt} + & \\ \frac{B'}{2} \int_0^t e^{-B(t-\tau)} \left(I_1\left(\frac{B'\tau}{2}\right) - \right. & \quad (20) \\ \left. I_0\left(\frac{B'\tau}{2}\right)\right) e^{-B'\tau/2} d\tau \Bigg]\Bigg] & \end{aligned}$$

where

$$Z_{v0} = \left(\frac{\eta_0}{\epsilon_r}\right) \left(\epsilon_r \mu_r - \sin^2\theta\right)^{1/2} \quad (21)$$

$$B = \frac{\sigma}{\epsilon_r \epsilon_0} \quad (22)$$

$$B' = \frac{\sigma \mu_r}{\epsilon_0 \left(\epsilon_r \mu_r - \sin^2\theta\right)} \quad (23)$$

and η_0 is the free space wave impedance. For horizontal polarization and the same incidence angle θ, the time-domain impulse response is

$$\begin{aligned} Z_{sh}(t) = Z_{h0} \Bigg[\delta(t) + \frac{B'}{2} e^{-B't/2} \Bigg[I_1\left(\frac{B't}{2}\right) - & \\ I_0\left(\frac{B't}{2}\right) \Bigg]\Bigg] & \quad (24) \end{aligned}$$

where

$$Z_{h0} = \eta_0 \mu_r \left(\epsilon_r \mu_r - \sin^2\theta\right)^{-1/2} \quad (25)$$

$$B' = \frac{\sigma \mu_r}{\epsilon_0 \left(\epsilon_r \mu_r - \sin^2\theta\right)} \quad (26)$$

The time-domain surface impedance impulse responses in (20) and (24) are approximated by a weighted sum of decaying exponentials as

$$Z_s(t) \approx \sum_{j=1}^{N_x} a_j \, e^{b_j t} \quad (27)$$

and this approximation was obtained again using Prony's method [29]. The discrete version of the time-domain

SIBC in (19) is given by

$$\vec{E} = \sum_{m=0}^{n-1} Z_s(m)\, \vec{J}_s(n-m) = \sum_{j=1}^{N_x} \vec{F}_j(n) \quad (28)$$

where n is the FDTD time step index, N_x is the number of terms in the approximation of (27) and $\vec{F}_j(n)$ is the recursive updating variable given by

$$\vec{F}_j(n) = a_j\, \vec{J}_s(n) + B_j\, \vec{F}_j(n-1) \quad (29)$$

and $B_j = e^{b_j \Delta T}$. For N_x terms in the exponential approximation, this method requires N_x variables for storage, $2N_x$ multiplies and $2N_x - 1$ adds to update the SIBC. Again, all values are on a per-cell, per-dimension basis. Example problems in this paper were a infinitely long wire over ground (two-dimensional) and a dipole antenna over ground (three-dimensional). All results agreed very well with analytical or conventional FDTD solutions. This approach requires recomputing the surface impedance impulse response and the corresponding exponential approximation for each incidence angle. For problems involving complex bodies with many different incidence angles, it is more efficient to use a formulation which is independent of the incidence angle such as Maloney and Smith's [28]. For most practical problems where an SIBC is applicable, this is a valid approach, since either the permittivity or conductivity will be large; which means the wave impedance will be approximately equal for both polarizations and independent of incidence angle. For those problems of low permittivity or conductivity, it may be more efficient to simply grid the volume of the object and apply conventional FDTD over the entire volume rather than apply an angle-dependent SIBC. However, the overhead trade-offs associated with this SIBC are currently unknown.

Beggs *et al.*

The FDTD SIBC implementation proposed by Beggs *et al.* [31] begins with the same high conductivity approximation for the surface impedance used by Riley and Turner (equation (12)). The modified time-domain surface impedance impulse response presented in (14) also exhibits a decaying behavior. The difference between this SIBC implementation and Riley and Turner's is that the impulse response (equation (14)) was approximated by a series of weighted exponentials with different characteristic time constants. Prony's method [29] was again used to obtain the weights and time constants and the final recursive FDTD update equation is given by

$$H_y^{n+1/2}(k+1/2) = H_y^{n-1/2}(k+1/2) - \frac{Z_1}{1+Z_1 Z_0(0)} \sum_{i=1}^{Q} \psi_i^n(k+1/2) + \frac{\Delta t}{\mu_0 \Delta z\,(1+Z_1 Z_0(0))} E_x^n(k) \quad (30)$$

for a one-dimensional FDTD grid with impedance boundary at cell $k+1$ and field components H_y and E_x. The recursive updating variable is updated with the equation

$$\psi_i^n(k+1/2) = \Big(H_y^{n-1/2}(k+1/2) - H_y^{n-3/2}(k+1/2)\Big)\, a_i e^{\alpha_i} + e^{\alpha_i} \psi_i^{n-1}(k+1/2) \quad (31)$$

where

$$Z_1 = \frac{1}{\mu_0 \Delta z} \sqrt{\frac{\mu \Delta t}{\pi \sigma}} \quad (32)$$

$$Z_0 = \sum_{i=1}^{Q} a_i \quad (33)$$

are constants and a_i and α_i are terms that result from the exponential Prony approximation of the SIBC impulse response. For Q terms in this exponential approximation, this method requires Q storage locations and $2Q+2$ multiplies and adds to update the magnetic field adjacent to the impedance boundary. Examples presented in this paper were reflection from a lossy dielectric half-space and a two-dimensional problem of scattering from a square cylinder for the TM polarization. The results for these examples were in good agreement with analytical and conventional FDTD calculations. However, this approach is limited to those geometries which are highly conducting (i.e. $\sigma/\omega\epsilon \gg 1$). Also note that a non-dispersive implementation similar to Yee's was presented in [31]. Extensive two- and three-dimensional results based upon this SIBC were presented in [32].

Oh *et al.*

Oh and Schutte-Aine proposed an efficient and recursive FDTD SIBC implementation in a recent paper [33]. In this approach, the frequency-domain surface impedance of (3) is rewritten as a normalized impedance function given by

$$Z_n(s') = \frac{Z_s(s')}{Z_i} = \sqrt{\frac{s'}{s'+1}} \quad (34)$$

where $s' = s/a$. This normalized surface impedance function is approximated in the frequency domain by a series of first order rational functions of the form

$$Z_n(s') \approx 1 - \sum_{l=1}^{L} \frac{C_l}{s'+\omega_l} \quad (35)$$

This approximation is over the real axis interval $s' = [0, 3]$, which will accommodate most materials up to several tens of Gigahertz. The residues C_l and poles ω_l are given for sixth, seventh and eighth order approximations in [33]. The final FDTD update equation is given by

$$\vec{E}_{tan}(n\Delta t) = Z_i \left[\hat{n} \times \vec{H}(n\Delta t)\right] - \sum_{i=1}^{L} \vec{A}_i(n\Delta t) \quad (36)$$

where n is the FDTD time step index, Δt is the time step, L is the number of terms in the approximation and $\vec{A}_i$ is the recursive updating variable given by

$$\vec{A}_i(n\Delta t) = p_{i1}\left[\hat{n} \times \vec{H}(n\Delta t)\right] + \quad (37)$$
$$p_{i2}\left[\hat{n} \times \vec{H}((n-1)\Delta t)\right] + p_{i3}\vec{A}_i((n-1)\Delta t)$$

The terms p_{i1}, p_{i2} and p_{i3} are given by equations (8c)-(8e) in [33] and are constants that can be precomputed and stored for use in (37). These coefficients were obtained by a direct evaluation of the convolution integral of the time-domain, surface impedance impulse response with the tangential magnetic field. For L terms in the exponential approximation, $L+1$ storage locations are required, $3L$ adds and $3L+1$ multiplies are required to update the SIBC. All values are on a per-cell, per-dimension basis. Example problems for this FDTD SIBC implementation included reflection from a lossy dielectric half-space, reflection from a thin lossy dielectric layer backed by a perfect conductor, and a two-dimensional problem of scattering from a square cylinder for the TM polarization. The numerical results agreed well with analytical solutions and with conventional FDTD calculations for the square cylinder problem. This approach was reformulated using Z-transforms in a recent paper [34].

3 Applicability of the SIBC in general

For electrically thick objects and for transient applications, the SIBC methods of choice are those proposed by Maloney and Smith [28], Kellali *et al.* [30] and Oh *et al.* [33]. All of these methods employ an efficient updating scheme using recursion and they each will work both for high conductivity and for low-loss, large permittivity materials. It was demonstrated in the previous section that these three methods have very similar computational requirements. Kellali *et al.*'s method can be used in situations where the wave impedance is highly dependent on the incidence angle; whereas the other two methods can be used in all other situations. The non-dispersive methods offer a simpler alternative for time-harmonic applications and the thin-layer methods are very similar in computational requirements and implementation. So, most of the methods surveyed in this paper can be used in many different practical problems.

When applying a surface impedance boundary condition in either the frequency domain or time domain, two questions always remain: "When should the SIBC be applied" and "What is the accuracy of the SIBC?" Knowing when to apply the SIBC is a very subjective judgment on the part of the user. According to [28] and [31], as the conductivity of the lossy material increases, so does the potential for computational savings. At some point, however, the SIBC is no longer necessary because applying a perfectly conducting boundary condition would provide acceptable results. Therefore, the SIBC should be applied in situations where the complex index of refraction, $N = \sqrt{\tilde{\epsilon}_r}$, is large, but the response of the material differs significantly from that of a perfect conductor.

Several authors have investigated the accuracy of the impedance boundary condition as applied to scattering problems. Alexopoulos and Tadler [12] investigated the accuracy of the impedance boundary condition as applied to scattering from small cylinders ($ka \leq 1$) as a function of the radius of curvature and material parameters. They found for an H polarized (TE) incident plane wave, the envelope of maximum error was about three times greater for a cylinder with $ka = 0.63$ than for a cylinder with $ka = 1.0$. Therefore, the error for plane wave scattering from cylinders is sensitive to the radius of curvature. However, many values of refractive index, both large and small, provided very accurate results. They also concluded when using a magnetic line source illumination, less attention has to be paid to the value of the refractive index and curvature for a line source close to the surface than for the plane wave excitation. Wang [16] investigated the accuracy of the impedance boundary condition when applied to cylindrical and spherical surfaces. He concluded that a minimum requirement for the imaginary part of the complex index of refraction is

$$\Im(N) \geq \frac{2.3}{k_0 a_{min}} \quad (38)$$

where $\Im$ denotes the imaginary part and a_{min} is the minimum radius of curvature of the object. White and Mittra [19] studied the impedance boundary condition applied to scattering from loaded troughs and found that surface impedance results agreed well with Surface Integral Equation (SIE) results if the depth of the trough was greater than or equal to the skin depth of the loading material. This means that the general SIBCs surveyed in this paper are applicable if the thickness of the material is much greater than the skin depth. For thin layers where the material thickness is less than the skin depth, thin-layer SIBC methods can be applied. White and Mittra [19] also found for dielectrics with lower loss, the agreement was worse since the skin depth was larger. Thus, some general guidelines exist for application of the surface impedance boundary condition.

In terms of accuracy, it is extremely difficult to characterize the overall effect of the different SIBC implementations. For example, the Prony approximation of the time-domain surface impedance impulse response introduces one error source, but the one-half cell spacing between the E and H fields tangent to the surface introduces yet another error source. The error associated with the Prony approximation can be quantified individually, but it is difficult to gauge the effect of these error sources in the final accuracy for any given problem. This is due to the presence of other error sources inherent in the FDTD method such as the dispersion, stair-casing and reflections from the terminating boundaries. But it has been demonstrated qualitatively in several FDTD SIBC implementations that a better time-domain Prony approximation or a frequency-domain impedance approximation results in a more accurate solution.

Overall, the dispersive FDTD SIBC implementations are superior for transient applications, while the non-dispersive FDTD SIBC methods are acceptable alternatives for time-harmonic applications. One major drawback with the high conductivity SIBC approaches presented in [27] and [31] is that they will not work for materials having low loss and a large permittivity. The complex index of refraction, N, is still large, but these methods were based upon the material being a good conductor. For low loss and high permittivity materials, the methods presented in [28] or [30] are more applicable. Another potential drawback of all FDTD SIBC implementations is they can not be applied directly to objects that may have a gradient in conductivity. In theory, a SIBC could be applied in that situation, but a frequency-domain surface impedance function similar to (2) would have to be developed to account for the stratification of the media. The corresponding FDTD implementation would be obtained by application of the various techniques presented in the different SIBC methods surveyed in this paper.

4 Conclusion

This paper has briefly summarized several thick-layer surface impedance boundary conditions for the FDTD method. These SIBC approaches generally fall into two categories: dispersive and non-dispersive. The dispersive implementations work over a broad frequency range and are usually implemented in FDTD for recursive updating of the SIBC. The non-dispersive approaches are most accurate for a single frequency and the update equations are generally very straightforward. The SIBC methods were also compared in terms of computational requirements and it was found that most methods are very similar in this regard.

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National Airspace System Architecture and CEM Contributions

Ray Perez
Editor, ACES Newsletter

The Air Traffic Management System (ATMS) in US is designed to provide an efficient control of the airplane traffic through out the US. Most of this traffic is contributed by commercial airlines but also includes private and corporate aircraft using the same airspace and the same Federal Aviation Administration (FAA) air traffic management structure. You can simplistically consider the air traffic system as "highways in the skies" . The air traffic in the US is the most congested in the world. Several other countries are also experiencing these growing pains but the US is by far the most troublesome in terms of potential future difficulties for ATMS. It is expected that air traffic in the US alone will double from present levels by the year 2020 and this will bring the present ATMS to the brink or collapse.

The trouble with the present ATMS is that it was designed in the early days of commercial aviation and has not received any significant improvement since then. Presently, the air traffic is through pre-established routes along highly congested air corridors (or air highways). For example, a flight from Los Angeles to New York will follow only an established route that will take the aircraft from Los Angeles—to—Las Vegas—to—Denver—to—Kansas City—to—Saint Louis—to—Pittsburgh—to—Philadelphia—to—New York. Some variations of this route may be available depending on the weather and traffic conditions at a given airport. The flow of traffic is through Air Traffic control (ATC) towers and Terminal Radar Approach Control (TRACON) stations for each terminal city in the route and through Air Route Traffic Control Centers (ARTCC) for en route trajectories. This type of ATMS is susceptible to several types of failures which can be highly disruptive: a) any failed ATC, TRACON or ARTCC facility (electrical, mechanical, human induced failures) can seriously disable the routes going through that single point failure point, b) weather induced failures or weather induced difficulties at any ATC, TRACON, or ARTCC facility can likewise cause air traffic disruptions. c) already highly congested air corridors can become even more of a problem in the future as air traffic increases in capacity. The consequences of any of these disruptions translate immediately into flight delays, cancel flights,and re-routing of destinations, all of which are highly undesirables for the traveling passengers.

The long term solution for the foreseeing difficulties of the present ATMS is the introduction by the FAA of the "free flight" concept to be fully implemented by 2020. In the free flight concept ATMS will be implemented using technologies, procedures, and concepts intended to meet the needs and replace all together the present system. Rather than pre-established routes of flights, the aircraft and its crew will be able to choose the most effective route for its destination based on a series of data inputs gathered from a number of sources. The new ATMS will manage these inputs and the selected routes chosen and will keep track of each outcome. The ATMS will be modernized incrementally. New systems will replace older ones, and new capabilities derived from advanced technologies and/or procedures will be added. The new capabilities will be a result of integrating new systems, air space changes, procedures, training, avionics, and rulemaking. The evolution is described as follows with possible contributions of CEM to ATMS briefly described also.

Navigation, Landing, and Lighting Systems. The ground based navigation infrastructure will transition to a satellite based system that uses the Global Positioning System (GPS) augmented by the Wide Area Augmentation System (WAAS) and the Local Area Augmentation System (LAAS).The WAAS and the LAAS systems are also wireless/satellite based systems in development for traffic management. This satellite-based navigation and landing architecture will provide the basis for ATMS wide direct routing and guidance signals for precision approaches to most runway ends, and it will reduce the variety of navigational avionics required aboard aircraft. Some ground based navigational systems may be retained to back up satellite based navigational operations along principal air routes and at high capacity airports.

Contributions that CEM could make to ATMS in this arena are: a) adaptive and smart antenna design (for aircraft mainly), b) wireless signal propagation models, including attenuation, fading, and multipath, c) interference modeling and mitigation of crosstalk.

Surveillance. The ATMS architecture calls for evolution from current primary and secondary radar systems to digital radar and automatic dependent surveillance (ADS). This change is designed to improve and extend surveillance coverage and provide the necessary flexibility for free flight. After data from weather radar become available on the new en route controller displays (i.e DSR), primary radar will be phased out of en route airspace.

A new radar for approach control services (the ASR-11) will include weather-detection capability. The weather capability of the ASR-9 radar will be improved with the addition of the weather system processor (WSP). Primary radar will also be installed at more airports for airport surface surveillance. Secondary surveillance radar (SSR) with selective interrogation (SI) capability will be used in both en route and terminal airspace.

Contribution that CEM could make to ATMS in this arena are: a) radar cross section (RCS), b) doppler design, c) antenna design, and d) atmospheric propagation models.

Communications. The FAA will transition from analog voice and commercial service provider data link communications to an integrated digital communications capability. Data link communications in Phase 1 will evolve as new applications are tested. Implementation of data links will reduce voice channel congestion and increase the capacity of each very high frequency (VHF) frequency. During Phase 2, the FAA will begin replacing its analog air-ground radio infrastructure with digital radios (next generation air ground communication system (NEXCOM). The capability of NEXCOM radios to provide digital voice and data communications will be implemented gradually during Phases 2 and 3. Ground-ground operational and administrative communications systems will be combined into an integrated, ground digital telecommunication system.

Contribution that CEM could make to ATMS in this arena are: a) electromagnetic interference, b) crosstalk.

Avionics. Aircraft are expected to gradually transition to avionics that use satellite technology (GPS WAAS/LAAS) for navigation , landing, and reporting position information to other aircraft (ADS-B) and surveillance systems. The GPS WAAS/LAAS receivers will enable pilots to navigate via direct routes and to fly precision instrument approaches to virtually any runway. Aircraft radios will also be replaced for compatibility infrastructure. New, multifunctional cockpit displays will show the position of nearby ADS-B equipped aircraft, provide moving map displays, and present data-linked information, such as graphical weather and notices to airmen. Lengthy transition periods are designed into the architecture schedules of all ATMS users.

Contribution that CEM could make to ATMS in this arena are: a) antenna design, b) wireless signal propagation models, including attenuation, fading, and multipath, c) signal integrity, d) interference.

Oceanic and Offshore. During Phase 1, manual aircraft tracking that currently relies upon verbal pilot position reports will transition to satellite based position reports receive via data link. Communications between oceanic controllers and pilots will also be through satellite data link. During Phase 2, the oceanic infrastructure will be upgraded to use automatic data linked position reports for automated aircraft tracking. In Phase 3, as the oceanic communications, surveillance, and automation capabilities for air traffic management improve, separation between properly equipped aircraft will continue to be reduced.

Contribution that CEM could make to ATMS in this arena are: a) antenna design, b) wireless signal propagation models, including attenuation, fading, and multipath, c) signal integrity, d) interference.

Terminal. A combination of ground automation and airborne systems will allow flexible departure and arrival routes and reduce or eliminate speed and altitude restrictions. During Phases 1 and 2, the existing terminal automation system will be replaced with the STARS. During Phase 2, the terminal automation infrastructure will evolve to incorporate new air traffic control functions such as ADS and weather information from the Integrated Terminal Weather System (ITWS). During Phase 3, the hardware and software will be improved to accommodate advance controller tools such as conformance monitoring, conflict detection, and enhanced arrival/departure sequencing. These tools will enable controllers to maintain clear weather aircraft-acceptance rates at airports during inclement weather conditions.

Contribution that CEM could make to ATMS in this arena are : concurrent engineering methods

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AN	ACES Newsletter
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*	Pre- or postprocessor for another computational electromagnetics code
**	Administrative reference only: no technical discussion (This designation and the index do not include bibliographic references)
Page No.	The first page of each paper in which the indicated code or technique is discussed

Special Issue Topics:

AJ No. 2 – Special Issue on Computational Electromagnetics and High-Performance Computing

NOTE: the inclusion of any computer code in this index does not guarantee that the code is available to the general ACES membership. Where the authors do not give their code a specific name, the computational method used is cited in the index. The codes in this index may not all be general-purpose codes with extensive user-oriented features – some may only be suitable for specific applications. While every effort has been made to be as accurate and comprehensive as possible, it is perhaps inevitable that there will be errors and/or omissions. We apologize in advance for any inconvenience or embarrassment caused by these.

Allen W. Glisson and Ahmed A. Kishk, Editors-in-Chief, ACES Journal
5 September 1999

Computer Code/ Technique	*Issue*	*Page No.*
ADF	AN No. 1	10**
Aperture polarizability	AJ No. 3	234
Cavity Green's function	AJ No. 3	234
CDIF	AJ No. 1	25
CEM tools review	AN No. 1	16**
CGM	AJ No. 3	272
Cylindrical antenna kernel	AJ No. 1	71
EFIE	AJ No. 3	226
EM neural network	AN No. 3	11
EMA3D	AJ No. 2 (SI)	179
ESA-GTD	AN No. 1	10**
FDTD	AJ No. 2 (SI)	147
	AJ No. 2 (SI)	168
	AN No. 2	19
	AJ No. 1	14
FEKO	AJ No. 2 (SI)	87
G1DMULT	AJ No. 3	243
Genetic algorithm	AN No. 1	10**
GMRES	AJ No. 1	4
GO	AN No. 2	13
	AJ No. 1	63
GRASP	AN No. 1	10**
GRC method (modified)	AJ No. 1	4
GRECO	AJ No. 3	255
Hybrid FEM/MoM	AJ No. 3	283
Hybrid FEM/SBR	AJ No. 1	43
	AJ No. 1	52
Hybrid MoM/SBR	AJ No. 1	43
IE-AP	AJ No. 2 (SI)	107
IETD	AJ No. 2 (SI)	131
Kirchoff Integral	AJ No. 1	63
LC	AJ No. 2 (SI)	160
MAGMAS	AN No. 1	10**
MBPE	AJ No. 3	283
MEI	AJ No. 2 (SI)	213
MFIE	AJ No. 3	272
MiniNEC	AN No. 1	26
Modal frequency FEA	AJ No. 2 (SI)	205
MPI	AJ No. 2 (SI)	107
	AJ No. 2 (SI)	87
MPIE	AJ No. 2 (SI)	197
NEC	AN No. 1	12
	AN No. 1	26
	AJ No. 1	25

ABSTRACTS OF *ACES JOURNAL* PAPERS

VOLUME 13, 1998

This compilation of abstracts is updated annually and is normally published in the second issue of the *ACES Newsletter* of the following year. The abstracts were scanned using a digital scanner and were converted to text using a program for character recognition. We extend the sincere thank and appreciation of the *ACES Journal* to Mr. Jamie Vernon who undertook this task and overcame several difficulties with the character recognition process. The document was proofread only once. As Editors-in-Chief, we accept full responsibility for any errors and/or omissions that appear in the text. We apologize in advance for any inconvenience or embarrassment caused by such errors.

Allen W. Glisson and Ahmed A. Kishk, Editors-in-Chief, ACES Journal
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ITERATIVE SOLUTION OF MULTIPLE RIGHT HAND SIDE MATRIX EQUATIONS FOR FREQUENCY DOMAIN MONOSTATIC RADAR CROSS SECTION CALCULATIONS

M. D. Pocock and S. P. Walker

Monostatic rcs characterisation using integral equation methods in the frequency domain requires the solution of very large matrix equations with multiple right hand sides. Although costly for a single right hand side, direct methods are attractive in that subsequent right hand sides are very cheap. Iterative methods are much cheaper for a single right hand side, but if the whole solution must be repeated for each, they become much more expensive. We investigate here the performance of a simple modification to the GCR algorithm, which allows solutions for an essentially unlimited number of right hand sides to be obtained for a modest multiple of the cost of the first. For the cases investigated, with up to 360 right hand sides on bodies up to 15 wavelengths long, with matrices up to 20,440 by 20,440 in size, this multiple was below ~10. Costs seem to rise with the number of right hand sides till the surface field is in some sense characterised, and thereafter subsequent illumination angles are essentially free. An investigation of cost scaling on a set of spheres, ranging from ~1 to 7 wavelengths in diameter, seems to indicate the cost of full monostatic characterisation to scale with about the fifth power of frequency. **[Vol. 13, No. 1 (1998), pp. 4-13]**

A FDTD SURFACE IMPEDANCE BOUNDARY CONDITION USING Z-TRANSFORMS

John H. Beggs

The surface-impedance boundary condition for the Finite-Difference, Time-Domain (FDTD) method is reformulated using digital filtering theory and Z transforms. The approach expands upon recent work in developing an efficient surface-impedance boundary condition for FDTD. The present work involves formulating the surface-impedance boundary condition in the frequency domain for a lossy dielectric half-space and for a thin lossy dielectric layer backed by a perfect conductor. The impedance function of the lossy medium is approximated with a series of low-pass filters. This approximation is independent of material properties and these low-pass filters are converted to corresponding digital filters using Z-transform theory. The FDTD surface-impedance boundary condition is reformulated in the Z domain, and the corresponding time-domain electric field sequence updating equation involves a recursive formula. Results are presented for both one and two-dimensional test problems. **[Vol. 13, No. 1 (1998), pp. 14-24]**

SHIPBOARD HFDF SYSTEM SIMULATION

Jeffrey B. Knorr

NEC 4.1 has been used to compute the responses of the antennas in a shipboard high frequency direction finding system which employs the CIDF algorithm to derive bearing estimates. This paper discusses the computational results as well as the performance of the simulation in which the results were utilized. **[Vol. 13, No. 1 (1998), pp. 25-42]**

HYBRID MOM/SBR METHOD TO COMPUTE SCATTERING FROM A SLOT ARRAY ANTENNA IN A COMPLEX GEOMETRY

Andrew D. Greenwood and Jian-Ming Jin

A method of moments (MoM) code has been developed to compute the scattering from a planar or cylindrically conformal slot array antenna. By hybridizing the MoM with the shooting and bouncing ray (SBR) method, the scattering from a large, complex target with a slot array antenna can be computed. The scattering problem can be decomposed using the field equivalence principle such that the MoM is employed to model the slot array while the SBR method is used to compute the scattering from the large, complex target. Sample results show the utility of the method and the need to include slot array scattering when computing the RCS of a complex target. **[Vol. 13, No. 1 (1998), pp. 43-51]**

EFFECTS OF GAPS AMONG PANELS IN RADIO ASTRONOMY REFLECTOR ANTENNAS

Giuseppe Pelosi, Roberto Coccioli, and Alessio Gaggelli

The main reflector of antennas used for radio astronomy consists of hundreds of panels among which, for various reasons, small gaps are left. In this paper, the effects of these gaps on the field scattered by the reflector are analyzed by means of a hybrid numerical technique which combines the Finite Element Method (FEM) and the Method of Moments (MoM). Numerical results pertaining to the case of an incident plane wave are presented, and the effects of the introduction of corrugations inside the gaps to minimize the power flowing through the gaps themselves are discussed. **[Vol. 13, No. 1 (1998), pp. 52-57]**

SOME EXPERIENCES IN USING NEC2 TO SIMULATE RADIATION FROM SLOTS ON CYLINDERS

S. H. H. Lim, H. E. Green, and C. E. Brander

A numerical method based on use of the NEC2 code has been used to study radiation from a slot in the surface of a conducting cylinder and the results used in a comparison with the eigenfunction series solution. The two cases of an axial and circumferential slot have been taken as representative between them of the more general case of an inclined slot. In the case of a circumferential slot, truncation of the cylinder to finite length has been found in all cases to lead to numerical and analytic results which are in poor agreement and this has been accounted for with an argument based on the geometrical theory of diffraction. However this alone is not enough to explain what is observed with axial slots where, for small cylinders, agreement of the two approaches is good but fails for larger cylinders. It is postulated that this is due to excitation of waveguide modes on the inside of the larger cylinders and the result confirmed by closing the ends of the cylinder in the NEC2 model with a system of radial wires, when agreement is again restored. **[Vol. 13, No. 1 (1998), pp. 58-62]**

A KIRCHHOFF INTEGRAL APPROACH FOR DECIMETRIC RADIOWAVE PROPAGATION IN URBAN AREAS

L. Pisani, F. Rapetti, and C. Vittoli

We consider a three-dimensional approach based on the Kirchhoff's method in order to predict electromagnetic waves propagation in urban environments. In particular, we are interested here in the evaluation of the electromagnetic field on very large three-dimensional domains (typically with linear dimensions of the order of hundreds of meters) generated by a high frequency source (typically of the order of 1GHz which corresponds to a wavelength of about 30 centimeters). Some numerical tests and comparisons with experimental measurements have been done to validate this approach. **[Vol. 13, No. 1 (1998), pp. 63-70]**

ON THE BOUNDED PART OF THE KERNEL IN THE CYLINDRICAL ANTENNA INTEGRAL EQUATION

M. P. Ramachandran

The kernel in the cylindrical antenna integral equation was partitioned by Schelkunoff into a complete elliptic integral and a bounded integral. This paper gives an exact expression for the bounded part. **[Vol. 13, No. 1 (1998), pp. 71-77]**

APPLICATION OF INTEGRAL EQUATION AND HYBRID TECHNIQUES TO THE PARALLEL COMPUTATION OF ELECTROMAGNETIC FIELDS IN A DISTRIBUTED MEMORY ENVIRONMENT

Ulrich Jakobus

This paper describes the parallelization of the method of moments and hybrid code FEKO for execution on massively parallel supercomputers with a distributed memory as well as on clusters of connected workstations. The parallel implementation of the different phases of the solution process, e.g. matrix fill, solution of the system of linear equations, and near- and far-field computation is discussed in detail. Several results for different applications are given and the achieved performance is presented. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 87-98]**

RUNNING SUPERNEC ON THE 22 PROCESSOR IBM-SP2 AT SOUTHAMPTON UNIVERSITY

D. C. Nitch, A. P.C. Fourie, and J. S. Reeve

SuperNEC (SNEC) is an object-oriented version of NEC-2 which has been modified to execute on a network of distributed memory processors. The matrix filling, solving and pattern computation routines are capable of running in parallel. A number of structures have been simulated using this code on the 22 processor IBM-SP2 machine at Southampton University. The principal problem studied was the DC-3 at 90 MHz. LU decomposition and an iterative matrix solution scheme were used in the study. The simulation time for this structure (which includes 3-D radiation patterns) dropped from 2.5 hours on a single processor to about 17 minutes when simulated on 12 processors using LU decomposition. Execution times are about half of these times when using the iterative solver. The far field patterns obtained from the simulation are compared with measured data and show good agreement. The largest problem tackled on the IBM machine was the DC-3 simulated at 160 MHz. This problem requires 17035 segments and was simulated in 5.3 hours on 21 processors. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 99-106]**

HIGHLY PARALLEL IMPLEMENTATION OF THE 3D INTEGRAL EQUATION ASYMPTOTIC PHASE METHOD FOR ELECTROMAGNETIC SCATTERING

Xianneng Shen, Aaron W. Davis, Keith R. Aberegg, and Andrew F. Peterson

In this paper, we discuss the implementation of the 3D Integral Equation-Asymptotic Phase (IE-AP) method using the parallel architecture IBM RS/6000 SP. The IE-AP method is a hybrid numerical/asymptotic approach for electromagnetic scattering that attempts to reduce the number of unknowns required to accurately model electrically large structures. The IE-AP method will be described, and results will be reported for the parallel matrix fill implementation, and the relative performance of the PESSL and PETSc toolkits for parallel matrix solution. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 107-115]**

PERFORMANCE OPTIMIZATION OF AN INTEGRAL EQUATION CODE FOR JET ENGINE SCATTERING ON CRAY-C90

Mikhail Smelyanskiy, Edward S. Davidson, and John L. Volakis

The numerical solution of Maxwell's equations is a computationally intensive task and use of high-performance parallel computing facilities is necessary for the larger class of practical problems in scattering, propagation and antenna modeling. It is therefore necessary to carefully consider algorithm optimizations aimed at improving the code's run time performance on the computing platform employed. Although some performance improvement can be derived from compiler-level optimizations, further speed-up may involve manual effort in algorithm restructuring, data layout, and parallelization. This paper focuses on the manual optimizations used to improve the performance of a moment method code for the analysis of a cylindrically periodic structure, as is the case with a jet engine. We describe the steps taken which resulted in nearly two orders of magnitude improvement over the original version of the code. A 16-processor shared-memory CRAY-C90 vector supercomputer was employed. Our optimization took advantage of SSD its solid-state storage, enabled better loop vectorizations, parallelized the *matrix_fill* routine, and called appropriate CRAY-C90 library routines. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 116-130]**

OPTIMISATION AND LARGE SCALE COMPUTATION IN INTEGRAL EQUATION SCATTERING ANALYSES

S. J. Dodson, S. P. Walker, and M. J. Bluck

The kinds of difficulties posed by large scattering computations change as larger problems are addressed. Unfavourable cost scalings make the performance of small, core, portions of code dominant, and require that they, and the overall code structure, be optimised for large scale computation. This is discussed in the context of rcs and scattering computations of multi-wavelength bodies using a time domain integral equation treatment. Examples presented include the NASA almond evaluated at 25 wavelengths long, and an assembly of 101 spherical scatterers of ~1/2 wavelength diameter each, occupying a volume of side ~250 wavelengths. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 131-146]**

PERFORMANCE MODELING OF THE FINITE-DIFFERENCE TIME-DOMAIN METHOD ON PARALLEL SYSTEMS

James E. Lumpp, Jr., Shashi K. Mazumdar, and Stephen D. Gedney

As high-performance parallel codes are developed or ported to new architectures, it is often difficult to quantify the causes of performance problems. Models of program performance can provide users with insight into the effect of system and program parameters on performance, can help programmers tune applications, and can help programmers make decisions about processor allocation. This paper introduces a modeling technique applied to the Finite-Difference Time-Domain (FDTD) algorithm. The technique models the performance of an existing application in terms of the size of the problem being solved and the number of processors. The models show that for sufficiently large problem sizes the algorithm performs well. However, for smaller problem sizes or when too many processors are used, the models show that parallel overheads become significant. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 147-159]**

IMPLEMENTATION AND APPLICATION OF A FD-TD SIMULATION TOOL FOR THE ANALYSIS OF COMPLEX 3D STRUCTURES

Kevin Thomas, Gary Haussmann, Melinda Piket-May, and Roger J. Gravrok

This paper presents information about the development of an electromagnetic analysis tool "LC" which integrates the Finite-Difference Time-Domain (FD-TD) method with an interactive Graphical User Interface (GUI). The paper will discuss the program implementation and design; many issues in the implementation have surfaced, concerning the problem of producing a graphical model editor/simulator that runs efficiently on various hardware systems. The paper will also explore how the solver's capabilities aid design engineers when investigating and solving packaging and interconnect design issues as well as the program's application to engineering problems. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 160-167]**

OPTIMIZING THE PARALLEL IMPLEMENTATION OF A FINITE DIFFERENCE TIME DOMAIN CODE ON A MULTI-USER NETWORK OF WORKSTATIONS

J. V. Mullan, C. J. Gillan, and V. F. Fusco

The implementation of a parallel, three dimensional, finite difference time domain (FDTD) computer program is considered and applied to a test scattering problem on a multi-user network of desktop workstations. The computation has primarily been done on a local area network (LAN) using six identical HP 9000/715 workstations (i.e. a homogeneous environment) with the Parallel Virtual Machine (PVM) software being employed as the communications harness.

In this paper the sequential and parallel FDTD approaches are reviewed. We investigate the factors which cause a reduction in efficiency in the latter, such as host allocation and load balancing. We propose a task migration process, which is efficient for the FDTD algorithm, as a partial solution. The advantages of this approach are discussed and further developments based on available computational resources are suggested. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 168-178]**

PARALLEL COMPUTATION OF LARGE-SCALE ELECTROMAGNETIC FIELD DISTRIBUTIONS

Peter S. Excell, Adam D. Tinniswood, and Kathleen Haigh-Hutchinson

Some experience of the use of high-frequency electromagnetics software on parallel computers is reported. Types of such computers are reviewed and approaches to the parallelisation of existing serial software are discussed. A practical large-scale problem is presented involving the modelling in very fine detail of electromagnetic penetration into biological systems. This was tested on state-of-the-art parallel computers and important practical and strategic aspects of the experience derived are discussed. It was found that considerable programmer effort was required to optimise the software to use the computer architecture effectively, but that efficient acceleration of the run-times of typical computational tasks could be achieved, provided that the tasks were large and were partitioned optimally. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 179-187]**

A DEDICATED TLM ARRAY PROCESSOR

D. Stothard and S. C. Pomeroy

The transmission line matrix (TLM) method is introduced and the specific issue of computational efficiency is discussed. The implementation of TLM on parallel computers is studied leading to the creation of a highly efficient processor designed specifically for TLM. Limitations introduced by the connection strategies employed by most parallel architectures are overcome through the use of a novel data routing architecture. The basic idea is extended to include stub loaded and three-dimensional TLM. The development of a prototype processor is discussed and potential applications are given. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 188-196]**

BANDWIDTH REDUCED FULL-WAVE SIMULATION OF LOSSLESS AND THIN PLANAR MICROSTRIP CIRCUITS

A. Caproni, F. Cervelli, M. Mongiardo, L. Tarricone, and F. Malucelli

We present a full-wave, high-performance, numerical scheme for the analysis of planar microstrip circuits which is based on an efficient electromagnetic formulation of the field problem and on the bandwidth reduction of the discretized sparse matrix.

The above mentioned electromagnetic efficiency is attained by considering a Mixed Potential Integral Equation (MPIE) with the kernel expressed by closed-form spatial-domain Green's functions; as a consequence, the reaction integrals are evaluated by using just one-dimensional numerical integration over a finite spatial domain. Moment method discretization of the MPIE leads to the corresponding matrix problem.

The accurate analysis of the matrix properties shows that a sparsity of 70-85% in the discretized linear system can be routinely enforced without significantly altering the solution accuracy.

A new scheme for the sparse matrix bandwidth reduction, particularly tailored for electromagnetic problems, can be therefore introduced, leading to considerable reductions of the simulation time. Results are presented demonstrating that the use of a bandwidth reduction strategy coupled with efficient problem-matched Green's functions allows as to obtain speed-ups in simulation time of more than one order of magnitude with respect to standard state of the art implementations. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 197-204]**

SPEEDUP USING A MODAL FREQUENCY METHOD FOR FINITE ELEMENT ANALYSIS OF A DUAL-MODE MICROWAVE FILTER

John R. Brauer

Computer time required for finite element analysis of microwave filters is reduced by more than an order of magnitude by using modal frequency rather than direct frequency methods. In the conventional direct frequency method, the number of unknowns is equal to the number of edge degrees of freedom. Instead, the new modal frequency method first computes the 3D modes and then uses them as basis functions, thereby greatly reducing the number of degrees of freedom. The two methods are applied to the European benchmark problem of a dual-mode microwave filter. The modal frequency method obtains essentially the same results as the direct frequency method, but when analyzing 201 frequencies it yields a speedup factor of 15. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 205-212]**

A FAST MEI SCHEME FOR THE COMPUTATION OF SCATTERING BY VERY LARGE CYLINDERS

Y. Liu, K. Lan, K. K. Mei, and E. K. N. Yung

A fast scheme for measured equation of invariance (MEI) method is presented in this paper. The scheme combines a strategic technique of the interpolation and extrapolation of MEI coefficients with a special algorithm of cyclic block band matrix to fast solve the scattering problems of very large conducting cylinders. The circumferential dimension of scattering objects could exceed 10,000 wavelength. Computational speed could be 2-3 order faster than conventional MEI method. The fast scheme is especially applicable to scattering problems of very large conducting objects in which other numerical methods may fail. **[Vol. 13, No. 2 (1998), Special Issue on Computational Electromagnetics and High-performance Computing, pp. 213-225]**

A STABILIZING SCHEME FOR THE EXPLICIT TIME-DOMAIN INTEGRAL-EQUATION ALGORITHM

S. Kashyap, M. Burton, and A. Louie

The stability of the explicit version of the solution of the time-marching electric-field integral-equation continues to depend on the specifics of the application. The design of stability-enhancing schemes seems to be more of an art than a science. A contribution to this art is made with a design that is stable where others are not, and the practical issues of implementation, accuracy, and efficiency in both time and memory are addressed. **[Vol. 13, No. 3 (1998), pp. 226-233]**

BROAD BAND MODELLING OF ELECTROMAGNETIC WAVE COUPLING TO SCATTERERS INSIDE A METALLIC CAVITY

J. v. Hagen, W. Tabbara, and D. Lecointe

In this paper we present an approach based on the method of moments for the solution of an electromagnetic compatibility problem. We determine the results of the impact of an electromagnetic wave on metallic housings with small holes. By separating the interior and the exterior of the housing we are able to use the Green's functions of the cavity. The number of unknowns is therefore reduced compared to solutions using the free space Green's functions. Different sets of functions (either local or global) are used for the method of moments (MoM). Furthermore, we present a method to generate broad band data from only a few computations by using an "intelligent" interpolation procedure. Finally, we present an experimental setup and compare our computations with measurements. **[Vol. 13, No. 3 (1998), pp. 234-242]**

AN ALGORITHM FOR CALCULATING GREEN'S FUNCTIONS OF PLANAR, CIRCULAR CYLINDRICAL, AND SPHERICAL MULTILAYER SUBSTRATES

Zvonimir Šipuš, Per-Simon Kildal, Robert Leijon, and Martin Johansson

We introduce an algorithm for calculating spectral domain Green's functions of planar, circular, cylindrical, and spherical multilayer structures. The three spectral domain problems are interpreted as multilayer spatial domain problems with electromagnetic sources in the forms of current sheets, tubes, and shells, respectively, and with harmonic spatial variation. The algorithm, which is the same for all three geometries, is based on dividing these three field problems into appropriate subproblems by using equivalence, and on determining the tangential field components at the interfaces between the layers of the structure. The algorithm is implemented into three versions of a Fortran routine called G1DMULT, one version for each geometry. The only difference between the three versions is in two subroutines which calculate the fields due to harmonic current sheets, tubes, and shells, respectively, located in an infinite homogeneous material. We have tested the routine by calculating the properties of microstrip patch antennas and periodic structures. **[Vol. 13, No. 3 (1998), pp. 243-254]**

DISCRETIZATION ERRORS IN THE GRAPHICAL COMPUTATION OF THE PHYSICAL OPTICS SURFACE INTEGRAL

Juan M. Rius, Daniel Burgos, and Angel Cardama

This paper studies the sources of discretization errors in the graphical computation of PO surface integrals. Three different PO models that associate to screen pixels patches of different shape and orientation are presented. The RCS versus frequency results obtained for a sphere show that when the resolution in the surface discretization is high enough for the working frequency, the best results are obtained with the triangle mesh PO model (Gordon formula) [2], but the tangent plane approximation of J.S. Asvestas [13] achieves the best trade-off between CPU time and accuracy. When the resolution in the surface discretization is not high enough for the working frequency, the best results are obtained in most cases with the heuristic approximation of J.M. Rius [11] [12], due to the use of interpolated unit normals in pixels inside the flat triangles of the rendering model. **[Vol. 13, No. 3 (1998), pp. 255-263]**

ANALYSIS AND DESIGN OF PLANAR WAVEGUIDE SLOT ARRAYS USING SCATTERING MATRIX APPROACH

Karthikeyan Mahadevan, Hesham A. Auda, and Charles E. Smith

A scattering matrix approach to the analysis and design of planar waveguide slot arrays is described in this paper. The new method employs the scattering matrix for TE_{10} and TE_{20} (to the waveguide axis) modes of isolated slot in the broad wall of a rectangular waveguide, rather than the admittance of the slot derived from approximate shunt or series lumped element model for the slot. The method fully accounts for the external mutual coupling due to the TE_{10} and TE_{20} modes on the slot, and can be easily extended to include higher order waveguide modes. Furthermore, it takes into account the deviation of the slot aperture from the sinusoidal distribution that is normally assumed with a nearly resonant slot. Numerical results demonstrating the viability of the scattering matrix approach, including an example for the design of a 2 x 3 planar array of longitudinal slots, are presented. **[Vol. 13, No. 3 (1998), pp. 264-271]**

EFFICIENT CGM APPLICATION FOR SCATTERING AND RADIATION OF ANTENNAS ON BOARD ARBITRARY STRUCTURES

Olga M. Conde and Manuel F. C·tedra

A technique based on an iterative scheme and a current-based method has been developed to determine the scattering and propagation characteristics of arbitrary structures and environments. To obtain a high degree of accuracy, parametric surfaces (NURBS) have been used to model the body surface. The technique solves the MFIE (Magnetic Field Integral Equation) defined over the body surface. The aim of the method is to make the analysis avoiding the memory and CPU time restrictions imposed by low frequency methods such as Method of Moments. Approximate expressions, based on dipole moment formulations, are applied to speed-up the calculations. Two initial guesses for the CGM (Conjugate Gradient Method) have been compared in order to see which one presents the best relationship between convergence and CPU time. Results are presented showing the behavior of the developed methods comparing them with measurements and other electromagnetic methods. **[Vol. 13, No. 3 (1998), pp. 272-282]**

FAST FREQUENCY RESPONSE CALCULATIONS OF CAVITY-BACKED APERTURE ANTENNAS USING HYBRID FEM/MOM TECHNIQUE IN CONJUNCTION WITH MODEL BASED PARAMETER ESTIMATION

C. J. Reddy, M. D. Deshpande, B. R. Cockrell, and F. B. Beck

Model Based Parameter Estimation (MBPE) is presented in conjunction with the hybrid Finite Element Method (FEM)/Method of Moments (MoM) technique for fast computation of the input characteristics of cavity-backed aperture antennas over a frequency range. The hybrid FEM/MoM technique is used to form an integro-partial-differential equation to compute the electric field distribution of, a cavity-backed aperture antenna. In MBPE, the electric field is expanded as a rational function of two polynomials. The coefficients of the rational function are obtained using the frequency derivatives of the integro-partial-differential equation formed by the hybrid FEM/MoM technique. Using the rational function approximation, the electric field is calculated and the input characteristics of the antenna are obtained over the frequency range. Numerical results for an open coaxial line and a cavity-backed microstrip patch antenna are presented. Good agreement between MBPE and the solutions over individual frequencies is observed. CPU timings for all numerical calculations are presented. **[Vol. 13, No. 3 (1998), pp. 283-290]**

IMPLICITNESS AND STABILITY OF TIME DOMAIN INTEGRAL EQUATION SCATTERING ANALYSES

S. J. Dodson, S. P. Walker, and M. J. Bluck

Time domain integral equation analysis of scattering problems has been inhibited by the instability generally observed. Usual treatments are explicit. We here describe an implicit approach, which allows timesteps to be selected to model the temporal variation of the field, rather than being constrained to small values by the need for the wave propagation during a timestep to be less than the smallest nodal spacing. For realistic bodies, this alone can result in computational cost savings by a significant factor. We present an investigation of the stability of the implicit approach, and show that it is much less prone to instability than the explicit. For realistic bodies, with rationally chosen timesteps, the implicit approach is for all practical purposes stable. This is so without recourse to the various temporal averaging schemes which have been proposed for stabilisation of the explicit form. **[Vol. 13, No. 3 (1998), pp. 291-302]**

VALIDATION OF, AND LIMITATIONS ON, THE USE OF NEC-4 FOR RADIATION FROM

ANTENNAS BURIED WITHIN A HOMOGENEOUS HALF-SPACE

David B. Davidson and H. du Toit Mouton

The use of the computer program NEC-4 for the simulation of radiation from buried antennas is considered. NEC-4 uses the "exact" Sommerfield integral formulation for stratified media (in NEC-4, restricted to an homogeneous half-space). Although the formulation is rigorous, certain approximations have to be made for numerical implementation. The formulation, and some of these issues, is outlined in the paper. Several validation examples comparing results computed using NEC-4 and results available in the literature are presented for antennas buried in various typical media, including ground, fresh water, and the sea. Satisfactory agreement has generally been obtained; where differences have been noted, we have able to explain most in terms of approximate implementation issues. **[Vol. 13, No. 3 (1998), pp. 302-309]**

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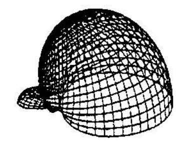

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Areas and topics:

Code performance analysis	Computational studies of physics	Code validation
Computer hardware issues	Practical code application	New, fixed, and enhanced codes

Applications and Techniques:

Antennas	Bioelectromagnetics	Scattering
Visualization	Wave propagation	Radar cross section
Integral & Differential Equations	Finite Difference & Finite Element	Frequency-domain & Time-domain
Diffraction	Modal Expansion	Physical Optics

INSTRUCTIONS FOR AUTHORS AND TIMETABLE

Submission Deadline - November 1, 1999: Electronic submission preferred (Microsoft Word). Otherwise submit three copies of a full-length, camera-ready paper to the Technical Program Chairman. Specific format required; please request instructions via e-mail or see on-line instructions. **Authors notified of acceptance by December 1, 1999.**

For all questions regarding the ACES Symposium please contact **Douglas H. Werner**, Technical Program Chair
The Pennsylvania State University, 211A Electrical Engineering East, University Park, PA 16802
Tel: (814) 863-2946, Fax: (814) 865-7065, E-mail: **aces@engr.psu.edu**
or visit ACES on line at: **http://aces.ee.olemiss.edu**

EARLY REGISTRATION FEES

ACES MEMBERS $300	STUDENT/RETIRED/UNEMPLOYED	$130 (no proceedings)
NON-MEMBER $350	STUDENT/RETIRED/UNEMPLOYED	$165(includes proceedings)

$500 BEST-PAPER PRIZE

A $500 prize will be awarded to the authors of the best non-student paper accepted for the 16th Annual Review.

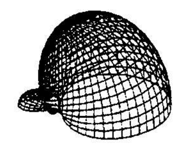
$200 BEST STUDENT PAPER CONTEST

This will be for the best student paper accepted for the 16th Annual Review. The prize will include: 1) free Annual Review registration for the following year; 2) one free short course; and 3) $200 cash for the paper.

2000 ACES Symposium Sponsored by: ACES, NPS, PSU, UNR, U OF NV, MSU, UWI, SWRI
In cooperation with: IEEE Antennas and Propagation Society, IEEE Electromagnetic Compatibility Society and USNC/URSI

Technical Program Chair	Symposium Co-Chair	Symposium Co-Chair	Vendor Chair	Symposium Administrator	Short Course Chair	Publicity Chair
Douglas H. Werner Penn State University	Randy Haupt Utah State University	Ping juan L. Werner Penn State DuBois Campus	Leo C. Kempel Michigan State University	Richard W. Adler Naval Postgraduate School	Susan C. Hagness University of Wisconsin	Keith A. Lysiak Southwest Research Institute

CALL FOR PAPERS



THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY

The 16th Annual Review of Progress in Applied Computational Electromagnetics
March 20 - 25, 2000
Naval Postgraduate School, Monterey, California
Share Your Knowledge and Expertise with Your Colleagues

The Annual ACES Symposium is an ideal opportunity to participate in a large gathering of EM analysis enthusiasts. The purpose of the Symposium is to bring analysts together to share information and experience about the practical application of EM analysis using computational methods. The symposium offerings include technical presentations, demonstrations, vendor booths, short courses, and hands-on workshops. All aspects of electromagnetic computational analysis are represented.

The ACES Symposium is a highly influential outlet for promoting awareness of recent technical contributions to the advancement of computational electromagnetics. Attendance and professional program paper participation from non-ACES members and from outside North America are encouraged and welcome.

Papers may address general issues in applied computational electromagnetics, or may focus on specific applications, techniques, codes, or computational issues of potential interest to the Applied Computational Electromagnetics Society membership.

Areas and topics

Computational studies of basic physics	Computer hardware issues
Examples of practical code application	Code validation
New codes, algorithms, code enhancements, and code fixes	Code performance analysis

Partial list of applications

Communications systems	Microwave components	Wireless	Radar Imaging
Remote sensing & geophysics	EMP EMI/EMC	Shielding Fiberoptics	Radar cross section
Dielectric & magnetic materials	MIMIC technology	Visualization	Fiberoptics
Non-destructive evaluation	Wave propagation	Eddy currents	Direction finding
Propagation through plasmas	Bioelectromagnetics	Inverse scattering	Antennas

Partial list of techniques

Diffraction theories	Moment methods	Physical optics
Frequency-domain & Time-domain techniques	Hybrid methods	Modal expansions
Finite difference & finite element analysis	Numerical optimization	
Integral equation & differential equation techniques	Perturbation methods	

INSTRUCTIONS FOR AUTHORS AND TIMETABLE

Submission Deadline - November 1, 1999: Electronic submission preferred (Microsoft Word). Otherwise submit three copies of a full-length, camera-ready paper to the Technical Program Chairman. Please supply the following data for the corresponding authors: name, address, email address, FAX, and phone numbers. **Authors notified of acceptance by December 1, 1999.**

PAPER FORMATTING REQUIREMENTS

The recommended paper length is 6 pages, with 8 pages as a maximum, including figures. The paper should be camera-ready (good resolution, clearly readable when reduced to the final print of 6x9 inch paper). The paper should be printed on 8-1/2x11 inch papers with 13/16 side margins, 1-1/16 inch top margin, and 1 inch on the bottom. On the first page, place title 1-1/2 inches from top with authors, affiliations, and e-mail addresses beneath the title. Single spaced type using 10 or 12 point font size, entire text should be justified (flush left and flush right). No typed page numbers, but number your pages lightly in pencil on the back of each page.

For all questions regarding the ACES Symposium please contact:
Douglas H. Werner, Technical Program Chair
The Pennsylvania State University, 211A Electrical Engineering East, University Park, PA 16802
Tel: (814) 863-2946, Fax: (814) 865-7065, E-mail: **aces@engr.psu.edu**
or visit ACES on line at: **http://aces.ee.olemiss.edu** and **www.emclab.umr.edu/aces**.

EARLY REGISTRATION FEES

ACES member	$300	Student/Retired/Unemployed	$130 (no proceedings)
Non-member	$350	Student/Retired/Unemployed	$165 (includes proceedings)

Each conference registration is entitled to publish two papers in the proceedings free of charge. Excess pages over a paper limit of 8 will be charged $15/page.

$500 BEST-PAPER PRIZE

A $500 prize will be awarded to the authors of the best non-student paper accepted for the 16th Annual Review. Papers will be judged by a special ACES prize-paper Committee according to the following criteria:

1. Based on established electromagnetic (EM) theory
2. Reliable data
3. Computational EM results
4. Practical applications
5. Estimates of computational errors
6. Significant new conclusions

$200 BEST STUDENT PAPER CONTEST

This will be for the best student paper accepted for the 16th Annual Review. (Student must be the presenter on the paper chosen). Submissions will be judged by three (3) members of the BoD. The prizes for the student presenter and his/her principal advisor will consist of: (1) free Annual Review registration for the following year; (2) one free short course taken during the 2000 or 2001 Annual Review; and (3) $200 cash for the paper.

2000 ACES Symposium Sponsored by: ACES, NPS, PSU, UNR, UTAH STATE U, MSU, UWI, SWRI
In cooperation with: The IEEE Antennas and Propagation Society,
The IEEE Electromagnetic Compatibility Society and USNC/URSI

Technical Program Chair	Symposium Co-Chair	Symposium Co-Chair	Vendor Chair	Symposium Administrator	Short Course Chair	Publicity Chair
Douglas H. Werner Penn State University	Randy Haupt Utah State University	Ping juan L. Werner Penn State DuBois Campus	Leo C. Kempel Michigan State University	Richard W. Adler Naval Postgraduate School	Susan C. Hagness University of Wisconsin	Keith A. Lysiak Southwest Research Institute

STUDENT BEST PAPER CONTEST

This will be for the "Best Paper",

submitted for publication in the 2000,

16th Annual Review of Progress.

(Student must be the presenter

on the paper chosen)

Submissions will be judged

by three (3) members of the BoD.

The prizes for the Student presenter

and his principal advisor will consist of:

(1) free Annual Review Attendance

for the following year;

(2) one free short course taken during the

2000 or 2001 Annual Review;

and

(3) $200 cash for the paper.

MOTELS / HOTEL LIST FOR MARCH 2000 ACES SYMPOSIUM

20-25 MARCH 2000

**** (WITHIN WALKING DISTANCE OF NPS)**

FIRESIDE LODGE (**) (1 star)
1131 10th St. Monterey, CA 93940
Phone: (831) 373-4172 FAX: (831) 655-5640
Rates: **Govt**. $79.---**Conf**. $79 + tax

STAGECOACH MOTEL (**) (1 Star)
1111 10th St. Monterey, CA 93940
Phone: (831) 373-3632 FAX: (831)-648-1734
Rates: **Govt**. $69.- $75---**Conf**. $69 + tax

MONTEREY BAY LODGE (**) (2 Star)
55 Camino Aguajito, Monterey, CA 93940
Phone: (831) 372-8057 FAX:(831) 655-2933
Rates: **Govt**. $41.65.**Conf**. $67.15 + tax
most rates apply for Mon thru Thursday

MONTEREY HILTON (**) (3 Star)
1000 Aguajito Rd. Monterey, CA 93940
(831) 373-6141 FAX: (831)375-2367
Rates: **Govt**. $71.- **Conf**. $125-135 + tax

HYATT HOTEL & RESORT (**) (4 Star)
1 Old Golf Course Rd. Monterey, CA 93940
Phone: (831) 372-1234 FAX: (831)-375-6985
Rates: **Govt**. $71.- 146; **Conf**. $149-184 + tax

SUPER 8 MOTEL (2 Star)
2050 Fremont St. Monterey, CA. 93940
Phone: (831) 373-3081 FAX: (831) 372-6730
Rates: **Govt**. $49-Mon-Thurs, -$59 Fri-Sat-1bed
Conf. $59 Mon-Thurs; $69 Fri-Sat 2 bed + tax

(1) MOTELS **WEEKEND RATES MAY BE HIGHER** THAN WEEKDAYS. (2) **MENTION THAT YOU ARE ATTENDING THE "ACES" CONFERENCE** AT NPS WHEN BOOKING (3) CUT OFF DATE FOR CONFERENCE RATES IS USUALLY ONE MONTH PRIOR TO START OF CONFERENCE. (CHECK WITH THE HOTEL IF YOU NEED SPECIAL ARRANGEMENTS) (4) **ATTENDEES** ON **GOVT ORDERS DO NOT PAY TAX**. ATTENDEES PAYING CONF. RATE, PAYS TAX.

IMPORTANT INFORMATION FOR ACES ATTENDEES, PLEASE READ.

Hotel room tax exemption requires all of the following documents: (1) Travel Orders, (2) Payment by government issued AMEX/VISA card; (3) Govt./Military identification. Regarding Govt orders: prevailing perdiem lodging rate at time of arrival will be honored. Attendees on Govt. orders do NOT pay city tax; every other attendee pays city tax!

When you book a room, mention that you are attending the "ACES" Conference, at NPS, and ask for either Government, or Conference rates.

There is NO Conference PARKING at the Naval Postgraduate School or on nearby streets, so we advise you to book a room within walking distance, or plan to use a taxi.

Third Street Gate is the closest gate to the Conference Registration location. IT MAY NOT BE OPEN DURING CONFERENCE DUE TO INCREASED SECURITY. The Ninth Street gate is always open.

AIRLINE INFORMATION

The following airlines make connections from Los Angeles and San Francisco, CA. to Monterey, CA: American & United. Delta/Sky West serves from SFO only and US Air/Express serves from LAX only. There is no airline connection directly from San Jose, CA to Monterey, CA. You can fly to San Jose, but then you must rent a car.

THINGS TO DO AND SEE IN THE MONTEREY BAY AREA

There are many activities for children and adults not attending the Conference. The colorful blue Monterey Bay is a vision of historic Monterey, rich with natural beauty and many attractions from Fisherman's Wharf, (be sure to try the seafood cocktails), to Cannery Row, the Monterey Adobes and city parks, the Monterey Bay Aquarium, Maritime Museum of Monterey, and Pacific Grove Museum of Natural History. The "Artichoke Capital of the World" is only 15 miles from Monterey, in Castroville.

Other things to do include: driving the17-Mile Drive in Pebble Beach; Whale watching, bicycle riding, roller blading, surfing, ocean kyaking, in Pacific Grove; taking a stroll on the white sandy beach in Carmel, a visit to Mission San Carlos Borromeo Del Rio Carmelo, in Carmel, etc. The Monterey Peninsula has 20 Golf Courses. Carmel has many Art Galleries. Wine tasting tours. For more information, call the Monterey Peninsula Chamber of Commerce, Visitors and Convention Bureau at (831) 649-1770.

CALL FOR PAPERS

THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY

ANNOUNCES A SPECIAL ISSUE OF THE ACES JOURNAL ON

EVOLUTIONARY METHODS IN COMPUTATIONAL ELECTROMAGNETICS

The Applied Computational Electromagnetics Society is pleased to announce the publication of a 2000 Special Issue of the ACES Journal on applications and advances in evolutionary computing methods applied to computational electromagnetics. The objectives of this special issue are to present applications and advances in evolutionary methods applied to antennas, scattering, EMC, microwave filters, and other relevant electromagnetic problems. Prospective authors are encouraged to submit papers of archival value that address these objectives and other suggested topics listed below.

SUGGESTED TOPICS

- genetic algorithms
- genetic programming
- evolutionary algorithms
- electromagnetic applications of computational evolutionary methods
- advances in GA operators and algorithms
- advances in EA and genetic programming

DEADLINE FOR PAPERS IS DECEMBER 20, 1999

Potential contributors wishing to discuss the suitability of their contribution to the special issue may contact on of the following two Guest Editors by email or phone:

Prof. Randy L. Haupt haupt@ieee.org **Tel: (435) 797-2841**
Prof. J. Michael Johnson jmjohnson@ieee.org **Tel: (775) 784-6485**

All submissions for this special issue should be addressed to:

Special Issue on Evolutionary Methods
Prof. Randy Haupt
Utah State University
Dept. of Electrical and Computer Engineering
4120 Old Main Hill
Logan, UT 84322-4120

CALL FOR PAPERS

THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY

ANNOUNCES A SPECIAL ISSUE OF THE ACES JOURNAL ON

COMPUTATIONAL ELECTROMAGNETIC TECHNIQUES IN MOBILE WIRELESS COMMUNICATIONS

The Applied Computational Electromagnetics Society is pleased to announce the publication of a Special Issue of the ACES Journal on the role that computational electromagnetics plays in the design and analysis of wireless communications components, subsystems, and systems. The complexity of present wireless mobile architectures and the future complexities of wideband wireless mobile systems has sparked an interest in computational electromagnetics (CEM) as one of the many tools needed for the design of third generation mobile wireless communications systems. The purpose of this special issue is to draw analysts, designers, and management from both industry and academia to outline their ideas and research on the role of CEM in present or future wireless designs. Applications oriented papers are highly encouraged.

SUGGESTED TOPICS

Applications of computational electromagnetic techniques on any of the following:

- Smart and adaptive antennas
- PCS, Mobile, Gateways, Satellite antennas
- Propagation Models
- Atmospheric Models
- Systems design
- Correlation of measurement techniques and models
- Electromagnetic Interference
- Bioelectromagnetics
- LEO, MEO, Satellites Communications
- Digital/Analog components design
- RF components design

DEADLINE FOR PAPERS IS MARCH 28, 2000

Expected Publication Date is Fall 2000 Issue of ACES Journal

Please submit 4 copies of papers to either of the Guest Editors listed below. The review process will commence as papers are received. Notification of accepted papers will be made immediately as papers are reviewed.

Ray Perez
c/o:Lockheed Martin Astronautics
MS: S8800 P.O Box 179
Denver, Colorado 80201, USA
phone: 303-977-5845
fax: 303-971-4306
email:ray.j.perez@lmco.com

Chris Holloway
NTIA/ITS.T
325 Broadway
Boulder, Colorado 80303, USA
phone: 303-497-6184
fax: 303-497-3680
email:cholloway@its.bldrdoc.gov

CALL FOR PAPERS

THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY

ANNOUNCES A SPECIAL ISSUE OF THE ACES JOURNAL ON

COMPUTATIONAL BIOELECTROMAGNETICS

The Applied Computational Electromagnetics Society is pleased to announce the publication of a Special Issue of the ACES Journal on applications and advances in methods and applications in computational bioelectromagnetics. The objectives of this special issue are to present advances in computational techniques, reviews and/or comparisons of methods, and applications of computational bioelectromagnetics. Prospective authors are encouraged to submit papers of archival value that address these objectives and other suggested topics listed below.

SUGGESTED TOPICS

- Applications of computational bioelectromagnetics
  - Cellular telephone analysis, design, etc.
  - Medical imaging
  - EM Safety analysis
  - Etc.
- Methods used for computational bioelectromagnetics
  - Finite-difference time-domain
  - Finite element method
  - Other methods
- Models for computational bioelectromagnetics
  - High resolution human body models
  - Electrical properties of human tissue
- Comparisons of methods, models, or techniques

DEADLINE FOR PAPERS IS AUGUST 25, 2000

Potential contributors wishing to discuss the suitability of their contribution to the special issue may contact one of the following three Guest Editors by email or phone:

Cynthia Furse	**furse@ece.usu.edu**	**Tel: (435) 797-2870**
Susan Hagness	**hagness@engr.wisc.edu**	**Tel: (608) 265-5739**
Ulrich Jakobus	**jakobus@ihf.uni-stuttgart.de**	**Tel: +49 (0)711 685-7420**

All submissions for this special issue should be addressed to:

Cynthia Furse -- Special Issue on Bioelectromagnetics
Dept. of Electrical and Computer Engineering
Utah State University
Logan, UT 84322-4120

CALL FOR PAPERS

MTT IMS' 00

SESSIONS ON HF/VHF/UHF TECHNOLOGY

Boston, Massachusetts – June 2000

The IEEE Microwave Theory and Techniques (MTT) Society has formed a new technical committee (MTT-17) for HF, VHF, and UHF Technology. Its purpose is to help MTT address the needs of the 26,000 RF engineers who work at frequencies below 1 GHz.

We have sponsored special sessions at IMS'97, and '98 and a regular session at IMS'99. We are looking forward to continuing these sessions on HF/VHF/UHF technology at IMS'00 in Boston (June 11-16, 2000). Papers can address any area of technology that is of particular interest to RF engineers, including:

- Receiver and associated DSP
- Transmitters and power amplifiers
- Applications such as plasma/laser drivers and MRI
- Filters and matching networks
- Components (transistors, diodes, mixers, etc.)

DEADLINE FOR PAPERS IS NOVEMBER 29, 1999 FOR PAPER FORM .
DEADLINE FOR PAPERS IS DECEMBER 6, 1999 FOR ELECTRONIC FORM

Proposals including a 30-50 word abstract and a 500-1000 word summary must be submitted by DECEMBER 6, 1999 in electronic form or by NOVEMBER 29, 1999 in paper form. For full information, see:http://www.mtt.org/ims2000. When submitting, please note that HF/VHF/UHF Technology is TOPIC CATEGORY 8 on the author's information form. To ensure that your submission is not accidentally routed to another committee, it is recommended that you send a copy of your proposal to F.H. Raab at the address shown below.

Please distribute this notice to your colleagues.

Questions about the HF/VHF/UHF committee or sessions should be directed to:
Dr. Frederick H. Raab
Green Mountain Radio Research
50 Vermont Avenue
Colchester, VT, 05446, USA
Fax: (802) 655-9670
E-mail: f.raab@ieee.org

EUROEM 2000, EDINBURGH, SCOTLAND

CALL FOR PAPERS

The Organising Committee has great pleasure in inviting you to submit papers for the EUROEM 2000 conference being held in Edinburgh, Scotland from 30 May - 2 June 2000.

EUROEM 2000 continues the tradition of the EUROEM/AMEREM Conference Series, drawing together the 12th High Power Electromagnetics Conference, the 5th Ultra-Wideband Short Pulse Electromagnetics Conference and the 5th Unexploded Ordnance Detection and Range Remediation Conference.

Papers are solicited which describe original work suitable for the three conferences comprising EUROEM 2000. The **deadline** for receipt of abstracts is **Friday, 14 January 2000.**

Authors are requested to submit a one page abstract, original plus 3 copies in **camera-ready format** by the deadline date to: EUROEM 2000, Concorde Services Ltd, Suite 325, Pentagon Business Centre, Washington Street, Glasgow G3 8AZ, Scotland, UK. You should specify at the time of submission whether your paper is for HPEM, UWB-SP or UXO and specify a topic (see the full list on the website).

The abstract must consist of at least 250 words and must be limited to one page, including figures. Since there will be a reduction of about 70% of the original linear dimensions, letters and symbols in all diagrams should be sufficiently large and clear. Do not include list of references; a few open-literature references may be included parenthetically, for example (R L Lewis & J R Johler, Radio Sci 2, 75-81, 1976). Acknowledgement of financial support is not deemed appropriate. **Please note that it is the authors' responsibility and not that of the Conference Committee, to see that their abstract and paper are cleared for public release.**

All abstracts must be written in English. The text should be typed single space on A4 (8.27" x 11.69" or 210 x 297 mm) white paper. Margins should be 1.5" on left and right and sides and 1" top and bottom of page. The title should be centred in capital letters 1 inch from the top of the page. Author's name and complete organisational affiliation should be two lines below the title. For multiple authors, the **expected presenter** should be indicated by an **asterisk**. The text should start three lines below the last name. Double space between paragraphs.

Alternatively, you may submit your abstract via the web. **NB: Web submissions should be plain text only, no graphics allowed. If using graphics please submit camera-ready copy by post.**

A camera-ready paper will be requested prior to the conference, for accepted UWB-SP presentations. Instructions will be sent to the relevant authors.

For additional information please contact the Conference Secretariat, Concorde Services at (Tel) +44 (0)141 221 5411 or (Fax) +44 (0)141 221 2411 or visit our web site at: http://www.mcs.dundee.ac.uk:8080/~euroem

5TH INTERNATIONAL WORKSHOP ON

FINITE ELEMENTS FOR MICROWAVE ENGINEERING

FINAL CALL FOR PAPERS

GRAND CHALLENGES FOR NEW MILLENNIUM

John Hancock Conference Center, Boston, Massachusetts, USA
June 8-9, 2000

The 5th Finite Elements Workshop for Microwave Engineering will be organized by Electrical and Computer Engineering Department, Worcester Polytechnic Institute in cooperation with University of Florence, Italy and will be held on June 8-9, 2000 at John Hancock Conference Center, Boston, Massachusetts, U.S.A.

The workshop provides an international forum for reporting and discussing recent progresses and advances in the finite element technologies for microwave engineering. The details of the workshop can be found in http://ece.wpi.edu~jinlee.

February 1, 2000: One-page Abstract due
March 1, 2000: Acceptance Notification will be mailed to the corresponding author of the paper.
April 15, 2000: Pre-Register

Authors are invited to submit an original (camera-ready) one-page abstract of no less than 250 words. The abstract should explain clearly the content and relevance of the proposed contribution. No acknowledgments should be included. Your cover letter should include the complete mailing address, telephone, fax number, and e-mail address (if available) for the corresponding author. Please mail abstracts-do not send via facsimile. Fulll paper is due at the conference and will be under regular peer review process. Accepted papers will be published in a special issue of Electromagnetics, 2001.

Each presenting author is required to register, via a non-refundable **pre-registration fee of US$100** and must be sent by April 15, 2000. The registration fee, **to be determined,** will include the Workshop program and proceedings, attendance at all technical sessions, refreshments, the opening reception, and the banquet.

Local arrangements should be directed to:
Ms. Yurong Sun
5th Finite Element Wkshop for Microwave Engineering
EM/CAD Lab, ECE Department, WPI
100 Institute Road
Worcester, MA 01609, USA
Tel: 508-831-5757 Fax: 508-831-5491
Email: ysun@ece.wpi.edu

Abstracts should be directed to:
Prof. Jin-Fa Lee
5th Finite Element Wkshop for Microwave Engineering
EMCAD Lab, ECE Dept, WPI.
100 Institute Road
Worcester, MA 01609, USA
Tel: 508-831-5778, Fax: 508-831-5491
Email: jinlee@ece.wpi.edu

ABSTRACT GUIDELINES

Submit in English. Use single-spaced, 8.5x11 inch paper; using 12 point Times Roman or and equivalent serif typeface. Set margins to 25mm (1 inch) and set paragraph indentation to 3.5mm (0.14 inch). Type title in bold letters; centered at the top. Below title, center name of the author(s) with affiliation and complete mailing address.

ADVANCE PROGRAM, AND INFORMATION SENT BY MAY 1, 2000

Registration: Travel, lodging, registration and local information will be mailed with Advance Program by May 1, 2000. The advance registration fee for all participants, including session chairpersons and authors, is US$100. The fee includes the Workshop program and proceedings, attendance at all technical sessions, refreshments, the opening reception and the banquet.

LOCATION

The Workshop is planned to be held at the John Hancock Conference Center, Boston, MA, USA, on Thursday and Friday, June 8-9, 2000. Boston is the favorite conference venue in the Northeast US and one of the most popular conference cities in the US. The city is beautiful and alive. The charm and attractions of historic Boston should create an enjoyable environment for the workshop.

ORGANIZATION

Chairs

Z.J. Cendes, Ansoft Corp., Pittsburgh, PA, U.S.A
G. Pelosi, University of Florence, Italy

Secretary

J.F. Lee, WPI, Worcester, MA, U.S.A
R. Lee, Ohio State University, Columbus, OH, U.S.A

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R. Dyczij-Edlinger, Ansoft, Pittsburgh, PA, U.S.A
J. Jin, University of Illinois, Urbana-Champaign, IL, U.S.A
E. Lucas, Northrop Grumman Corp., Baltimore, MD, U.S.A

FINAL CALL FOR PAPERS

INTERNATIONAL SEMINAR

DAY on DIFFRACTION — *MILLENNIUM WORKSHOP*

St.Petersburg, Russia — May 29 - June 1, 2000

ORGANIZED BY
Faculty of Physics of St. Petersburg University
St. Petersburg Branch of Steklov Mathematical Institute
Euler International Mathematical Institute, St.Petersburg

JOINTLY WITH
University of Florence
University of Michigan

TECHNICALLY CO-SPONSORED BY
IEEE Antennas and Propagation Society

CO-SPONSORED BY
Russian Foundation for Basis Researches

STEERING COMMITTEE
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V.S. Buldyrev, St. Petersburg Univ., St. Petersburg
G. Pelosi, Univ. of Florence, Florence, Italy
J.L. Volakis, Univ. of Michigan, Ann Arbor, USA

LOCAL ORGANIZING COMMITTEE
I.V. Andronov (publications)
V.E. Grikurov (secretary)
A.P. Kiselev, M.A. Lyalinov
E.V. Novikova (visa support)

SESSIONS TO BE ORGANIZED

MATHEMATICAL ASPECTS OF WAVE PROPAGATION	M. Babich (Russia), S.Yu. Dobrokhotov (Russia)
NEW DIRECTIONS IN ASYMPTOTIC TECHNIQUES	G. Manara (Italy), V.S. Buldyrev (Russia)
CANONICAL DIFFRACTION PROBLEMS	V. P. Smyshlyaev (U.K.), G. Pelosi (Italy)
DIFFRACTION ON NON-SMOOTH OBSTACLES	Giraud (France), A.H. Serbest (Turkey), J.M. Bernard (France)
EM ANALYSIS TECHNIQUES	R. Tibrio (Italy)
UNDERWATER ACOUSTICS	G. Makrakis(Greece), N.S. Grigor'eva (Russia)
FLUID DYNAMICS	N.G. Kuznetsov (Russia), J. Ockendon (U.K.)
WAVES IN ELASTIC MEDIA	A.P. Kiselev (Russia)
PLATES, SHELLS AND VIBRATION	P.E. Tovstik (Russia)
NONLINEAR PHENOMENA	A. Samsonov (Russia)
NON-STATIONARY PHENOMENA	V.V. Borisov (Russia)

Proposals for session's organizing concerning various nature wave phenomena are encouraged!

Working language is English

The registration fee is 150 USD

IMPORTANT DEADLINES

Proposals for session organizing	ASAP
Papers submissions	Feb. 1, 2000
Acceptance of papers	March 1, 2000
Registration	April 1, 2000

Early registration is necessary to finalize visa formalities in time.
Registration fee is encouraged but not requested at this stage.

WAYS OF SUBMISSION

1. Electronic submission (mostly preferred!)

I.V. Andronov iva@aa2628.spb.edu
V.E. Grikurov grikurov@mph.phys.spbu.ru
A.P. Kiselev kiselev@pdmi.ras.ru

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