APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY (ACES)

NEWSLETTER

Vol. 9 No. 3 November 1994

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ACES NEWSLETTER STAFF

EDITORS

ACES JOURNAL

ACES NEWSLETTER AND JOURNAL COPY INFORMATION

Issue	Copy Deadline
March	January 13 (A CHANGE)
July	May 25
November	September 25

For further information on the ***ACES JOURNAL,*** contact Prof. Duncan Baker, address on page 2.

For the ***ACES NEWSLETTER*** send copy to Ray Perez in the following formats:

1. A hardcopy.
2. Camera ready hardcopy of any figures.
3. If possible also send text on a floppy disk. We can read any version of MICROSOFT-WORD and ASCII files on both IBM and Macintosh disks. On IBM disks we can also read WORDPERFECT and WORDSTAR files. If any software other than MICROSOFT WORD has been used on Macintosh Disks, contact the Managing Editor, Richard W. Adler BEFORE submitting a diskette. If it is not possible to send a Macintosh disk then the hardcopy should be in Courier font only for scanning purposes.

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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APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY (ACES)

OFFICER'S REPORTS

PRESIDENT'S COMMENTS

I was quite pleased with the recent special issue of the ACES Journal that dealt with the numerical computation of low-frequency electromagnetic fields. The guest editors for the special issue, Adalbert Konrad and Doug Lavers, make the important point "..that both sides of the computational electromagnetics community should work to establish mutual linkages since there is a considerable common ground to our research efforts." The two sides that Adalbert and Doug refer to, of course, are the high- and low-frequency sides.

I strongly endorse this philosophy for two reasons: my own work deals mainly with eddy-current nondestructive evaluation, and my company has developed a commercial code to solve such problems, which is based on volume-integral equations. The research that went into the development of the model that is the basis for this code came largely from work that was published in the IEEE Antennas and Propagation Society, and the IEEE Microwave Theory and Techniques Transactions. Both of these transactions deal with 'high-frequency' problems, yet I found their papers to be eminently suited for developing a 'low-frequency' eddy-current scattering code.

The second reason for endorsing the philosophy espoused by the editors, is that ACES should deal with all aspects of computational electromagnetics. Our credentials for solving (high-frequency) radiation and scattering problems are quite in order, so it is gratifying to me to see us get into the arena that deals also with inductances, torques, and motional emfs. If it starts with Maxwell's equations, it ought to end up in the ACES Journal (or Newsletter). I'm certain that we'll see more interdisciplinary papers and projects in the future.

I continue to be impressed with the number of radio amateurs who regularly use NEC, or are interested in using it, to solve antenna problems. This is a very practical application of computational electromagnetics, as Perry Wheless suggests in the July 1994 issue of the Newsletter. Perry is even talking about having a social gathering for ACES hams at ACES'95—talk about outreach! I like that idea; by making ACES accessible to hams, we may give them a home. Pass the word to those radio amateurs who are not yet members of ACES that we are interested in them. This is another side of the computational electromagnetics community that should be linked up to ACES.

Harold A. Sabbagh
Sabbagh Associates, Inc.
PO Box 7706
4639 Morningside Drive
Bloomington, IN 47408
Phone: (812) 339-8273
FAX: (812) 339-8292
email:has@sabbagh.com

PERMANENT STANDING COMMITTEES OF ACES INC.

COMMITTEE	CHAIRMAN	ADDRESS
NOMINATIONS	Stan Kubina	Concordia U/ECE Dept. 7141 Sherbrooke St. West, Montreal, Quebec, CANADA , H4B 1R6
ELECTIONS	Doug Werner	Penn State U/ARL P.O. Box 30 University Park, PA 16804
FINANCE	Andrew Peterson	Georgia Institute of Technology School of ECE Atlanta, GA 30332-0250
WAYS & MEANS	Frank Walker	Boeing Defense and Space Gp. P.O. Box 3999, MS 82-11 Seattle, WA 98124-2499
PUBLICATIONS	Perry Wheless	University of Alabama P.O. Box 11134 Tuscaloosa, AL 35486-3008
CONFERENCE	Richard Adler	ECE Dept. Code ECAB Naval Postgraduate School 833 Dyer Rd, Room 437 Monterey, CA 93943-5121
AWARDS	David Stein	Consultant PO Box 169 Linthicum Heights, MD 21090

MEMBERSHIP ACTIVITY COMMITTEES OF ACES INC.

COMMITTEE	CHAIRMAN	ADDRESS
CODE USER GROUP	Russell Taylor	McDonnell Douglas Helicopters 5000 E. McDowell Rd. Mesa, AZ 85205
SOFTWARE EXCHANGE	Randy Jost	SRI International 12510 Cliff Edge Dr. Herndon, VA 22070
SOFTWARE PERFORMANCE STANDARDS	Donald Pflug	Rome Laboratory/ERST 525 Brooks Rd. Griffiss AFB, NY 13441-4505
AI & EXPERT SYSTEMS	Wayne Harader	Ball Communications PO Box 1235 Broomfield, CO 80020
HISTORICAL	Robert Bevensee	Boma Enterprises PO Box 812 Alamo, CA 94507

ACES COMMITTEES MEMBERS

[NOTE: Fax number is used when available, if no fax is available, phone, or e-mail is supplied. NM means non-member of ACES, C93, etc, means he attended Conf 93]

ACES UK CHAPTER

Tony Brown	EASAT Ant. Ltd. Chilworth, Parkwood Dr. Baldwins, New Castle-Under Lyme, UK St5 5EU Fax: 44 782 209-060

AI & EXPERT SYSTEMS

Andrew Drozd	Kaman Sci, 258 Genesee St. UTICA, NY 13502, Fax: 315-734-3699 (NM, C92,93)
Stephen Fast	ARL/UT, 1202 Tremont, Cedar Park, TX 78613, Phone: 512-259-8543
Wayne Harader	Ball Aerospace, PO Box 1538, Broomfield, CO 80038-1538 Fax: 303-460-2884

AWARDS

Stan Kubina	Concordia U, 7141 Sherbrooke St. W, Montreal, Que, CANADA H4B1R6, Fax: 514-848-8652
John Rockway	NRAD, 2603 Deerpark, San Diego, CA 92110, Fax: 619-553-3791
Hal Sabbagh	Sabbagh Assoc. 4635 Morningside Dr. Bloomington, IN 47408, Fax: 812-339-8292
David Stein	Consultant, PO Box 169, Linthicum Heights, MD 21090, E-MAIL:74250.3402@COMPUSERVE.COM

CODE USERS GROUP

Richard Adler	NPGS, Code ECAB/833 Dyer Rd, Rm 437, Monterey, CA 93943-5121, Fax: 408-649-0300
Ruediger Anders	Applied EM Engr, 282 Martis Pl., Mahwah, NJ 07430, Fax: 201-512-0571
Tom Birnbaum	Delfin Sys, 111 Bean Creek Rd, #121, Scotts Valley, CA 95066, E-MAIL:BIRNBAUM@DELFIN.COM
Jim Breakall	PSU, 306 EE East, University Park, PA 16802, Fax: 814-865-3105
Tim Coffey	NRL, 4555 Overlook Ave, SW, Washington, DC 20375-5000 (NM)
Atef Elsherbeni	U of Miss, Anderson Hall, Box #13, University, MS 38677, Fax: 601-232-7231
Jeff Fath	1025 Killarney St, Roseville, CA 95747-6064, Fax: 916-643-1053
Christian Hafner	EM Gp, Zurich, Switzerland CH 8092, Fax: 41 1 261 1026
David Hudson	Lockheed, PO Box 33, Dept 1-331, Ontario, CA 91761, Fax: 909-395-6500
Henry Karwacki	Lockheed Sanders, 95 Canal St, PO Box 868, Nashua, NH 03061-0868, Fax: 603-885-8256
Bernard McHenry	CSR. Box 4127, MS/2210, Patrick AFB, FL 32925-0127, Fax: 407-494-5759
Mike McKaughan	US Coast Guard, 15 Mohegan Ave New London, CT 06320-4195, Fax: 203-444-8546
Lorant Muth	Natl. Inst. of Standards & Tech, 325 Broadway, Boulder, CO 80303 Phone: 303-497-3603 (NM, C92)
Chris Smith	12455 Donovan Lane, Colorado Springs, CO 80908-3805, Fax: 719-599-1942
Russell Taylor	McDonnell Douglas, 5000 E. McDowell Rd, Mesa, AZ 85205, Fax: 602-891-6003
Frank Walker	Boeing Def & Sp Gp, PO Box 3999, MS 82-11, Seattle, WA 98124-2499, Fax: 206-773-4173

CONFERENCE

Richard Adler	NPGS, Code ECAB/833 Dyer Rd, Rm 437, Monterey, CA 93943-5121, Fax: 408-649-0300
Dennis Andersh	Wright Lab/AARA, 2010 5th St. Bldg 23, Wright Patterson AFB, OH 45433-7001, Fax: 513-255-1100
Jeff Fath	1025 Killarney St. Roseville, CA 95747-6004, Fax: 916-643-1053
Pat Foster	Microwave & Ant. Sys., 16 Peachfield Rd, Gt. Malvern, Worc, UK WR14 4AP, Fax: 44-684-573509
Richard Gordon	U of Miss, PO Box 2435, University, MS 38677, Fax: 601-232-7231
Jim Logan	NCCOSC, 53225 Millimeter St. Rm 110, San Diego, CA 92152-7304, Fax: 619-553-3791
Ray Luebbers	PSU, 121 EE East, University Park, PA 16802, Fax: 814-865-7065
John Rockway	(NRAD), 2603 Deerpark, San Diego, CA 92110, Fax: 619-553-3791
Andy Terzuoli	AFIT, PO Box 3402, Dayton, OH 45401-3402, Fax: 513-476-4055
Frank Walker	Boeing Def & Sp Gp., PO Box 3999, MS 82-11, Seattle, WA 98124-2499, Fax: 206-773-4173
Perry Wheless	U of Alabama, Box 870286 Tuscaloosa, AL 35487-0286, Fax: 205-348-6959

ELECTIONS

Doug Werner	PSU, ARL, PO Box 30, University Park, PA 16804, Fax: 814-865-3105

ACES COMMITTEES MEMBERS(CONT.)

EXECUTIVE

Richard Adler	NPGS, Code ECAB/833 Dyer Rd, Rm 437, Monterey, CA 93943-5121, Fax: 408-649-0300
Jim Logan	NCCOSC, 53225 Millimeter St. Rm 110, San Diego, CA 92152-7304, Fax: 619-553-3791
Ray Luebbers	PSU, 121 EE East, University Park, PA 16802, Fax: 814-865-7065
Andrew Peterson	GA Inst of Tech, School of EE, Atlanta, GA 30332-0250, Fax: 404-853-9171
Hal Sabbagh	Sabbagh Associates, 4635 Morningside Dr. Bloomington, IN 47408, Fax: 812-339-8292
Frank Walker	Boeing Def & Sp Gp., PO Box 3999, MS 82-11, Seattle, WA 98124-2499, Fax: 206-773-4173
Perry Wheless	U of Alabama, Box 870286 Tuscaloosa, AL 35487-0286, Fax: 205-348-6959

FINANCE

Richard Adler	NPGS, Code ECAB/833 Dyer Rd, Rm 437, Monterey, CA 93943-5121, Fax: 408-649-0300
Jim Logan	NCCOSC, 53225 Millimeter St. Rm 110, San Diego, CA, 92152-7304, Fax: 619-553-3791
Ray Luebbers	PSU, 121 EE East, University Park, PA 16802, Fax: 814-865-7065
Andrew Peterson	GA Inst of Tech, School of EE, Atlanta, GA 30332-0250, Fax: 404-853-9171

HISTORICAL

Robert Bevensee	BOMA Enterprises, PO Box 812, Alamo, CA 94507-0812, Fax: 510-743-0381

NOMINATIONS

Stan Kubina	Concordia U, ECE Dept, 7141 Sherbrooke St. West, Montreal, Que, CANADA H4B 1R6
Jim Logan	NCCOSC, 53225 Millimeter St. Rm 110, San Diego, CA 92152-7304, Fax: 619-553-3791
Andrew Peterson	GA Inst of Tech, School of EE, Atlanta, GA 30332-0250, Fax: 404-853-9171

PUBLICATIONS

Richard Adler	NPGS, Code ECAB/833 Dyer Rd, Rm 437, Monterey, CA 93943-5121, Fax: 408-649-0300
Duncan Baker	U of Pretoria, EE Dept, Pretoria, S. AFRICA, 0002, Fax: 27 12 43 3254
Robert Bevensee	BOMA Enterprises, PO Box 812, Alamo, CA 94507-0812, Fax: 510-743-0381
David Davidson	U of Stellenbosch, EE Dept, Stellenbosch, S. AFRICA, 7600, Fax: 27 21 808 4981
Adalbert Konrad	U of Toronto, ECE Dept, 10 King's College Rd, Toronto, On, CANADA, Fax:416-971-2325
Reinaldo Perez	Jet Prop. Lab, 4800 Oak Grove Dr/MS 301-460, Pasadena, CA 91109, Fax: 818-393-4699
David Stein	Consultant,PO Box 169, Linthicum Heights, MD 21090 E-mail:74250.3402@COMPUSERVE.COM
Frank Walker	Boeing Def & Sp Gp., PO Box 3999, MS 82-11, Seattle, WA 98124-2499, Fax: 206-773-4173
Perry Wheless	U of Alabama, Box 870286, Tuscaloosa, AL 35486-3008, Fax: 205-348-6959

SOFTWARE EXCHANGE

Richard Adler	NPGS, Code ECAB/833 Dyer Rd, Rm 437, Monterey, CA 93943-5121, Fax: 408-649-0300
Ruediger Anders	282 Martis Pl., Mahwah, NJ 07430 Fax: 201-512-0571
Kenn Atkinson	2560 Huntingdon Ave, Alexandria, VA 22303, (C93)
Tom Birnbaum	Delfin Sys, 111 Bean Creek Rd, #121, Scotts Valley, CA 95066, E-mail:BIRNBAUM@DELFIN.COM
Jim Breakall	PSU, 306 EE East, University Park, PA 16802, Fax: 814-865-3105
Buddy Coffey	5617 Palomino Dr. NW, Albuquerque, NM 87120, Fax: 505-831-1031
Atef Elsherbeni	U of Miss, Anderson Hall, Box #13, University, MS 38677, Fax: 601-232-7231
Stephen Fast	ARL/UT, 10926 Jollyville Rd, Austin, TX 78759, Fax: 512-835-3259
Pat Foster	Microwave & Ant. Sys., 16 Peachfield Rd, Gt. Malvern, Worc, UK WR14 4AP, Fax: 44-684-573509
Todd Hubing	U of MO, 219 EE Bldg, Rolla, MO 65401-0249, Fax: 314-341-4532
Magdy Iskander	3280 MEB, Salt Lake City, UT 84112, Fax: 801-581-8692 (C94)
Stan Kubina	Concordia U, ECE Dept, 7141 Sherbrooke St. West, Montreal, Que, CANADA H4B 1R6
Jim Logan	NCCOSC, 53225 Millimeter St. Rm 110, San Diego, CA 92152-7304, Fax: 619-553-3791
James Masi	EE Dept/Box 2168, Springfield, MA 01119, Fax: 413-782-1746 (C92)
Mike McKaughan	15 Mohegan Ave New London, CT 06320-4195, Fax: 203-444-8546
Steven Merrill	300 Nickerson Rd, Marborough, MA 01752, Fax: 508-460-8100 (C93, NM)
Ed Miller	Ohio U, ECE Dept, 331 Stocker CTR, Athens, OH 45701 Email:EMILLER@BOBCAT.ENT.OHIOU.EDU

SOFTWARE EXCHANGE

Lorant Muth	325 Broadway, Boulder, CO 80303
Malcolm Packer	SAIC, 300 Nickerson Rd, Marlborough, MA 01752, Fax: 508-460-8100
Andrew Peterson	GA Inst of Tech, School of EE, Atlanta, GA 30332-0250, Fax: 404-853-9171
John Rockway	(NRAD) 2603 Deerpark, San Diego, CA 92110, Fax: 619-553-3791
Kenneth Siarkiewicz	Rome Lab, 525 Brooks Rd, Griffiss AFB, NY 13441-4505, Fax: 315-330-7083
David Stein	Consultant, PO Box 169, Linthicum Heights, MD 21090 E-mail:74250.3402@COMPUSERVE.COM
Andy Terzuoli	AFIT, PO Box 3402, Dayton, OH 45401-3402, Fax: 513-476-4055
Frank Walker	Boeing Def & Sp. Gp, PO Box 3999, MS 82-11, Seattle, WA, 98124-2499, Fax: 206-773-4173

SOFTWARE PERFORMANCE STANDARDS

Ruediger Anders	282 Martis Pl., Mahwah, NJ 07430 Fax: 201-512-0571
Robert Burkholder	OSU, 1320 Kinnear Rd, Columbus, OH 43212, Fax: 614-292-7297
Atef Elsherbeni	U of Miss, Anderson Hall, Box #13, University, MS 38677, Fax: 601-232-7231
Jeff Fath	1025 Killarney St. Roseville, CA 95747-6004, Fax: 916-643-1053
Pat Foster	Microwave & Ant. Sys., 16 Peachfield Rd, Gt. Malvern, Worc, UK WR14 4AP, Fax: 44-684-573509
Michael Hazlett	2010 5th St., Wright Patterson AFB, OH 45433-7001, Fax: 513-476-4414
Wolfgang Hoefer	U of Victoria, Box 3055, 3800 Finnerty Rd, Victoria, BC, CANADA V8W 3P6, Fax: 604-721-6230
Loredana Marinelli	Dept of Defense, Maribyrnong, Vic, Australia 3032, Fax: 61-03-318-3421(C93, NM)
Lorant Muth	325 Broadway, Boulder, CO 80303
Alan Nott	Engr. Dev Est, Private Bag 12, Ascot Vale, Vic, Australia 3032, Fax: 61-03-318-3421
Andrew Peterson	GA Inst of Tech, School of EE, Atlanta, GA 30332-0250, Fax: 404-853-9171
Hal Sabbagh	Sabbagh Assoc. 4635 Morningside Dr. Bloomington, IN 47408, Fax: 812-339-8292
Frank Walker	Boeing Def & SPace Gp, PO Box 3999, MS 82-11, Seattle, WA 98124-2499, Fax: 206-773-4173

WAYS & MEANS

Richard Adler	NPGS, Code ECAB/833 Dyer Rd, Rm 437, Monterey, CA 93943-5121, Fax: 408-649-0300
Jim Logan	NCCOSC, 53225 Millimeter St. Rm 110, San Diego, CA 92152-7304, Fax: 619-553-3791
Ed Miller	Ohio U, ECE Dept, 331 Stocker CTR, Athens, OH 45701 Email:EMILLER@BOBCAT.ENT.OHIOU.EDU
John Rockway	(NRAD), 2603 Deerpark, San Diego, CA 92110, Fax: 619-553-3791
Frank Walker	Boeing Def & Space Gp, PO Box 3999, MS 82-11, Seattle, WA 98124-2499, Fax: 206-773-4173

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). Candidate 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.

The names and terms of the present members of the Board are as follows:

James K. Breakall	1995	Ray J. Luebbers	1996	Duncan Baker	1997
Dr. Pat Foster	1995	Harold A. Sabbagh	1996	Edmund K. Miller	1997
Frank E. Walker	1995	W. Perry Wheless, Jr	1996	Andrew F. Peterson	1997

Stan Kubina
Chairman

ACES FINANCE COMMITTEE

The primary role of the finance committee is to oversee the society 5-year budget and update it at regular intervals. In addition, this year the Committee has been asked to address a number of other issues related to finance. These issues include:

(1) Prepare a charter for the proposed Committee Handbook, to be forwarded to Perry Wheless by late 1994 or so.

(2) Determine an appropriate investment strategy for the ACES reserves (CD's, stocks, ???).

(3) Determine an appropriate student conference registration fee (the fee is currently $150 including conference proceedings).

(4) Develop a policy regarding the use of ACES funds to subsidize banquet dinners, director's dinners, and other perks.

(5) Investigate the trade-off between membership dues, conference registration fees, and publication charges (subscriptions, page charges, etc.) with regard to their impact on overall ACES finances. Propose a specific recommendation to the Board of Directors as to what the target level of reserves should be and how the various sources of income should be balanced. Progress on these issues are as follows:

The previous 5-year budget (March 29, 1994) is being revised and extended to the year 1999. Overall, the society remains "in the black" into the foreseeable future, with projected reserves growing to the $100K level during 1996. It appears that we have the resources to publish three journals per year, pending BoD approval, and still increase our reserves. Of course, these projection assume that the conferences and short courses remain "in the black" and that membership does not fall significantly below the 75 institutional and 400 individual members projected throughout these years.

A charter has been drafted and will be delivered to Perry Wheless in the next few months.

The committee is divided on the investment strategy for our reserves. With the increase in rates of return on Certificates of Deposit, perhaps while this issue is being considered we should move an additional $20K from the main checking account into CDs. If we are going to keep our reserves in CDs, it would be advisable to use long-term CDs and to divide the reserves into at least 4 different CDs, each maturing at a different time of the year. This way we can get long-term yields but still have access to the money at regular intervals without penalty.

The committee is still considering the student registration fee and the use of ACES funds to subsidize officers, other BoD members, etc. Once the budget is updated and finalized, the committee will address task (5).

Submitted by Andrew F. Peterson, Acting Chair

ACES PUBLICATIONS

You are reading the third **ACES Newsletter** for 1994, and the third **ACES Journal** issue (Vol. 9, No. 3) was included in this mailing, as well. Vol. 9, No. 1 of the **ACES Journal** (March 1994) was 103 pages long and was comprised of contributed papers. The first issue 1994 of the **ACES Newsletter** was 61 pages long. Vol. 9, No. 2 of the **ACES Journal** (July 1994) was 185 pages long and contained seven contributed papers in addition to the excellent Special Section on the Numerical Computation of Low Frequency Electromagnetic Fields produced by guest editors A. Konrad and J.D. Lavers. The second 1994 issue of the **ACES Newsletter** was 91 pages long and was the first issue with the newly revised "department" areas orchestrated by Newsletter Editor-in-Chief Ray Perez.

The new style guidelines developed by Duncan Baker have been in use for two issues of the **ACES Journal**. So far, the results have been very positive. There have been no complaints from any author(s), and compliance with the guidelines has been excellent during this evaluation period. It is apparent that the page count in both Vol. 9, issues 1 and 2, was substantially reduced by the new format.

The overall impact of the recently enacted Excessive Length Page Charge and Voluntary Page Charge policies is unclear. A few authors may have joined ACES to take advantage of the larger "free" page allocation (12 versus 8) afforded to members. The experience to date is inadequate to draw any firm conclusions.

The paper submission rate has been somewhat lower than usual since May, 1994. Again, we have heard no complaints about the new policies, but it is possible that the page charge conditions are a discouragement factor. At this time, prospective authors should note both that (1) the **ACES Journal** is now in an excellent position for rapid turnaround on manuscripts, and (2) we would greatly appreciate any feedback regarding impact of the page charge policies.

Managing Editor Richard W. Adler has researched the costs for color printing, which necessarily must be paid by authors requesting this special service, and a summary report ("Color Printing Costs for the **ACES Journal** and **ACES Newsletter**") was published on page 86 in the July Newsletter. Authors with a preference for color graphics should familiarize themselves with Dick's report.

Ray Perez has settled into the role of **ACES Newsletter** Editor-in-Chief, and has energetically launched several initiatives. The quality and appearance of the 1994 Journals and Newsletters have been excellent. Both Ray Perez and Duncan Baker are to be congratulated (and thanked) for their efforts and accomplishments in 1994.

Publications was allocated 515 pages for publication of three issues of the **ACES Journal** in 1994 (two issues at 180 pages each and a third issue at 155 pages). Thanks to the economy of the new paper format, we actually printed less than 515 pages. The ACES Board of Directors has been asked to approve the same allocation for 1995.

We are receptive to the proposal of Special Issue topics at any time. I will discuss the two Special Issue projects now under way in the next Publications report.

W. Perry Wheless, Jr.
ACES Editor-in-Chief / Publications Chair
e-mail wwheless@ua1vm.ua.edu

ACES CONFERENCE COMMITTEE

The 1995 conference dates have been set as 20 - 25 March at the Naval Postgraduate School. We have the two meeting rooms that were used in 1993. The Ballroom is reserved for the Interactive Session, vendor displays and the Wine and Cheese Buffet on Tuesday 21st and the La Novia Room is reserved for Wednesday 22nd for the Awards Banquet, with the La Novia Terrace set up as a cash bar before the banquet.

The 1995 Conference chairman is Ray Luebbers, acting as the Technical Chair with co-chairmen Richard Gordon as the Publications Chair and Paul Goggans as the Publicity Chair. A budget for chairs was recommended based on past expenses, at $5,000, to be used to supplement the support that the chairmen can obtain from their employers.

The committee will work with the Board of Directors and the conference chairs to setup specific times and places at conference for committee meetings. Useful BOD meetings cannot be held until after the committees have had a time to meet and report to the board.

Respectfully submitted,
Richard W. Adler, Chairman

HISTORICAL COMMITTEE

During the summer of 1994 I consulted old ACES documents, Newsletters, and Journals and wrote the first draft of "The History of the Applied Computational Electromagnetics Society (ACES) 1985-1994". The draft occupied nearly 16 single-spaced pages. I mailed copies the middle of September to R. Adler, R. Anders, D. Baker, J. Breakall, A. Fleming, P. Foster, S. Kubina, J. Logan, R. Luebbers, E. Miller, H. Sabbagh, D. Stein, M. Thorburn, F. Walker, and P. Wheless and solicited their comments, information, and corrections by middle November.

I realize that others may disagree with the content of this draft and/or the format employed, and may wish to present the history in a different fashion. When I receive all the comments from the reviewers I will endeavor earnestly to satisfy them all in the second draft, planned for completion by January 1, 1995.

Respectfully submitted
Robert M. Bevensee
Chairman, Historical Committee

AWARDS COMMITTEE

David Stein, Chairman

We anticipate presenting substantially fewer awards than we presented last year, now that our "catching up" has been completed. Nonetheless, we remain committed to our objectives to recognize technical achievement, outstanding papers, and service to ACES, where such service is evaluated in terms of DEEDS and CONTRIBUTIONS as opposed to titles of elected or appointed office. As in the recent past, we are particularly interested in recognizing those individuals who contribute substantially to ACES but in non-prominent capacities.

The suggestion to replace plaques with certificates (as used by the IEEE) has been considered. At present, this would be a most unwise move; or at best (in terms of US currency), it is "penny-wise and dollar-foolish." ACES, to a far greater extent than the IEEE, needs to inspire additional volunteer service on the part of our members. Our continued viability and our very existence depend on volunteer service, and although we usually have more than enough candidates for positions as Directors, we have been less fortunate at the committee level. Furthermore, as one of you has observed, several individuals who are highly active in the IEEE are ACES members (hence, a new ad hoc committee to inspire service within ACES). Our awards program is only a small part of the total answer, but those who favor certificates are hereby invited to step forward with better ideas on motivation. In any event, it is imperative that we continue showing our appreciation to our people. If the IEEE does not value and appreciate their volunteer labor as much as we value and appreciate ours, then that is their problem.

Furthermore, unless we want to become a "Junior IEEE," let's not use their policies, procedures, actions, etc. as a categorical basis for our own. This is not in the best interests of either organization.

AD HOC COMMITTEE TO INSPIRE SERVICE WITHIN ACES

I have formed a small ad hoc committee to identify ways in which we can inspire our members to volunteer for positions of leadership and service within ACES. The developments which led to the formation of this "Tiger Team" are as follows:

1. Our primary limitation to date has been manpower, and our very existence and viability depend upon volunteer labor, ESPECIALLY IN LIGHT OF THE CHALLENGES PRESENTED BY NEW COMPETITION AND BY R&D BUDGET CONSTRAINTS. Even prior to these new challenges, several of our early members who are not longer with us were hoping for more than an annual symposium and a publication, but the other promising activities and services talked about in the late 1980s never manifested in time.

2. Although we generally have more candidates than open positions at the Board level, historically we have been less successful in inspiring people to serve at the committee level, especially in areas other than Symposia and Publications.

3. Those ACES members who choose to "become involved" often opt to serve other professional societies such as the IEEE in preference to ACES.

I have invited Stan Kubina, Jim Logan, Perry Wheless, and Dick Adler to serve on the committee with me, and they have accepted.

We anticipate presenting recommendations at the March 1995 ACES Board of Directors meeting.

USER GROUP COMMITTEE

The required mechanisms for distribution of appropriate materials are in place with Todd Hubing's anonymous ftp site at University of Missouri, Rolla and the MMACE system. Todd tells me that there is considerable activity at UMR (primarily code downloading). We have not loaded anything of significance on the MMACE machine.

The principal objective now is to collect solved problems, and other documentation needed to help new and inexperienced users of particular codes to be more effective. Don Pflug has indicated that he will soon have both some measured data and some GEMACS solved problems. Stan Kubina indicated in March that he is another potential source of some of what is needed.

If any of you have suggestions of others from whom I can solicit input, I will be happy to request specific data from them.

Russ Taylor

SOFTWARE EXCHANGE COMMITTEE

In terms of the software exchange committee, we have been somewhat dormant the first half of the ACES year (April to April). This has been my fault due to workload and changes in job situation. Since that is behind me, my objectives for the next six months are to finish the e-mail directory and set up a mechanism to let the membership exchange the work that they have done, both in terms of code and problem sets. I still have a couple of computer/telecommunications-related articles that I want to write, but I won't be able to finish them until after the upcoming PE exam at the end of October.

Randy Jost

Dr. Randy J. Jost
SRI International
1611 N. Kent St.
Arlington, VA 22209-2111

Internet: jost@washpost.wdc.sri.com
Phone: 703-247-8415
FAX: 703-247-8537

(Additional input from R Adler:)

There will be an upgrade to NEEDS 2.0, during the first quarter of 1995. It will contain fixes to bugs in NEC-81 (NEC2 for 16-bit PC and 640K base memory/300 unknowns), executable versions of NEC2DPC (NEC2 for 32-bit PC with extended memory/2000 unknowns), and an upgraded WINDOWS version of IGUANA to allow VGA graphics and WINDOWS device drivers for printers and plotters.

In addition, the commercial software package NECOPT (a NEC2PC with smart optimizer) demo disk will be made available to ACES members. ACES now has an on-demand software distribution "secretary" to handle all software mailings and software info requests

The "Software Sourcebook", that Frank Walker is trying desperately to complete between Boeing's ill-fated down-sizing actions that have been consuming all of his waking hours, will be welcomed by all.

SOFTWARE PERFORMANCE & STANDARDS COMMITTEE

A candidate for a canonical problem has been received from Adrian C. Hamilton, Huntington Engineering, UK. This problem determines the fields which penetrate an open-ended cylinder using three different CEM codes and techniques. The problem is difficult because the interior fields are small compared to the incident fields and depend in a critical way on the aperture modeling. The fields are computed using the MCS/EMAS finite element code and are compared to results from TFDS (a total field finite difference time domain code commercially available) and BOR3 (a method of moments code). The problem statement and results obtained appear suitable to qualify this contribution as a canonical problem.

Considerable effort has been expended at Rome Laboratory to construct a special test article that will prove useful in measuring and validating the software performance of a variety of computational electromagnetics (CEM) codes and analysis techniques. The test article, called the Transformable Scale Aircraft-Like Model (TSAM), is a metallic structure, roughly a 1/20 scale model of a wide-bodied aircraft upon which are mounted a suite of simple monopole-like antennas. The structure geometry is simplified deliberately (e.g. capped elliptical cylinder for fuselage, flat plates for wings & horizontal & vertical stabilizers & engine mounts, and four circular capped cylinders for engine nacelles) to permit very accurate geometry modeling of TSAM by a variety of CEM codes. Differences in calculated and measured results, e.g., platform based antenna patterns, antenna-to-antenna coupling etc, reflect algorithm and software implementation error once measurement errors are accounted for. A measurement program currently is underway at Rome Laboratory to measure the patterns of six monopole antennas mounted on TSAM (3 on top of fuselage, 3 on bottom) and all antenna-to-antenna coupling and isolation to include the effects of the TSAM platform. Because of its aircraft-like structure and simple geometry, platform effects will be present and measurable yet in a simple enough form to make simulation and analysis CEM calculations possible with a variety of codes. The transformable nature of TSAM makes it possible to add or subtract airframe features and determine these effects on the antenna patterns and couplings. It is planned that these measurements be made available to ACES through the Software Performance and Standards Committee and will serve as a complement to the already existing body of canonical software problems. Finally the TSAM is projected to evolve into more sophisticated forms permitting a variety of new measurements to be made.

Dr. Donald Pflug
Rome Laboratory/ERPT 525 Brooks Road
Griffiss AFB, NY 13441-4505
(315) 330-7642/DSN 587-7642
e-mail:pflugd@ers.rl.af.mil

REPORT FROM ACES UK CHAPTER

The UK Chapter is continuing to expand. We are targeting a 100% growth rate during 1994, which will make us over 40 members. Interestingly, we continue to attract a high percentage of corporate members, currently about 35%.

A constitution has been drafted and was circulated at the last Board of Directors meeting and to the UK Chapter Committee. This will be presented for adoption by the UK membership at the next AGM, to be held on November 2nd, 1994.

Our next one day meeting will be held in London and will be addressed by Dick Adler who has the morning to fill! The afternoon will be given over to papers from members. We are expecting a full programme and good audience.

One interesting area in the relationship between ACES UK and various European countries. We are in receipt of a number of enquiries from Europe about joining the UK Chapter. The UK Committee feels an input is needed from the BoD on this matter and would appreciate guidance.

Dr. A.K. Brown
Chairman

CEM NEWS FROM EUROPE

Coordinated by Pat Foster, MAAS, UK

The input on German activities in the CEM field is being held over for a future issue. Chris Emson of Vector Fields Limited is preparing an input on Low Frequency work in the United Kingdom which will appear in a future issue. Dr. Brian Austin of the Dept. of Electrical Engineering and Electronics, University of Liverpool, writes of his research projects in Computational Electromagnetics as follows:

Method of Moments: This has been in progress for the last eight years, involves primarily the use of MoM for the analysis and design of special-purpose antenna systems on complex structures. This work has made considerable use of the Numerical Electromagnetics Code (NEC-2) for modelling HF and VHF antennas on vehicles. Of interest has been the interaction of various unconventional antennas with the imperfectly conducting bodywork of the host vehicle with specific attention being directed at antennas which were either embedded in or printed on the glass windows of the vehicle. The study identified the interaction mechanisms which occur at frequencies around 100MHz and showed how the radiation characteristics can be changed to produce desirable patterns by means of appropriate feeding schemes [1].

Characteristic Modes: A parallel research study has investigated the "characteristic mode" approach which has involved the determination of eigen modes which are typical of any current-carrying geometrical structure, in particular as applied to motor vehicles and their associated antennas operating at HF. Characteristic modes can be determined from the impedance matrix within a typical moment method model of the structure in question. The matrix must be symmetrical, implying use of a Galerkin procedure. The NEC-2 code is not Galerkin whereas the MININEC code is but the pc-based version (BASIC) is severely limited in the size of problem which can be handled. A considerable amount of work was done to adapt a FORTRAN version of MININEC, which has no inherent size limitation so that characteristics modes on any conducting structure can be computed. The results have been very promising and the particular current modes which produce specific radiation patterns have been identified. An application of this technique has attracted research funding and work is well advanced in developing an optimised vehicle antenna system for near vertical incidence skywave (NVIS) propagation [2].

Material Investigation: Collaborative work with the Department of Civil Engineering deals with the use of radar for investigating structures of concrete and similar materials. In parallel with a measurement program using commercial "ground-probing" radar equipment, CEM studies are under way to complement this work. A special purpose, large diameter, transmission line has been constructed [3} so that the relative permittivity and conductivity of typical concrete-based materials used in civil engineering construction can be measured across a very wide range of frequencies using Time Domain techniques. The results are Fourier Transformed to the Frequency Domain. To support this work, a finite element model of the transmission line has been set up. The agreement between experimental and theoretical results is good. The computational procedure can now be applied to complex civil engineering structures. A promising ray tracing approach has also been examined. This multi-disciplinary project has attracted considerable research funding and the program is being extended to under-water structures.

Power Distribution Systems: A research program examines the electric fields produced by power distribution systems in order to develop a method of remotely sensing voltages, currents and other physical characteristics of a multi-conductor transmission system. Systems of infinite parallel conductors in two dimensions have been examined analytically and also using a finite element technique (commercial software). The computations are time-stepped to produce three phase system response which requires large amounts of computer time. The agreement between the analytical and computed results has not been good when the sensitivity of distant field values to specific power system changes is examined. Work is in progress to identify the causes of these errors in the commercial software.

Dr. Andy McCowen of Swansea University [5] writes:

The Computational Electromagnetics group resides in the Dept. of Electrical and Electronic Engineering at the University of Wales in Swansea. Dr. Andy McCowen leads a small group of research assistants and postgraduate students whose work is centered on the development of code and techniques to solve time--independent scattering problems in the resonance region. "In-house" codes have been applied to the following topics.

Microwave Hyperthermia: In conjunction with Hammersmith Hospital, a facility has been developed to model the specific absorption (SAR) associated with arbitrary arrays of two particular types of microwave antenna, the current sheet applicator (CSA), which was developed at Hammersmith for the treatment of breast cancer, and the embedded dipole antenna which is a thin (needle-like" antenna for the treatment of deep-seated tumors. The facility models the SAR for an array of antennas with arbitrary configuration in a homogeneous medium of body tissue. The computed electric fields can then be used as the incident field distribution for the scattering problem caused by inhomogeneous regions of fat/bone/muscle et cetera. The scattering is solved by a conjugate gradient FFT (CGFFT) method applied to the EFIE and its application has shown up significant changes in the predicted SAR distributions compared to the homogeneous models.

Mixed Conductor/Dielectric Scatterer: With the current interest in microstrip structures, new codes are being developed to model microstrip on infinite and finite substrates. Efficient CGFFT methods have been used to solve for infinite substrates. Basically these schemes are efficient because they solve only for the 2D currents on the microstrip by making use of a modified Green's function to account for the infinite layered and grounded substrate. To model finite substrates, a new CGFFT method has been developed to solve the full 3D EFIE efficiently (abstract submitted to ACES 95). A general purpose MoM code has also been developed, based on Rao, Wilton and Glisson's formulation, and this is currently being used on small microstrip antennas to validate results from the CGFFT code.

Near-fields: The computation of near -fields via MoM is a standard post-processing procedure but it is prohibitively expensive in CPU and memory if the whole of the near-field region surrounding a scatterer in the resonance region is to be viewed. Once a solution to the 3D EFIE has been computed by the CGFFT method, a post-processing procedure (Abstract submitted to ACES 95) based on the same method allows for the efficient calculation of the nearfields. A comparison of the near-fields computed by MoM and CGFFT has shown good agreement for small dielectric and mixed conductor/dielectric scatterers.

1 B. A. Austin and R.K. Najm, 'Conformal on-glass vehicle antennas at VHF', IEE Conf., ICAP93, p 900-903.

2 B.A. Austin and K.P. Murray, 'Synthesis of Vehicular antenna NVIS radiation patterns using the method of characteristic modes', Proc IEE on Micro, Antennas and Prop, Vol 141, No. 3, 1994, p 151-154.

3 M.R. Shaw, S.G. Millard, M.A. Houldon, B.A. Austin and J.H. Bungey, 'A large diameter transmission line for the measurement of the relative permittivity of construction materials', British J of NDT, Vol 35, No. 12, 1993, p 696-704.

4 Dr. Austin can be reached on ee104@liverpool.ac.uk (e-mail) or (0)51 794 4540 (FAX)

5 Dr. McCowen can be reached on A.MCCOWEN@SWAN.AC.UK (3-mail) or (0) 792 295868 (FAX)

MODELER'S NOTES

Gerald J. Burke

Modeler's Notes for this issue will be confined to NEC–4 and NEC–2 for the Macintosh. The distribution status of NEC–4 has still not been resolved. It seems to be agreed that it no longer needs to be Military Critical Technology and can be distributed through LLNL/DoE. However, we have not yet worked out a new way to handle the distribution. At this time we still require that the NEC Order Form be filled out to release it as a code in development, and also need a letter from a DoD contracting office representative authorizing us to send the code.

NEC–4 has now been updated to NEC–4.1, which includes three modifications to the solution algorithm, three new commands and a revised User's manual. Future shipments will be of NEC–4.1, and the revised code and manual have been sent to about 40 people who had received the original NEC–4. New features in NEC–4.1 are:

- The moment-method solution for charge at a junction has been modified to avoid instability in the solution for junctions of many wires with differing lengths.
- The exact form for the field due to wire end caps is used on the wire axis.
- A faster form was used for evaluating the integral of e^{-jkR}/R for large R.
- The tolerance was tightened in the test for parallel and overlapping segments.
- Commands have been added to compute near E and H fields along lines in space and to evaluate the line integral along the path.

The main impetus for getting a new version out was to correct an instability in the solution for some wire junctions. This problem has shown up in several models, but the worst was an antenna modeled by Lance Koyama at NRAD, which was an inverted cone over a ground plane driven from a single vertical wire segment at its base. The junction of many wires with differing lengths, resulting from the hexagonal outline of the cone, triggered the problem.

NEC–4, like NEC–2 and 3, applies an a priori condition on the distribution of charge at a junction rather than including additional unknowns for the junction in the MM impedance matrix. In NEC–2 and 3 the charge condition is based on a relation derived by Wu and King by considering a tapered wire [1]. Their result is the same as the condition that Schelkunoff and Friis [2] obtained for junctions of "loosely coupled wires" by enforcing continuity of scalar potential at the junction while considering each wire to be infinite in length and isolated from other wires. NEC–4 takes the approach of Schelkunoff and Friis a step further by treating the wires at a junction as semi-infinite, with the actual radius and position relative to other wires. The distribution of charge density among the wires is determined from a moment-method solution for continuity of potential across the junction. At a junction of many wires the charge density decreases rapidly along each wire as the junction is approached, since charge of the same sign wants to spread out. However, in the thin-wire approximation the actual wire ends overlap, so with a factor such as unequal segment lengths thrown in it not surprising that the computed charge density may become small and alternate in sign between wires at such a junction. The fix in NEC–4.1 was simply to use the value of charge density at a small distance back from the junction on each wire, as determined by the wire radius and number of wires. With this modification the solution remained stable for the examples tested. Comparisons with the careful surface model of stepped-radius wires [3] and checks of power balance using average gain were as good or better than with NEC–4.0. In particular, the solution for Lance's antenna yielded an average gain around 1.12, as compared to 1.32 with the NEC–2/3 charge condition and garbage with the NEC–4.0 treatment. Hopefully this modification will take care of the problem permanently, but just in case, a new command JN has been added to NEC–4.1 so that the user can switch between the moment-method solution for charge at junctions and the condition used in NEC–2 and 3.

In NEC–4.0 the field due to a wire end cap should have been evaluated with a simple, exact expression for points on the axis of the cap. However, I had switched a e^{-jka} to $1-jka$ to test the effect on solution time and forgot to switch it back. This problem has been fixed in NEC–4.1, and gives better results for thicker wires.

The integral of e^{-jkR}/R over a segment is evaluated in NEC–4 by integrating the terms in a five-term expansion of the exponential about $R = R_0$, where R_0 is the distance from the center of the segment to the evaluation point. The series evaluation is faster than numerical integration, but results in severe loss of precision when R is greater than about ten times the segment length. The roundoff error gets worse with more terms in the series, while the truncation error gets smaller. NEC–4.0 switched to a three-point Gaussian integration for R greater than six times the segment length. NEC–4.1 now uses a series that is accurate for large R. Evaluation of the series is about three times faster than the three-point Gaussian integration. However, it makes little difference in running time since it is a small part of the solution.

The tolerance in testing for parallel segments involved subroutine SEGXCT which checks for segments that are parallel and overlapping (duplicate segments or wires) or segments that intersect or pass close enough to violate the thin-wire approximation. In NEC–4.0 the segments were treated as parallel if the square of the angle between them was less than 10^{-3}. This was a little to loose a tolerance, and resulted in a false warning in a model that I was running. Hence the tolerance was reduced to 10^{-6} so that the sine of the angle was less than 10^{-3} for parallel segments. However, after the 40+ new copies of NEC–4.1 had been sent out we again heard from Lance Koyama with a problem that gave a false warning about nearly intersecting segments. It turned out that the model involved segments that were very nearly, but not quite, parallel. With the old, loose test the segments were tested as parallel and found not to be overlapping. With the tighter tolerance in NEC–4.1 the segments were recognized as not parallel and were tested for intersection. Since finding the intersection point of nearly parallel lines is an ill-conditioned problem, the single precision code was not up to the task. The safest fix was determined to be converting part of subroutine SEGXCT to double precision (the double precision NEC–4.1 did not have a problem). People who have received NEC–4.1 prior to September 14, 1994 should add the declaration

```
      REAL*8 DSX,DSY,DSZ,SLEN,DTX,DTY,DTZ,TLEN,TOL,SDTS,TDTS,SDOTT,DEN,
     &       SXX,TXX,SDX,SDY,SDZ,TDX,TDY,TDZ,DMINS
```

at the beginning of subroutine SEGXCT in the single precision nec4s.f file.

Commands have also been added to NEC–4 to compute the near electric or magnetic field along straight lines between specified points in space. These commands, LE for electric field and LH for magnetic field, complement the NE and NH commands that compute field values over a grid of points with increments in x, y and z. The LE and LH commands print the component of the field along the specified line and two components normal to the line, in the horizontal plane and in the vertical plane containing the line. In addition, the commands compute the line integral of the field component along the specified line. Line integrals are computed for each LE or LH command, and also a cumulative line integral is printed when several LE or LH commands are grouped together, so piecewise linear and possibly closed paths can be integrated.

In addition to these changes in the code, the NEC–4 User's manual has been revised to include the new commands JN, LE and LH, and the output for the examples is now from the double precision NEC–4.1. The output in the original manual was from an early version of NEC–4, and did not exactly agree with that produced by the code that was released.

The Modeler's Notes column in the July Newsletter included a comparison of running times of NEC–2 for a 300 segment wire model on several computers and PCs. It was noted there that the Absoft MacFortran II, Version 3.2 compiler produced code that ran substantially faster than the code from the MacFortran/020 compiler on a Macintosh. This was particularly true for a Mac Quadra since the MacFortran II compiler can produce code that takes full advantage of the 68040 processor. However, after mailing the column to ACES I took a closer look at the output for the NEC–2 examples and found that all was not well with the results for models involving surface patches. In fact scattering by a sphere, with patches and no wires, give a result of zero or "NaN". The problem was traced to subroutine HINTG that evaluates the magnetic field due to a patch. When the -O option, for general optimization, was removed from the compilation the code gave the correct result, but of course was slower. On calling Absoft I was told that yes, there is a bug that occasionally pops up in optimization in the Version 3.2 and 3.3 compilers. The proper way to get around it would be to remove the -O optimization and add individual optimization options until the problem occurred to find the offending option. However, they suggested an expedient approach of compiling HINTG with -O and the additional option of -z which instructs the compiler to "consider folding leaf procedures only." While HINTG is itself a leaf procedure, the -z causes enough of a change in the way that the optimizer works to escape the bug. Ordinarily I would try to cure a problem like this by making small changes in the code to alter the compilation process, but this bug was very robust, occurring in both double and single precision codes and seemingly immune to code changes except for the insertion of print statements to track it down. There was a recent report on the nec-list@ee.ubc.CA news server that the nec2d in ftp.netcom.com gave incorrect results for patches when compiled with the Salford compiler for DOS. One might wonder whether there could be some common ancestry in these compilers.

With the -z option used on HINTG the code now seems to run properly. I compiled it with the -s option for static variable allocation, and also added the -N9 option for frequent command-. checks so that it can be interrupted and can run in the background under MultiFinder or System 7. The -s should not be necessary and seems to slow the code down somewhat. However, without doing a thorough test of all features of the code, I feel more comfortable with static variable allocation. Since we occasionally get requests for NEC–2 for the Mac from people who do not have a compiler, I have set up executable code files for single precision and double precision, 300 and 600 segments maximum and optimized for 68040 as well as general 68020/30/40. While the 68040 code is faster on a Quadra, it will crash other Macs.

Hopefully by the next Newsletter I will be able to report on the performance of Absoft's new compiler for the Power PC Macs which Absoft says is free of the optimization bug that got subroutine HINTG. The question is what other goodies does it have waiting for us? MacWeek had reported that Motorola would release a Fortran compiler for the Power PC Macs in July, but when I checked with Motorola on September 1 the story was "no compiler yet; check again in a couple of weeks."

References:

[1] T. T. Wu and R. W. P. King, "The Tapered Antenna and its Application to the Junction Problem for Thin Wires," *IEEE Trans. Antennas and Propagation*, Vol. AP-24, pp. 42-45, 1976.

[2] S. A. Schelkunoff and H. T. Friis, *Antennas: Theory and Practice*, Wiley, New York, 1952.

[3] A. W. Glisson and D. R. Wilton, *Numerical Procedures for Handling Stepped-Radius Wire Junctions*, Department of Electrical Engineering, University of Mississippi, March 1979.

Computational Electromagnetic Modeling Codes on the Internet

Todd Hubing
University of Missouri-Rolla

Introduction

The widespread popularity of the internet has made it much easier for the authors of numerical electromagnetic modeling codes to distribute their software. In the past, the time and expense associated with copying software to diskettes or tapes and mailing them to each prospective code user prevented many code developers from making their software widely available. Now, a number of numerical electromagnetic modeling codes are available either free of charge (freeware) or for a nominal charge (shareware) that the user pays after trying out the software and deciding to keep it.

This article provides a brief description of computational electromagnetic modeling codes that are available as freeware or shareware on the internet. These are codes that were known to the author at the time the article was written. It is very likely that there are additional numerical EM codes on the internet that are not mentioned here. If you are aware of any of these codes, please bring them to the attention of the author at *thubing@ee.umr.edu*. We will publish an updated listing in a future issue of the ACES Newsletter.

Most of the codes in this article were announced or discussed in the usenet newsgroup *sci.physics.electromag*. If you are looking for a modeling code with specific capabilities, try posting your requirements to this newsgroup. Many expert users of commercial and non-commercial electromagnetic modeling codes monitor *sci.physics.electromag*. Questions about the capabilities or availability of computer modeling codes usually generate a number of responses.

Moment Method Codes

The Numerical Electromagnetics Modeling code (NEC) is probably the best-known and most widely used of all 3D, full-wave electromagnetic modeling codes. NEC2 is available by anonymous ftp from *ftp.netcom.com* in the directory */pub/rander/NEC*. NEC2 is a thin wire and/or surface patch modeling code. The original source code is in FORTRAN and executable codes are available for a variety of PCs and workstations.

A static 3D moment method is employed by three codes available at *rle-vlsi.mit.edu*. *Fasthenry*, *Fastcap*, and *Fastlap* are codes designed to calculate the resistance, capacitance, and inductance of 3D geometries.

Finite Element Method Codes

ELCUT is a 2D finite element modeling code for solving plane and axisymmetric problems of electrostatics, non-linear DC magnetics, current flow, non-linear heat transfer, and stress analysis. It is shareware and runs on IBM-compatible PCs. This software has gotten excellent reviews on the internet. ELCUT is available by anonymous ftp from *OAK.Oakland.edu* in the *SimTel/msdos/plot* directory.

A 3D finite element modeling code called EMAP2 is available at *emclab.ee.umr.edu* in the */pub/emap* directory. EMAP2 is a node-based code that is useful for modeling waveguide or resonant cavity problems.

Finite Difference Time Domain Codes

The 3D finite difference time domain code listed in Appendix B of the book, *The Finite Difference Time Domain Method for Electromagnetics*, is available in the */pub/aces/fdtd* directory at *emclab.ee.umr.edu.* The authors of the book and the code are K.S. Kunz and R.J. Luebbers.

XFDTD is a 2D finite difference time domain code with a simple X-window interface. It is available at *microwave.jpl.nasa.gov* in the */pub* directory.

Other Useful Codes

A demo version of the Multiple Multipole Code (MMP) is available from *sirius.ethz.ch.* MMP is an electromagnetic modeling code that employs the generalized multipole technique. Also on this site are some sample data files and a very good graphical user interface that runs on Sun workstations.

DDSCAT is a code that can be used to calculate scattering and absorption of electromagnetic radiation by arbitrary targets. It uses a method called Discrete Dipole Approximation (DDA) in which the target is replaced by an array of point dipoles. DDSCAT is available by anonymous ftp from *astro.princeton.edu* in the directory */draine/scat/ddscat/vers4b.*

A Fortran code for calculating the scattering from dielectric spheres using the Mie Series is available in a file called *MIEV.tar* at *microwave.jpl.nasa.gov* . A similar code for MicroSoft Windows called *mietab42.zip* is in the directory */pub/pc/win3/misc* at *ftp.cica.indiana.edu.*

ACCURACY & PUBLICATION: REQUIRING QUANTITATIVE ACCURACY STATEMENTS TO ACCOMPANY EM DATA

With the proliferation of quantitative results in EM arising from more sophisticated experimental apparatus and from almost-universal use of computer models, the need to accompany such data with accuracy (or error) estimates is becoming acute. It's not unusual to find published articles that contain numerical results having no independent confirmation of their accuracy or even lacking any discussion of how good the author considers the results to be. And, when accuracy is actually considered, it is becoming quite common to find results from another numerical computation, such as a moment-method model, referred to as the "exact" solution without any accompanying measured data. Furthermore, in such cases, the usual discussion finds only qualitative descriptors such as "good agreement" or "excellent results" being used. Even when accuracy is quantitatively addressed, the comments made about it are usually inconsistent and incomplete. For example, one author might consider only impedance errors important, another might view peak gain the primary quantity of interest, and still another might cite shifts in pattern nulls the limiting factor.

Consequently, with few exceptions, the reader is left with only a fuzzy, qualitative interpretation of accuracy and error concerning the results included in a publication. Even less insight is offered the reader concerning the accuracy and error characteristics of the process (computational or experimental) used to generate that data if that same process were to be used for substantially similar problems. The situation only gets more fuzzy when the reader wonders about the accuracy of that process and its error characteristics when used for substantially different problems.

Various attempts have been made to acquire a better quantitative understanding of how good are the results produced by measurement and computation as presented in professional forums. Two workshops on the topic of software validation were held at the 1989 and 1990 AP-S Symposia.

A series of articles on validation of soundwave propagation models were presented in a recent issue of the Journal of the Acoustics Society of America and a special issue of the ACES Journal was devoted to validation of CEM (Computational Electromagnetics) models. However, progress has been slow in promoting a consistent "validation ethic" in not only the ACES Journal and meeting proceedings, but in other media as well, such as the various EM-related IEEE Transactions, and other similar publications. A possible explanation for why little progress in validation has occurred is having too-ambitious goals. For various reasons, it might be more productive to approach this problem incrementally rather than expecting its unit-step solution.

This is a viewpoint that has been discussed at recent ACES meetings and which was also proposed (by E. K. Miller), debated, and endorsed nearly unanimously at a meeting of the Magazine Editorial Board of the Antennas and Propagation Society at the 1994 Seattle Symposium. It was concluded there that the issue of validation of results and their quantitative accuracy remains critically important to the CEM community, and also that taking a first, albeit small, step is better than continuing the status quo. We are therefore requesting consideration by the members of the proposal that the following draft policy be imposed on all future submittals to the ACES Newsletter and Journal. We anticipate that a similar policy will be implemented by the AP-S Magazine, and, possibly modified, by the AP-S Transactions as soon as the policy's utility has been established.

The policy to be implemented would require an author to add a separate section following the introduction to an article, where statements of the following general form, with whatever elaboration is appropriate, will be included. Note that further elaboration of each item can also be contained in the body of the article, but it is imperative that this summary section be included in any case. While the guidelines below were written specially for numerical computations, the first three apply as well to measured results.

1. "The results presented here are estimated to be accurate to ________," where quantitative statements such as: "The error in peak gain is ~ 0.5 dB; and/or "Nulls in the scattering pattern are located to within ~ deg; and/or "Input impedance is obtained to within 5 ohms; and/or "etc. are made.

2. "This estimate is based on using the following kind(s) of validation exercise(s) _____," where whatever experimental, analytical and/or computational validation that has been used is summarized.

3. "The kinds of problems for which the above error/accuracy statement can be made for this process include _____," where the problem geometry and electrical characteristics are summarized.

4. "Nominal sampling densities required to achieve these estimated accuracies are _____," where wavelength-dependent and/or geometry-dependent values are given.

5. "The operation count needed to exercise the model reported here is estimated nominally to be Af^x, . . . " or some equivalent statement, where numerical values for A and x are given. Note that while providing computer running times is acceptable, that alone is insufficient because there is such a variation in computer architectures that model-to-model comparisons based on running time are not very informative.

6. ". . . and the variable storage need to exercise this model is estimated nominally to be Bf^y," where again numerical values for B and y are given.

Ed Miller
Ohio University, ECE Dept.
Stocker Center
Athens, OH 45701

The Practical CEMist
- *practical topics in communications* -

Perry Wheless, K4CWW

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Dr. W. Perry Wheless, Jr.
P.O. Box 11134
Tuscaloosa, AL 35486-3008
Office phone 205-348-1757
FAX 205-348-6959
Home phone 205-759-4586
Internet e-mail wwheless@ua1vm.ua.edu

You are invited to share your experience and knowledge of practical topics in communications involving computational electromagnetics with the ACES membership. Several dozen ACES members are known to have the results of relevant work on hand, and I have received many statements of intent to contribute. Unfortunately, these well-meaning individuals generally continue to walk that famous road "paved with good intentions." Perhaps this Call for Papers will help put their steps onto the right path! If you have not previously expressed an interest in authoring an article for this department but have some practical information you would like to see disseminated and recorded in an archival publication for future reference, please get in touch with me at your earliest convenience. We are interested in developing a broad author base for future contributions of material to this column.

Ham Radio Dinner at ACES'95: If there is any interest, a dinner meeting of radio amateurs in ACES at the 1995 annual Symposium in Monterey, CA, can be easily organized. Please let me know if you wish to have such an event started. I would appreciate a short note, on your QSL card or otherwise, if you think the proposal has merit and you would like to participate.

HF Operating: The regular operations on 7.160 MHz by Jim Breakall (WA3FET), Dick Adler (K3CXZ), Al Christman (KB8I) and Perry Wheless (K4CWW) have become sporadic over the past two months. It's a crying shame that work has a way of interfering with our hobbies! However, it is possible that some ACES schedule on either the 40 or 20-meter bands can be established for the future. If you would like to see this happen, please get in touch with me.

Next Issue: I am hopeful that we will have an interesting article on propagation prediction finally completed in time for the next installment. Also, you may anticipate seeing some case study results using the NEC-OPT software package which has just recently been released by Paragon Technologies, Inc., State College, PA. I would like to acknowledge the excellent support of Todd Erdley, Vice President of Paragon, for the development of some articles for this department using their new product; it was not quite possible to get a paper ready for this issue of the *ACES Newsletter*, but you will have something to look forward to in the next issue. I know that many of you are anxious to see some application results obtained with this exciting new tool, and that you will be most favorably impressed with its capabilities.

This Issue: HF communicators using horizontal dipoles or dipole-like wire antennas often assume that the most effective radio link will be established when both receiving and transmitting antennas are orientated broadside to each other. However, it turns out that the endfire vertical radiation from low-height antennas can be stronger than the broadside horizontal component. The feature article for this installment of **The Practical CEMist** presents some useful information, based on NEC modeling, regarding the "best" orientation. Veteran radio engineers have likely learned the findings of this study through experience, but newcomers to HF communications may be somewhat surprised by the results. The article conclusions are supported by several years of practical on-air dx experience "over-the-Pole" at 14 MHz with a low-height antenna orientated North-South.

Rick David (WC4Q) received the M.S. degree from The University of Alabama in 1993. He was an Instructor of Electrical Engineering 1993-1994, and has recently joined the U.S. Coast Guard in Virginia, where he will be engineering HF communication systems.

Some Practical Aspects of Low–Height Dipoles Used for HF Communications

R.J. David, Jr., and W.P. Wheless, Jr.

Department of Electrical Engineering
University of Alabama
Tuscaloosa, AL 35487

ABSTRACT

Horizontal dipole antennas, both $\lambda/2$ and extended–length, are deployed extensively in 3–30 MHz (HF) radio communication sytems. In many cases, the antenna is in close proximity to the earth's surface. Broadside, horizontally polarized radiation is generally assumed to be the dominant characteristic of such horizontal dipoles. However, on–axis (endfire) vertically polarized radiation at low elevation angles above the horizon can be comparable to, or even exceed the strength of the horizontal broadside component. The Numerical Electromagnetics Code (NEC) has been used to investigate radiation pattern profiles selected to show the features of the endfire radiation. The on–axis predicted field from NEC is compared to measured values for an 18.1 MHz $\lambda/2$ dipole at several heights above real ground to illustrate the reliability of the predictions of the code.

INTRODUCTION

Radiation characteristics of horizontal dipoles in free space and above ideal ground have been documented extensively. The most common depiction of dipole radiation is an azimuth plot of $|E_\phi|$ in the $z = 0$ plane, which has fostered a widespread misconception that other radiation pattern profiles are insignificant. It is commonly believed, even among communications engineers, that the generally correct deployment of a horizontal dipole antenna is directly broadside to the distant station in the HF communications link. Contrary to that belief, it is possible to show that the on–axis vertically polarized radiation from a horizontal dipole close to real ground can be highly effective, and even superior, for two–way hf communications when compared to the horizontally polarized broadside lobe/component.

In this study, the $+z$ axis is taken to be perpendicular to the earth–air interface, with $z = 0$ corresponding to the interface plane. The vertical component, E_v, is the E–field component perpendicular to the earth–air interface (i.e., parallel to the z axis). Through various radiation profile plots developed in the course of this study, many interesting and relatively unknown characteristics of endfire vertically polarized radiation from horizontal dipole antennas near real ground can be seen. At low heights above ground, it is shown that the broadside radiation intensity becomes attenuated while the axial radiation becomes relatively more significant. When the dipole is very near to the earth (lower than approximately 0.1λ) and radiation at a low elevation angle above the horizon is involved in the propagation path, it may be better to orient the dipole axis toward the distant station rather than employ the standard broadside orientation.

MEASURED DATA

On–axis horizontal plane field strength measurements on an 18.1 MHz $\lambda/2$ dipole at various heights above real ground were made at the Cedar Vally, UT, antenna test range operated by Eyring, Inc., Provo, UT. The dipole was supported in the center and off each end by three wooden masts as depicted in Figure 1. The vertical component of electric field, E_v, was measured on–axis at a distance of 147 meters from the dipole's center. Each mast was equipped with a sliding block and halyard so that desired elevations of the antenna from ground level to twenty feet above ground could be attained precisely. Impedance, VSWR, and field strength data was collected at heights of zero to twenty feet above ground in two–foot increments. Because the feed–point impedances were transformed through a 1.5:1 balun, they cannot be directly compared to NEC impedance predictions, and this paper considers only radiation pattern features. Constant rf power was maintained to the antenna feed point for all elevations above ground, and the vertical component of electric field was measured with a Rhode & Schwarz ESH2 receiver with HFH2–Z2 loop antenna. The center of the loop antenna was 1.5 meters above the ground.

Ground parameters at the antenna site were measured by Eyring personnel using an inverted monopole technique [1]. Actual measured values of ground conductivity, σ, and relative permittivity, ϵ_r, were used in the numerical analysis.

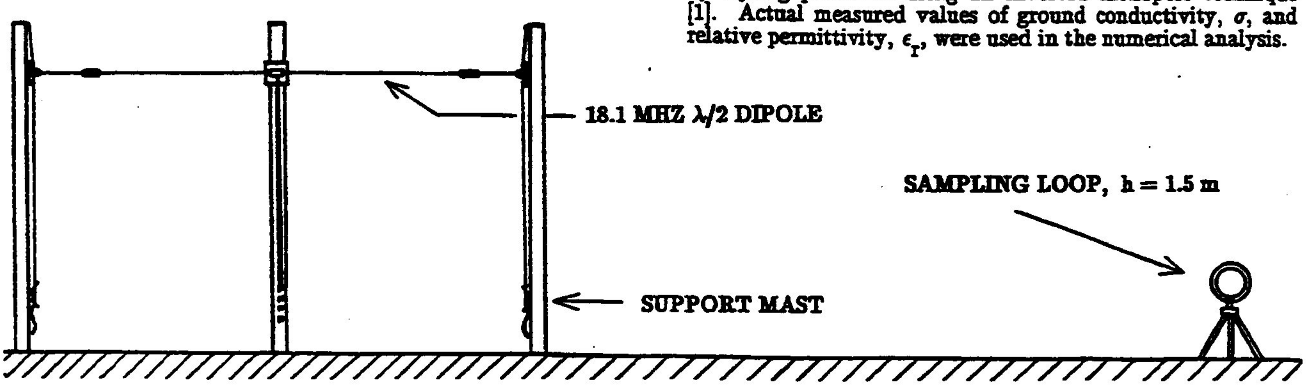


Figure 1. Adjustable–height dipole above real ground and E_v receiving loop antenna.

NUMERICAL ANALYSIS

The widely used modeling code, NEC (Numerical Electromagnetics Code) [2,3], was selected for use in this study because it has the capability of modeling wire antennas near to the earth–air interface [4]. The version of NEC employed in this study uses the thin wire approximation to the electric–field integral equation in a moment method solution, with the effect of real ground included by the Sommerfeld integrals.

First, predicted field strength values from NEC were compared with the limited measured data, described above, to test NEC's ability to accurately predict radiation field strengths in this case. NEC reports values of E_θ and E_ϕ, where E_θ becomes synonymous with E_v in the horizontal plane. The computed and measured field strengths are presented in Table 1, which shows excellent agreement except for the case when the antenna was actually resting on the ground at elevation zero. It was noted in the course of the measurements that the antenna VSWR was a negligible factor except when the dipole was lying on the ground, and the large mismatch in that case partially accounts for the discrepancy between computed and measured E_v. Also, one expects the numerical analysis to break down (or at least degenerate in quality) when the antenna is placed right on the interface.

Plotting of the NEC output data was performed using the Broadband Antenna Test System (BATS) software developed by the Communications Division of Eyring, Inc.

GENERAL RESULTS

All the radiation pattern profiles in this study (Figures 2 – 12) were computed with NEC on an IBM 3090 mainframe computer using measured parameter values of $\sigma = 10.3$ mS/m and dielectric constant $\epsilon_r = 10.4$, except for Figures 15 and 16 where typical (but unmeasured) West Alabama parameter values of $\sigma = 3$ mS/m and $\epsilon_r = 10.4$ were used. The vertical E–field component, E_v, is plotted as the "vertical" field in Figures 2,3, and 6–11 because this component is of greater immediate interest for this study than the spherical component E_θ. E_θ is frequently used elsewhere because it is perpendicular to the (radial) direction of propagation and in the plane containing the z–axis, making it the "vertical" component of interest in many cases. To illustrate the difference in information, E_θ is plotted in Figures 15 and 16; for example, E_v would be zero along the vertical (90°) axis in Figure 15 for all three plots, whereas E_θ on the 90° axis represents a strong purely horizontal component.

The gain versus azimuth plots of Figures 9 – 14 show E_ϕ and E_v, in two groups of three plots each, with the orientation of the antenna sketched on the plot for clarity. In the context of NEC, the horizontal dipole is aligned with the y–axis, with its center at the origin; in the context of BATS and for the measurements program, the antenna was aligned due North–South.

SPECIFIC RESULTS

Figure 2 shows E_v gain versus elevation for the three 18.1 MHz horizontal dipole heights of 2, 10, and 20 feet above ground, on–axis (in the plane containing both the antenna and the z axis). Figure 3 presents similar information, but in a plane at azimuth angle $\phi = 45°$. The dipole at elevation two feet exhibits 1 to 3 dB gain over the 20′ high dipole for elevation angles between 0° and 15° above the horizon.

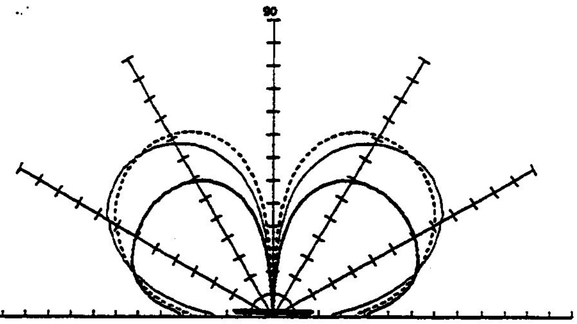
Gain versus elevation plots at 2′, 10′, and 20′ height of E_ϕ broadside to the dipole and at 45° from broadside, respectively, are presented in Figure 4 and Figure 5. Clearly, the overall performance of the dipole improves with increasing height.

For ease of comparison, Figure 6 superimposes the on–axis vertical component E_v with the broadside E_ϕ component on a single plot for a dipole height of 2′. Here, the competitive gain of the endfire vertical component at low elevation angles is apparent. Figure 7 is a similar comparison for dipole height 10′; the broadside horizontal component has gained some advantage. Finally in this particular series, Figure 8 shows a decided advantage for the broadside

TABLE 1

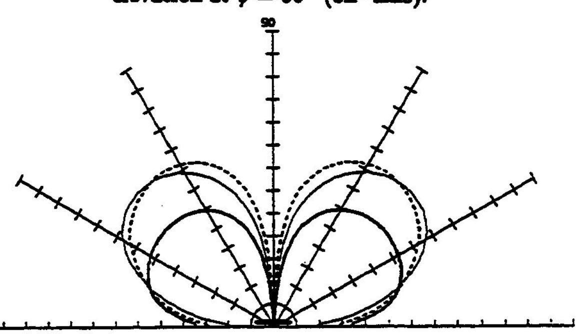
MEASURED AND COMPUTED E_v AT 147 M ON–AXIS FROM 18.1 MHZ λ/2 DIPOLE CENTER FOR P_{rad} = 10 W

Height (feet)	NEC Computed (dBμV/m)	Measured (dBμV/m)
20	82.4	81.1
18	82.8	82.0
16	83.3	82.5
14	83.9	83.8
12	84.6	84.8
10	85.5	84.6
8	86.5	86.0
6	87.3	87.0
4	87.7	87.3
2	87.1	86.5
0	84.4	79.8



2′ height ---- 10′ height —— 20′ height
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 2. 18.1 MHz λ/2 dipole, E_v gain versus elevation at $\phi = 90°$ (on–axis).



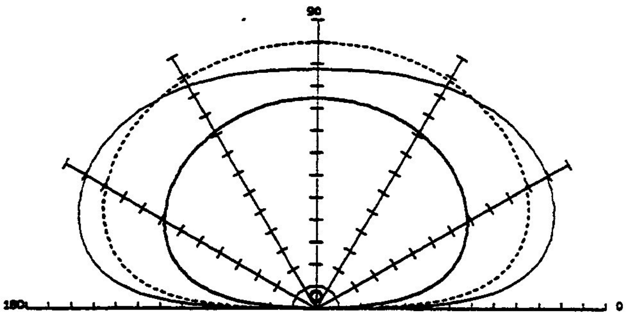
2′ height ---- 10′ height —— 20′ height
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 3. 18.1 MHz λ/2 dipole, E_v gain versus elevation at $\phi = 45°$.

radiation when the dipole height is increased to 20′. At 18.1 MHz, 20′ in free space corresponds to 0.37λ, and the strong broadside performance at this height is not surprising.

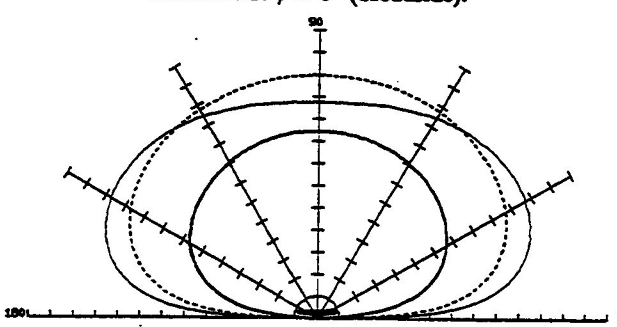
One series of E_V gain plots appears in Figures 9, 10, and 11. Each plot is an azimuth plot at a fixed elevation angle of 5°, 15°, or 25°. In the 5° and 15° elevation angle plots, the dipole at height 2′ exhibits several dB gain over the 20′ high dipole, in agreement with Figure 2. The gain advantage of the low dipole decreases with increasing elevation angle and, at 25° elevation as shown in Figure 11, the 2′ high dipole has lost its edge over the higher antennas.

Another series of gain versus azimuth plots appears in Figures 12, 13, and 14, where now the E_ϕ component is shown at elevation angles of 5°, 15°, and 25°. This is more akin to the information traditionally presented in antenna texts, and shows that the broadside (horizontal component) performance of low dipoles is very poor at low elevation angles.



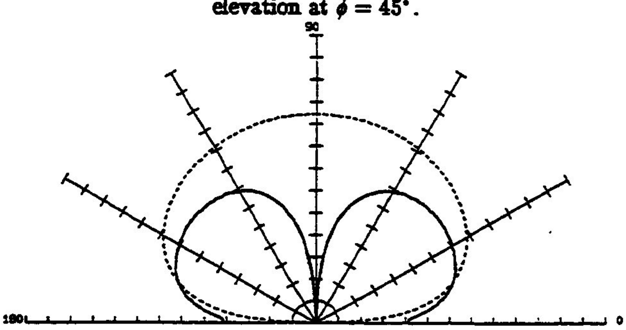
2′ height ---- 10′ height —— 20′ height
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 4. 18.1 MHz λ/2 dipole, E_ϕ gain versus elevation at $\phi = 0°$ (broadside).



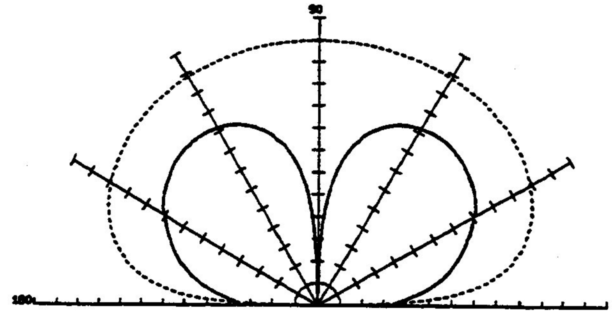
2′ height ---- 10′ height —— 20′ height
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 5. 18.1 MHz λ/2 dipole, E_ϕ gain versus elevation at $\phi = 45°$.



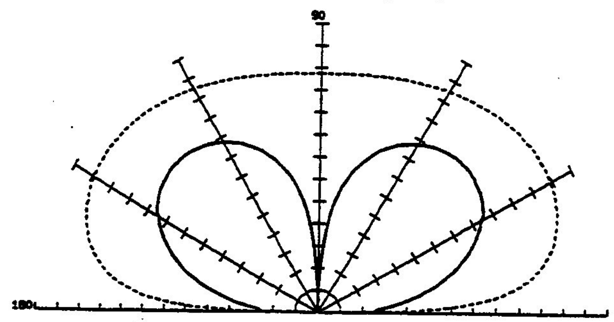
E_V at $\phi = 90°$ ---- E_ϕ at $\phi = 0°$
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 6. 18.1 MHz λ/2 dipole, gain versus elevation of 2′ high dipole.



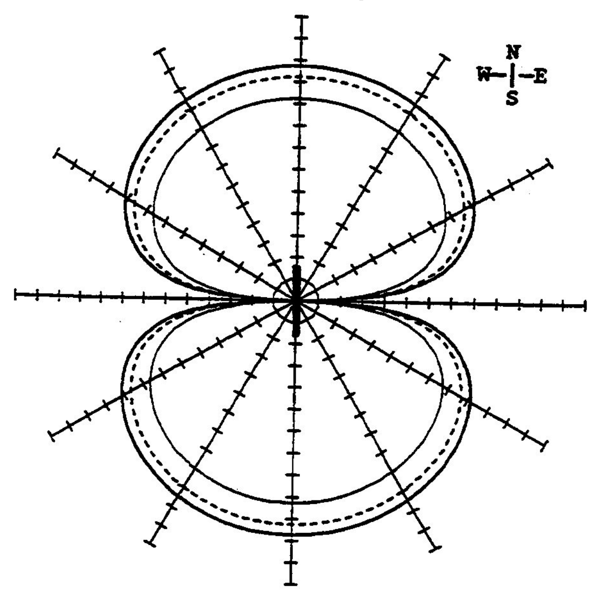
E_V at $\phi = 90°$ ---- E_ϕ at $\phi = 0°$
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 7. 18.1 MHz λ/2 dipole, gain versus elevation of 10′ high dipole.



E_V at $\phi = 90°$ ---- E_ϕ at $\phi = 0°$
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 8. 18.1 MHz λ/2 dipole, gain versus elevation of 20′ high dipole.



2′ height ---- 10′ height —— 20′ height
Gain scale: 3 dB/div Scale Maximum: –9 dBi

Figure 9. 18.1 MHz λ/2 dipole, E_V gain versus azimuth at elevation angle 5°.

As a first extension of these findings, the capability to raise endfire gain by increasing the length of a low dipole has been explored through one specific case study. The center–fed dipole length is extended to 140′ at a height of 10′ above ground, the operating frequency is maintained at

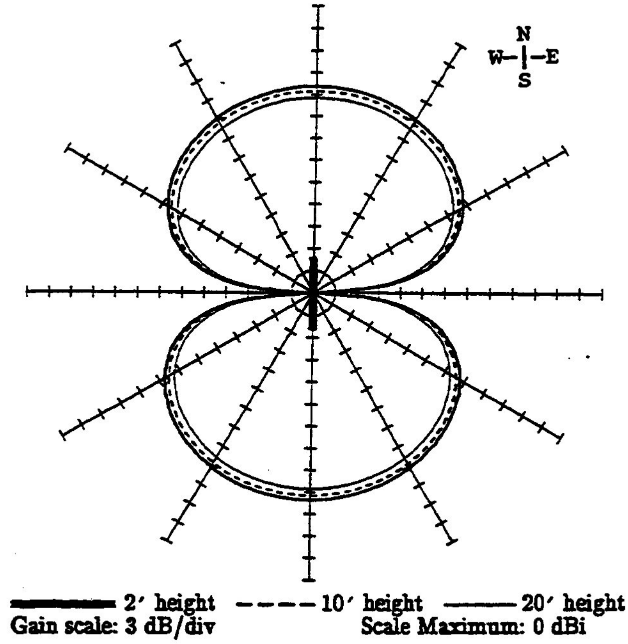


Figure 10. 18.1 MHz $\lambda/2$ dipole, E_v gain versus azimuth at elevation angle 15°.

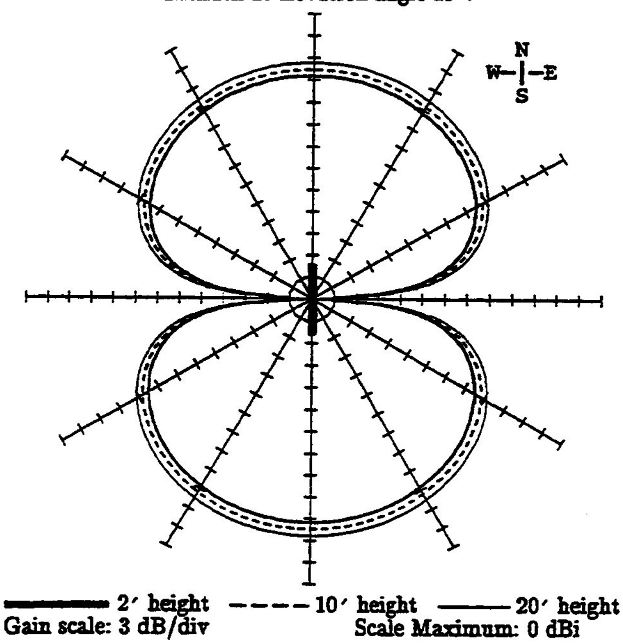


Figure 11. 18.1 MHz $\lambda/2$ dipole, E_v gain versus azimuth at elevation angle 25°.

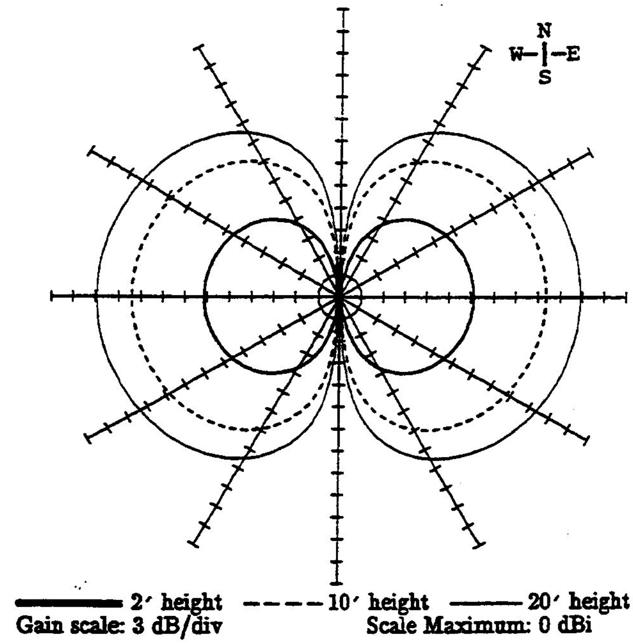


Figure 12. 18.1 MHz $\lambda/2$ dipole, E_ϕ gain versus azimuth at elevation angle 5°.

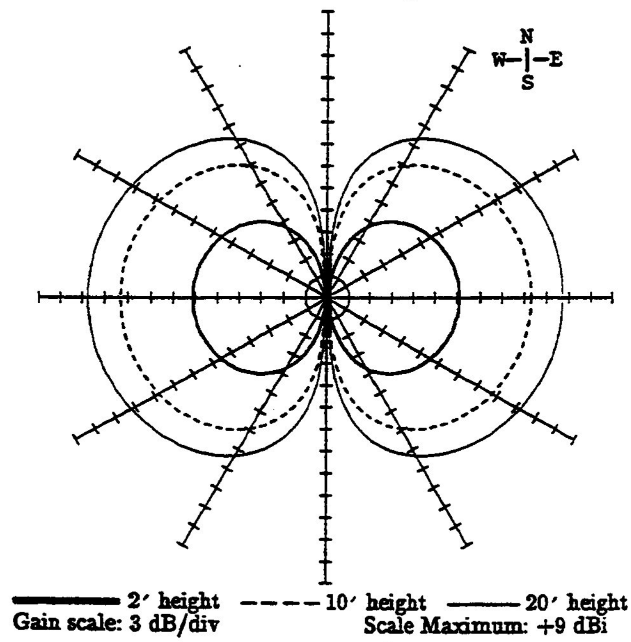
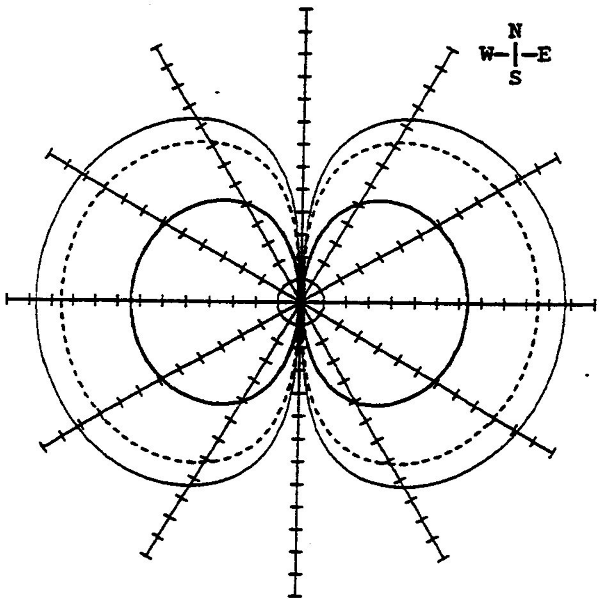


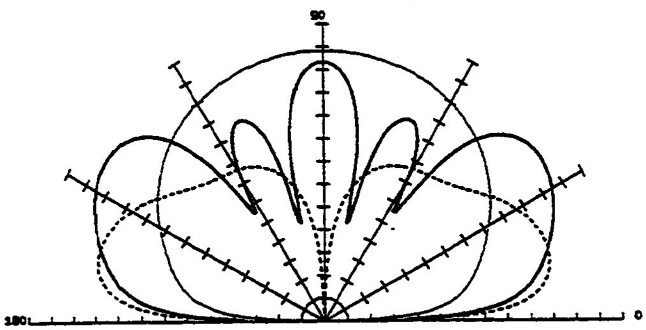
Figure 13. 18.1 MHz $\lambda/2$ dipole, E_ϕ gain versus azimuth at elevation angle 15°.

18.1 MHz, and the ground parameters are changed to representative (unmeasured) values for West Alabama of σ = 3 mS/m and ϵ_r = 10.4. This matches the geometry/environment for an actual antenna which has been in use by one of the authors with consistently favorable endfire results over a period of several years. Computed performance from NEC for this extended–length dipole was compared to the predicted performance of a $\lambda/2$ dipole operating against the same ground parameters at the same height, and also against the computed performance of an elevated $\lambda/4$ vertical radiator with its base at a height of 9′ above ground and operating against four horizontal radials at azimuth angles ϕ = 45°,135°,225°, and 315°. The patterns of all three antennas are simultaneously plotted in Figures 15 and 16. Figure 15 shows gain versus elevation angle for E_θ (see earlier discussion regarding E_θ and E_v), where the 140′ dipole exhibits a substantial 6 to 9 dB advantage over the vertical antenna over the elevation angle range 30° to 50°, while remaining competitive with the ground plane antenna at lower elevation angles. With an elevation angle of 35° for illustration, Figure 16 graphically shows the on–axis advantage of the extended–length dipole over the vertical antenna, as well as the endfire improvement which has resulted from extending the overall dipole length from $\lambda/2$ to approximately 2.75λ.



▬▬ 2′ height ---- 10′ height ——— 20′ height
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 14. 18.1 MHz λ/2 dipole, E_ϕ gain versus azimuth at elevation angle 25°.



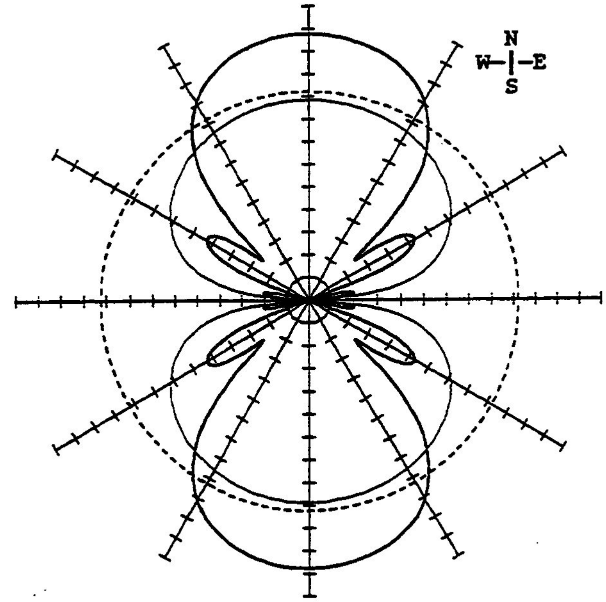
▬▬ 140′ dipole --- λ/4 vertical ——— 20′ λ/2 dipole
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 15. 18.1 MHz E_θ gain versus elevation at ϕ = 90° for three antennas.

CONCLUSIONS

Through a variety of computed radiation pattern profiles and a limited measurements program, this study has revealed and documented some characteristics of endfire radiation from low–elevation horizontal wire dipole antennas. There are circumstances where a λ/2 dipole will give better performance in the axial orientation, rather than broadside. Generally, this appears to become the case when one is constrained to deploy the horizontal dipole at a height less than approximately 0.1λ above ground. While data on extended length antennas is limited at this time, it appears that a substantial advantage can accrue to the endfire radiation by making the dipole length greater than λ/2.

The results presented in this paper should be of interest to communications engineers working with systems in the HF spectrum. In future work, more radiation pattern profiles will be generated for different geometries and ground environments in an effort to more clearly delineate when endfire versus broadside orientation is preferable in a given application. Also, phased arrays of λ/2 dipoles will be considered.



▬▬ 140′ dipole --- λ/4 vertical ——— 20′ λ/2 dipole
Gain scale: 3 dB/div Scale Maximum: +9 dBi

Figure 16. 18.1 MHz E_θ gain versus azimuth at elevation angle 35° for three antennas.

ACKNOWLEDGMENT

Thanks are extended to Dr. Richard W. Adler of the Naval Postgraduate School for the loan of a Rhode & Schwarz receiver and loop antenna. The authors gratefully acknowledge the assistance and active support rendered by David L. Faust and Moray B. King of the Communications Systems Division of Eyring, Inc., Provo, Utah. Without their encouragement, provision of facilities, and software support, this study would not have been possible. They have been aware of and capitalizing on the advantages of low–profile, and even buried, wire antennas for years [5], and their patience in helping the authors along the learning curve on this subject is greatly appreciated.

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by Ray Perez

Signal Integrity and Computational Electromagnetics

In the past, analog and digital circuit simulators concerned themselves only with the logic flow and the calculations of all voltages and currents at any point within the circuit. The only areas of concern about interconnects (e.g PCB lands, vias...etc) were the delays between gates, and the RC loading of such interconnects. The increasing clock speeds and slew rates (or rise times) of chips requires than more than just logic delays associated with each gate be simulated. Transmission line effects in PCB and multichip modules (MCM) are becoming of increasing importance to avoid design problems which are often detected after fabrication. Transmission line effects in interconnects, backplanes, and connectors need to be considered if such effects as reflections, ringing, impedance mismatches, and crosstalk are to be avoided. The governing equations for a typical transmission line are

$$\frac{\partial V(\ell, t)}{\partial \ell} = -RI(\ell, t) - L\frac{\partial}{\partial t}I(\ell, t) \qquad (1a)$$

$$\frac{\partial I(\ell, t)}{\partial \ell} = -GV(\ell, t) - C\frac{\partial}{\partial t}V(\ell, t) \qquad (1b)$$

where C,L,R, and G are the per unit length (ℓ) parameters of the transmission line.

Consider the case of a simple driver-receiver circuit as shown in Figure 1. When a clock pulse transition (low-to-high & high-to-low) is present at the input of the driver, it is delayed, but it maintains its waveform if loading is minimal. At low speeds the receiver and interconnect loading is primerely capacitive and will only distort the waveform by slowing the rise time. At high speeds, transmission line effects must be considered, otherwise ringing will appear. As long as the interconnects are short with respect to clock frequency or signal rise time, the drivers will see the receiver as lumped loads. Ohm's law and Kirchhoff's laws will be sufficient to determine the output waveforms. Loading due to interconnects is considered as lumped capacitance to ground or as RC networks. As the interconnect becomes sufficiently long enough, the signal rise/fall times eventually matches the propagation time through the interconnect. The interconnect electrically isolates the driver from the receivers, which no longer function as loads to the driver. Now, within the time of the signal's transition between high and low voltages, the impedance of the interconnect becomes the load for the driver and also part of the input impedance to the receivers when an equivalent input impedance is considered for the receiver.

The main factors that determine the distortion effects in high speed circuits are: interconnect length, signal slew rate, and clock speed. The logic levels, dielectric material, and conductor resistance play a secondary role. Another cause of problems is the harmonics of trapezoidal clock pulses. The voltage levels of some of the harmonics can be higher than the threshold voltage noise margin of some devices at high frequencies. High speed digital design methodologies should be adopted when the propagation delay of the interconnect is 20-25% of the rise/fall time of the signal. The speeds, noise margin, and other electrical properties of the different logic families commonly used will determine the critical interconnect length above which transmission line effects are of concern as shown in Table 1.

Because of long interconnect behaving as transmission lines, many designers have started to used MCMs. MCMs are becoming in packaging technology as important as surface mount devices. The main advantage is the elimination of chip packages with associated parasitics. MCM are being used in telecommunication and optical communication systems. While the short run lengths in MCMs tend to reduce interconnect delay and other transmission line effects, the narrowness of the lines tend to create significant losses due to resistance and the skin effect, so that signals at higher frequencies tend to be degraded. Furthermore, because of the high density of microstrips and via structures, a higher incidence of crosstalk is observed in MCMs.

Most interconnects are composed of microstrip transmission lines. There are several ways to specify the parameters of these lines: a) characteristic impedance and transmission line delay, b) the characteristic impedance, the normalized electrical length relative to wavelength, the frequency at which this applies, and c) the inductance per unit length (L), the capacitance per unit length (C), and the physical length (l) of the line. At low frequencies where a quasi-TEM approximation is valid the characteristic parameters of the microstrip can be found from [1]:

For $W_{eff}/h \leq 1$

$$Z_o = \frac{60}{\sqrt{\epsilon_{r,eff}}} \ln\left[\frac{8h}{W_{eff}} + \frac{W_{eff}}{4h}\right] \qquad (2)$$

where

$$\epsilon_{r,eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}$$

$$x \left\{\left[1 + \frac{12h}{W_{eff}}\right]^{-1/2} + 0.04\left[1 - \frac{W_{eff}}{h}\right]^2\right\}$$

For $W_{eff}/h \geq 1$

$$Z_o = \frac{\dfrac{120\pi}{\sqrt{\epsilon_{r,eff}}}}{\dfrac{W_{eff}}{h} + 1.393 + 0.667\ln\left[\dfrac{W_{eff}}{h} + 1.444\right]} \qquad (3)$$

where

$$\epsilon_{r,eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} x \left[1 + \frac{12h}{W_{eff}}\right]^{-1/2}$$

the W_{eff}/h terms are given by

$$\frac{W_{eff}}{h} = \frac{W}{h} + \frac{1.25}{\pi}\frac{t}{h}\left[1 + \ln\left(\frac{2h}{t}\right)\right] \quad for \quad \frac{W}{h} \geq \frac{1}{2\pi}$$

$$\frac{W_{eff}}{h} = \frac{W}{h} + \frac{1.25}{\pi}\frac{t}{h}\left[1 + \ln\left(\frac{4\pi W}{t}\right)\right] \quad for \quad \frac{W}{h} \leq \frac{1}{2\pi}$$

$\epsilon_{r,eff}$ and W_{eff} are the effective dielectric constant and effective width of the microstrip, h is the height of the microstrip above the ground plane, and t is the conductor thickness as shown in Figure 2. The capacitance and inductance per unit length of a lossless microstrip line (R=G=0 in Equation 1) can be obtained by realizing that

$$Z_o = \sqrt{\frac{L}{C}} \qquad and \qquad \sqrt{LC} = \frac{\sqrt{\epsilon_{r,eff}}}{3x10^8}$$

Other relationships that apply are

$$transmission\ line\ delay = \ell\ x\ \sqrt{LC}$$

The normalized electrical length is given by

$$\ell\ x\ (f\ x\ \sqrt{LC})$$

where $f = 1/t_d$ and t_d is the line (lossless) propagation delay. It is expected that by the end of this decade clock frequencies will rise to 1 GHz, and even higher clock frequencies may come later on. When the microstrips become lossy (R and G terms included in Equation 1) the dispersive behavior of the microstrips must be considered. This gives rise to the following expressions for the characteristic impedance [2]

$$Z_o(f) = Z_o(f{=}0)\sqrt{\frac{\epsilon_{r,eff}(f{=}0)}{\epsilon_{r,eff}(f)}} \qquad (4)$$

$$\epsilon_{r,eff}(f) = \epsilon_r - \left[\frac{\epsilon_r - \epsilon_{r,eff}(f=0)}{1 + \frac{\epsilon_{r,eff}(f=0)}{\epsilon_r}\left(\frac{f}{f_t}\right)^2} \right]$$

where

$$f_t = \frac{Z_o(f=0)}{2\mu_o h}$$

and where $Z_o(f=0)$ and $\epsilon_{r,eff}(f=0)$ are given by Equation 2. The R and G terms in Equation (1) are given by the approximate expressions

$$R = \frac{\sqrt{\frac{\pi f \mu}{\sigma}}}{W} \qquad (5)$$

$$G = \frac{\{(\epsilon_{r,eff}(f=0) - 1)/(\epsilon_r - 1)\}\sigma_{eff}}{\sqrt{\epsilon_{r,eff}(f=0)}} \times \left[\frac{\sqrt{\frac{\mu}{\epsilon_o}}}{Z_o(f=0)} \right] \qquad (6)$$

where

$$\sigma_{eff} = \omega \epsilon_r \epsilon_o \tan\delta$$

and tan δ is the loss tangent.

Analytical expressions have been used above to derive the per-unit parameters of microstrip transmission lines which are needed for signal integrity analysis. Computational electromagnetic methods however, can also be used to accurately calculate such transmission line parameters. Presently, in the CAD-VLSI industry, computational methods are used to evaluate "high frequency" parameters (L,R,C) of transmission lines, bond wires, interconnects, and even connectors. These parameters are then "plugged-in" into a variety of circuit simulators to evaluate circuit performance. For example, the Boundary Element Method (BEM) is used as a "field solver" to compute the static parameter matrices which account for skin effects at specific frequencies of interest and from which the RLC models will be derived. The Finite Element Method (FEM) has also been used in this endeavor, though it has been suggested that such a tool has problems handling small skin depths [3]. Many of the commercially available EM software packages are pursuing, in their endeavors, the solution of these types of problems. Such approaches will expand significantly the appeal of electromagnetic tools for the solution of circuit simulation problems.

One of the major innovations that needs to be initiated in CAD/CAE systems for digital/analog design and analysis will be the incorporation of electromagnetic computational techniques in the design algorithms of circuit simulators. A field solver code using MOM, FEM, or BEM can serve as a "preprocessor" to a SPICE-like network analyzer code in the design of PCBs; and all within the same software tool. The field solver will accurately calculate all the interconnects inductances (including mutual inductances), capacitances and resistances. This information will then serve as an input file to a network analyzer together with the input files describing all the microelectronic components of the PCBs.

It is believed that the role of computational electromagnetics in circuit design is just beginning to show its promise.

References

[1] R.K.Hoffman, Handbook of Microwave Integrated Circuits, Artech House, 1987.
[2] C.Balanis, Advanced Engineering Electromagnetics, Chapter 8, Wiley Interscience, 1993
[3] T.Nguyen (private conversation at JPL)

Device Family	Typical Propagation, delay (ns)	Edge Speed (ns)	Noise Margin (mV)	Signal Swing (V)	Critical Interconnect length(cm)
CMOS	25	15	1000	4.7	10.0
HCMOS	8	6	1120	4.7	4.0
ACMOS	5	4	1250	4.7	2.7
TTL (H,LS,S)	6,9,3	3	300	3.0	3.5
ASTTL	2	1.2	300	3.0	1.0
Fast TTL	2.5	1.2	200	1.7	2.0
ECL 10KH	1	1.8	230	1.0	1.2
BiCMOS	1.2	0.7	200	1.0	0.5
ECL 100K	0.8	0.5	200	1.0	0.3
GaAs 10G	0.3	0.15	100	1.0	0.1

Table 1.0 Comparing critical interconnect lengths for several logic families.

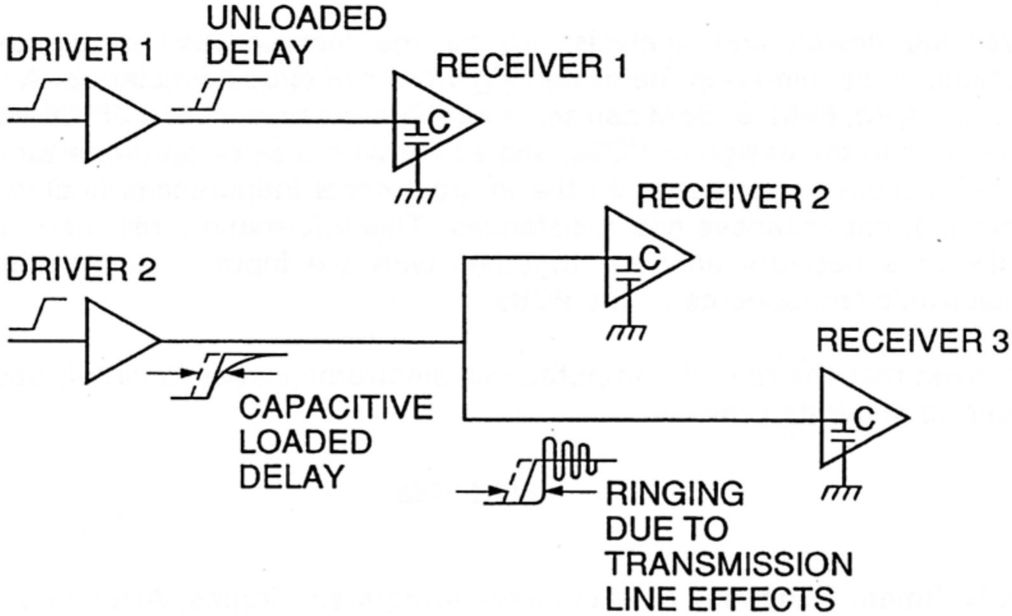

Figure 1.0 Transmission Line Effects in PCB Circuits

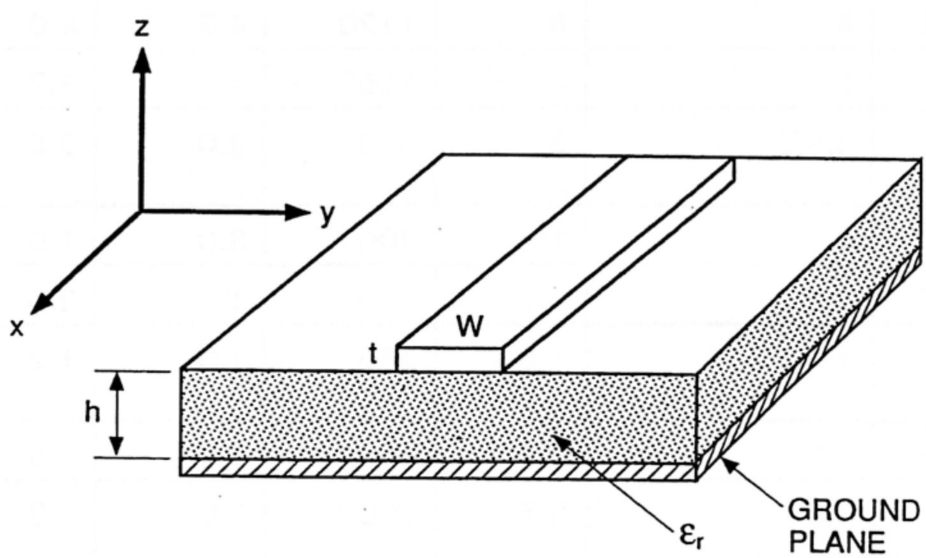

Figure 2.0 Typical Microstrip Configuration

On the Accuracy of Runge-Kutta Temporal Discretizations of Partial Differential Equations

David Gottlieb and Saul Abarbanel
Division of Mathematics
Brown University
Providence, RI 02912

Imposition of Intermediate Boundary Conditions For Runge Kutta Schemes

- The recent interest in long time integration is due to the need to tackle problems in areas such as aero-acoustics, electro-magnetics and others.
- This in turn necessitates working with higher order accurate spatial differencing operators.
- In many cases the time-stepping algorithm of choice is a multi-stage Runge-Kutta (RK) of temporal order of accuracy comparable to the spatial one.

The problem is how to impose the time dependent boundary conditions $g(t)$, dictated by the physics of the problem, in the intermediate steps of the Runge-Kutta schemes.

- The conventional way of dealing with the uncertainty of what is happening at the intermediate stages of the RK time advancement is to impose at $t + \alpha_\nu \Delta t$, the boundary value $g(t + \alpha_\nu \Delta t)$, where α_ν is the coefficient appropriate to the particular ν^{th} stage of the given RK algorithm.

  We have shown that this conventional boundary condition imposition leads to a numerical scheme which is only first order accurate in the neighborhood of the boundary, **leading to a global accuracy of second order only.**

- Another approach is to treat the time-dependent boundary condition, $g(t)$, as a source term in the governing partial differential equation (p.d.e), thereby avoiding the need to formally specify intermediate boundary conditions. However, it can be shown that procedure is equivalent to the conventional method with its attended problems.
- A third natural procedure is indeed not to specify any intermediate boundary condition, but to obtain them from the inner scheme. This method retains the accuracy of the spatial operator, but *significantly reduces the allowable time step for stability, rendering the scheme less attractive.*

Supported by AFOSR grant AF-93-0090

Why the Loss of Accuracy?

To illustrate the phenomenon of loss of accuracy due to the conventional imposition of inflow boundary conditions, we consider the following problem:

$$\frac{\partial u}{\partial t} + \frac{\partial u}{\partial x} = 0 \quad 0 \le x \le 1, t \ge 0 \tag{1}$$

$$u(0,t) = g(t) \tag{2}$$

The semi-discretized version of equations (1) - (2) is .

$$\frac{dv_i}{dt} = (QV(t))_i \quad i = 1, \ldots, N; t \ge 0 \tag{3}$$

$$v_0(t) = g(t) \tag{4}$$

where

- $V = v_i^T = [v_0, \ldots v_N]^T$ is the semi-discrete approximation which converges to $u(x_i, t)$ at the spatial grid points x_i (for stable discretizations);
- Q is the differentiation matrix representation of the derivative operator $-\frac{\partial}{\partial x}$.
- The specific form of Q depends on the algorithm used and in particular on the order of accuracy. For all finite difference operators on uniform grids (which suffices for the present purpose of illustration), we may write $Q = \Delta x^{-1} D$, where Δx is the mesh spacing.

The four-stage "classical" RK scheme integration, together with the conventionally imposed boundary conditions, is implemented as follows:

$$v_i^1 = v_i^n + \frac{\lambda}{2}(Dv^n)_i \quad i = 1, \ldots, N \tag{5}$$

$$v_0^1 = g(t + \frac{\Delta t}{2})$$

$$v_i^2 = v_i^n + \frac{\lambda}{2}(Dv^1)_i \quad i = 1, \ldots, N \tag{6}$$

$$v_0^2 = g(t + \frac{\Delta t}{2})$$

$$
\begin{aligned}
v_i^3 &= v_i^n + \lambda(Dv^2)_i \quad i = 1,\dots,N & (7)\\
v_0^3 &= g(t+\Delta t)\\
v_i^{n+1} &= v_i^n + \frac{\lambda}{6}[(Dv^n)_i + 2(Dv^1)_i + 2(Dv^2)_i + (Dv^3)_i] \quad i = 1,\dots,N & (8)\\
v_0^{n+1} &= g(t+\Delta t)
\end{aligned}
$$

where $\lambda = \Delta t/\Delta x$.

Note:

Equations (5 - 8) take the semi-discrete variable $v_i(t)$, from the time level n, to $v_i(t+\Delta t)$ at time level $n+1$.

For the purpose of analysis, the above system is rewritten in the following form, again with $V = [v_0, ... v_N]^T$:

$$
\begin{aligned}
V^1 &= V^n + \frac{\lambda}{2} DV^n + G^0 e_0 & (9)\\
V^2 &= V^n + \frac{\lambda}{2} DV^1 + G^1 e_0 & (10)\\
V^3 &= V^n + \lambda DV^2 + G^2 e_0 & (11)\\
V^{n+1} &= V^n + \frac{\lambda}{6}[DV^n + 2DV^1 + 2DV^2 + DV^3] + G^3 e_0 & (12)
\end{aligned}
$$

where $e_0 = [1, 0, ... 0]^T$, and

$$
\begin{aligned}
G^0 &= g(t+\frac{\Delta t}{2}) - v_0^n - \frac{\lambda}{2}(DV^n)_0 & (13)\\
G^1 &= g(t+\frac{\Delta t}{2}) - v_0^n - \frac{\lambda}{2}(DV^1)_0 & (14)\\
G^2 &= g(t+\Delta t) - v_0^n - \lambda(DV^2)_0 & (15)\\
G^3 &= g(t+\Delta t) - v_0^n - \frac{\lambda}{6}[DV^n + 2DV^1 + 2DV^2 + DV^3]_0 & (16)
\end{aligned}
$$

It may be shown that since the G^j are not zero for time dependent BC - the order of accuracy deteriorates to second order globally!!

Correction for the Linear Case (Maxwell?)

The remedy for the above dilemma suggests itself when one examines equations (13-16).

Note that if we set

$$G^0 = G^1 = G^2 = 0$$

,

Then

$$V^{n+1} = u(t + \Delta t) + O(\Delta t^5) + e_0 G^3$$

.

But, If

$$G^0 = G^1 = G^2 = 0$$

,

Then

$$G^3 = O(\Delta t^5)$$

,

and we have the correct order for V^{n+1}.

To achieve these identities we specifically use in equations (5-8) the following expressions for the intermediate boundary conditions:

$$v_0^1 = g(t) + \frac{\Delta t}{2} g'(t) \tag{17}$$

$$v_0^2 = g(t) + \frac{\Delta t}{2} g'(t) + \frac{\Delta t^2}{4} g''(t) \tag{18}$$

$$v_0^3 = g(t) + \Delta t g'(t) + \frac{\Delta t^2}{2} g''(t) + \frac{\Delta t^3}{4} g'''(t) \tag{19}$$

(Note that equations (17 - 19) are precisely the intermediate boundary conditions obtained by numerically integrating $\frac{d^3u}{dt^3} = g'''(t)$ with the classical fourth order RK scheme.)

EDITORIAL

Computational Electromagnetics in the New Age of Telecommunications

Part 1: An Introduction

by Ray Perez

It is being said in technical circles that we are at the brink of a telecommunications revolution. This industry, by conservative estimates, is expected to reach $10 billion by the end of the decade. Some knowledgeable experts in this area call the technical innovations in the telecommunications industry the equivalent of the invention of the automobile or electricity. Though these opinions can be debated (e.g. wireless communications is based on technology that has evolved in the last twenty years), the fact is that it is transforming, not only the way people conduct business, but also the way people do some of the simplest everyday tasks. Often, in the public mind, the connotations of this revolution are associated with the widespread use of personal communication services (PCS) such as cellular phones, pagers, personal digital assistants,..etc. This progress however, goes well beyond these more visible technologies. The areas of integrated synchronous digital networks (ISDN), fiber optics, computer technology, satellite technology, and microelectronics are also part of the telecommunications breakthroughs.

Some of the future changes to come are:

a) Millions of people will be able to carry "personal communicators" which will combine the capabilities of computer technology and telephones in a single mobile instrument. The communicators can become fax machines, calendars, address books, sketch pads, pagers and phones, with the insertion of function modules the size of a credit card.

b) People will have a personal telephone number that can be called from/to anywhere in the world. A similar "house communicator" will connect the communication systems in the house, and will merge telephone, television, and computers into one system.

c) Computers will speak and understand spoken language and all computer commands can be voice activated.

d) Cellular phones will have built-in computers that can make calls, take and deliver messages and perform many tasks now performed by secretaries. A phone will become so small that you can wear it as if it were a wrist watch. Two-way videophones will become a common occurrence practically everywhere.

There are basically three forces driving this revolution:

1) Advances in microelectronics: There are presently more microprocessors in the market than people on the earth. The power of each strip doubles every 18 months without a price increase. The development of ASIC technology and RF has put many functions into a single chip, especially for digital communication circuits. Analog circuits are increasingly being replaced by digital counterparts (e.g., phase-locked loops) which are not only smaller but can also incorporate many other circuit functions.

2) Fiber optics: Last year fiber optic lasers could transmit about 3-4 billion bits of data/sec, or 50,000 phone conversations on a fiber link. Soon we can expect an increase to one trillion bits/sec,or 70 million phone conversations. These digital phone lines will make 1000-channel TV and two--way videophones possible. Optical amplifiers, multimode fibers, and soliton technology are driving these optimistic assessments.

3) Digital satellite technology will use high band frequencies to move phone data. Satellites will be smaller, cheaper to build, and manufactured faster. As many as 1000 small satellites are expected to be built within the next 10 years. Satellites will be of two kind: sun-synchronous for low-and medium-altitude orbits. Examples of the former are Iridium and Teledesic satellite systems (~ 900 at about 400 mile altitude). An example of the latter is the Odyssey satellite system (~ 20 at 5000 mile altitude). Geosynchronous satellites (~ 12 at 20,000 mile altitude) will still be used for television transmission.

In the next three issues of the ACES Newsletter we will explore the implications of the global telecommunications revolution on computational electromagnetics. Great opportunities lie ahead for engineers well-versed in EM computational tools as well as RF/MW and analog/digital design. In the first issue we will cover the role that computational electromagnetics can play in: a) the design of new small antennas, and b) the analysis of wave propagation. In the following issue we will explore how helpful computational electromagnetics can be in the design of RF/MW circuits about 1 GHz, including issues of signal integrity and interface problems. The third and last issue will discuss the use of computational electromagnetics in CAD/CAE tools for circuit design.

BOOK REVIEW

"Methods in Electromagnetic Wave Propagation"

Reviewed by Ray Perez

A solid mathematical background is required of all students of electromagnetic (EM) theory and wave propagation. D.S. Jones, in his book, does a very good job in revealing the most important mathematical concepts behind the most commonly taught EM concepts, computational techniques, and other related subjects. The book also covers many topics in EM theory fairly well, but it is much more generalized in its approach and is not as applied as most engineering EM books. A common complaint from electrical engineering faculty, who regularly teach EM theory, is that students often lack the mathematical foundations for effectively learning electromagnetics. This book goes a long way in solving this problem and it can be recommended as a supplement to most graduate level EM textbooks already in the market.

The first five chapters provide the mathematical fundamentals concerning computational methods. Variational methods (Chapter 4), integral equations (Chapter 5), and finite elements (Chapter 5) are well covered. Chapters 6 through 9 deal with wave propagation, whether radiated by a source or scattered by an obstacle. Chapter 6 is concerned with antennas (wires, solids and dielectrics) analyzed in the frequency domain. The time domain analysis is covered in chapter 7, including the singularity expansion method. The Geometric Theory of Diffraction is covered extensively in Chapter 8. Chapter 9 covers inverse scattering, holography, adaptive arrays and other applications of interest.

Chapter 1 discusses some mathematical foundations of numerical analysis and is divided into four parts: interpolation and approximation, solution of equations, matrices, and linear equations (including the generalized inverse). The material is of an introductory nature and is a synthesized version of material typical of the subjects found in Functional Analysis books at the undergraduate and graduate level. Many theorems and proofs are provided. Chapter 2 covers difference equations and introduces EM for the first time. The objective is to use Maxwell's equations in differential forms to cover waveguides. Chapter 3 is an introduction to variational methods. In Chapter 3 operators and eigenvalues are described extensively. The following material is covered: Hilbert space, linear operators, bounded linear operators, integral and partial differential equations, unbounded operators, and eigenvalue problems. Chapter 4 introduces variational methods. The material starts with a good discussion on the derivatives of linear operators (including the mean-value theorem and higher derivatives) and it is followed by mathematical optimization (or minimization) techniques. Variational principles (minimization of a function on any space) are then covered with several examples.

The numerical aspects of variational methods are discussed in Chapter 5. It is the main purpose of variational methods to provide bounds on approximations. Among the subjects discussed are Galerkin's method, positive definite operators, and stability. Integral equations are covered, followed by finite elements and finite difference techniques. Chapter 6 deals with the development and application of electric and magnetic integral equations in the analysis of antennas. The chapter is devoted to three types of antennas: a) wire antennas (perfectly conducting infinite, semi-infinite, and finite wires), including curve, log-periodic, and arrays, b) solid antennas such as wire grids and surface patches, and c) dielectric antennas. The treatment of dielectric antennas is very good and it includes both cylindrical and generalized shapes.

Most man-made electromagnetic phenomena are not of transient nature (e.g., transmitters are mostly of single frequency), but natural electromagnetic phenomena is often of transient nature (multiple frequencies). Chapter 7 is devoted to different approaches in the analysis of transient phenomena. Material covered include: finite methods, integral equations in the time domain (e.g. numerical methods for thin wires), Fourier and Laplace transforms, and the singularity expansion method. Chapter 8 is an extensive treatment of the Geometric Theory of Diffraction (GTD). This, in my opinion, is the best chapter in the book. The chapter starts with a high frequency (HF) approximation of Maxwell's equations and then derives the HF transport equations for the electric and magnetic fields as well as the ray equations. Geometrical optics is introduced in detail, and so is Fermat's principle. Because differential equations are intrinsic with GTD, the chapter pauses, for a few pages, to review the most common methods for solving ordinary differential equations. Since geometrical optics fail at the edges, GTD is introduced in this chapter. The following GTD topics are covered in detail: caustics, reflection by stratification, diffraction by edges, edge rays, double edge diffraction, wedge diffraction, and curvative diffraction. Examples of GTD applications discussed are reflector antennas and optical fibers. The last chapter in the book, (Chapter 9) is titled source detection. The location of an electromagnetic disturbance could be of importance because one may want to know where a source of radiation or scattering is located, or one may wish to eliminate them. These types of problems are classified into two groups: inverse scattering (for low and high frequencies) and inverse source problems. An application of inverse scattering reviewed is the hologram. Statistical considerations and far-field cross-correlation techniques are dealt with in the analysis of inverse source problems.

CALL FOR PAPERS

THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY ANNOUNCES A SPECIAL ISSUE OF THE ACES JOURNAL ON:

ADVANCES IN THE APPLICATION OF THE METHOD OF MOMENTS TO ELECTROMAGNETIC RADIATION AND SCATTERING PROBLEMS

The Applied Computational Electromagnetics Society is pleased to announce the publication of a 1995 Special Issue of the ACES Journal on the use of the Method of Moments in the evaluation of electromagnetic radiation and scattering problems. The objectives of this special issue are: (1) to provide the computational electromagnetics community with an assessment of the current capabilities and uses of the Method of Moments for electromagnetics problems from the low-frequency to the high-frequency regimes and (2) to provide information on recent advances that may extend range of applicability and usefulness of the Method of Moments. Prospective authors are encouraged to submit papers of archival value that address these objectives and other suggested topics listed below.

SUGGESTED TOPICS

- Modeling Guidelines for Complex Geometries
- Accuracy Assessment and Improvement
- Special Formulations: Low Frequency/High Frequency
- Hybrid Method of Moment Approaches
- New Integral Equation Formulations
- Parallelization of Moment Method Codes
- Novel Equivalence Principle Applications for the Method of Moments
- Fast Matrix Computation/Solution Techniques
- Large-Scale Problems

DEADLINE FOR PAPERS IS MARCH 31, 1995

Send papers and inquiries to:

A.W. Glisson and A.A.Kishk
Special Guest Editors
Department of Electrical Engineering
University of Mississippi
University, MS 38677

Tel: (601) 232-5353
FAX: (601) 232-7231
E-mail: eeallen@vm.cc.olemiss.edu

Call for Papers

The Applied Computational Electromagnetics Society
Announces a Special Issue of the ACES Journal on:

Applied Mathematics: meeting the challenges presented by Computational Electromagnetics

The objectives of this special issue are a) to illuminate some of the current mathematical techniques in computational electromagnetics, by a series of review or survey articles, and b) to initiate and encourage interaction between the applied mathematics community on the one hand, and the electrical engineers and physicists on the other. Papers submitted must address mathematical problems arising in computational electromagnetics, and the conclusions must have, moreover, some practical value. Contact the Guest Editors.

Suggested Topics:

⋆ Integral equations and integrodifferential equations
⋆ Eigenfunction expansions, both interior and exterior
⋆ Selfadjoint, as well as non-selfadjoint, operator approximation
⋆ Singularity expansion method, scattering poles, natural modes
⋆ Diffraction and asymptotics, application of special functions

⋆ Variational principles, Galerkin and related methods
⋆ Finite element methods, finite difference methods
⋆ The radiation boundary problem

⋆ Solution of large scale linear systems
⋆ Eigenvalue estimation, especially for non-selfadjoint problems
⋆ Optimization, conjugate and bi-conjugate gradient methods, GMRES
⋆ Numerical evaluation of integrals with oscillatory or singular integrands

Wherever possible, attention should be given to error estimates. This is not just a difficult mathematical issue[1], it is absolutely vital for all engineering considerations and it is still largely unresolved in computational electromagnetics. Modern numerical analysis seems not to have lived up to its basic premise, because we do not yet possess useful error estimates.

The deadline for papers is June 30, 1995.
Mail one hard copy to each of the Guest Editors:

Eugene Tomer
Applied Mathematics and Computing
150 Hernandez Avenue
San Francisco, CA 94127, USA
Tel: (415) 665-9555 Fax: (415) 731-3551
e-mail: etomer@netcom.com

Andrew F. Peterson
School of Electrical Engineering
Georgia Institute of Technology
Atlanta, GA 30332, USA
Tel: (404) 853-9831 Fax: (404) 853-9171
e-mail: ap16@prism.gatech.edu

[1] See, e.g., S.G. Mikhlin, *Error Analysis in Numerical Processes,* Wiley, 1991.

THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY
ANNOUNCES

The 11th Annual Review of Progress in Applied Computational Electromagnetics

March 20-25, 1995

Naval Postgraduate School, Monterey, CA

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 features four areas of interest: technical paper session, demonstrations, vendor booths and short courses. All aspects of electromagnetic computational analysis are represented, but particular emphasis will be placed on numerical methods, expecially those validated by experiment. The Technical Program will feature numerical methods in electromagnetics used to treat real life applications. The Symposium will also include invited speakers and interactive forums. Contact Ray Luebbers (814) 865-2362 for details.

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.

Technical Program Chairman
Ray Luebbers
Penn State University
320 EE East
University Park, PA 16802
Phone (814) 865-2362
Fax: (814) 865-7065
E-mail: LU4@psuvm.psu.edu

Symposium Administrator
Richard W. Adler
ECE Dept/Code ECAB
Naval Postgrad School
833 Dyer Rd, Room 437
Monterey, CA 93943-5121
Phone (408)646-1111
Fax (408) 649-0300
E-mail: 5541304@mcimail.com

Publication Chairman
Richard K. Gordon
EE Dept. Univ of Mississippi
Anderson Hall, Box 41
University, MS 38677
Phone (601) 232-5388
Fax: (601) 232-7231
E-mail: eegordon@vm.cc.olemiss.edu

Publicity Chairman
Paul M. Goggans
EE Dept. Univ. of Mississippi
Anderson Hall, Box 1
University, MS 38677
Phone: (601) 232-5854
Fax: (601) 232-7231
E-mail: eepmg@cotton.vislab.olemiss.edu

Short Course Chairman
Robert Lee
Ohio State Univ, EE Dept.
2015 Neil Ave.
Columbus, OH 43210-1272
Phone (614) 292-1433
Fax (614) 292-7596
E-mail:lee@ee.eng.ohio-state.edu

1996 ACES Symposium Chairman
Richard K. Gordon
EE Dept. Univ of Mississippi
Anderson Hall, Box 41
University, MS 38677
Phone (601) 232-5388
Fax: (601) 232-7231
E-mail: eegordon@vm.cc.olemiss.edu

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PRELIMINARY AGENDA

The Eleventh Annual Review of Progress in Applied Computational Electromagnetics

NAVAL POSTGRADUATE SCHOOL
20-25 MARCH 1995

Ray Luebbers
Technical Program Chairman

MONDAY 20 MARCH

0830-1630 **SHORT COURSE (FULL-DAY)**
"Finite Elements for Electromagnetics" by John Brauer, MacNeal-Schwendler Corporation

0830-1630 **SHORT COURSE (FULL-DAY)**
"GEMACS from A-Z" by Buddy Coffey, Advanced EM

0830-1630 **SHORT COURSE (FULL-DAY)**
"Physical Wavelets" by Gerald Kaiser, University of Massachusetts at Lowell

0830-1200 **SHORT COURSE (HALF-DAY)**
"The Multiple Multipole Program (MMP): Theory, Practical Use and Latest Features" by Pascal Leuchtmann, Swiss Federal Institute of Technology

1300-1630 **SHORT COURSE (HALF-DAY)**
"Verification and Validation of Computational Software" by E.K. Miller, Ohio University

1800-2030 **CONFERENCE REGISTRATION** 103 Glasgow Hall

1600-1800 **BOARD OF DIRECTORS MEETING** 102 Glasgow Hall
(Members are invited to observe)

1830 **BOARD OF DIRECTORS DINNER**

TUESDAY 21 MARCH

0700 **CONFERENCE REGISTRATION** 103 Glasgow Hall

0700-0800 **CONTINENTAL BREAKFAST**

0730 **ACES BUSINESS MEETING** President Hal Sabbagh 102 Glasgow Hall

0800 **WELCOME** Ray Luebbers 102 Glasgow Hall

SESSION 1: SCATTERING (Parallel with Sessions 2 & 3)
Chair:

0840 "Improved Algorithms for T-Matrix Computations of EM Scattering by Spheroidal Objects" by V.A. Babenko

0900 "Analysis of Scattering by Cluster of Nonspherical Particles Based on Complete Mathematical Models" by Y.A. Eremin, N.W. Orlov and V.I. Rozenbert

0920 "Investigation of Electromagnetic Scattering by Any Conducting Surface Using Quasi-Solution Concept (QSC)" by Y. A. Eremin and M.K. Zimnov

0940 "RCS of High Permitivity Cubes Computed with the TLM Method" by C. Eswarappa and W.J.R. Hoefer

1000 **BREAK**

1020 "Scattering Analysis of Antenna Installation/Panels on a Curved Surface Using Uniform Field Integration Method" by J.J. Kim and O.B. Kesler

1040 "Efficient Extraction of the Near-Field from CGFTT Methods Applied to Scatterers in the Resonance Region" by A. McCowan

1100 "A CCGFT Method Applied to the Scattering from Finite Size Microstrip Antenna" by A. McCowan

1120 "Sharing of Experience at Cray Research with Electromagnetic Scattering Code JUNCTION 2.0" by J.A. Crow

LUNCH

TUESDAY MORNING 21 MARCH

SESSION 2: LOW FREQUENCY (Parallel with Sessions 1 & 3)
Chair:

0840 "Computation of Eddy Current in Laminated Iron Cores" by O. Biro and K. Preis

0900 "New Contribution to the Study of Fault Currents Distribution in the Ground Systems" by H.O. Brodskyn, by M.H. Giarolla, J.R. Cardoso, N.M. Aba and A. Passaro

0920 "On the Oscillatory Phenomena of Eddy Currents Along the A, V-Y Interface" by Z. Chang, Q. Hu, S. Gao, Z. Liu, C. Ye and M. Wu

0940 "A New MMP-Code for Static Field Computation" by M. Gnos and P. Leuchtmann

1000 **BREAK**

1020 "Eddy Current Sensor for Measuring Simultaneously the Conductivity of Metallic Plates and Lift-off" by M.Q. Le and D. Placko

1040 "The Electrostatic Characterization of a N-Element Planar Array Using the Singularity Expansion Method" by J.E. Mooney and L. Riggs

1100 "A Volume-Integral Code for Electromagnetic Nondestructive Evaluation" by R.K. Murphy, H.A. Sabbagh, J.C. Treece and L.W. Woo

1120 "Molten Aluminum Flow Induced by High Magnetic Fields" by W.P. Wheless, Jr.

1140 "Numerical Modelling of EMC in Underground Power Cable Systems with the Hybrid FE-BE Method" by J. Shen and A. Kost

LUNCH

SESSION 3: RESEARCH AND ENGINEERING FRAMEWORK FOR CEM (Parallel with Sessions 1 & 2)
Organizer: K. Siarkiewicz

0840 "Research and Engineering Framework (REF) for Computational Electromagnetics" (Invited Paper) B. Hantman, K. Siarkiewicz, J. Labelle and R. Jackson

0900 "Data Dictionary Specification for Computational Electromagnetics" (Invited Paper) by J.A. Evans

0920 "DT_NURBS - A Geometry Engine for Integration of the MMACE Data" (Invited Paper) by B. Ames

0940 "Research and Engineering Framework (REF): Standardized Grid Generation" (Invited Paper) by L.W. Woo, J.La Belle and B. Hantman

1000 **BREAK**

1020 "Visualization and Standards" (Invited Paper) by J. Cugini

1040 "A Visualization Toolkit for Computational Electromagnetics" (Invited Paper) by B. Joseph

1100 "MMACE-Lessons for the Development of a CEM Computational Environment" (Invited Paper) by R.G. Hicks and K. Siarkiewicz

LUNCH

TUESDAY AFTERNOON 21 MARCH

1400-1800 **TUESDAY AFTERNOON** Barbara McNitt Ballroom, Herrmann Hall, NPS

1400-1800 **INTERACTIVE TECHNICAL SESSION, VENDOR BOOTHS AND WINE AND CHEESE BUFFET**

0730 **CONTINENTAL BREAKFAST**

SESSION 4: "OPTIMIZATION TECHNIQUES IN APPLIED ELECTROMAGNETICS" (Parallel with Sessions 5 & 6)
Organizer: O. A. Mohammed

0840 "An Optimization Approach to Reduce the Discretization Error in Finite Element Explicit Solution Scheme" (Invited Paper) by M. Feliziani, E. Latini and F. Maradei

0900 "Analysis and Design of a Reentrant Resonant Cavity Applicator for Radio Frequency Hyperthermia System" (Invited Paper) by Y. Kanal, T. Tsukamoto, K. Toyama, T. Kashiwa, Y. Saitch and M. Miyakawa

0920 "Analysis of Loaded Cavities Using the Constitutive Error Approach" (Invited Paper) by R. Albanese, R. Fresa, R. Martone and G. Rubinacci

0940 "The Design of Electromagnetic Devices using Knowledge Based Systems and Sensitivity Information" (Invited paper) by D.A. Lowther, D.N. Dyck and R. Rong

1000 **BREAK**

1020 "A Computer Program for the Design of Superconducting Accelerator Magnets" (Invited Paper) by S. Russenchuck

1040 "Application of Optimization to the Design of Electromechanical Devices" (Invited Paper) by J.K. Sykulski and Y.B. Cheng

1100 "Genetic Algorithms for the Optimal Design of Electromagnetic Devices" (Invited Paper) by O.A. Mohammed and G.F. Uler

1120 "Linear Constraints - Gradient Technique for the Inverse Problem of Shape Optimization" (Invited Paper) by A.A. Arakadan and S. Subramaniam

1140 "Shape Optimization in Electrostatics: Gradient and Stochastic Methods (First Three Years of Experience)" (Invited Paper) by L. Krahanbuhl, A. Nicolas and J.De Vasconcelos

LUNCH

SESSION 5: COMPUTATIONAL ELECTROMAGNETICS APPLIED TO SHIP DESIGN (Parallel with Sessions 4 & 6)
Organizers: J. Newcomb and J. Logan

0840 "The NAVSEA Electromagnetic Engineering Program" (Invited Paper) by N. Baron, J. Eadie and J. Caybulski

0900 "Electromagnetic Engineering System Architecture" (Invited Paper) by J. Winston

0920 "EM Engineering Ray Tracing and Casting Model: Development and Application" (Invited Paper) by L. Gray

0940 "Ship Transition Frequency EM Environment Analysis Requirements" (Invited Paper) by J. Piper

1000 **BREAK**

1020 "Finite Volume Time Domain Analysis of Ship Topside EM Environment Features" (Invited Paper) by B. Hall, A. Mohammadian. C. Rowell and V. Shankar

1040 "EM Engineering Ship End-to-End Application" (Invited Paper) by L. Carlson

1100 "EM Engineering Applied to Patrol Craft (PC-1)" (Invited Paper) by D. Tam, C. Azu and M. Soyka

1120 "Shipboard Antenna Pattern Visualization and Analysis" (Invited Paper) by L.C. Russell, J.C. Logan, J.W. Rockway and D.F. Schwartz

LUNCH

SESSION 6: FINITE DIFFERENCE TIME DOMAIN (Parallel with Sessions 4 & 5)
Organizer: J. Beggs

0840 "Computational Analysis of Radiation from an Elliptical Shaped End Radiator" (Invited Paper) by S.A. Blocher, E.A. Baca and J.H. Beggs

0900 "A Time Domain Harmonic Oscillator Model for an FDTD Treatment of Lossy Dielectrics" (Invited Paper) by K.Kunz

0920 "FDTD Modeling of Electromagnetic Wave Interaction with Composite Random Sheets" (Invited Paper) by J.G. Maloney and B.L. Shirley

0940 "An Improved Near to Far Field FDTD Algorithm" (Invited Paper) by K Kunz

1000 **BREAK**

1020 "Unstructured Finite-Volume Modeling in Computational Electromagnetics" (Invited Paper) by D.J. Riley and C.D. Turner

1040 "Simple Radiating Boundary Conditions for Nonorthogonal Meshes with Parallel Computing Concerns" (Invited paper) by D. Steich, N. Madsen, G. Cook and B. Eme

1100 "FDTD Simulation of High-Intensity, Ultrashort Laser Pulses for X-ray Generation" (Invited Paper) by D. Sullivan

1120 "Hybrid Finite Difference Time Domain and Finite Volume Time Domain in Solving Maxwell's Equations" (Invited Paper) by K.S. Yee and J.S. Chen

1140 "Reducing the Number of Time Steps Needed for FDTD Antenna and Microstrip Calculations" (Invited Paper) by R. Luebbers and H.S. Langdon

1200 **LUNCH**

WEDNESDAY AFTERNOON 22 MARCH

SESSION 7: TIME DOMAIN FDTD (Parallel with Sessions 9 & 10)
Chair: J. Fang

1320 "Scattering from Coated Targets Using a Frequency-Dependent Surface Impedance Boundary Condition in FDTD" by C.W. Penney, R.J. Luebbers and J.W. Schuster

1340 "A 3-D Perfectly Matched Medium by Coordinate Stretching" by W.C. Chew and W.H. Weedon

1400 "Perfectly Matched Anisotropic Absorbers for Finite Element Applications in Electromagnetics" by D.M. Kingsland, Z.S. Sacks and J.F. Lee

1420 "Modification of Berenger's Perfect Matched Layer for the Absorption of Electromagnetic Waves in Layered Media" by M. Gribbons, S.K. Lee and A.C. Cangellaris

1440 "FDTD Modeling of Ground-Penetrating Radar Antennas" by B.J. Zook

1500 **BREAK**

1520 "A FVTD Algorithm for Maxwell's Equations on Massively Parallel Machines" by V, Ahuja and L.N. Long

1540 "The Piecewise Linear Recursive Convolution Method for Incorporating Dispersive Media into FDTD" by D.F. Kelley and R.J. Luebbers

1600 "Combining Different Coordinate Systems in the Time Domain Finite Difference Method" by J. Mrozowski and M. Okoniewski

1620 "Time Domain Response of Simulated 2D Composite Scatterers" by A.Z. Elsherbeni and P. Goggans

1640 "An Object-Oriented Approach to Writing Computational Electromagnetics Codes" by M. Zimmerman and P. Mallasch

SESSION 8: MOM (Parallel with Sessions 7 & 9)
Chair:

1600 "Moment Method Analysis of Dielectric Covered Radiating Slots Using Alternative Green's Function Approach" by S. Christopher, V.V.S. Prakash, A.K. Singh and N. Balakrishnan

1620 "Tail Rotor Modulation: Experimental and MoM Results" by J.M. Harris and M.L. Wheeler

1640 "Computation of E-Field Distribution of Low Gain Antenna on Conducting Body of Revolution" by J.Liu, J. Wang and Y. Gao

1700 "An Implementation of an Exact Scheme for Problem Decomposition Via the Use of Aperture Admittance" by D.L. Wilkes, C.C. Cha and T. Krauss

SESSION 9: FAST ALGORITHMS FOR COMPUTATIONAL ELECTROMAGNETICS" (Parallel with Sessions 7 & 10)
Organizers: E Michielssen and W. Chew

1320 "On the Use of Wavelet-like Basic Functions in the Finite Element Analysis of Elliptic Problems" (Invited Paper) by R.K. Gordon

1340 "Fast Wavelet Algorithm (FWA) for Moment Method Analysis of Electromagnetic Problems" (Invited Paper) by K. Sabertfakhri and L.P.B. Katehi

1400 "Far Field Approximation for Fast Calculation of the RCS of large Objects" (Invited Paper) by C.C. Lu and W.C.Chow

1420 "The Parameter Estimation Technique (PET): Speeding Up Dense Matrix Method" (Invited Paper) by C. Hafner

1440 "A Novel Scheme for Massively Parallel Solution of Maxwell's Equations using FDTD" (Invited Paper) by M.A. Jensen and Y. Rahmat-Sami

1500 **BREAK**

1520 "Reduction of the Filling Time of Method of Moments Matrices" (Invited Paper) by G. Vacchi, P. Pirinoli, L. Matskovita and M. Orefice

1540 "The Fast Multipole Method for Large 2D Scatterers" (Invited Paper) by L.R. Hamilton, J.J. Ottusch, M.A. Stalzer, R.S. Turley, J.L. Visher and S.M. Wandzura

1600 "A Multi-level Domain Decomposition Algorithm for Analyzing Scattering from Large Structures" (Invited Paper) by E. Michielssen and A. Boag

1620 "A 3D Fast Multipole Method for Electromagnetics with Multiple Levels" (Invited paper) by B. Dembart and E. Yip.

1640 "Fast Multipole Method Solution of Combined Field Integral Equation" by J.M. Song and W.C. Chow

SESSION 10: MICROWAVE AND GUIDED WAVE (Parallel with Sessions 7 and 9)
Chair:

1320 "Optimization of Aperiodic Conducting Grids" by R.L. Haupt

1340 "Computer-aided Characterization of Periodic Cylindrical Microstrip Lines Using Finite and Infinite Element Methods" by M.A. Kolbshdari

1400 "An Alternative Formulation of the Tranverse Resonance Technique" by A.G. Nato, S. Ariguel, H. Aubert, D. Bajon and H. Baudrand

1420 "Scattering Characteristics of Dissimilar Waveguide Slot Couplers" by A. Singh and K.S. Christopher

1440 "Computer-Simulation of Isotropic, Two-Dimensional Guided-Wave Propagation" by R.A. Speciale

1500 **BREAK**

1520 "Wave-Field Patterns on Electrically Large Networks" by R.A. Speciale

1540 "Analysis of Ultra-Short Pulse Propagation on Uniform and Tapered Printed Transmission Lines" by R.A.O. Veliz and J.R. Souza

0730 **CONTINENTAL BREAKFAST**

SESSION 11: RECENT DEVELOPMENTS IN FDTD ANALYSIS" (Parallel with Sessions 12 & 13)
Organizers: M. Piket-May and D. Katz

0840 "Simulation of Microwave Circuits by FDTD Method" (Invited Paper) by C.N. Kuo, B. Houshmand and T. Itoh

0900 "Adaptation of FDTD Techniques to Acoustic Modeling" (Invited Paper) by J.G. Maloney and K.E. Cummings

0920 "FDTD Investigation of the Antenna-Tissue Interaction for Cellular and Satellite Systems" (Invited Paper) by Y. Rahmat-Samii and M.A. Jensen

0940 "Ultrawide Band Termination of Waveguiding Structures for FDTD Simulations in 2D and 3D" (Invited Paper) by C.E. Reuter, R.M. Joseph, E.T. Thiele, D.S. Katz and A. Taflove

1000 **BREAK**

1020 "FDTD Modeling of Ultrashort Optical Pulse Interactions with Nonresonant and Resonant Materials and Stuctures" (Invited Paper) by R.W. Ziolkowski

1040 "Time Domain Analysis of Electromagnetic Wave Propagation in Nonlinear Dielectric Slab" by G. Miano, C. Serpica, L. Verolino and F. Villone

1100 "An Efficient Sub-gridding Algorithm for FDTD" by D.T. Shimizu, M. Okoniewski and M.M. Stuchly

1120 "From the Berenger PML ABC to Micro-Lasers: Recent Advances in FDTD Modeling Techniques" (Invited Paper) by A. Taflove

SESSION 12: PROPAGATION (Parallel with Sessions 11 & 13)
Organizer: K. Chamberlin

0840 "Terrain and Refractivity Effects in a Coastal Environment" by A. Barrios

0900 "A Model for Multipath Interference Due to Terrain Scattering on Line-of-Sight Microwave Radio" by C.H. Bianchi, K. Chamberlin and K. Sivaprasad

0920 "Capabilities and Limitations Associated with Using GTD to Model Propagation Path Loss in the Presence of Irregular Terrain" by K. Chamberlin

0940 "Comparison of Electromagnetic Wave Propagation Computer Programs" by S.A. Fast and T.H. Koschmieder

1000 **BREAK**

1020 "A Model for Estimating Electro-Magnetic Wave Attenuation in a Forest Environment" by C. Lemak and C. Welch

1040 "Validation of the Radio Physical Optics Propagation Model" by R.A. Paulus

1100 "VTRPE: A Variable Terrain Electromagnetic Parabolic Equation Model" by F.J. Ryan

1120 "Estimating Tropospheric Refractivity Fields Using a Nonlinear Gauss-Markov Procedure and the PE Model" by D. Boyer and F.J. Ryan

1140 "Modeling of Radio Wave Ducting Over Regular Boundary" by I.P. Zolotarev

LUNCH

SESSION 13: PARALLELIZATION OF EM CODES (Parallel with Sessions 11 & 12)
Organizers: J.L. Volakis and A. Chatterjee

0840 "Adventures in Time-Domain CEM Using Structured/Unstructured Formulations and Massively Parallel Architectures" by V. Shankar, C. Rowell, W.F. Hall and A. Mohammadian

0900 "Parallel Solutions of Maxwell's Equations in the Time-Domain" (Invited Paper) by N. Madsen, B. Eme, D. Steich and G. Cook

0920 "Parallelization of the Carlos-3D Method of Moments Code" (Invited Paper) by J.M. Putnam, D.D. Car and J.D. Kotulski

0940 "Parallel Computing for Electromagnetism at ONERA" (Invited Paper) by A.De La Bourdonnaye, P. Leca and F.X. Roux

1000 **BREAK**

THURSDAY MORNING 23 MARCH

SESSION 13 PARALLELIZATION OF EM CODES (CONTINUED)

1020 "The Performance of the Parallel Solution of the Quasi-Minimal Residual (QMR) Method on the 2D Mesh Architectures" (Invited Paper) by L. Hamandi, O. Ozguner and R. Lee

1040 "Advanced Parallel Solver Techniques" (Invited Paper) by A.S. King

1100 "A Parallel Fast Multipole Method" (Invited Paper) by M.A. Steizer

LUNCH

THURSDAY AFTERNOON 23 MARCH

SESSION 14: ELECTROMAGNETIC MODELING TECHNIQUES FOR INTEGRATED OPTICS (Parallel with Sessions 15 & 17)
Organizer: A. Cangellaris

1320 "Analysis and Design of Guided-wave Optical Devices Using Finite-Difference Time-Domain Method" (Invited Paper) by S.I. Chaudhuri and S.T. Chu

1340 "Vectorial Analysis of Optical Waveguides by the Method of Lines" (Invited Paper) by R. Pregis and W. Pascher

1400 "Vector Finite Element Analysis of Lossless and Lossy Dielectric Waveguides" (Invited Paper) by P. Cheung and A. Gopinath

1420 "Finite Element Analysis of Integrated Optical Structures" (Invited Paper) by by F.A. Fernandez, F. DiPasquale and J.B. Davies

1440 "Analysis of Coupled Nonlinear Optical Waveguides by Matrix Method" by V. Tripathi, A. Weisshaar and H.S. Chang

1500 **BREAK**

1520 "NL-FDTD Modeling of Linear and Nonlinear Corrugated Waveguiding Systems for Integrated Optics Applications" (Invited Paper) by R.W. Ziolkowski and J.B. Judkins

SESSION 15: TOPICS IN FRACTAL AND WAVELET ELECTRODYNAMICS (Parallel with Sessions 14 & 17)
Organizer: D.H. Werner and P. Werner

1320 "An Overview of Fractal Electrodynamics Research" (Invited Paper) by D.H. Werner

1340 "Fractal Arrays and Fractal Radiation Patterns" (Invited Paper) by P.L. Werner and D.H. Werner

1400 "Wavelet Transforms and Time/Time-scale Analysis" (Invited Paper) by R.K. Young and T.G. Goldsberry

1420 "Wavelet-based Processing to Efficiently Achieve Broadband Monostatic and/or Passive Cross-Sensor Processing" (Invited Paper) by R.K. Young and L.H. Sibul

1440 "The Intervalilo Wavelets with Application in the Surface Integral Equations" (Invited Paper) by G.W. Pan and J.Y. Du

1500 **BREAK**

1520 "Radar Cross Section Data Reduction Using Wavelets" by A.S. Ali, S.E. Duval and R.L. Haupt

SESSION 16: NEC APPLICATIONS (Parallel with Session 18)
Organizer: J. Breakall

1600 "Computationally Efficient and Accurate Approximations for Impedance Matrix Elements of NEC-Type Method of Moments Formulations" by D.H. Werner, S.E. Metker and J.A. Huffman

1620 "Development of the Coupled-Resonator Antenna Principle-A Computer Modeling Case History" by G. Breed

1640 "Predicting Phase Anomalies of LORAN C. Signals in an Urban Environment Using the Numerical Electromagnetics Code (NEC)" by M.E. McKaughan, B.B. Peterson, W.M. Randall and P. Arts

SESSION 17: FEM (Parallel with Sessions 14 & 15
Chair:

1320 "Numerically Characterizing Electro-magnetic Fields Local to the Edge of a Conducting Strip Using a Matched Asymptotic Technique and the Finite Element Method" by A.S. Ali and C.L. Holloway

1340 "An Enhanced 'A Posteriori' Remeshing Algorithm for Adaptive Meshing of 2D Finite Element Problems" by P. Girdinio, A. Manella and G. Mollinari

1400 "Finite Element Analysis of Waveguides Using Edge-Based Magnetic Vector Potential and Nodal-Based Electric Scalar Potential" by J.F. Lee, G. Lizalek and J. Brauer

1420 "A Scattering Analysis of Laser Beam Wave by Groove Pits on Optical Memory Disk by Using FEM with BEM" by Y. Miauzski and K. Tanaka

1440 "3D Nodal and Mixed-Based Elements for Unbounded Microwave Problems" by A. Nicolas, L. Nicolas, and J.L. Yao-bi

1500 **BREAK**

1520 "A Rationale for the Use of Mixed-order Basis Functions within Finite Element Solutions of the Vector Helmholtz Equation" by A.F. Peterson and D.R. Wilton

1540 "Finite Element Waveguide Simulator Techniques" by J.R. Sanford and N.M. Johansson

1600 "A Solution for Open Boundary Electromagnetic Field Problems by Mapped Infinite and Virtual Elements" by L.H.A. de Medelros and A. Reizer

1620 "Spectral Finite Element Methods for the Simulation of Electromagnetic Interactions with Electrically Long Structures" (Invited paper) by A.C. Cangellaris and D. Hart

SESSION 18: PARALLEL COMPUTATION (Parallel with Session 16)
Chair:

1540 "Implementation of the Finite-difference Time-Domain Method on Parallel Computers" by R.S. David and L.T. Wills

1600 "Parallelized FDTD for Antenna Radiation Pattern Calculations" by Z.M. Liu, A.S. Mohan, T. Aubrey, and W.R. Belcher

1620 "Accurate MoM Scattering Calculations Using Massively Parallel Computation" by J.S. Bagby

1640 "A Tool Box for Parallelization of Moments Method Codes" by E. Yip, B. Blakely, L. Johnson, D. Jurgens and R. Kochhar

1700 "Calculation of Electromagnetic Fields with the Multiple Multipole Method (MMP Method) on Parallel Computers" by C. Tudziers and H. Singer

1720 "Parallelization of the Parametric Patch Moment Method Code" by X. Shen G. Cheng, G.E. Mortensen, C.C. Cha and G.C. Fox

FRIDAY MORNING 24 MARCH

SESSION 19: EM ANALYSIS TECHNIQUES FOR ELECTRICALLY LARGE CAVITIES (Parallel with Sessions 20 & 21)
Organizer: D. Pflug

0730 **CONTINENTAL BREAKFAST**

0840 "Application of Modal and Plane Wave Expansions to Modeling Large Jet Engine Cavities" (Invited Paper) by J.L. Karty and J.M. Roedder

0900 "An Extension of Shooting and Bouncing Rays for Dielectric Loaded Cavities" (Invited Paper) by M. Christensen and S.W. Lee

0920 "Xpatch Simulation of Large Inlet Structures" (Invited Paper) by R. Bhalla and H. Ling

0940 "An Interative Physical Optics Approach for the EM Analysis of Cavities and Other Multi-Bounce Geometries" (Invited Paper) by R.J. Burkholder

1000 **BREAK**

1020 "Improved Ray Basis in the Hybrid Analysis of EM Scattering by Large Open Cavities" (Invited Paper) by R.J. Burkholder, P.H. Pathak, H.T. Chou, D. Andersh and J. Fath

1040 "Overlapping Modal and Geometric Symmetries for Computing Jet Engine Inlet Scattering" (Invited Paper) by D.C. Ross, J.L. Volakis, H.T. Anastassiu and D. Andersh

SESSION 20: ACCURACY ESTIMATION BY ELECTROMAGNETIC MODELING (Parallel with Sessions 19 & 21)
Organizer: B.M. Wandzura

0840 "On the Roles of Coefficient Accuracy, Metrix Condition Number and size, and Compute Precision on Matrix-Solution Accuracy" (Invited Paper) by E.K. Miller

0900 "Numerical Accuracy Issues in Finite Element Frequency Domain Solutions of Radar Scattering Problems" (Invited Paper) by J. D'Angelo

0920 "Accuracy in Computation of Matrix Elements of Singular Kernels" by S.M. Wandzura

0940 "Accuracy Estimation and High Order Methods" by L.R. Hamilton, J.J. Ottusch, M.A. Stalzer, R.S. Turley, J.L. Visher, and S.M. Wandzura

1000 **BREAK**

1020 "Accuracy Issues in Time-Domain CEM Using Structured/Unstructured Formulations" (Invited Paper) by V. Shankar and W.F. Hall

1040 "An Accuracy Study for the 3D Hybrid Finite Element Method of Moments SWITCH Code" (Invited Paper) by G.E. Antille and Y.C. Ma

1100 "Requiring Quantitative Accuracy Statements in EM Data" (Invited Paper) by E.K. Miller

LUNCH

SESSION 21: PDE METHODS IN ELECTROMAGNETICS (Parallel with Sessions 19 & 20)
Organizers: R. Lee and J.F. Lee

0840 "Scalar and Vector Potential Methods for Low Frequency Computational Electromagnetics Using Nodal Finite Elements" (Invited Paper) by W.E. Boyse

0900 "Large-Scale Computation of 3D Scattering Using Conformal ABCs on Massively Parallel Architectures" (Invited Paper) by A. Chattarjee and J.L. Volakis

0920 "A Characteristic-Based 3D Time Domain Maxwell Equation Solver" (Invited Paper) by K.C. Hill and J.S. Shang

0940 "Finite Element Solution of Eddy Current Problems in Electromagnetics" (Invited Paper) by O.A. Mohammed

1000 **BREAK**

1020 "Ten Years of Evolution of the FDTD-like Conformal Technique" (Invited Paper) by K.S. Yee

1040 "Whitney Elements Time Domain (WETD) Methods for Solving Three-Dimensional Waveguide Discontinuities" (Invited Paper) by J. Lee

1100 "An FDTD/FVTD 2D-Algorithm" by J.S. Chen, J.V. Prodan and K.S. Yee

LUNCH

SESSION 22: INTERFACES AND VISUALIZATION (Parallel with Sessions 23 & 24)
Chair:

1320 "Dosimetry in a Voxel Modal of the Head" by P.J. Dimbylow

1340 "A Graphical User Interface for the NEC-BSC" by L.W. Henderson and R.J. Marhefka

1400 "3D Visual Solution for Dispersive Relations of Non-Uniform Waveguides" by B.J.Kapilevich and T.A. Rahman

1420 "AM Broadcast Prediction System" by M.J. Packer and A.P. Tsitsopoulos

1440 "A FDTD Visualization Tool for MS-Windows" by C.D. Taylor, Jr. and A.Z. Elsherbeni

1500 **BREAK**

1520 "Computer Code for Field Calculation and Visualization in Quasioptics" by Y.V. Kopylov

SESSION 23: VALIDATION (Parallel with Sessions 22 & 24)
Chair:

1320 "Transformable Scale Aircraft-Like Modal (TSAM) for Validation of Computational Electromagnetic Modals and Algorithms: Initial Configuration and Results" by D.R. Pflug and D. Warren

1340 "Measurement Study for Validation of Electromagnetic Scattering Codes on a Complex 3D Target" by J. Jurgens and T. Kienberger

1400 "Code Validation of Aircraft Scattering Parameters Using IR Thermograms" by J. Norgard, R. Sega, M. Siefert, T. Blocher and A. Pesta

1420 "Validation Using a Moment Method Approach with Exact Object Representation" by J.A. Larsson, S. Ljung and B. Wahlgren

1440 "A New Angle on a Low Cost Ground Screen for Model Testing in the Undergraduate Antennas Laboratory [Looking at Near Vertical Incidence Skywaves (NVIS) for a Coast Guard Patrol Boat]" by M.E. McKaughan, W.M. Randall and B. Nutter

1500 **BREAK**

1520 "IR Measurement for Validating EM Analysis Tools" by M. Seifert, T. Blocher and A. Pesta

SESSION 24: EM THEORY I (Parallel with Sessions 22 & 23)
Chair:

1320 "Conversion of Mechanical Energy to Electromagnetic Energy" by R.J. Bevensee

1340 "Numerical Solution of Highly Oscillatory Solutions of the Wave Equation" by B. Enquist, E. Fatemi, and S. Osher

1400 "Analysis of Micro-Contamination of Silicon Wafers Based on Discrete Sources Method (DSM)" by Y.A. Eremin and N.W. Orlov

1420 "Analysis of Convergence Properties of Projection Methods for Solving CEM Applications" by V.I. Ivakhnanka, A.V. Kukk, E.E. Tyrtyshrikov, A.Y. Yeremin and N.L Zemarashkin

1440 "Block-Toeplitz Structure-Based Solution Strategies for CEM Problems" by V.J. Ivakhnanka and E.E. Tyrtyshrikov

1500 **BREAK**

1520 "Image Transfer Characteristics of Aerosole with Irregularly Shaped Particles" by A.A. Kokhanovsky

1540 "A New Method for Solving Scattering Problems with Conducting Media in the Time Domain" by M. Schinke and K. Reiss

1600 "A STEM (Statistical Electromagnetics) Research Program" by W.P. Wheless, Jr., C.B. Wallace and W.D. Prather

1620 "Calculation of Space-Time Filter for Laser Dopplar Velosimeter (LDV)" by V. Zemlyanskiy and N. Divnich

SESSION 25: EM THEORY II (Parallel with Session 26)
Chair:

1540 "Application of the Radiation Condition Integral Equations to Electromagnetic Scattering" by P.C. Colby

1600 "The Two-Dimensional Finite Integral Techniques Combined with the Measured Equation of Invariance Applied to Transverse Electric Open Region Scattering Problems" by G.K. Gothard and S.M. Rao

1620 "Artificial Transparent Boundaries in Computational Quasioptics" by A.V. Popov

1640 "Determination of the Complex Aperture Distribution of a Planar Spiral Antenna from 3D Far-Field Radiation Pattern Data" by M. Kluskens, W. Lippincott and M. Kragslott

1700 "Algorithm for Solving Surface Integral Equations for Electrically Large Impenetrable Scatterers" by E. Bleszynski and M. Bleszynski

SESSION 26: EMI/EMC/EMP (Parallel with Session 25)
Chair:

1540 "Analysis of Electromagnetic Interference at an Ocean Observation Post" by L. Bai and J.F. Dai

1600 "Enforcing Correlation on Statistically Generated Cable Drivers" by R. Holland and R. St. John

1620 "Analysis of Different Contributions to the Coupling Between Reflector Antennas on a Satellite" by C. Park and P. Ramanujam

1640 "Simple Radiation Models in Lieu of EMC Radiated Emissions Testing" by R. Perez

SATURDAY 25 MARCH SHORT COURSES

0830-1630 **SHORT COURSE (FULL-DAY)**
"Using Mathematical Software for Computational Electromagnetics" by Jovan Lebaric, Naval Postgraduate School

0830-1630 **SHORT COURSE (FULL-DAY)**
"Wire Antenna Modeling Using NEC" by Richard Adler, Naval Postgraduate School, Jim Breakall, Penn State University, and Gerry Burke, Lawrence Livermore National Lab

0830-1630 **SHORT COURSE (FULL-DAY)**
"FDTD, Generalized FDTD and FVTD Techniques in Solving Maxwell"s Equations" by Kane Yee, Lockheed

SHORT COURSES AT THE 11TH ANNUAL REVIEW OF PROGRESS IN APPLIED COMPUTATIONAL ELECTROMAGNETICS

The Applied Computational Electromagnetics Society (ACES) is pleased to announce eight short courses to be offered with its annual meeting of March 20-25, 1995. The short courses will be held on Monday and Saturday. Registration begins at 7:30 AM on Monday, 20 March 1995. [Note: Tues-Fri. will be the technical sessions, and vendor exhibits]. ACES has the right to cancel a course at any time with full refund. For further information contact Richard W. Adler, Symposium Administrator, Phone: 408-646-1111, Fax: (408) 649-0300, E-mail: 554-1304@mcimail.com

COURSE INFORMATION

"FINITE ELEMENTS FOR ELECTROMAGNETICS" by John Brauer, MacNeal-Schwendler Corp.

The course will develop and apply nodal-based and edge-based finite elements, including higher order isoparametric hexahedrons. Local and global mesh truncation techniques of various kinds will be examined. Applications will include antennas, microwave circuits, nonlinear magnetic apparatus, electronic packaging, and electromagnetic compatibility. (Full-day, Monday, 20 March)

"GEMACS FROM A-Z" by Buddy Coffey, Advanced EM.

The General Electromagnetic Model for the Analysis of Complex Systems (GEMACS) includes capabilities for method of moments, uniform theory of diffraction, finite differences, and numerically rigorous hybrids of any and all techniques. The code is supported by a rich command and geometry language consisting of over 100 commands. The Short Course will walk the user through the GEMACS command set and geometry elements as electromagnetic models are constructed for practical EM problems, such as antenna radiation, structure coupling, scattering, etc. Emphasis is on "how to" and participants are encouraged to bring portable computers to the class. A complimentary copy of the unlimited distribution version of the GEMACS software will be given to each participant. (Full-day, Monday 20 March)

"USING MATHEMATICAL SOFTWARE FOR COMPUTATIONAL ELECTROMAGNETICS" by Jovan Lebaric, Naval Postgraduate School.

The ability of MATHCAD to solve electrostatic (Superposition Integral Solution) and radiation/scattering (method of moments) problems is presented. MATLAB is used to obtain a finite difference solution of 2-D static problems where the open boundary is handled via Transparent Grid Termination (TGT). Also, MATLAB is used for 2D-FDTD wave simulations with extensions to 3-D. Open boundaries are handled with the Discrete Boundary Impulse Response (DBIR). All attendees will receive a copy of a MATLAB 2D electrostatic/magnetostatic FD program and a copy of the MATLAB 2D FDTD program. A PC for each attendee will be available for use with the class. (Full-day, Saturday 25 March)

"PHYSICAL WAVELETS" by Gerald Kaiser, University of Massachusetts at Lowell.

Wavelet analysis is a mathematical method allowing efficient representation of signals, usually without any connection to physics. We show that the PDE's governing EM and acoustics imply the existence of physical wavelets from which all other EM and acoustic waves can be built. These wavelets behave simply under propagation and scattering which should make them useful for radar and other imaging methods. (Full-day, Monday 20 March)

WIRE ANTENNA MODELING USING NEC" by Dick Adler, Naval Postgraduate School, Jim Breakall, Penn State University, and Gerry Burke, Lawrence Livermore National Lab.

Historical background in wire antenna modeling is reviewed, tracing the development and capabilities of NEC-MoM codes 1, 2, 3 and 4. Modeling guidelines, code limitations, and lessons learned during two decades of NEC use are explained. Recent advances in user interfaces and optimizer applications are detailed. Several visualization programs are demonstrated. (Full-day, Saturday 25 March)

SHORT COURSES AT THE 11TH ANNUAL REVIEW OF PROGRESS IN APPLIED COMPUTATIONAL ELECTROMAGNETICS(CONT.)

"FDTD, GENERALIZED FDTD AND FVTD TECHNIQUES IN SOLVING MAXWELL'S EQUATIONS" by Kane Yee, Lockheed.

The workshop will provide a coherent account of the development of the finite difference time domain (FDTD) and its generalization in solving Maxwell's equations. The generalized FDTD, which is based on the surface-curve integral form of the Maxwell's equations, will be emphasized in the derivation of the numerical algorithms. The finite volume time domain (FVTD), which is based on the volume-surface integral forms of the Maxwell's equations, can be very convenient when unstructured grids are employed. Boundary condition simulation will be emphasized. (Full-day, Saturday 25 March)

"VERIFICATION AND VALIDATION OF COMPUTATIONAL SOFTWARE" by E.K. Miller, Ohio University.

One of the most time-consuming activities associated with developing and applying EM computer models is that of verifying code (software) performance and validating the model results. Few available computational packages offer the user any built-in assistance in resolving these important issues. This lecture will discuss the kinds of errors that most commonly occur in modeling, and present numerous examples of validation checks that can be considered. Also discussed are the kinds of information that can be realistically expected from a computer model and how and why the computed results might differ from physical reality. (Half-day, Monday 20 March)

"THE MULTIPLE MULTIPOLE PROGRAM (MMP): THEORY, PRACTICAL USE AND LATEST FEATURES" by Pascal Leuchtmann.

A brief summary of theoretical background, in particular MMP as opposed to moment methods, is presented. This is followed by a discussion of basic modeling ideas and their application to scattering problems, dosimetry, near field optics, antennas, waveguides, etc. We also examine the 'art of MMP' and their automatization. Practical demonstrations (field movies etc.) are shown with a notebook workstation. (Half-day, Monday 20 March)

THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY

11TH ANNUAL REVIEW OF PROGRESS
IN APPLIED COMPUTATIONAL ELECTROMAGNETICS

March 20 - 25, 1995
Naval Postgraduate School
Monterey, CA

Registration Form

Please print (NOTE: CONFERENCE REGISTRATION FEE DOES NOT INCLUDE ACES MEMBERSHIP FEE)

LAST NAME ____ FIRST NAME ____ MIDDLE INITIAL ____

COMPANY/ORGANIZATION/UNIVERSITY ____ DEPARTMENT/MAIL STATION ____ PHONE ____ FAX ____

MAILING ADDRESS ____

CITY ____ PROVINCE/STATE ____ COUNTRY ____ ZIP/POSTAL CODE ____

TELEPHONE ____ FAX ____ AMATEUR RADIO CALL SIGN ____

PLEASE CHECK APPROPRIATE BOXES.	BEFORE 3/3/95	3/4/95 TO 3/13/95	AFTER 3/13/95	TOTAL COST
ACES MEMBER	$245	$260	$275	
NON-MEMBER	$260	$270	$285	
FULL-TIME STUDENT * (no proceedings)	$115	$115	$115	
RETIRED/UNEMPLOYED	$150 (includes proc.)	$150	$150	
BANQUET	$ 28			

Short Courses

Fees do NOT include attendance at the symposium. Short courses can be taken without attendance at symposium, if desired.
Fees for a Half-day and full day course are: $90 or $140, before 3/3/95; $100 or $150, 3/6-3/13/95; $110 or $160, after 3/13/95.

☐ **"FINITE ELEMENTS for ELECTROMAGNETICS" by John Brauer**
Full-day, Monday — ☐ $140 ☐ $150 ☐ $160

☐ **"GEMACS FROM A-Z" by Buddy Coffey**
Full-day, Monday — ☐ $140 ☐ $150 ☐ $160

☐ **"USING MATHEMATICAL SOFTWARE for COMPUTATIONAL ELECTROMAGNETICS"**
by Jovan Lebaric, Full-day, Saturday — ☐ $140 ☐ $150 ☐ $160

☐ **"PHYSICAL WAVELETS" by Gerald Kaiser**
Full-day, Monday — ☐ $140 ☐ $150 ☐ $160

☐ **"WIRE ANTENNA MODELING USING NEC" by Dick Adler, Jim Breakall, and Gerry Burke**
Full-day, Saturday — ☐ $140 ☐ $150 ☐ $160

☐ **"FDTD, GENERALIZED FDTD and FVTD TECHNIQUES in SOLVING MAXWELL'S EQUATIONS"**
by Kane Yee, Full-day, Saturday — ☐ $140 ☐ $150 ☐ $160

☐ **"VERIFICATION and VALIDATION of COMPUTATIONAL SOFTWARE: by E.K. Miller**
Half-day, Monday — ☐ $ 90 ☐ $100 ☐ $110

☐ **"THE MULTIPLE MULTIPOLE PROGRAM (MMP): THEORY, PRACTICAL USE and LATEST FEATURES" by Pascal Leuchtmann, Half-day, Monday** — ☐ $ 90 ☐ $100 ☐ $110

Method of payment:
☐ A bank check for the total amount is enclosed.(1)
☐ Traveler's checks for the total amount are enclosed.(2)
☐ International Money Order is enclosed.(3)
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Card No. ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

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SIGNATURE MANDATORY

Non-USA participants may remit via (1) **Bank Checks**, if (a) drawn on a U.S. Bank, (b) have bank address, (c) contain series of (9) digit mandatory routing numbers; (2) **Traveler's Checks** (in U.S. $$); **(3) International Money Order** drawn in U.S. funds, payable in U.S.; (4) **Credit Cards:** Visa or Master Card.

Total Remittance (U.S. Dollars Only) $ ____________

MOTELS / HOTELS LIST FOR 1995 ACES SYMPOSIUM

(PRELIMINARY LISTING)

FIRESIDE LODGE (**) (1 star)
1131 10th St. Monterey, CA 93940
(408) 373-4172
Govt. Rate $55 (tax: see below)
Conference Rate: $69 + 10% tax.
Make reservations by 2/17/95

HYATT HOTEL & RESORT (**) (4 Star)
1 Old Golf Course Rd. Monterey, CA 93940
(408) 372-1234
Govt. Rate: $74 S $101.50 D (tax: see below)
Conference Rate: $102/single $127 D + 10% tax.
Block of rooms reserved. 24-30 rooms reserved.
Make reservations by 2/15/95

HOLIDAY INN (**) (3 Star)
1000 Aguajito Rd. Monterey, CA 93940
(408) 373-6141
Govt. Rate $74 (tax: see below)
Conference Rate: $89 + 10% tax
Block of rooms reserved.
Make reservations by 2/24/95

STAGECOACH MOTEL (**) (1 Star)
1111 10th St. Monterey, CA 93940
(408) 373-3632
Govt. Rate $49 (tax: see below)
Conference rate: $49 Single, $59Double +10% tax
POC: Sales Director
Make reservations by 2/20/95

SUPER 8 MOTEL (2 Star)
2050 Fremont St. Monterey, CA. 93940
(408) 373-3081
Govt. Rate $40 thru Thursday
Conference rate: same as Govt rate, + 10% tax.
Make reservations by 2/20/95

** (Within walking distance of NPS)

HOW TO AVOID PAYING THE MONTEREY 10% CITY TAX:
(THIS APPLIES ONLY TO THOSE USING GOVERNMENT TRAVEL ORDERS)

TAX EXEMPTION APPLIES WITH ALL OF THE FOLLOWING DOCUMENTS:
(1) PAYMENT BY GOVERNMENT AMERICAN EXPRESS CARD
(2) TRAVEL ORDERS
(3) GOV'T/MILITARY IDENTIFICATION CARD.

ALL CONFERENCE ATTENDEES SHOULD DO THE FOLLOWING:

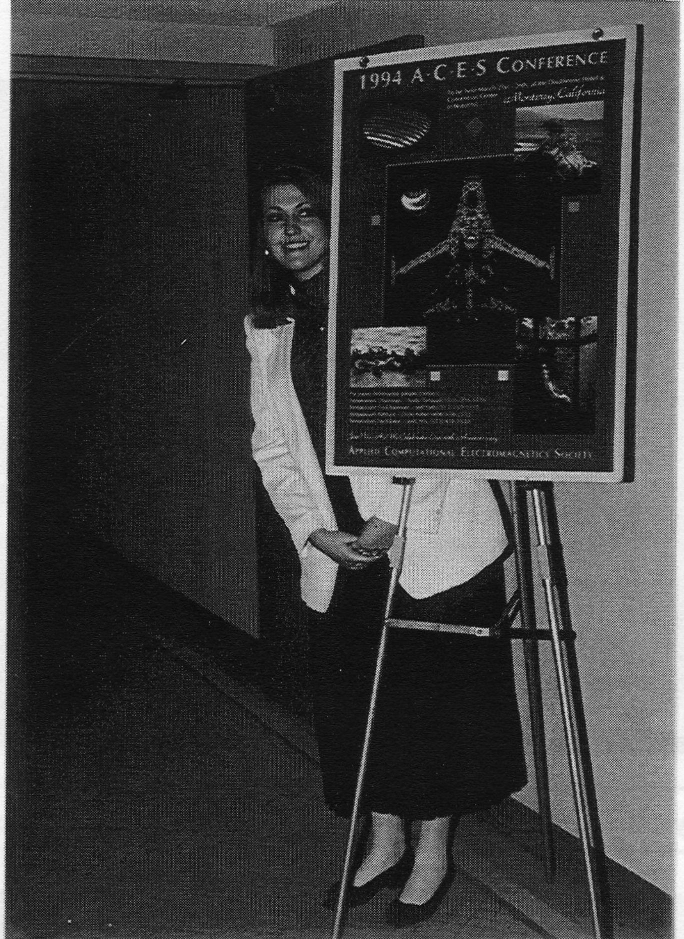
REMEMBER TO MENTION THAT YOU ARE ATTENDING THE "ACES" CONFERENCE AT THE NAVAL POSTGRADUATE SCHOOL;
and
ASK FOR GOVERNMENT, PROMOTIONAL, OR CONFERENCE RATES.

NOTE: THERE IS NO PARKING ON CAMPUS

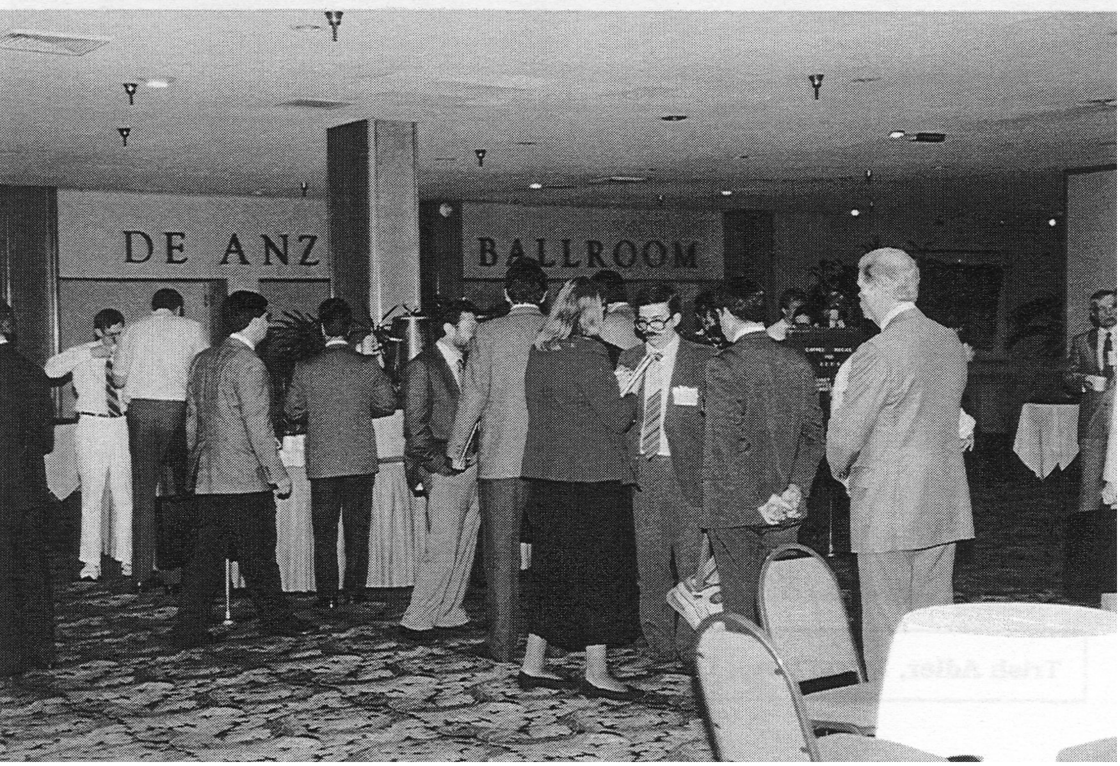
AND

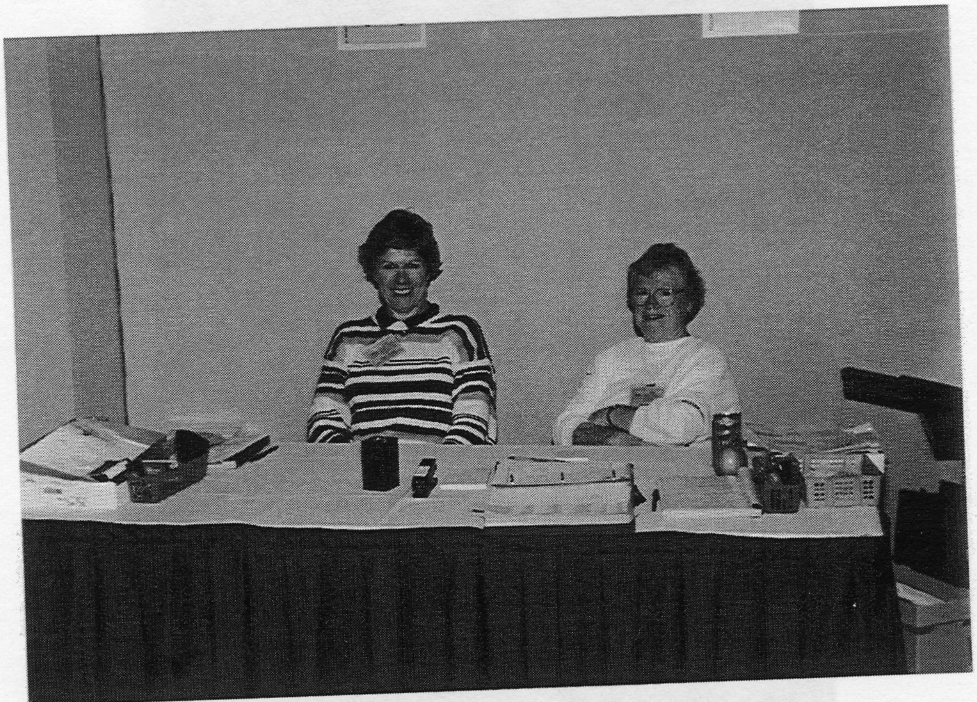
NO STREET PARKING WITHIN SEVERAL BLOCKS OF NPS.
(we recommend taxis, walking, etc)

BEFORE ARRIVAL AT NPS, THOSE TRAVELING ON GOVERNMENT TRAVEL ORDERS MUST CONTACT THE NPS BOQ OFFICE TO RECEIVE A NON-AVAILABILITY CERTIFICATION NUMBER. WITHOUT THIS NUMBER PREASSIGNED, THE BOQ WILL NOT STAMP TRAVEL ORDERS WITH NON-AVAILABILITY CONFIRMATION. NPS BOQ PHONE NUMBER IS AV 878-2060/9 OR 408-656-2060/9.



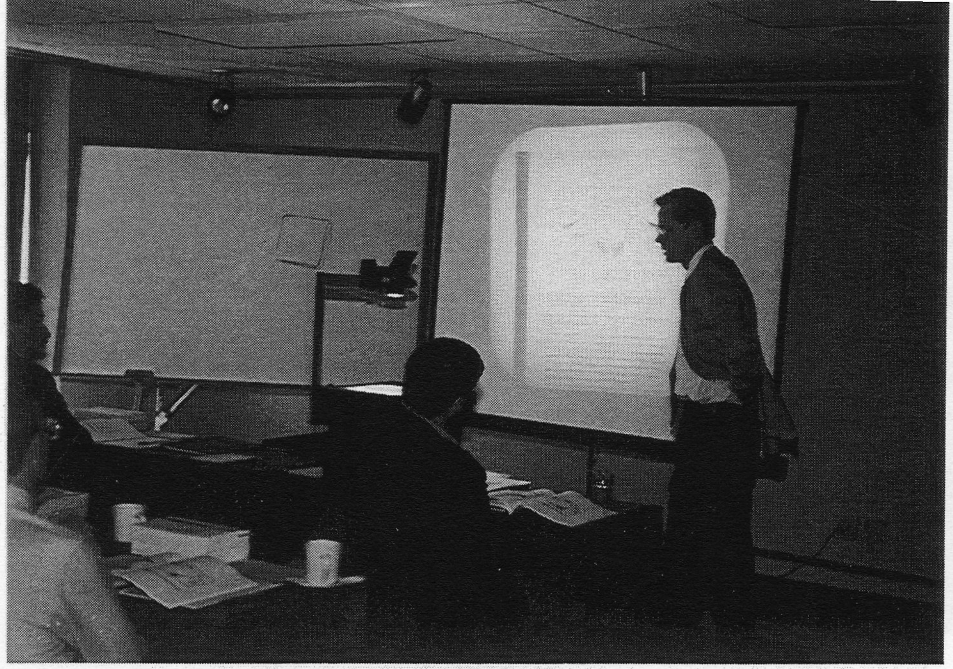
Jodi Nix, Conf. facilitator, wonders if she is dreaming or if this is finally IT!





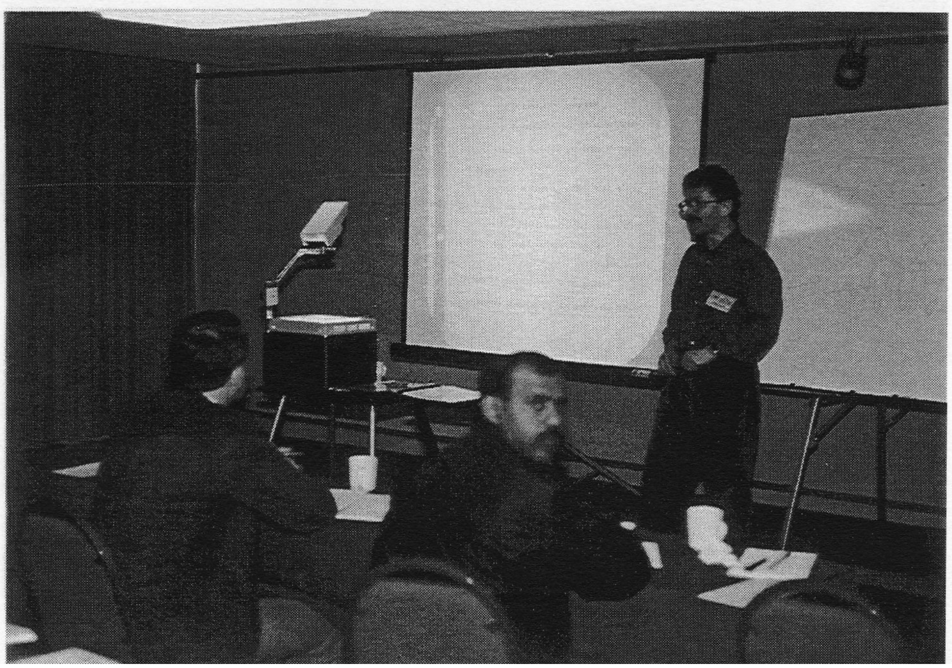
JoEllyn Knapp and Pat Adler, ready for the registration rush

Trish Adler, Marie Doty, Gloria White and Wendy Adler, at your service

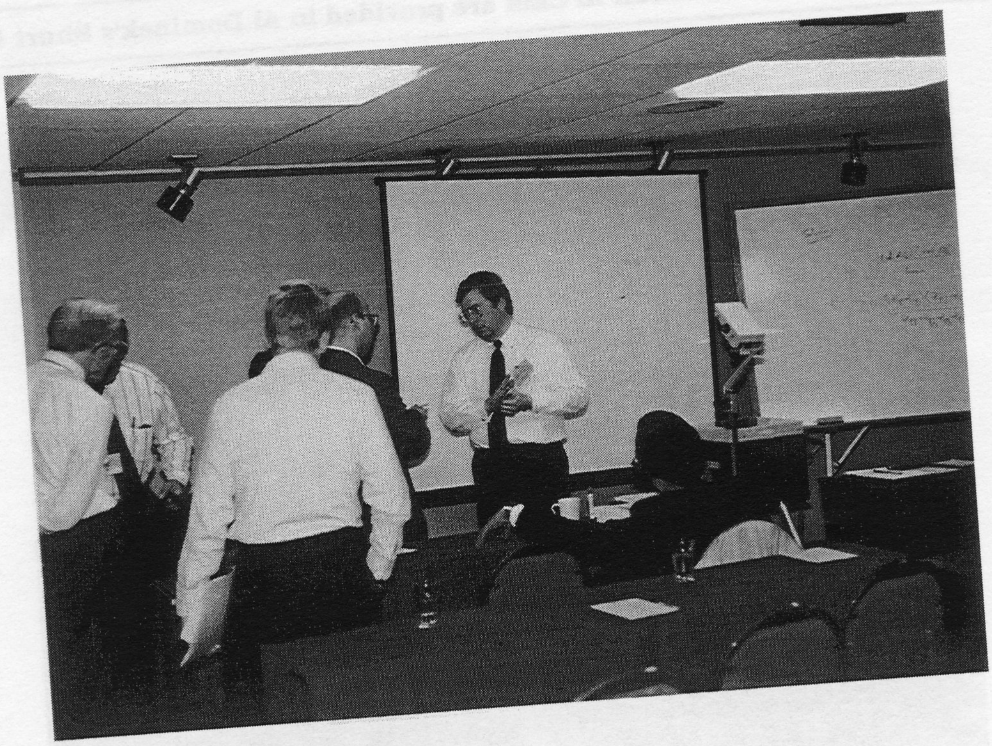


The venerable Ed Miller, encourages ideas, in his short course.

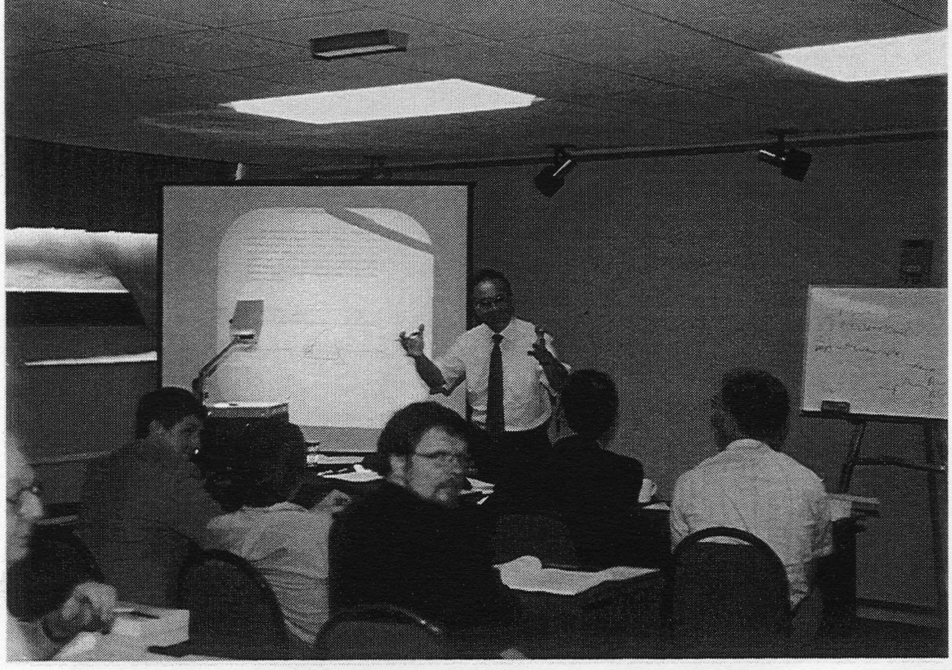
Guidelines on Model Validation in CEM are provided in Al Dominek's Short Co



The venerable Ed Miller, exchanges ideas, in his short course.



"Mr. GEMACS", Buddy Coffey, during his short course break, listening to a GEMACS user.



Leon Cohen "plows new ground" as he proposes approaches to non-stationary processes.

Arje Nachman expounds

Arje Nachman expounds

Dick Adler, talking to Andy Peterson, new ACES Treasurer