APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY (ACES)

NEWSLETTER

Vol. 9 No. 2 July 1994

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ACES NEWSLETTER STAFF

EDITOR-IN-CHIEF, NEWSLETTER
Ray Perez
Jet Propulsion Lab. Mail Sta. 301-460
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109, U.S.A.
Phone:(818) 354-9771
Fax: (818) 393-4699
E-mail:Perez@sec-521.jpl.nasa.gov

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

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

MANAGING EDITOR
Richard W. Adler
Pat Adler, Production Assistant
Naval Postgraduate School/ECE Department
Code ECAB, 833 Dyer Road, Room 437
Monterey, CA 93943-1913, U.S.A.
Phone: 408-646-1111
Fax: 408-649-0300
email:554-1304@mcimail.com

EDITORS

CEM NEWS FROM EUROPE
Pat R. Foster
Microwaves and Antenna Systems
16 Peachfield Road
Great Malvern, Worc, UK WR14 4AP
Phone: +44 684 5744057
Fax: +44 684 573509

TECHNICAL FEATURE ARTICLE
Todd Hubing
University of Missouri, Rolla/EE Dept.
219 Electrical Engineering Building
Rolla, MO 65401-0249, U.S.A.
Phone:(314) 341-6069
Fax: (314) 341-4532
e-mail:thubing@ee.umr.edu

MODELER'S NOTES
Gerald Burke
Lawrence Livermore National Labs.
Box 5504/1-156
Livermore, CA 94550, U.S.A.
Phone:(510) 422-8414
Fax: (510) 422-3013
e-mail:Burke@icaen.llnl.gov

PERSPECTIVES IN CEM
Andrew J. Terzuoli, Jr.
Air Force Institute of Technology
P.O. Box 3402
Dayton, OH 45401-3402, U.S.A.
Phone:(513) 255-4717
Fax: (513) 476-4055

ADVERTISING, REPORTS
Paul Zeineddin
The MITRE Corporation
Dept. J-023, Mail Stop Z450
7525 Colshire Drive
McLean, VA 22102-3481, U.S.A.
Phone:(703) 883-3677
Fax: (703) 883-5914

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

TUTORIAL
James Drewniak
University of Missouri-Rolla
Dept. Electrical Engineering
221 Engineering Res. Lab.
Rolla, MO 65401-0249 U.S.A.
Phone:(314) 341-4969
Fax: (314) 341-4532
e-mail:drewniak@ee.umr.edu

ACES JOURNAL

EDITOR-IN-CHIEF
Duncan Baker
EE Department
University of Pretoria
0002 Pretoria, SOUTH AFRICA
Phone: +27 12 420 2775
Fax: +27 12 43 3254
e-mail:duncan.baker@ee.up.ac.za

ASSOCIATE EDITOR-IN-CHIEF
Adalbert Konrad
ECE Department
University of Toronto
10 King's College Road
Toronto, Ontario, CANADA M5S 1A4
Phone:(416) 978 1808
e-mail:konrad@power.ele.utoronto.ca

ACES NEWSLETTER AND JOURNAL COPY INFORMATION

Issue	Copy Deadline
March	January 25
July	May 25
November	September 25

For further information on the ***ACES JOURNAL,*** contact Prof. Duncan Baker at the above address.

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.

AUTHORSHIP AND BERNE COPYRIGHT CONVENTION

The opinions, statements and facts contained in this Newsletter are solely the opinions of the authors and/or sources identified with each article. Articles with no author can be attributed to the editors or to the committee head in the case of committee reports. The United States recently became part of the Berne Copyright Convention. Under the Berne Convention, the copyright for an article in this newsletter is legally held by the author(s) of the article since no explicit copyright notice appears in the newsletter.

OFFICER'S REPORTS

PRESIDENT'S COMMENT

The 10th Annual Review was a resounding success. Elsewhere in this issue are the actual financial data, but you can be certain that the Review succeeded in terms of finances, attendance (242, which is a record), and quality of papers.

There are a number of reasons for this success, but, clearly, the primary one was the outstanding effort made by Andy Terzuoli and the team he assembled, which consisted of Jeff Fath, of Wright-Patterson Air Force Base, and Jodi Nix, of VEDA Corporation. Without Andy's support the Conference simply could not have achieved the results that it did. I, for one, will always be grateful to Andy, Jeff, and Jodi for making our 10th one to remember.

Dave Stein, chairman of the Awards Committee, gave a record number of awards, but that was quite appropriate for a tenth anniversary gala. Probably we've been a little chintzy with awards in the past. Congratulations to all who were recognized.

I believe that ACES is becoming recognized as being the pre-eminent society dedicated to computational electromagnetics, and as such, it should reach out to all people who have an interest in CEM. This includes others than Ph.D researchers, or those who hope to be Ph.D researchers. Are you aware of the number of ham radio operators who use NEC? Why aren't they members of ACES? Are we creating a society that could be hospitable to such people? As a result of a discussion at the annual BoD meeting, we are looking into this question, and are considering structured dues, and publications, that could be attractive to hams. We welcome your thoughts on these ideas.

ACES is also considering developing marketing strategies to promote itself and its products, perhaps to the extent of hiring a marketing director who would be paid on a commission basis. If you believe that you have strengths in this area, and would like to be considered for this task, please contact Frank Walker, who is our vice-president and chairman of the Ways and Means Committee, or me.

There are a number of other matters that I will discuss in the future, but right now I have to go home and mow the lawn.

Have a very pleasant summer.

Hal Sabbagh

SECRETARY'S REPORT

ACES BOARD OF DIRECTORS MEETING
20 March 1994

The Board of Directors of the Applied Computational Electromagnetics Society, Inc. met in Monterey, CA, at the DoubleTree hotel on Sunday, 20 March 1994. President Harold Sabbagh presided. In addition to ACES Executive Officer Richard W. Adler, the following Board members were in attendance: Jim Breakall, Pat Foster, Ed Miller, Andy Peterson, Hal Sabbagh, Frank Walker, and Perry Wheless. Ray Luebbers arrived late in the meeting. After the minutes of the previous meeting were approved, it was reported that Todd Hubing has an FTP site established at the University of Missouri - Rolla which is available for downloading software. There was subsequent discussion of new CEM exchange vehicles available on the Internet such as the sci.physics.electromag UseNet group, and that ACES should be involved in these new activities. Russ Taylor, Todd Hubing, and Randy Jost are principal ACES contact points in this area.

A preliminary ACES'94 conference report was received from Jodi Nix. Approximately 151 papers appear in this year's Proceedings. As of March 20, approximately 134 authors were expected at the conference and there were 217 registrants. Jodi noted that promotion of ACES at the AP-S and SIAM conferences was particularly effective this year. Previous registration figures are approximately 207 for 1993, 168 for 1992, and 145 for 1991.

Details of the Finance Committee report are omitted here because there is a separate report in this Newsletter. The financial condition of ACES has improved substantially over the past two years, and the Executive Committee (Hal Sabbagh, Frank Walker, Perry Wheless, Andy Peterson, and Richard W. Adler) was charged to work with the Finance Committee to develop an investment strategy for managing the reserve funds.

Several motions were introduced by Perry Wheless. The final wording of these motions, which were passed, follows:

"All Committee Chairs (for both Permanent Standing and Membership Activity Committees) shall convene their Committees with sufficient frequency to appropriately consider and act on all Committee business; each Committee shall have a minimum number of annual meetings stipulated in its Charter. Meetings can be by telephone or in person. Official meeting reports shall be submitted to the Board of Directors in a written format suitable for publication in the ACES Newsletter. A minimal formal report of "no activity" may be acceptable in warrantable cases. The Secretary will forward all reports accepted by the Board to the ACES Newsletter Editor-in-Chief for publication in the next Newsletter."

"That the final wording of Motion 1 [above], upon passage by the membership, shall be inserted into the Bylaws as a new SECTION 4. SPECIFIC COMMITTEE MEETING AND REPORTING REQUIREMENTS under existing ARTICLE 7. COMMITTEES. Notification of the proposed Bylaw amendment will be published in the first 1995 ACES Newsletter and membership action concluded at the ACES '95 annual Meeting of Members."

"Committees are encouraged to teleconference future meetings, to the extent possible. As part of its Charter, the Conference Committee shall canvass the Committee Chairs in advance of the annual (conference) meeting to determine the need for at-conference meetings. The Conference Committee will coordinate the meeting times and locations for all at-conference Committee meetings. Communications with individual Committee members shall be the responsibility of the Committee Chair." "A budget line item shall be created for appropriate Committee expenses. The Executive Officer and Treasurer shall cooperatively determine an appropriate first year's allocation and investigate convenient billing and payment methods, such as an ACES telephone credit card for this specific purpose."

"The annual BoD meeting shall be changed to the afternoon or evening of the first conference day with Technical Paper sessions, with the annual Meeting of Members changed to the morning of the next day. The installation of newly elected Directors and the new Executive Committee shall coincide with the Meeting of Members. Advance notice of the annual (conference) meeting in the first ACES Newsletter of the year shall be modified to reflect these changes, effective in 1995."

"Chairs (as of 1 April 1994) of the Permanent Standing Committees are hereby charged (1) to review the Charter and Membership Restrictions writeups contained in the 6/29/93 meeting minutes pertinent to their respective committees, and (2) to submit revised writeups to the Board of Directors for consideration as nominal operating guidelines at the next regular meeting of the Board. All revised writeups shall be submitted to Perry Wheless, ACES Secretary, at least one month prior to the meeting for consolidation typing and advance distribution to all Directors".

"Committee Charters, Membership Restrictions, and related descriptions of Committee structure and operation shall be compiled by the Secretary into an ACES Committee Handbook prior to the ACES'95 regularly scheduled BoD business meeting. This Handbook will serve to guide the President, Directors, and Committee Chairs of ACES by providing information concerning Committee responsibilities and assignments in a manner that will assist with the achievement of successful Committee performance. As guidelines, it shall not be mandatory for Committees to follow such suggestions; only the Bylaws of the Applied Computational Electromagnetics Society are official and binding. However, Chairs will be expected to coordinate and clear substantial deviations from the nominal operating descriptions with the President. Chairs of Standing Committees serve at the pleasure of the President, providing ultimate accountability for acceptable Committee performance."

Nominations and Elections reported the results of the most recent election for three Directors, whose terms are 1994 - 1997. Ed Miller, Andy Peterson, and Duncan Baker were elected.

Committee Chairs for both Standing Committees and Membership Activity Committees were announced by President Hal Sabbagh. A listing of the 1994 Chairs appears elsewhere in the Newsletter.

Executive Officer Richard W. Adler was charged to determine the cost of conducting the second yearly Board of Directors meeting by teleconference as an alternative to meeting at the IEEE AP-S conference as has been the traditional practice. It has been subsequently decided that a teleconference meeting will be tried as an experiment in 1994.

The Ways and Means committee, with incoming Chair Frank Walker for 1994, was charged by the President to pursue new sources of funding for ACES consistent with our non-profit status. Also, Hal Sabbagh indicated a desire for ACES to reach out to code users such as radio amateurs as a source of new members. The ACES Newsletter is starting new departments which should appeal to users of codes such as ELNEC and MININEC.

Other committee reports were received. The Conference Committee discussed ACES'95 plans. Ray Luebbers of Penn State University is the Symposium Chairman for ACES'95. The 1996 Chairman is Richard Gordon of the University of Mississippi. A motion to fund a vendor booth at the 1994 IEEE AP-S conference in Seattle was passed. This booth will promote ACES and the ACES'95 Symposium at AP-S, and the project will be conducted by Frank Walker.

Pat Foster distributed copies of the Draft Constitution for the ACES UK Chapter. A Constitution adoption vote is scheduled for September in the UK.

W. Perry Wheless, Jr.
ACES Secretary

THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY

Treasurer's Report

May 31, 1994

The following figures include all transactions between January 1, 1994 and May 31, 1994.

ASSETS

BANK ACCOUNTS	**1 JAN 1994**	**31 MAY 1994**
MAIN CHECKING	24,648	74,174
EDITOR CHECKING	1,437	2,708
SECRETARY CHECKING	1,972	3,356
SAVINGS	304	306
CD #1	11,439	11,503
CD #2	11,439	11,503
TOTAL ASSETS	$51,239	$103,550

LIABILITIES:	None	None

INCOME	**January - May 1994**
CONFERENCE	84,377
PUBLICATIONS	3,197
MEMBERSHIP	20,596
SOFTWARE	1,455
INTEREST & MISC.	3,602
TOTAL	$113,227

EXPENSE	**January - May 1994**
CONFERENCE	42,296
PUBLICATIONS & FLYERS	5,358
SOFTWARE	201
SERVICES (LEGAL, TAXES)	5
POSTAGE	5,562
SUPPLIES & MISC.	9,194
TOTAL	$62,616

NET INCREASE FOR 1994 (For First 5 months)	**$50,611**

Andrew F. Peterson, Treasurer

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 Harrader	Ball Communications PO Box 1235 Broomfield, CO 80020
HISTORICAL	Robert Bevensee	Boma Enterprises PO Box 812 Alamo, CA 94507

COMMITTEE REPORTS

ACES PUBLICATION

The ACES Publications Committee met on Monday 21 March 1994, in Monterey, CA, during the ACES *10th Annual Review of Progress in Applied Computational Electromagnetics* Symposium. Richard Adler, Duncan Baker, Ray Perez, David Stein, Frank Walker, and Perry Wheless were present. This Committee report documents, for membership information and archival purposes, the major actions taken at that meeting. Richard Adler, Duncan Baker, and Ray Perez have authored contributions which appear separately, but are incorporated as part of this report by reference.

Duncan Baker, **ACES Journal** Editor-in-Chief, has worked for some six months on progressive development of three author guides applicable to **ACES Journal** papers. These guides (treating Style Requirements, Fonts for Use in Camera-Ready Copy, and Requirements for Camera-Ready Copy) were adopted for use in their present form for a period of one year. This will allow consideration of any appropriate changes at next year's Committee meeting, based on a year's operational experience 'in the field'. The full text of these guides appear later in this **ACES Newsletter**, and prospective authors should take a little time to familiarize themselves with this information. While certain provisions have been implemented to more efficiently utilize the annual page allocation for printing the **ACES Journal**, authors should note that they will not be precluded from publication because of limited computer hardware/ software available to them. Anyone whose paper is accepted on the basis of merit, but cannot comply with the format guidelines, will be advised and assisted by Duncan Baker on a case-by-case basis to achieve an acceptable camera-ready manuscript with the author's available computer resources.

Also in connection with the **ACES Journal**, two page charge policies were formally adopted. Drafts of these policies were circulated (twice) earlier to the ACES Editorial Board members for comment, and several constructive suggestions were received. The final wording of these policies was:

> **EXCESSIVE LENGTH PAGE CHARGE POLICY**: A mandatory EXCESSIVE LENGTH charge of $75.00 per page is required for each paper longer than **twelve (12) printed pages where <u>any author</u> is an ACES member**, or **eight (8) printed pages where <u>no author</u> is a member of ACES**. If the author(s) will not agree to pay the mandatory EXCESSIVE LENGTH page charges, the author(s) will be required to reduce the final manuscript to twelve pages or less when any author is an ACES member, eight pages or less when no author is a member of ACES, including all figures and illustrations, before the paper will be published. The **ACES Journal** Editor-in-Chief may, at his discretion, waive the page limit for one paper per issue.
>
> **VOLUNTARY PAGE CHARGE POLICY**: After a manuscript has been accepted for publication, the company or institution *designated by the first author* will be requested to pay a charge of $75 per printed page to partially cover the cost of publication. **Page charges for the first twelve (12) pages where any author is an ACES member, or first eight (8) pages where no author is a member of ACES, are not obligatory** nor is their payment a prerequisite for publication. EXCESSIVE LENGTH PAGE CHARGES (see separate policy statement) apply to papers longer than twelve (12) pages when any author is an ACES member, or eight (8) pages when no author is an ACES member, and are mandatory. Authors with questions about ACES page charge policies should contact the **ACES Journal** Editor-in-Chief directly.

The final action associated purely with the **ACES Journal** was adoption of the following operational guideline:

PRIORITY COURTESY GUIDELINE: The **ACES Journal** is subject to printed page limitations, by issue, set annually by the ACES Executive Committee. The available pages for a given issue, therefore, may be less than the total pages of accepted papers; whenever this occurs, **(i) members of ACES and (ii) those non-members who agree to pay Voluntary Page Charges for their full paper (all pages)** will be given priority for early publications. Publications of accepted papers from other non-members, in such circumstances, will be deferred to the first subsequent issue with available pages.

Abbreviated versions of the Excessive Length and Voluntary Page Charge Policies will be printed on the ACES Journal cover in the future.

An issue affecting both the ACES Journal and ACES Newsletter in the expectation that color printing will be required occasionally in the future. Managing Editor Richard W. Adler has researched the costs for color printing, which necessarily must be paid by authors requesting this special service, and has prepared the summary statement of our current policy ("Color Printing Costs for the ACES Journal and ACES Newsletter") which appears later in this Newsletter.

Ray Perez has settled into the role of ACES Newsletter Editor-in-Chief, and has energetically launched several initiatives. So that I would not be putting words into Ray's mouth, I asked him to submit a separate report discussing the changges and status of the ACES Newsletter. You should definitely read Ray's account in order to gain some appreciation of some plans for the future direction of the Newsletter.

It is an opportune time for prospective Journal/Newsletter authors to step forward and submit the results of their work and experiences with computational electromagnetics to ACES Publications. All associated with ACES Publications are striving to satisfy the high expectations commensurate with ACES membership dues, and to stimulate more ACES membership activity and involvement with ACES Publications.

For convenient reference, it is noted here, that Ray Perez is available by e-mail at address perez@sec-521.jpl.nasa.gov, and the preferred e-mail address for Duncan Baker is duncan.baker@ee.up.ac.za. For those who have experienced trouble reaching me, please note that the "1" in my e-mail is the numerical one. Keep those e-mail's and papers coming!

Finally, the Publications Committee welcomes Frank Walker, who was assigned as a non-voting member to the Committee for 1994-1995 by ACES President Hal Sabbagh in connection with Frank's project to develop and disseminate a CEM Software Sourcebook. More details about the nature and scope of this particular activity will be forthcoming in a later Publications Committee report.

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

ACES NEWSLETTER

The July 1994 issue of the ACES Newsletter was the first one I had the privilege of putting together as the new and untested Editor-in-Chief. I was appointed by Perry Wheless, Editor-in-Chief of ACES publications, to assume this responsibility which was previously held by Paul Elliot. David B. Davidson is the Associate Editor-in-Chief.

As the new Editor-in-Chief of the ACES Newsletter I am grateful for the support and assistance that through the years I obtained from Paul Elliot, David Stein, and Dick Adler. I want to express my sincere thanks to all the members of the ACES Editorial Board for their support and encouragement as I assume this new position.

Starting with the July issue, the ACES Newsletter will expand considerably the types and number of articles that our readers will be able to enjoy. Recognizing that such an ambitious goal requires a good degree of commitment and cooperation, I decided to solicit the help of several of our members. The ACES Newsletter now has seven (7) new editors. Each editor will be in charge of a different column for the Newsletter. Seven new columns will appear in each issue:

1) CEM News from Europe
2) Modeler's Notes
3) Technical Feature Article
4)Perspectives in CEM
5) Advertising & Reports
6) The Practical CEMist
7) Tutorial.

The ACES members in charge of each of these columns can be found under "ACES Newsletter Staff" in this and all future issues of the newsletter. In addition to these articles we will have, throughout the year, book reviews that emphasize either directly or indirectly the field of computational electromagnetics. Either myself or a guest reviewer will provide reviews on new books that may be of interest to our readers. I want to express thanks and appreciation to the Associate Editor-in-Chief and each of our editors for their willingness to assume these responsibilities on behalf of the ACES Newsletter.

To all the members of ACES and specially to those who take time from their busy schedules to read the ACES Newsletter, I want to let you know that feedback and inputs are extremely important. I encourage you to contact me, or an editor, with comments and observations about what you see or would like to see in the ACES Newsletter. Furthermore, if you have a contribution for the newsletter that you think may fit in any of the above columns, please contact the appropriate editor for proper consideration.

Ray Perez
Editor-in-Chief, ACES Newsletter

SOFTWARE EXCHANGE

Current members of the ACES Software Exchange Committee

Committee Officers		Telephone	E-mail
Frank Walker	Chairman	206-773-8600	Walker@atomic.boeing.com
Randy Jost	Vice-Chairman	703-247-8415	Jost@wdc.sri.com
Todd Hubing	Secretary	314-341-6069	Thubing@ee.umr.edu
Members-at-large			
Dick Adler	Distribution	408--656-2352	554-1304@mcimail.com
Jim Breakall	NEC S/W	814-865-6337	Breakall@cssia.psu.edu
Magdy Iskander	CAEME Director	801-581-6944	Iskander@ee.utah.edu
Peter Lee	NOSC S/W	619-553-5089	Li_st@manta.nosc.mil
Jim Logan	NEEDS S/W	619-553-3780	Logan@manta.nosc.mil
Steven Merrill	SAIC	508-460-9500	Scm0@ubar.saic.com
Ed Miller	LLNL		Emiller@meediv.lanl.gov
Malcolm Packer	SAIC	508-460-9500	Birst@ubar.saic.com
Andy Peterson	S/W Standards	404-853-9831	Ap16@prism.gatech.edu
John Rockway	NEEDS S/W	619-553-3791	Rockway@manta.nosc.mil
Ken Siarkiewicz	Rome Labs	315-330-2465	Siarkiewiczk@lonex.rl.af.mil
David Stein	Low Freq S/W	703-524-2117	74250.3402@compuserve.com
Russ Taylor	Code User Group	602-891-5539	Taylor%hyades.decnet.orion mdhc.mdc.com
Andy Terzuoli	AF Inst Tech	513-255-3576	Terzuoli@galaxy.afit.af.mil
N. Balakrishman			BALKI@nsslc.gcn.uoknor.edu
Alex Anger	HP Marketing		Alexa@hpnmaaa.sr.hp.com
Nancy Compernolle	ANSOFT		nancy@ansoft.com
Steve Fraasch			Steve_Fraasch@atk.com
Dan Roesler			Droesler@cacd.cr.rockwell.com

The charter of the Software Exchange Committee is to promote identifiction and distribution of useful EM computational software to ACES members. The primary activity currently underway involves the publication of a Software Source Book in which commercial, military, and academic software codes are listed as a reference for members. In addition, Russ Taylor of the Software User's Group has implemented a bulletin board by which ACES members can access and share information including available software.

The tso ACES Software Exchange Committee (Softx) meeting reports, provided to the March and June ACES Board of Directors (BoD) meetings, were published in the July ACES Newsletter. The Software Exchange Committee has not convened a meeting since that time. The next meeting of this committee is scheduled for 0800 on Monday, March 21, in the Bonsai III room of the DoubleTree Convention Center in Monterey.

The first order of business at this year's first Softx meeting will be the election of new officers. Currently we have myself, Frank Walker as Chairman, Randy Jost as Vice-Chairman, and Todd Hubing as Secretary. I have served two terms as Chairman and it is appropriate that we select a new Chairman for the coming year. I intend to commit my time this next year to my other ACES obligations, the first of which is the publication of the Software Source Book. The results of our nomination process will be forwarded to the ACES President, Hal Sabbagh, for confirmation in the event that he is unable to attend our meeting in person.

The Software Source Book is nearing completion in preparation for the printing of the first edition. We have a color cover design courtesy of Veda and the Air Force Institute of Technology. The design is similar to that developed for posters promoting our 10th anniversary conference. The Boeing Company has agreed to provide publishing services. The Software Source Book will not be ready in time for distribution at conference. The first edition will be mailed to conference attendees in the next few months. courtesy of the Boeing Company.

We have received a proposal from J. Rockway and the MININEC developers to distribute MININEC on a profit sharing basis. Currently ACES does not have software distribution or licensing agreements of any kind. This issue will be addressed at the March '94 BoD meeting. The result will allow ACES to establish a policy for distribution of licensed software for a fee. There are other software developers who are interested in distribution of software through ACES, many without fee considerations. In addition, the military is willing to allow the distribution of some versions of distribution restricted codes such as NEC, GEMACS, and IEMCAP. Our primary task for software distribution at this years BoD meeting will be to establish guidelines for ACES distribution of software in general, and specifically for licensed or Government restricted distribution software. Once this issue is resolved, procedures for distribution and support can follow.

As this will be my last report as the Chairman of the Software Exchange Committee, I would like to express my gratitude to those of you who have been so helpful with discussion and suggestions concerning our implementation of ACES software distribution. The Software Source Book is nearing completion of the first edition. There is great hope that this publication will become yet another standard by which ACES is recognized as a leading society in computational electromagnetics worldwide. In addition to the publication of the Software Source Book, I will move on to the duties of the ACES Vice President and my newly appointed assignment as Chair of the Ways-and-Means Committee. Thank you all.

Frank Walker

AWARDS COMMITTEE

Fifteen service awards and three outstanding paper awards were presented at the 1994 ACES Awards Banquet. The unprecedented number of awards reflects our strength as a professional society and our renewed commitment to recognize individuals who have contributed substantially to ACES but in non-prominent capacities. (Prior to 1993, awards had been presented primarily to ACES Symposium Chairpersons and also to ACES Presidents completing their terms of office, but although these awards were well deserved, no elected or appointed officer can be effective in the absence of support at the committee level).

The awards banquet commenced with a short history of the ACES awards program and with re recognition of last year's service award recipients, the first people to be honored for substantial service in capacities lacking only in ACES wide visibility:

Pat Foster (United Kingdom), who played a pivotal role in forming the ACES UK Chapter. Pat, the 1992 ACES Symposium Chairperson, now serves on the ACES Board of Directors.

Tony Fleming (Australia), who arranged the first ACES organized regional workshop and who implemented new workshop concepts and publicity funding concepts. The nucleus of a future Australian Chapter of ACES evolved from this workshop and from Tony's other promotional efforts, which doubled individual ACES memberships in Australia/New Zealand and which likewise increased institutional memberships substantially. The highly acclaimed ***ACES Journal*** Special Issue on Bioelectromagnetic Computations, for which Tony served as (Co) Guest Editor, enhanced ACES visibility throughout the bioelectromagnetics community.

Duncan Baker (South Africa), a leader and major contributor in our efforts to formulate standards of publication for the ***ACES Journal*** who also orchestrated several special promotional projects including the invited paper project. In recruiting several new ACES members within South Africa and in publishing several ***ACES Journal*** papers, Duncan has consistently led by example. He now serves as Editor-in-Chief of the ***ACES Journal*** and was recently elected to the ACES Board of Directors.

Perry Wheless (USA), who demonstrated innovation and leadership in arranging "ACES '93," including new types of sessions. Perry now serves on the ACES Board of Directors and as ACES Editor in-Chief / Publications Chairperson.

Also recognized were the services of the ACES'94 Symposium registration staff, **Trish Adler, Marie Doty, Gloria White, Wendy Adler, JoEllyn Knapp** and **Pat Adler**. Some of these people have served on our Symposium registration staff for several successive years.

Next, Perry Wheless and Duncan Baker presented the Outstanding Paper Awards. The **OUTSTANDING PAPER AWARD (formerly**, the BEST PAPER AWARD) is presented to authors of exceptionally meritorious papers either published in the ***ACES Journal*** or presented in an annual ACES Symposium. To date, permanent procedures for award recipient selection exist only for ***ACES Journal*** papers and have been established in cooperation with the ACES Editorial Board. The 1994 Outstanding Paper Award was presented to:

Reinaldo Perez (USA), for his innovations in using computational electromagnetics methods to teach electromagnetic compatibility, as published in Volume 8, Issue 1 of the ***ACES Journal***. Reinaldo's paper has elucidated the fundamentals of electromagnetic compatibility and interference.

R. Craig Baucke (USA), for his innovations in automating the synthesis and optimization of the design of resistive taper strips, as published in Volume 8, Issue 2 of the ***ACES Journal***. Craig's contributions minimize the need for tedious trial and error computations.

Kent Davey (USA), for his innovations in analyzing eddy current problems with velocity effects, as published in Volume 8, Issue 2 of the ***ACES Journal***. In publishing this paper, Kent has expanded the applicability of existing field analysis software.

Provisions also exist for a **TECHNICAL ACHIEVEMENT AWARD**, which is presented to ACES members who demonstrate technical achievement in applied electromagnetic modeling through activities other than ACES Publications. Appropriate factors for consideration include achievements that support computational techniques, electromagnetic modeling software, code validation, and emphasis on applications, rather than electromagnetic theory. However, no technical achievement awards were presented in 1994, because permanent procedures for award recipient selection have not yet been established.

Finally, the following service awards were presented:

VALUED SERVICE AWARD -- This award is presented to individuals in recognition of major contributions to single events or functions of ACES. The 1994 Valued Service Award was presented to:

Christopher C. Smith (USA), for his exemplary foresight and initiative in establishing the ACES Code User Group Committee and laying the foundation for its services to code developers and users.

Jodi Nix (USA), for her exemplary initiative and innovation, in her capacity as ACES '94 Symposium Facilitator, in promoting ACES '94 worldwide and in arranging new types of symposium activities and technical sessions.

NOTE: Traditionally, the Valued Service Award been presented to the Symposium Chairperson, but henceforth (as the result of circumstances which transpired a few years ago), the presentation of this award will be after the respective symposium is concluded and in essence will be delayed one year. For this reason, the meritorious service rendered by ACES'94 Symposium Chairperson ***Andy Terzuoli*** will be officially recognized next year. It is also noted that "ACES'94" is the first annual symposium for which a Facilitator was appointed in addition to a Symposium Chairperson.

EXEMPLARY SERVICE AWARD: This award is presented to individuals who have served ACES above and beyond the call of duty at the committee (or equivalent) level while **NOT** occupying a prominent position within ACES. Exemplary service shall normally assume the form of spearheading a project; however, in some cases, exceptional service throughout a sustained period may also qualify. The Officers, Directors, and committee chairpersons (including the Editor in Chief) shall be ineligible for this award, except that in rare cases, they may receive this award for exemplary service which pre dates their election or appointment to these respective positions. The 1994 Exemplary Service Award was presented to:

John W. "Wes" Williams (USA), for substantial contributions at the committee level in scholarlypublications. In addition to formulating our initial standards of publication, Wes arranged the inclusion of the ***ACES Journal*** in abstracting/indexing services and (together with Duncan Baker) spearheaded the invited paper project. Wes has also arranged our annual International Publications Dinner for five consecutive years.

Reinaldo Perez (USA), for substantial contributions at the committee level in publications and in special promotional and marketing projects. One of Reinaldo's major contributions was the obtaining and publishing of several ***ACES Newsletter*** articles from funding agency representatives. Not content to confine his service to publications, he made ACES more visible worldwide through publicizing ACES within other professional societies and through special promotional projects. Reinaldo now serves as Editor of the ***ACES Newsletter***.

Adalbert Konrad (Canada), for substantial contributions at the committee level in scholarly publications, intersociety relations, and special promotional projects. Adalbert served as a liaison with other computational electromagnetics communities and (together with Hal Sabbagh) laid the groundwork for the joint ACES -TEAM Benchmark Problem Solution Workshops. In addition, he recruited new Editors for areas of computational electromagnetics not previously represented on the ACES Editorial Board, on which he now serves as Associate Editor in Chief of the ***ACES Journal***.

Kenzo Miya (Japan), for substantial contributions at the committee level in promoting ACES within other professional communities and within Japan.

Harold A. Sabbagh (USA), for substantial contributions at the committee level in regional activities, intersociety relations, and validation of computational techniques. Hal's efforts launched the ACES Regional Workshop program and benchmark problem solution program and also paved the way for joint activities with TEAM. Hal now serves as President of ACES; however, his aforementioned contributions were made prior to his election to high office.

MAINSTAY AWARD -- This award recognizes individuals who have devoted their time, efforts, and expertise throughout Sustained period to benefit the functions and activities of ACES. The 1994 Mainstay Award was presented to:

John W. "Jay" Rockway (USA), for initiative and sustained service in starting the ACES annual short course program and pioneering the program during 1991, 1992, and 1993.

Lee Corrington (USA), for initiative and sustained service in starting the ACES awards program and pioneering the program during 1990-1992.

Shing Ted Li (USA), for initiative and sustained service in starting the ACES elections by mail program and pioneering the program during 1989-1992.

Pat Adler (USA), for her initiative and sustained service throughout a nine year period, in publications production, symposium support, and member services administration.

FOUNDERS AWARD -- This award recognizes individuals who, while serving ACES, have demonstrated exceptional vision and leadership as exemplified by the "founding fathers" of ACES. Recipients need not be ACES Officers or Committee Chairpersons. The 1994 Founders Award was presented to:

Paul Elliot (USA), for demonstrating exceptional vision and leadership, as exemplified by the Founders of ACES, in his distinguished and sustained service as Editor of the ***ACES Newsletter*** and as an innovator in technical publishing. During Paul's term of service, the ***ACES Newsletter*** not only obtained top quality articles for publication but also started new features including a code reference index and a Perspectives column which promotes exchange of viewpoints. Furthermore, Paul masterfully identified and capitalized upon opportunities to publicize ACES within other professional societies.

A.K.(Tony) Brown (United Kingdom), for demonstrating exceptional vision and leadership, as exemplified by the Founders of ACES, in his distinguished and sustained service as co founder of the NEC UK Users Group and of the first regional Chapter of ACES, and whose efforts culminated in a substantial increase in European membership, participation, and visibility.

James C. Logan (USA), for demonstrating exceptional vision and leadership, as exemplified by the Founders of ACES, in his distinuguished and sustained service as Financial Officer, during which time he singlehandedly established the ACES budget and investment strategy, thereby placing ACES on a sound financial foundation during an era of worldwide research budget constraints. Jim has served as Treasurer, Vice President, and President of ACES.

Richard W. Adler (USA), for demonstrating exceptional vision and leadership, as exemplified by the Founders of ACES, in his distinguished and sustained service as Executive Officer, Symposium Local Arrangements Coordinator, and Managing Editor of the ACES Publications, in his former capacity as Secretary, and in his unofficial capacity as Strategic Planner. Dick continues his service as Executive Officer and as Managing Editor.

All service award recipients were selected on the basis of contributions made to ACES -- **NOT** on the basis of offices or other positions held. Only as a result of their volunteer service have the achievements, the activities, and even the existence of ACES been possible.

Every ACES member is encouraged to submit nominations for outstanding paper, technical achievement, and service awards to be presented in 1995. The ACES awards program is our primary means to acknowledge identifiable contributions to ACES and to the professional community, and your participation in the process is essential. Instructions and guidelines will be published in the next issue of the ***ACES Newsletter***.

Until then, please join me in saluting our award-winners -- our achievers and leaders!

David E. Stein
Chairperson, Awards Committee

NOMINATIONS COMMITTEE

At the time, members are invited and indeed urged to begin the nominations process for this election for three directors as outlined in this handbook. The names and terms of the present members of the Board are as follows:

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

Stan Kubina
Chairman

Names and addresses of Nominations Committee Members are:

Stan Kubina
Concordia University/ECE Dept.
7141 Sherbrooke St. West
Montreal, Quebec, CANADA H4B 1R6

Jim Logan
NRAD Code 824
271 Catalina Blvd.
San Diego, CA 92152

Andy Peterson
Georgia Inst. of Technology
School of Electr. Engr.
Atlanta, GA 30332-0255

REPORT FROM ACES UK CHAPTER

The growth of interest in CEM continues unabated with ACES UK promoting our membership hard!

We had a substantial presence at the 2nd International Conference on CEM sponsored by the Institute of Electrical Engineers (UK). This international event attracted a audience of 280 from UK, USA and Europe. The ACES booth attracted substantial interest.

We have also co-sponsored a IEEE EMC Society (UK and RI Chapter) Colloquium on Numerical Modelling for EMC.

Finally, the ACES UK Newsletter 1994 has just been produced. My thanks to Jeff Cox for the hard work in coordinating the Newsletter.

Dr. A.K. Brown
Managing Director
EASAT Antennas Ltd, Goodwin House
Leek Road, Hanley
Stoke on Trent, ST1 3NR, UK

CONTENTS

CEM NEWS FROM EUROPE

Coordinated by Pat Foster, MAAS, UK

This column is intended to provide a regular update on CEM activities in Europe with myself as coordinator. Experts from various European countries will be asked to write about activities in their country and Professor Karl Langenberg of the University of Kassel, Germany, has agreed to coordinate the next contribution. This issue's contribution is devoted to the state of CEM in the United Kingdom and, fortunately for me, there was a highly successful conference on Computational Electromagnetics held in Nottingham in April this year. As in other countries, interest in CEM varies widely between Universities and industry and between low frequency (eddy currents) and high frequency (RCS of aircraft engine intakes). A useful list may be generated of who does what in Universities (Table 1). Some of these will be dealt with in future columns. All low frequency CEM will be covered in a future column. This column is devoted to three of the Universities, Bradford, Bristol and Queen Mary and Westfield, London.

The group under Peter Excell of Bradford University has a wide range of interests in CEM. They use a 3-D FDTD code, EMA3D (from EMA Inc, Denver) to model biological interactions between the head and hand-held cellular telephones. One of their models has 8 million nodes and is run on a CRAY YMP. They are currently part of an ESPRIT[1] team with British Aerospace, FEGS and a French super-conductor centre to port this code to a range of parallel processing machines. Independent research is also in progress on porting various CEM programs to a KRS1 parallel processor. The first installation (of NEC) is underway at the moment. Bradford has also carried out work on superconductors, particularly of loop excited helices and, in conjunction with this, a Method of Moments code has been developed which deals with currents on curved wires. This has demonstrated that the current on a curved wire is far from uniform round the wire. Polynomial basis functions are used and the distribution round the wire is represented by a finite trigonometric series [1]. (Contact Dr. Peter Excell on p.s.excell@bradford.ac.uk).

The group at Bristol is particularly strong in FDTD and has adopted a powerful engineering approach to the problem of features in the structures which are smaller than the mesh size by using a correction factor. The results for several geometries of coupled dipoles have been compared with NEC [2].

Dr. A D Monk (Tony) of Queen Mary and Westfield College has contributed the following.

In terms of the software packages which are bought in, the two major packages are NEC-2 and GRASP7. (Added by PRF. Readers may not be familiar with GRASP7 which is supplied by TICRA of Denmark and is a comprehensive program for the analysis of reflector problems. It is the industry standard in Europe) NEC-2 is used almost exclusively for antenna problems and quite often provides validation of alternative CEM methods. GRASP7 is used for almost all our reflector modelling with the exception of the mesh reflector work (see later), including some current work concerned with the design of a shaped dual reflector feed system for the in-house mm-wave Compact Antenna Test Range (CATR).

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[1] ESPRIT is a series of research projects concerned with computing which are sponsored by the European Community. The team must be multi-national and contain representatives of academic and industrial establishments. There are moments when the European computing world seems to be playing a very fast game of Musical Chairs as various people try to set up a team of suitable partners.

Codes developed in house include:

1) Mesh Reflector Antennas

We use our design/analysis code including modules which perform an analysis of the mesh itself to accurately predict its profile [3]. The software allows us to synthesise shaped beams using numerical optimisation and also performs a variety of electromagnetic analyses.

2) Microstrip patches

We have developed a rigorous Green's function moment method analysis which can handle arbitrary patch shapes and also multiple dielectric layers (e.g. complex substrates and thermal blankets). The main application of this code is the design and analysis of spacecraft patch antenna arrays.

3) FDTD

We have developed out own general purpose code with arbitrary structures specified in Cartesian coordinates. At the moment, this is only set up for antenna problems but it could be adapted to RCS prediction. The main application of this code at the moment is the prediction of patterns of low gain antennas when mounted on structures and platforms.

4) MODAL MATCHING

Modal matching has been used waveguide structures such as junctions and internals, the main use has been the design and analysis of a variety of antenna feed horns. These include smooth-walled pyramidal and conical horns and corrugated and dielectric conical horns.

5) CATR

We have a variety of numerical models for this, to predict either the quiet zone fields or the measured pattern of an arbitrary test antenna in the quiet zone. Some of the models include the effects of both panel gaps and profile errors on the range reflector which can be significant at mm-wave frequencies [4].

Contact David Olver (a.d.olver@qmw.ac.uk) or Tony Monk (a.d.monk@qmw.ac.uk)

1 R.W. Abu-Alhameed and P.S. Excell, 'An Improved Physical Basis for Computer Modelling of Radiation from Curved Wires', IEE Conf No 384, CEM-94, Nottingham, 1994, p382-385

2 C.J. Railton, 'The Efficient Analysis of Cylindrical-resonators using a modified FDTD method', IEE Conf No 384, CEM-94, Nottingham, 1994, p331-334

3 P.J.B. Clarricoats and Zhou Hai, 'Improvements in the Design of Reconfigurable Reflector Antenna', ICAP93, Vol 1, p14-17

4 M. Philippakis and C.G. Parini, 'Effectiveness of Tape Treatment in Improving the Performance of a Panelled CATR at Millimetre Waves', ICAP93, Vol 1, p380-383

Table 1: Universities

Organisation	CEM Interests	Application Interests	Contact
University of Aberdeen	FEM	Meshing	J Penman
University of Belfast	FDTD	3-D antenna analysis	V F Fusco
Dept of Electrical Engineering, University of Bradford	MoM, Application of Mie Theory, Finite Integral Technique	Super-conductors, curved wires, Head-antenna interactions	Prof. P S Excell
Dept of Electrical Engineering, University of Bristol	FDTD	Microwave heating, dipoles, resonators	Dr. C J Railton
University of Cardiff	Discrete Spectral Index /FE	Leaky waveguide	G M Berry
University of Cambridge	FEM	Heating problems	Dr. R Ferrari
Dept of Mathematics, University of Dundee	FDTD, Time Domain EFIE	Wideband systems	Dr. P D Smith
Heriot Watt University	MoM	Stripline	A J Sangster
Dept of Mechanical Engineering, Imperial College	BEM	RCS	Dr. Simon Walker
Dept of Electrical Engineering	MoM	Ground vehicles, HF antennas	Dr. B A Austin
University of Newcastle	Field coupling	EMC	S Sali
Dept of Electrical Engineering, University of Nottingham	TLM, Finite Difference	EMC, antennas, closed structures	Prof. C Christopoulos
Dept of Electrical Engineering, Queen Mary & Westfield	FDTD, MoM, in-house reflector and horn codes	Antennas	Prof. A D Olver / Dr. A D Monk
Dept of Electrical Engineering, University of Swansea	FEM, CGFFT applied to EFIE	RCS of plates/cavities	Dr. A McCowen
York Electronics Centre, York University	Various inc TLM, FDTD, MoM	EMC	Dr. A Marvin

CONFERENCE REPORTS

CONFERENCE COMMITTEE

31 May 1994

The 1995 conference dates have been set as 20 - 24 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 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.

Preliminary indications of the success of ACES '94 are:

An increase in attendance of 17% (242 this year vs. 207 for 1993).

An increase in the number of papers presented at conference.
Up 29% from 119 in 1993 to 153 in 1994.

Conference income was up by	$23, 061
Conference expenses were up by	$16,147

Reserves from conference were up by $6,914.
(In 1993, reserves were $35,167 compared to $42,081 in 1994).

Respectfully submitted,
Richard W. Adler, Chairman

MINUTES OF THE ANNUAL PRESIDENT'S REPORT

The Annual Business Meeting of Members of the Applied Computational Electromagnetics Society, Inc. convened in the Steinbeck Forum of the DoubleTree Hotel in Monterey, CA, at 7:33AM on Tuesday, 22 March 1994. President Harold Sabbagh presided.

DIRECTOR'S PRESENT: Duncan Baker (new Director), Jim Breakall, Ed Miller, Andy Peterson, Hal Sabbagh, Frank Walker, and Perry Wheless. ACES Executive Officer Richard W. Adler was also present.

FINANCIAL REPORT: The Financial Report was published on page 11 of the March 1994 ***ACES Newsletter***, distributed earlier to the membership. MOTION by Andy Peterson to accept the Financial Report. SECOND by Ed Miller. The motion passed, with none opposed.

ELECTION REPORT: The results of the most recent election of three Directors was announced as follows:

Ed Miller - 168 votes
Andy Peterson - 129 votes
Duncan Baker - 124 votes
Adalbert Konrad - 111 votes

Ed Miller, Andy Peterson, and Duncan Baker were thus elected to terms expiring in 1997. It was announced that the original slate of five candidates was reduced to four when one had to withdraw for health reasons. It was also announced that a printing error (the omission of one candidate) on the first ballot made the distribution of a second ballot necessary.

ACTIVITIES OF INCORPORATION: Nothing to report this year.

BYLAW AMENDMENT: The motion to amend the Bylaws was printed on page 9 of the March 1994 ***ACES Newsletter***, distributed earlier to the membership. **ACTION**: the motion passed, with none opposed.

OTHER DISCUSSION: Andy Peterson noted that nominations for the next board of Directors election are open, and that Stan Kubina is the Nominations Committee Chair. Hal Sabbagh invited volunteers for various activities, particularly committees, and added that currently active committees (along with their Chairs) are documented on page 12 of the March 1994 ***ACES Newsletter.***

The President's Report was concluded at 7:49AM.

Submitted by:
W. Perry Wheless, Jr.
ACES Secretary

TECHNICAL FEATURE ARTICLE

Often by the time new ideas or results are published, they are no longer new. Beginning with this issue, the ACES Newsletter will include one or more Technical Feature Articles. These 2 to 6 page articles are designed to give electromagnetic modelers a preview of recent advances in computational electromagnetics.

This issue's Technical Feature Article was contributed by Douglas J. Riley and C. David Turner of Sandia National Laboratories. They describe a new method for merging a structured FDTD mesh with an unstructured FVTD mesh. The method permits unstructured meshes to be used in regions that require an unstructured mesh and computationally more efficient rectangular meshes to be used elsewhere. They also introduce a late-time stabilization technique for the finite-volume method.

Technical Feature Articles are peer-reviewed publications that provide the reader with a brief overview of research or measurement results relevant to computational electromagnetics. If you have an article that you would like to submit, please send it directly to:

Dr. Todd H. Hubing
Technical Feature Article Editor
219 Electrical Engineering
University of Missouri-Rolla
Rolla, MO 65401

If you want to discuss an idea for an article or determine whether a particular topic is appropriate for a Technical Feature Article, feel free to contact Todd directly by phone at (314) 341-6069, FAX at (314) 341-4532, or email at thubing@ee.umr.edu

Finite-Volume Hybrid-Grid (FVHG) Technique for the Solution of the Transient Maxwell's Equations

Douglas J. Riley and C. David Turner
Radiation and Electromagnetic Analysis Department
Sandia National Laboratories
Albuquerque, NM 87185-1166

Abstract

A technique to incorporate a 3D unstructured finite-volume grid into a traditional structured finite-difference time-domain (FDTD) mesh is presented. The interface between the grids is free from spatial interpolation. On the unstructured grid, an efficient and accurate finite-volume time-domain (FVTD) technique is introduced. The hybrid formulation enables complex geometries to be modeled locally within the FDTD rectangular volume; existing radiation boundary conditions and near-to-far-field transformations are then available. By retaining a large structured grid, considerable improvements are made in performance and memory requirements. Multiple unstructured regions can be embedded into the structured mesh. Commercial solid-modeling packages may be used to generate the unstructured grid with the proper termination requirements. Surface impedance effects are introduced into the non-orthogonal cells. Results for an impedance sphere are presented.

Introduction

Traditional FDTD codes have been used extensively over the past ten to twenty years for the EM analysis of geometries with low to moderate complexity. These codes are based on cubical hexahedron cells that model geometries with a staircase approximation. The advancement technique uses the Yee algorithm that can be written in terms of simple contour integrations [1]. Much research has been invested in the development of grid truncation techniques [2], near-to-far-field transformations [3], and sub-grid algorithms [4,5]. For geometries that conform to a rectangular grid, FDTD is accurate and very efficient. For arbitrary geometries, traditional FDTD is often inadequate [6].

Interest in the development of body conforming algorithms has been increasing over the past five years. Transient solvers based on computational fluid dynamics techniques [7], finite-volumes [8,9], local contour modifications [10], and overlapping non-rectangular and rectangular grids [11] are under development. It is not the intent of this paper to discuss the relative merits of all these methods. Instead, we briefly discuss a hybrid-grid algorithm, FVHG, that we have found to be robust, efficient, accurate, and stable, even for highly distorted grids with a variety of cell shapes. The FVHG algorithm uses traditional FDTD on the structured grid and a modified FVTD algorithm on the unstructured mesh. The use of both structured and unstructured grids is similar to the overlapping-grid method [11], but FVHG is free from spatial interpolation across mesh boundaries. The finite-volume technique is based on the Madsen-Ziolkowski method [8], but an alternative formulation that greatly improves performance and adds a variably dissipative time-integration scheme for late-time stabilization is introduced. An expanded paper is forthcoming.

Finite-Volume Algorithm

The non-orthogonal region is defined in terms of a primary grid and a derived grid. The vector fields are evaluated at the centroids of each cell, and therefore, the primary grid is equivalently labeled an **H**-grid, while the derived grid is equivalently labeled an **E**-grid. The centroids of one grid correspond to the vertices of the other. A typical **H**-grid cell, referenced as cell 1, is shown in Fig. 1. In general, the cells can be arbitrary convex polyhedrons. The **H**-field at the cell centroid, $\mathbf{H}_1$, is advanced using Faraday's law in integral form:

$$\mu\frac{\partial}{\partial t}\iiint_{V_1^h} \mathbf{H}_1\, dV_1^h = -\iint_A \hat{\mathbf{n}}_h \times \mathbf{E}\, dA \qquad (1)$$

The derived-grid edge, $\mathbf{s_e}$, connects the centroids of primary-grid cell 1 with a neighboring cell 2 (cell 2 not shown). The primary-grid edge, $\mathbf{s_h}$, connects $\mathbf{E}_1$ and $\mathbf{E}_2$, which denote the vector **E**-fields at the centroids of the derived-grid cells 1 and 2, respectively. $\hat{\mathbf{n}}_h$ denotes an average outward normal for each face of the primary-grid cell.

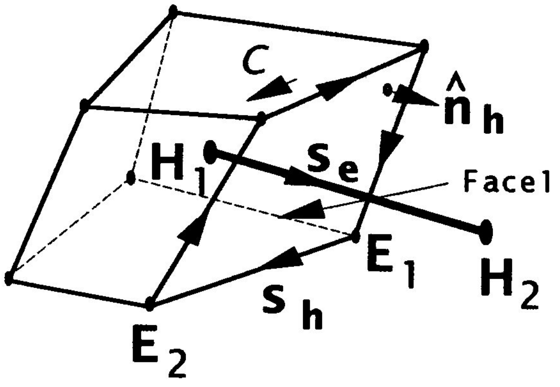

Fig. 1. Hexahedron primary-grid cell with E-field vertices.

To discretize (1), the area integral is evaluated in terms of a vector triple product around the perimeter of each face, $\mathbf{H}_1$ is assumed constant over the cell volume, V_1^h, and a second-order centered time difference is used (more will be said about the time integration in the late-time stabilization section). Ampere's law is similarly used to advance the **E** fields on the derived grid.

The cell-based surface integration completely specifies the vector field at the cell centroid. To obtain $\mathbf{H}_1$ from the discretized Eq. (1), an accurate approximation for **E** along the **H**-grid edges is required. Similarly, the derived grid requires an accurate approximation for **H** along the **E**-grid edges. One approximation is to form a volumetric average of the vector fields located at the edge endpoints. Although this has been found to work for certain grids, the approximation is not sufficient, in general. An improvement is made by *correcting* the normal component of this average using contour integration. This correction ensures that the integral of the field divergence over each cell is constant in time. For face 1 pierced by edge $\mathbf{s_e}$ shown in Fig. 1, the contour integral is given by

$$\mu\frac{\partial}{\partial t}\iint_A H_n^c\, dA = -\oint_C \mathbf{E}\cdot d\mathbf{l} \qquad (2)$$

where H_n^c denotes the normal component of the **H**-field on face 1 as obtained by the contour integration. An average **H**-field between primary-grid cells 1 and 2 in the direction of the derived-grid edge, s_e, is finally constructed by forming

$$\mathbf{H}\cdot\mathbf{s}_e = \frac{V_1^h\mathbf{H}_1 + V_2^h\mathbf{H}_2}{V_1^h + V_2^h}\cdot\mathbf{s}_e + \left[H_n^c - \left(\frac{V_1^h\mathbf{H}_1 + V_2^h\mathbf{H}_2}{V_1^h + V_2^h}\right)\cdot\hat{\mathbf{n}}_h\right]\left(\hat{\mathbf{n}}_h\cdot\mathbf{s}_e\right) \qquad (3)$$

When $\mathbf{s_e}$ and $\hat{\mathbf{n}}_h$ are parallel, only H_n^c contributes. Eq. (3) leads to a result that is equivalent to the technique described in [8], but since the evaluation is initially done over cells, repeated surface integrations for all edges associated with a given cell are avoided. For hexahedrons, computation time can be reduced by nearly a factor of six. The added cost in memory is, of course, storing the vector fields at the cell centroids, which for both grids is six times the number of cells; however, since the non-orthogonal region is localized within the computational volume, the overall increase in memory may not be significant.

It is noted that the cell-based technique integrates over each face twice. If memory is available, an additional improvement is obtained by indexing over faces and saving $\iint_A \hat{\mathbf{n}}_h \times \mathbf{E}\,dA$ and $\iint_A \hat{\mathbf{n}}_e \times \mathbf{H}\,dA$ for each face on the primary and derived grids, respectively. The fields at the cell centroids are then easily constructed.

Late-Time Stabilization

The finite-volume method can develop a late-time weak instability that manifests itself after several thousand, or perhaps only several hundred, time steps depending on the grid complexity. To address this issue, an alternative technique based exclusively on contour integration has been developed [9]. Vector fields at each cell vertex are constructed by 3x3 matrix inversion using the normal field components for three faces sharing the vertex node. The technique is known as the discrete surface integration (DSI) method.

Although this method has been found to significantly improve stability over the original FVTD method [8], we have observed that it may not obviate a late-time growth for complex grids. In addition, we have found that the grid-dependent node matrix becomes non-invertible when two required faces are co-planar. Also, for grids that require a full non-orthogonal advancement for a large percentage of the edges, DSI performance is reduced unless the node matrices and common-face pointers are stored. It is estimated that if more than 15-20% of the edges within the localized, unstructured region require the storage of this information, DSI memory requirements will exceed the storage added by the cell-based FVTD method.

A time-averaging technique similar to that used to improve the stability of the transient electric-field integral equation [12] has been found to considerably improve the late-time stability of the finite-volume method. The DSI technique will also benefit from the following scheme, but generally later in time.

The traditional second-order centered time difference is written as

$$\frac{\partial}{\partial t}\mathbf{H}_1\Big|_{t=(n+1)\Delta t} \rightarrow \frac{\mathbf{H}_1^{n+3/2} - \mathbf{H}_1^{n+1/2}}{\Delta t} \qquad (4)$$

A time average for $\mathbf{H}_1^{n+1/2}$ is the following

$$\mathbf{H}_1^{n+1/2} \equiv \frac{1}{(2+\alpha)}\left(\mathbf{H}_1^{n+3/2} + \alpha\,\mathbf{H}_1^{n+1/2} + \mathbf{H}_1^{n-1/2}\right) \quad (5)$$

where $\alpha \geq 1$. Time discretization of (1) with (4) and (5) leads to the advancement form

$$\mathbf{H}_1^{n+3/2} = \frac{1}{(1+\alpha)}\left(\alpha\,\mathbf{H}_1^{n+1/2} + \mathbf{H}_1^{n-1/2}\right) - \frac{(2+\alpha)}{(1+\alpha)}\frac{\Delta t}{\mu V_1^h}\iint_A \hat{\mathbf{n}}_h \times \mathbf{E}\,dA \qquad (6)$$

Note that as $\alpha \rightarrow \infty$, Eq. (6) returns to the usual centered time-difference form.

For finite values of α, the time average gives rise to dissipative time integration that provides increasing attenuation with increasing frequency. It behaves as a low-pass filter. The ideal pass band would allow unattenuated signals up to frequencies corresponding to 10-20 cells/wavelength, which is the typical resolution of the grid. The attenuation with increasing frequency effectively filters the non-resolved high-frequencies associated with the weak instability. Unfortunately, Eq. 5 only provides a leading-order, cosine profile, with a non-ideal pass band. The parameter, α, alters the profile. If the time average is used over all time, the effect is that even moderate frequencies are attenuated over large propagation distances (for small embedded grids, this effect may go unnoticed).

For the grids we have investigated, a successful implementation of the time average has been found by initially using $\alpha \to \infty$, with a reduced value for α being used only if a late-time instability develops. In this way, the early time high-frequency response is accurately resolved. The choice $\alpha = 4$ implemented on *either* the primary or derived unstructured grid has been found to be sufficient to attenuate any late-time growth. Larger values for α may be successful on certain grids.

A von Neumann stability analysis applied to a uniform structured grid using the averaged time-integration indicates that a slight tightening of the usual 3D Courant condition is required. This has been found to carry over to the embedded non-orthogonal, unstructured grids through numerical experiments.

Research is continuing in time-integration schemes, particularly with regard to the effectiveness of only applying the time-averaging behind the incident wavefront (this may be useful for large grids that require stabilization prior to the incident wave interacting with the entire object), and the development of superior averaging techniques that improve the filtering profile (higher-order terms will lead to increased computational and storage requirements).

Fig. 2 shows results for back scattering from a finite cylinder with flat end caps. The primary grid contained a highly distorted collection of wedges and hexahedrons. Curve 1 is the FVHG result using the original FVTD method in the unstructured grid (unstable at 0.6 μs), curve 2 is based on the DSI algorithm (unstable at 2 μs), while curve 3 uses the stabilized FVTD method. Curve 3 represents 21,000 time steps in the unstructured mesh. Up to the DSI instability, curves 2 and 3 are indistinguishable.

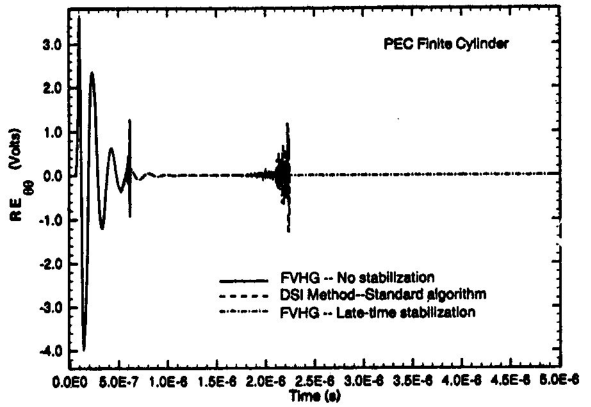

Fig. 2. Far back scattered field from a PEC cylinder. Axial polarization.

The results in Fig. 2 are based on single precision calculations. Using double precision delays the instability by 2000-3000 time steps. It is noted that several derived-grid edges do not intersect the common faces between primary-grid cells. The actual faces pierced can generally be detected and used in the FVHG method.

Surface Impedances

A first-order surface impedance approximation is included in the finite-volume algorithm by modifying the advancement equation for the cells on the **H**-grid that have a face on the object's surface. Specifically, for a surface face, A_S, with a local impedance, Z_S, the right-hand side of (1) is written as

$$-\iint_{A_s} \hat{\mathbf{n}}_h \times \mathbf{E}\, dA_s \cong Z_s \iint_{A_s} \hat{\mathbf{n}}_h \times (\hat{\mathbf{n}}_h \times \mathbf{H}_1)\, dA_s \qquad (7)$$

which is now coupled to the **H**-field being advanced because the right hand side must be time averaged to be properly time centered. A 3x3 matrix inversion is required for these surface cells. An alternative formulation has also been developed [13].

Equation (7) provides the dominant contribution to the effect of the surface impedance. Minor improvements can be made by: 1) extrapolating the **H**-field to the surface, and 2) correcting the **E**-fields used by the surface-cell faces which share edges with the surface face. Adding dispersion is done similar to traditional FDTD [14].

It is noted that a contour-based correction is not used for the faces that possess a single edge on the surface. This is because the surface **E**-field cannot be written exclusively in terms of the face-normal **H**-field obtained from contour integration, in general. Attempting to partition the **E**-field further complicates the implementation.

Mesh Interface

The non-orthogonal region is required to terminate on a rectangular surface with specified node locations. A cross section of the interface is shown in Fig. 3 The interface consists of orthogonal hexahedrons which are defined within an inner and outer boundary of fixed nodes. The **E**-fields on the inner and outer boundaries are FVTD and FDTD determined, respectively.

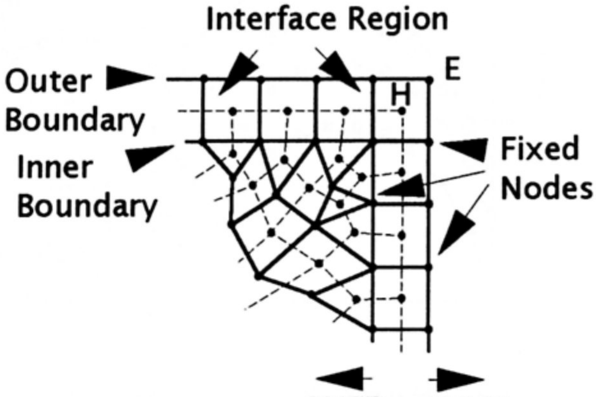

Fig. 3. Interface between unstructured and structured grids.

The advancement scheme is as follows. The **E**-fields in the structured region are initially advanced. The FDTD **E**-fields on the outer boundary are second-order time interpolated and mapped into the FVTD registers. The FVTD region is advanced (possibly) several sub-time steps as dictated by the Courant condition in this region. The FVTD **E**-fields are subsequently mapped into the FDTD registers on the inner boundary. Advancing the FDTD **H**-fields in the structured region completes the overall time step.

The scheme provides a seamless spatial connection between the unstructured and structured regions. The time-interpolation adds reflection error which could be eliminated by using the same Δt for all regions. The added error has not been found to create a significant problem, and the interpolation can substantially reduce execution time.

Grid Generation

As noted in the previous section, the non-orthogonal region is required to terminate on a rectangular surface with fixed node locations. This can be accomplished with limited generality by projecting a rectangular surface onto the object being modeled. Cubit [15] and INGRID [16] are two programs that can perform this task. More generally, arbitrary objects can be generated and gridded with the package PRO/Engineer™ by Parametric Technology, Inc. This software generates a tetrahedron primary grid with the required fixed termination nodes. Mapping the tetrahedrons to the structured orthogonal hexahedrons is accomplished by a transition layer. Again, a seamless connection between the unstructured and structured regions occurs. A future release of the Cubit program will provide a similar capability with a hexahedron unstructured grid. Of course, hexahedrons are appealing because of reduced cell count, but a trade-off is generally non-planar faces (it is noted that whatever non-orthogonal cells are used for the **H**-grid, the **E**-grid will generally possess non-planar faces). The accuracy provided by PRO/Engineer™ grids is presently under investigation.

Impedance Sphere

Results for scattering by a 2m-radius sphere are presented. A 22^3 unstructured region (generated by INGRID) is centrally embedded into a 120^3 structured grid. From an FVTD viewpoint, the total grid possessed approximately 10.5M edges (degrees of freedom). The structured region used a uniform spatial step of 0.25m and the maximum/minimum edge lengths on the primary and derived grids were 0.2913m, 0.0625m, 0.2736m, and 0.0638m, respectively. Three sub-time steps were required in the FVTD region for each time step in the structured region. The longest edge length of 0.29m leads to a 10-"cell"/wave-length resolution at about 100 MHz. A second-order Mur absorbing boundary condition was used.

A z-polarized wave is incident on the sphere. The sphere has a surface impedance defined by $Z = Z_S/377$. The far back-scattered field ($E_{\theta\theta}$) for a PEC sphere (Z=0) is shown in Fig. 4. Accuracy within about 1 dB occurs up to the 10-"cell"/wavelength point. As the surface impedance increases, so does the required spatial resolution. Results for several impedances are shown in Fig. 5. For the case Z=0.75, approximately 20-"cells"/wavelength are required for accurate results.

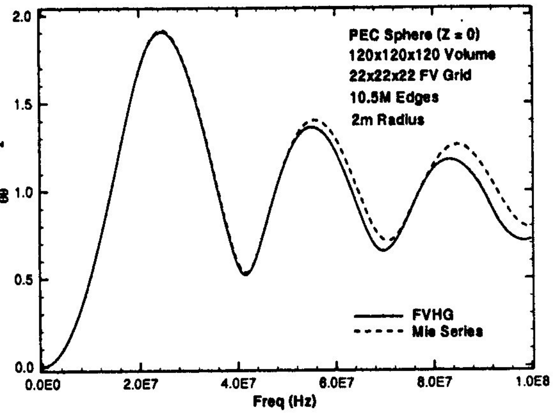

Fig. 4 Back scattered far field by a PEC sphere.

In terms of the unstructured region time step, this problem required approximately 0.15 μs/edge-time-step on an 8-processor desktop Sun SPARC 1000, including the far-field transformation. This figure will improve substantially on vector/parallel machines due to high vectorization in the structured grid. It is noted that on the 8-processor machine, simply advancing the structured region without the unstructured grid required approximately 0.11 μs/edge-time-step; thus, limited overhead is introduced with the FVHG technique for this problem. Of course, the overhead will increase as the relative size of the structured region decreases. The hybrid-grid formulation for the impedance sphere required approximately 20M words of memory. If desired, the sphere could be placed into a much smaller structured grid.

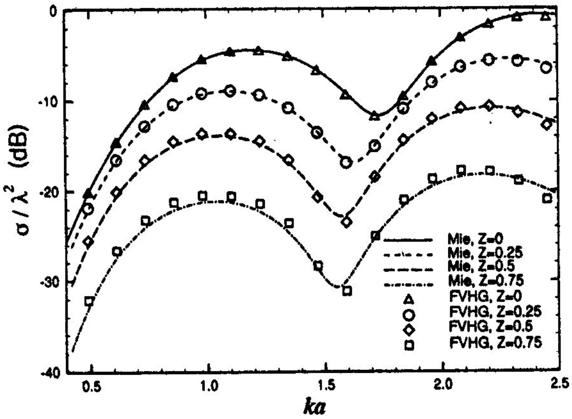

Fig. 5. Monostatic RCS for an impedance sphere

Concluding Remarks

An efficient transient Maxwell solver based on hybrid-grid structures has been briefly described. The FVHG technique provides a seamless connection between unstructured and structured grids that is free from spatial interpolation and, optionally, time-interpolation at the grid interface. By treating a non-orthogonal region as a local problem within a structured computational volume, computer resource requirements are greatly reduced while adding considerable modeling flexibility. Multiple unstructured regions are easily embedded.

Surface impedance effects and, in fact, many FDTD sub-grid techniques such as thin slots and wires carry over to the FVTD formulation. The availability of solid-modeling/grid-generation software facilitates the development of complex, multi-material models, but the accuracy of these grids remains under investigation.

A late-time stabilization technique was introduced to deter the development of weak instabilities associated with certain complex meshes. It is noted that while one mesh may require stabilization, another mesh of the same object may not. Time integration schemes with superior filtering profiles are presently under investigation.

The application of the FVHG technique proceeds as follows: 1) Generate the object of interest by using a solid-modeling tool, 2) Define a rectangular surface around the object with fixed boundary nodes that are spaced to connect to the exterior structured region, 3) Grid the space within the rectangular region, refining the mesh as needed (PRO/Engineer™ facilitates tasks 1-3, but often generates grids with wide variations in edge lengths), 4) Generate the necessary primary- and derived-grid information for the unstructured mesh using the FVHG preprocessor, 5) Define the desired location(s) for the unstructured grid within the structured mesh, and 6) Begin the simulation.

Development of the algorithm is continuing. Porting the method to the 1,904-node Intel Paragon at Sandia is expected to occur later this year.

Acknowledgments

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MODELER'S NOTES

Gerald J. Burke

Several months ago our editor Ray Perez contacted me and several others whose names now appear under the ACES Newsletter staff to ask for commitments to supply regular contributions for the Newsletter. I have been a member of ACES since its inception and have attended all ten of the annual conferences, but so far have avoided other than occasional involvement in the work of keeping either the organization or the publications going. Hence there seemed to be no room to escape and, hopefully, this column will become a regular item in the Newsletter. Instructions from Ray and Dick Adler have left the format open, with suggestions either to write about my own topics or solicit contributions from readers.

I probably will not do too well at applying the kind of pressure needed to get contributions, but if anyone wants to step forward they will be very welcome. The title Modeler's Notes leaves room to cover a wide range of topics in computational EM, but without some external input NEC will probably be the main topic. We do get occasional phone calls from NEC users with valuable suggestions or experiences from their modeling attempts, and these often get lost in the ongoing work. The Newsletter should provide an impetus to get these items out into the community. If anyone has any ideas or experiences (successes or failures) in modeling I hope they will give me a call or send a note to:

Jerry Burke, L-156
Lawrence Livermore National Labs.
P.O. Box 5504
Livermore, CA 94550

phone: 510-422-8414
FAX: 510-422-3013
e-mail: burke@icaen.llnl.gov

Also, if you have called before with a suggestion that seems to have fallen through the cracks, feel free to remind me.

The main news concerning NEC is the question of the availability of NEC–4, but with the deadline for this issue at hand the situation is still not clear. NEC-4, like NEC–3, has until now been classified as Military Critical Technology, so requestors in the U.S. had to have a DoD contract and have their need for the code verified by the Army through Ft. Huachuca. Requests from other countries had to be originated by their embassies through diplomatic channels. Recently the Army and Navy organizations that have sponsored NEC over the years have taken a new look at these restrictions, and considering the availability of other codes with equal or greater capabilities, have decided that the Military Critical classification on NEC can probably be dropped. The feeling was that the export restrictions should remain in effect for now. Once we get an official statement of the new policy from the DoD we will have to take the matter up with the LLNL code release office, since the Lab is a co-owner of the code, and the University of California retains a copyright on it. It is possible that the code can be released through the Lab's Technology Transfer program or possibly through ACES. For now, the code is being released, but we need a written request from the Army or Navy contracting office and also our usual order form required by DoE.

Getting away from NEC, a topic of importance to all modelers is the increasing speed of personal computers. Many have been using IBM-compatible or to a lesser extent Apple Macintosh machines for serious work for some time, and the current race between Intel and Motorola/Apple offers the prospect of much more powerful PCs at reasonable prices. In the April 1994 IEEE APS Magazine Ross Stone considered the question "Is it time for a Pentium?" with detailed information about the options available. The first PowerPC Macintosh models have just recently hit the market with impressive performance claims, and significantly more powerful models are expected next year.

I have recently been through the exercise of upgrading my Macintosh to a 68040 processor, and while the specifics are already out of date the experience may be of interest to Mac users considering similar moves. Hopefully it will not scare people out of opening the cover of their Mac, since I think I ran into some unusual bad luck. I had been using a Mac SE/30 since the model first came out. While the small black and white screen was a drawback, it was easy to put it in a bag and strap it on the back seat of the car, which was the degree of portability that I needed. An upgrade became essential with the arrival of Mathematica version 2.2 last summer. In version 2.2 the front end and kernel have been separated and communicate through Math Link which requires System 7. With the increased size of System 7 over System 6 and the need to allocate memory for both the front end and kernel, it would no longer fit in the 8 MB of RAM in my SE/30. Also, version 2.2 has gotten slower by as much as a factor of two for some operations. (A Wolfram representative said that while Math Link provides enhanced communication capabilities, the implementation for Mathematica may be a little cumbersome, and may be improved in future releases.)

Anyway, it seemed that more memory and a faster computer were in order, and to retain the portability and buy time for a possible jump to a PowerPC, I decided to upgrade the SE/30. Four 4 MB SIMMs and four of the old 1 MBs in the other bank would be more than enough for Mathematica. For more speed I decided on a 33 MHz 68040 accelerator and 128K cache from DayStar Digital. While not super fast, this would be about 4 to 5 times faster than the 16 MHz 68030 in the SE/30. The 4 MB SIMMs arrived first and were easy to install, although with the SE/30 you need to wrestle with a difficult to reach cable connector to get the motherboard out. The usual antistatic and grounding precautions must be followed and caution is needed in working around the attached CRT. However, the memory upgrade went without a problem.

When the accelerator arrived I eagerly repeated the procedure, expecting soon to have a faster Mac. The installation manual from DayStar is clearly written and illustrated and gives specific and detailed instructions for each model of Macintosh. The installation is relatively easy for the SE/30 since the accelerator, cache and adapter plug into the PDS slot alongside the CRT, and it is not necessary to remove the motherboard. For Mac II, IIx and IIcx models the CPU and AMU chips must be removed and an adapter plugged into their sockets. A chip pulling tool is supplied for this step. The manual states that most IIcx models have the CPU soldered in rather than in a socket, and it may be necessary to send the board to DayStar to have a socket installed.

While the installation was easy, when I put the Mac back together and turned it on it got to the end of the boot process and hung. On checking the Trouble Shooting section it looked like "incompatible formatting software" was a likely cause. I still do not fully understand this problem, but apparently most drivers for hard disks read and write with "blind transfers" rather than using handshaking. Normally you can switch such disks between processors running at different speeds without problems. However, for some reason documented in a maintenance note from Apple, a 68040 cannot use blind transfers to a disk formatted on an earlier member of the 68000 family. Once the disk has been formatted on a 68040 it can be used with blind transfers on that or any earlier 68000 processor. On removing the accelerator I got some further bad news: the data on my internal disk had been damaged by the failed blind transfers. The first step in the installation manual is to backup your disk, but if this has been done to 50 high-density floppies as I had done, it is not a welcome situation to have to restore. The first step should be to determine whether your disk uses blind transfers, and if it does, do not proceed until blind transfers have been turned off.

Apparently most disks use blind transfers, and turning them off may not be easy. The Apple utility cannot do it, and on calling MicroNet (whose utility I was using due to a disk disaster when the SE/30 was new) I was told that they do not make a utility that can operate without blind transfers. Two disk utilities that do let you turn off blind transfers are Silver Lining from La Cie and Hard Disk ToolKit by Hammer. Hard Disk ToolKit Personal Edition will not do it (it took a mail order/return cycle to learn this). I also took the opportunity to order an external hard disk to be less at the mercy of gremlins that might attack the internal one.

Once the disk was formatted without blind transfers and data restored, I again tried installing the accelerator. This time it managed to boot and display the desktop, but as soon as I tried to do anything it would hang. The DayStar representative (who was always readily available and helpful) suggested that I send the accelerator in to be checked. It returned with a message that it had tested OK, but that they had replaced it with one having a newer ROM. With this new board the computer was actually usable and showed the expected speed increase over the basic SE/30. However, when a window was scrolled or any other screen activity occurred, white lines would shoot across the screen. It was usable in this state, and I should have been satisfied with it, but the DayStar representative said the white lines should not occur. There followed about six weeks of going home almost every night to open up the SE/30 and check contacts, measure voltages, look for broken traces on the board, etc. We found a patch to System 7 that Apple said corrected a problem of white lines when scrolling a 16 inch Apple color monitor used on a Quadra, but that did not help the SE/30. After another return to DayStar where the accelerator checked OK, it seemed that there might be a problem on my motherboard. I was able to swap motherboards with another SE/30 that was not using an accelerator. This swap fixed the problem — for one week. Then it refused to boot at all. At this point it was apparent that professional help was in order, and I got a recommendation for a good Mac repairman and took it in. The verdict was something wrong on the motherboard such that it would not work with 4 MB SIMMs or with the accelerator, but it would work in its original configuration. Since getting my original motherboard back was now out of the question, and a new board from Apple costs almost as much as the SE/30 is worth ($465 to a dealer with trade-in but $950 to the customer) I am now writing this on a Quadra 650 that I got in January. Fortunately Mac's Place where I had purchased the accelerator and 4 MB SIMMs gave a full refund despite the three months that had elapsed since the purchase.

My experience with the accelerator was apparently unusual, since a number of them have been installed in Macs in our department at LLNL without any problems. The representative at DayStar did say that they seem to have more problems with SE/30s than with other models, perhaps because there is a lot crowded onto the board that was originally designed for a 68000 processor.

So far I am quite satisfied with the Quadra 650. It has a 33 MHz 68040 processor like the accelerator and the 14 inch color monitor is a big improvement over the SE/30. I am still able to put the processor and monitor in separate bags and strap them on the back seat of my car, but it is more awkward to carry and there are more cables to connect. Apple PowerBooks are looking interesting, but it would be nice to see more speed and memory capacity.

Now we are back to the question of whether to upgrade to a PowerPC, or rather when since they sound too interesting to pass up for long. One factor to consider is the availability of software that will run in native mode on the PPC, but that seems to be coming out at a good rate. Absoft has just announced a Fortran compiler for the Power Macs, and Language Systems probably has one also. Wolfram Research is shipping Mathematica for the Power Mac for $135 charge to present users of the Mac version. They report that on the Power Mac (80 MHz?) the Mathematica front end (plotting, etc.) runs up to 4 to 6 times faster than on a Quadra 650, and the kernel is up to 8 to 10 times faster. Of course the Power Macs will emulate a 68040 processor to run the old software, but according to the *Windows* newsletter put out at LLNL the version of the 68040 without floating-point unit is emulated, so 680X0 applications using floating-point operations may run much slower than on a Quadra. Another factor complicating the decision to upgrade is the prospect of still faster PPC models in the next year or so. According to the April 25 MacWeek, the PowerPC 604 should be available in Macintoshes in early 1995 and the full 64-bit 620 should be showing up in about a year.

To get an idea of where we are and of future prospects I tried comparing NEC running times on several computers. The speed comparisons for Macintosh are complicated by the use of two Fortran compilers. I started using the Absoft MacFortran/020 compiler. This was the 68020 extension of the MacFortran compiler originally developed by Absoft for Macs having just 128K bytes of RAM. Hence it had to be very small and fast, but is able to compile large programs without problems. With the latest version of toolbox.sub, it will produce code that will run on a Quadra, but it does not take full advantage of the 68040 processor. Several years ago Absoft released a new compiler called MacFortran II which is now up to version 3.3. I got the first version, but did not use it much since it was about 30 times slower in compiling than MacFortran/020. It did produce more efficient code. I have now upgraded to version 3.2, and find that it produces significantly faster code for a 68040 processor. It is still slow, taking 10 minutes and 47 seconds to compile and link NEC–2D on the Quadra 650, while MacFortran/020 does it in 54 seconds. However, the faster code is probably worth the wait. Also, MacFortran II has an option for "frequent command-. checks" that makes it easier to interrupt the code and also lets it run in the background under MultiFinder or System 7. You could save compilation time with MacFortran II by compiling the individual subroutines with a Build file (like UNIX make) but I am not yet set up for that mode. The Absoft MacFortran II compiler is apparently similar to the Language Systems Fortran Compiler, and both operate under MPW.

To compare speeds I ran the double precision NEC–2D code on a problem with 300 segments (30 parallel wires in a 5 × 6 array with 10 segments each and spaced by 0.2 wavelengths). One reason for 300 segments is that this was the absolute largest problem that we could run on a CDC 3800, probably around 1965, and that could only be done at night when they loaded a reduced operating system. Of course, now you can easily get enough RAM to run 1000 segments or more on a PC (maybe not so easily in DOS, after reading Dick Adler's contribution in the March Newsletter). I do not remember how long these runs took on the 3800, but it probably would not take too many of them to equal the cost of a new Power Mac. The CPU times to fill and factor the impedance matrix follow:

Computer	Fill (sec.)	Factor (sec.)	SPECfp92
Mac SE/30 (020 compiler)	585.1	679.0	
Mac IIci (020 compiler)	477.8	496.2	
Quadra 700 (020 compiler)	214.3	73.5	
SE/30, 33 MHz 68040 accel. (020 compiler)	160.0	66.9	
VAX 6330 (double precision)	112.6	225.7	
VAX 6330 (single precision)	59.7	66.6	
Quadra 650 (020 compiler)	158.5	54.3	
Quadra 650 (MF II compiler)	37.5	33.9	
IBM RS/6000 Model 550	8.9	19.2	72.2
IBM RS/6000 Model 550 (–O optimization)	6.5	8.0	72.2
Power Macintosh, PPC 601 (estimated)	8.3	5.5	105
DEC Alpha 3000/400	4.9	4.3	112

The floating-point SPECmark ratings are shown where I could find them. The time shown for the Power Macintosh was estimated from the Quadra 650 time. Absoft claims a factor of about 6.2 speedup for double precision LINPAK (9.7 for single precision) and 4 to 5 for less orderly operations like filling the matrix. They also say that their compiler operates in native mode on the PPC, so the time spent waiting for it to compile should be significantly less than for the present compiler. The speed of the SE/30 with accelerator and 128K cache is close to that of the Quadra 650. When the accelerator was used without the 128K cache the factor time was about twice as long while the fill time showed a small increase.

The speed for floating-point computations on an affordable PC is seen to have increased by almost two orders of magnitude since the SE/30 was introduced in early 1989. It seems like too much to hope for this rate of increase to be maintained, but the competition between Intel and Motorola should continue pushing up the speeds. According to an article in the April 25 MacWeek, Apple expects to start shipping Macs with the PPC 604 processor in the first half of 1995. They quote expected ratings of 160 SPECint92 and 165 SPECfp92 for the 100 MHz PPC 604, compared to 80 SPECint92 and 105 SPECfp92 for the present 80 MHz 601. However, the June MacWorld quotes IBM as rating the PPC 604 as 200 percent as fast as the 601 for integer operations and 120 percent as fast for floating point. Maybe they were adjusting for clock speeds, but I guess we will have to wait and see which is correct for Fortran code. The 604 incorporates six execution units (three integer, one floating point, load/store and branch) so will probably require a new compiler and other software to get the full advantage. The PPC 604 should be followed by the full 64-bit 620 model later next year. I have not seen any claims for the speed of the 620, and the price of a system to support it remains in question, but it should keep up the speed race. Of course the Pentium is still very competitive, although maybe a little behind for now for floating-point work.

Another toy that came with the Quadra 650 was a CD-ROM drive. This seems to have a lot of potential, and hopefully some really good disks will be showing up in the future. A colleague working in geophysics showed me an advertisement for GEOROM II from the Society of Exploration Geophysicists. On three disks this has:

- Complete full page images, color images and ASCII text for technical articles from 58 years of the journal Geophysics (1936-1993).
- Selected gray-scale images now available for Geophysics articles for the years 1990-1993.
- Complete full page images, color-gray images and ASCII text for technical articles, biographies, Presidents Page, Signals, News Briefs from 12 years of *The Leading Edge* (1982-1993).
- Robert Sheriff's *Encyclopedic Dictionary of Exploration Geophysics, 3rd Edition.*
- Complete Digital Cumulative Index, through 1993, of bibliographic references from SEG, EAEG, ASEG and CSEG publications.
- The supplemental disc now contains the ASCII text of all 58 years of *Geophysics* and 12 years of *The Leading Edge*, thus allowing for a search for key information without changing a disc or data base.
- The latest level of WordKeeper search and retrieve software for the PC-DOS and Macintosh interfaces.

The price to SEG members is $170 or $34 for an update. I have not seen anything like this from IEEE, but it would certainly be nice. At our library I was told that they have IEEE, IEE and other publications on CD-ROM, but the set is very expensive.

A CD-ROM that could be of interest to ACES members who are on the road a lot is the

Street Atlas USA by DeLorme ($99.95 for Macintosh or Windows), which is claimed to have maps showing every street in the United States. It seems to live up to that claim with the exception of areas developed in the last few years. Version 2 is dated 1993, but they cannot be expected to update the entire country for each new edition. Maps can be displayed in 14 magnitudes, where magnitude 3 outlines the 48 states, Alaska and Hawaii; and magnitude 16 shows streets with finite width and the names down the center. Names are shown for most city streets at the lowest levels, and many names that are not shown can be obtained by using the labeling tool, which also can label rivers, creeks and railroads. Street numbers can be obtained for blocks in cities of medium or larger size. Cities and towns, down to the tiniest spot can easily be located by name and state, Zip code or telephone number. However, airports are not in the Place index, so ones in built-up areas may take some searching unless you know just where to look. Also, airport terminals are not shown, so it is difficult to tell where you will be starting out. A key for the type of road is badly needed. Now you cannot distinguish between narrow public roads, private gated roads and dirt tracks in the wilderness. Primary and secondary highways are shown with distinctive lines, however. Another lack for our business is that most military bases are just blank spots on the maps, although Ft. Huachuca AZ is shown in good detail, including most buildings. Base names are not in the Place index, but many can be found in the Zip code index. In a data base of this size you would expect some errors, and that seems to be the case. Rome NY is shown near Ausable Forks, about 120 miles northeast of its actual location. At least that is where the name is and where the Place locator goes. The Zip code index finds the correct location for Rome and Griffiss AFB, northwest of Utica, and the streets seem to be correct. Just the city name has wandered. Also, the locator finds the small Red Bank NJ south of Camden but not the main one near Ft. Monmouth. Again the streets are probably correct, but the city name is missing. Overall, however, it seems to be a very nice product.

Well, guess I will wind this up, since it has gotten pretty far from EM modeling. Hopefully we will have some contributions from members on their ideas, work or experiences in modeling for the next issue. Perhaps I should add that most of the product names mentioned here are trademarks.

The Practical CEMist

- *practical topics in communications* -

Perry Wheless, K4CWW

Welcome to the second installment of **The Practical CEMist** in the *ACES Newsletter*. I have received a number of comments regarding this new department, and nearly all were both favorable and encouraging. There are many ACES members in a position, both by experience and facility with the practical topics of interest here, to be regular contributors to this column. Even if you have only one subject which you would like to see made available for the benefit of others in print, I urge you to prepare your manuscript and submit it as soon as possible. Compliments, while greatly appreciated, must be followed with good publishable material if this department is going to continue and succeed in the future. My mail box awaits your manuscript with eager anticipation!

The VHF amateur repeater frequencies in the March *Newsletter*, as well as the PL frequencies, were correct but the order of rx/tx frequencies, as printed, was reversed from customary. As a result, several hams were unsuccessful in accessing these repeaters at the ACES'94 Symposium in Monterey in March. I was able to access both repeaters with a low-power handheld from the Doubletree with no problem, but had very little time available for operating. We will try again next year, with a special effort to get hams together on Saturday and/or Sunday before the crunch of conference activities sets in. If you think we should try to arrange a short social gathering for ACES radio amateurs at ACES'95, please let me hear from you.

My sabbatical leave in New Mexico concluded in mid-May and I have returned to home base in Alabama, so future communications should be directed to the following:

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
Note: "1" = numeral one.

Because our feature article for this issue is relatively long, it has been decided that this installment of **The Practical CEMist** will consist of this one paper alone. The author, Al Christman, is well known in ACES and Al has provided some interesting and useful information in this paper regarding the "best" height above ground for yagi antennas employed in communication links at HF. Current plans for the next issue are for multiple papers, including one on the topic of HF propagation forecasting. The following biographical sketch will serve to introduce this issue's featured author:

Al Christman is currently completing his sixth year on the faculty of Grove City College (in western Pennsylvania) where he serves as Professor of Electrical Engineering. He worked on a Chemical Corps pilot project to destroy stockpiles of toxic nerve gases while on active duty with the U.S. Army during the Vietnam War, and also served with the infantry and field artillery. Later he was employed by U.S. Steel Corporation in their Gary District (southern West Virginia) operations where he worked in underground coal mines. More recently he performed antenna measurements and computer analyses at Lawrence Livermore National Laboratory in California, while completing the requirements for a Ph.D. in electrical and computer engineering from Ohio University. In the summer of 1993 he was a visiting professor of electrical engineering at the Pennsylvania State University. His main area of research is medium- and high-frequency antennas, and he is an active amateur radio operator. His wife Lynn is a non-traditional student majoring in religion at Grove City College, and they have a married daughter, Heather.

Finally, you may be interested to know that several members of ACES have been getting together on lower sideband in the vicinity of 7.160 MHz (nominally between 7.154 and 7.170). If you have the capability to operate there, keep an ear open for Jim Breakall (WA3FET), Dick Adler (K3CXZ), Al Christman (KB8I), or me. You are invited to join us whenever you can.

What Height is Right?

Al Christman, KB8I
Grove City College
100 Campus Dr, Grove City, PA 16127-2104

I. INTRODUCTION

Most hams begin their amateur-radio careers using an inverted-vee or vertical-monopole antenna, but eventually the time comes when they yearn for "something better." The "next step up" is often a rotatable Yagi-Uda antenna mounted on a suitable supporting structure. After the decision has been made to buy a tower and a beam, the first question asked is usually "which brand of antenna should I buy?," followed closely by "how high should I put it?" The goal of this article is to provide the information you will need in order to properly answer the **second** question.

II. HIGHER IS BETTER?

Often the old saying is heard: "the higher an antenna is, the better it will perform," or perhaps this variation: " if your antenna didn't come down last winter, then it wasn't high enough." Is it really true that high antennas **always** work better than low ones? Let's find out:

In actuality, the "best" antenna height is that which enables you to concentrate as much radiated RF energy as possible at the elevation angle (or take-off angle, TOA) which will provide the loudest signal at the desired receiving location. Depending upon the time of day, the season of the year, the portion of the sunspot cycle, the length of the path, and the operating frequency, that optimum TOA may be quite low or rather high, or perhaps somewhere in between. Generally speaking, TOAs which are relatively low are required for communicating over long distances, while shooting the breeze with the locals may call for a "cloud-burner" antenna which emits most of its radiation at elevation angles that are much higher. In fact, the "right" antenna height depends not only upon various physical and atmospheric factors, but also upon your personal goals as a ham. If you enjoy DXing or contesting, your needs are quite different from those of the guy or gal whose operating time is spent on state-side ragchews.

My friend Jim Breakall (WA3FET) and I have had many discussion over the years about the "optimum" antenna height. We decided that "someone" should do a detailed series of measurements in order to determine the actual elevation angle of signals arriving from various locations. Of course, for such a study to be really useful, it should cover **all** of the amateur bands, at **all** locations around the world, during **all** types of propagation conditions. Obviously, this is an extremely ambitious goal, and it would be very expensive to carry out an investigation of this kind.

Perhaps the best alternative is to perform a comprehensive propagation analysis utilizing one of the software packages which are now available. Instead of actually **measuring** the arrival angles, as suggested earlier, the propagation code would be used to **predict** the most-likely angles. Dean Straw, N6BV/1, has actually done this, and his work is currently being prepared for publication [1]. When the results of his research come onto the market, we should finally have a good grasp of the probable signal-arrival angles for any particular set of circumstances.

A few words of explanation may be helpful at this point. Our basic assumption is that the optimum TOA for transmitting purposes is equal to the most-probable elevation angle of the incoming (received) signals. Furthermore, when speaking of the "height" of an antenna, we must include the concept of electrical wavelength, rather than just the physical dimensions, such as feet or meters. A height above ground of 70 feet is roughly one wavelength at 14 MHz, but only 1/4 wavelength at 3.5 MHz. Thus, it becomes apparent that a horizontal dipole for the 20-meter band will perform much differently at 70 feet elevation than will a horizontal dipole for the 80-meter band which is also mounted at that same 70-foot level.

From the discussion above, we can conclude that it is highly unlikely for a **single** TOA to be "best" under all operating conditions. Rather, a **range** of elevation angles may be required, and that range could be quite large. What we must then do is attempt to find a single specific antenna height which will provide coverage over the entire span of desirable TOAs, or else consider some **other** alternatives. In addition to a wide beamwidth in the elevation plane at the front of the antenna, we would like to avoid sending RF energy in unwanted directions. Normally this means that we want to minimize the signal strength radiated off the back and sides of the beam at **all** TOAs.

III. STANDARD YAGI DESIGN

The reference antenna used for the studies shown here is a three-element Yagi-Uda array described by the late Dr. James Lawson, W2PV, in his classic book *Yagi Antenna Design*, which is available from the ARRL Bookstore [2]. The length of the boom is 0.3λ and all element radii are 0.000526λ. The dimensions for each element are:

$$\begin{aligned} \text{reflector length} &= 0.49404\lambda \\ \text{driven element length} &= 0.48572\lambda \\ \text{director length} &= 0.46525\lambda \end{aligned}$$

and the spacing between elements is held constant at 0.15λ.

IV. PATTERN ANALYSIS

The antenna described above was modeled using ELNEC, version 3.03 [3]. ELNEC is an aftermarket version of MiniNEC [4] which has been expanded and modified by Roy Lewallen, W7EL. It is user-friendly, and has excellent facilities for displaying antenna geometry and radiation patterns. All conductors in the model yagi are made of aluminum, with ten segments per element. For simplicity, the boom of the antenna and the tower itself were both omitted from the model. Because of the author's interest in DXing, the frequency was chosen as 14.225 MHz, the center of the DX portion of the 20-meter phone band. According to ELNEC, the forward gain of this beam (in **free space**) is 8.3 dBi, and the front-to-back ratio is 27.2 dB.

This three-element W2PV yagi was then modeled over "real" ground with a conductivity of 0.005 Siemens per meter and a relative permittivity of 13. The height was varied from 0.2 to 1.0 wavelengths, in steps of 0.1λ, and the results are given in figures 1 through 4. It can be seen that, **below** a half-wavelength in height, each pattern shows a significant amount of radiation off the back of the antenna. At heights **above** a half-wavelength there is still considerable radiation to the rear, plus a partial null at the front near TOAs in the range of 30° to 40°. In contrast, the yagi situated at $H = 0.5\lambda$ has none of these undesirable traits. The forward gain for the beam at this height is 12.3 dBi, the front-to-back ratio is 23 dB, and the half-power beamwidth (HPBW) in the **azimuthal** plane is 64°. The main lobe is not as broad in the **elevation** plane (where the HPBW is 29°), so the antenna does NOT cover **all** possible TOAs. Nevertheless, it appears that the best combination of clean pattern shape, good forward gain, and minimum radiation "off the back" occurs when the three-element beam is located about a half-wavelength above the ground.

Figure 5 shows the elevation pattern for the previously-mentioned three-element yagi, along with a ground-mounted quarter-wave vertical monopole and an inverted-vee with its apex at a height of one-half wavelength. Obviously the beam is much better than the vertical, and has about two S-units of additional gain over a wide range of TOAs. (Because of its poor response at high angles, including a complete null directly overhead, the vertical monopole may be useful in those instances where it is desired to **reject** all nearby signals, which presumably will arrive at elevation angles near the zenith.) Comparing the yagi to the inverted vee, we notice that the beam has more gain (at some angles as much as 7 dB) at all TOAs below 55°, but less radiation intensity at elevation angles above 55°. This inverted vee would probably be a better choice than the yagi for communicating over very short distances, and it would have even **more** gain at high TOAs if its apex were actually **decreased**. (We begin to suspect at this point that it might be necessary to have **more**

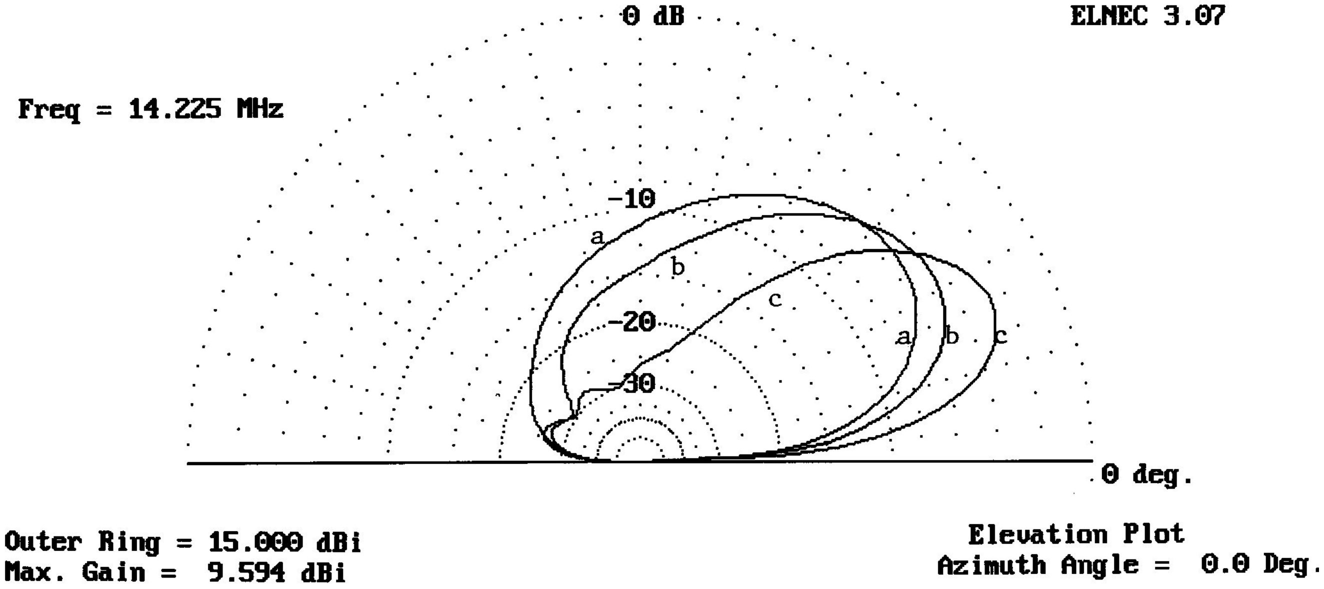

Figure 1. Elevation-plane radiation patterns for 3-element W2PV yagis at heights of (a) 0.2λ, (b) 0.3λ, and (c) 0.5λ.

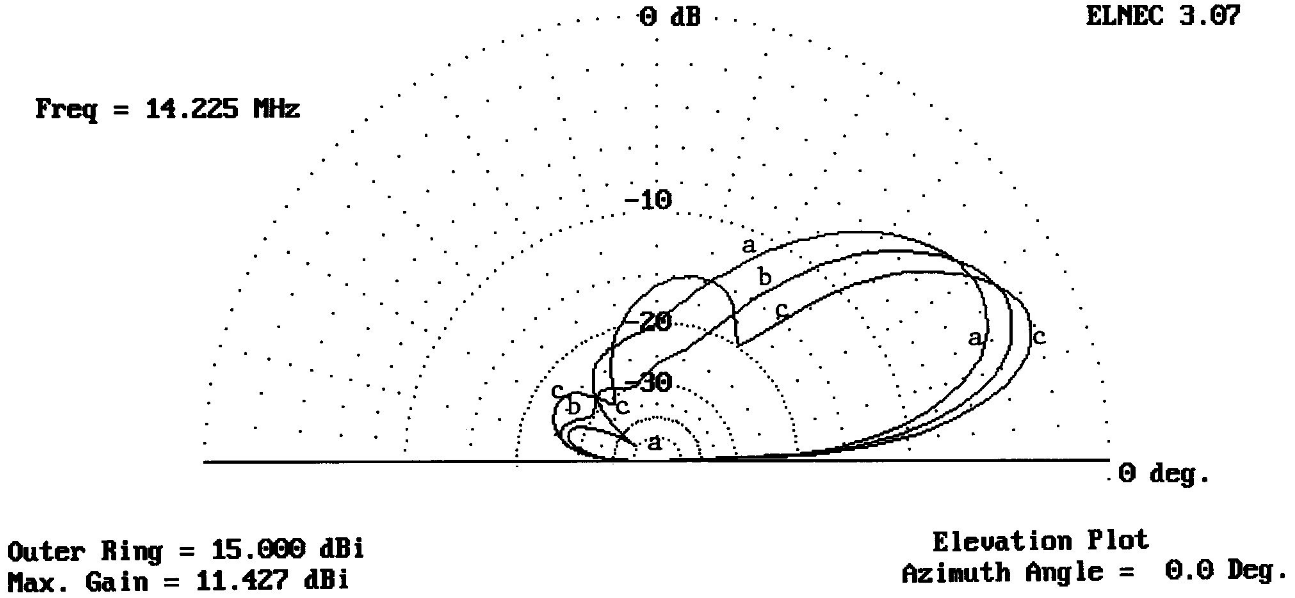

Figure 2. Elevation–plane radiation patterns for 3-element W2PV yagis at heights of (a) 0.4λ, (b) 0.5λ, and (c) 0.6λ.

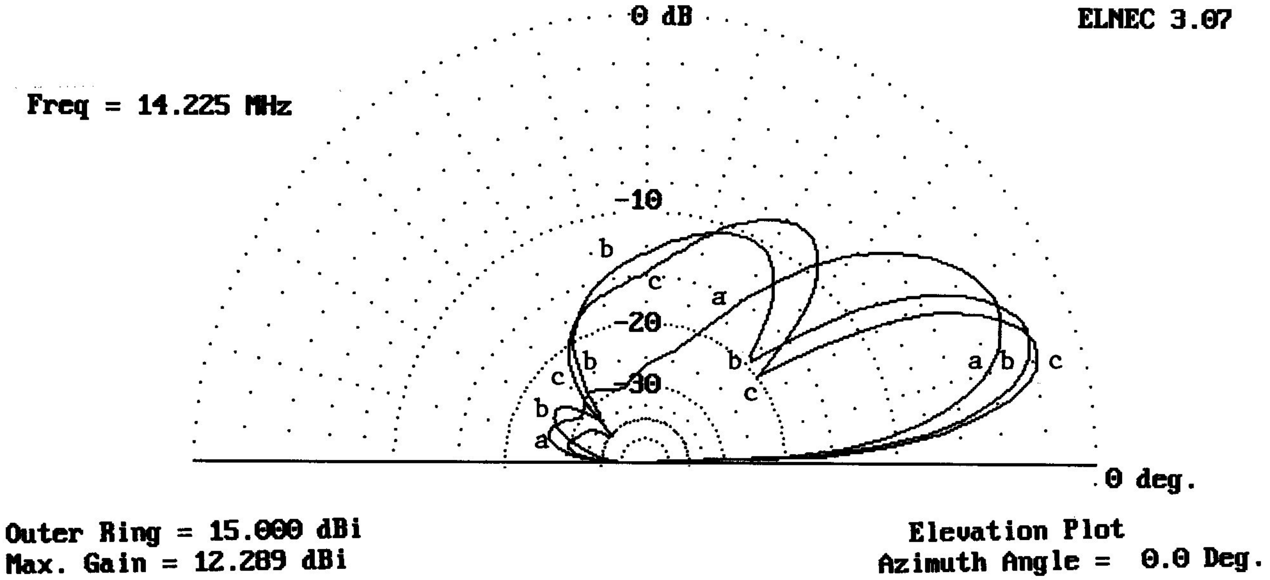

Figure 3. Elevation-plane radiation patterns for 3-element W2PV yagis at heights of (a) 0.5λ, (b) 0.7λ, and (c) 0.8λ.

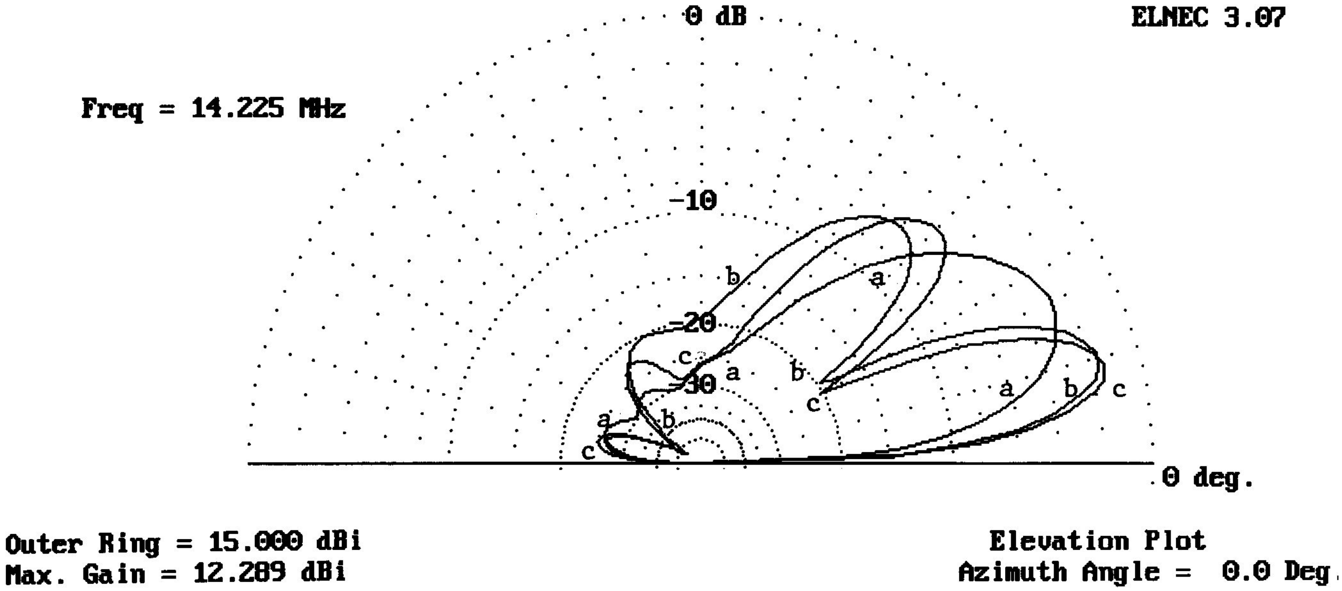

Figure 4. Elevation-plane radiation patterns for 3-element W2PV yagi at heights of (a) 0.5λ, (b) 0.9λ, and (c) 1.0λ.

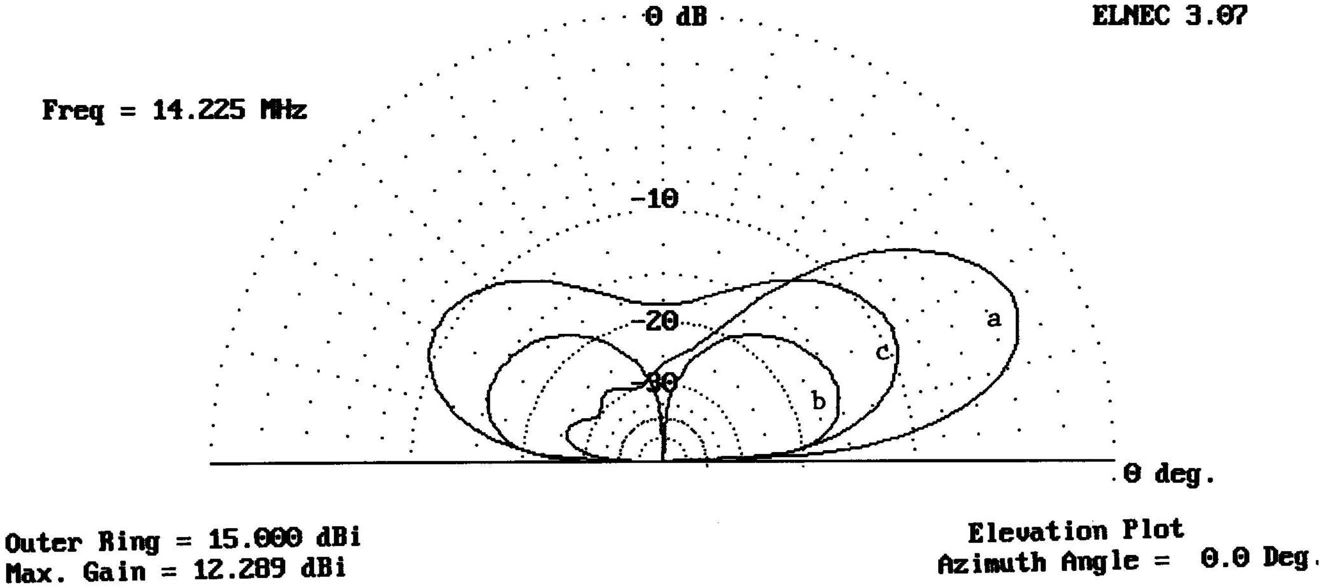

Figure 5. Comparison of elevation-plane radiation patterns for (a) 3-element yagi at H=0.5λ, (b) ground-mounted quarter-wave vertical, and (c) inverted-vee with apex at H=0.5λ.

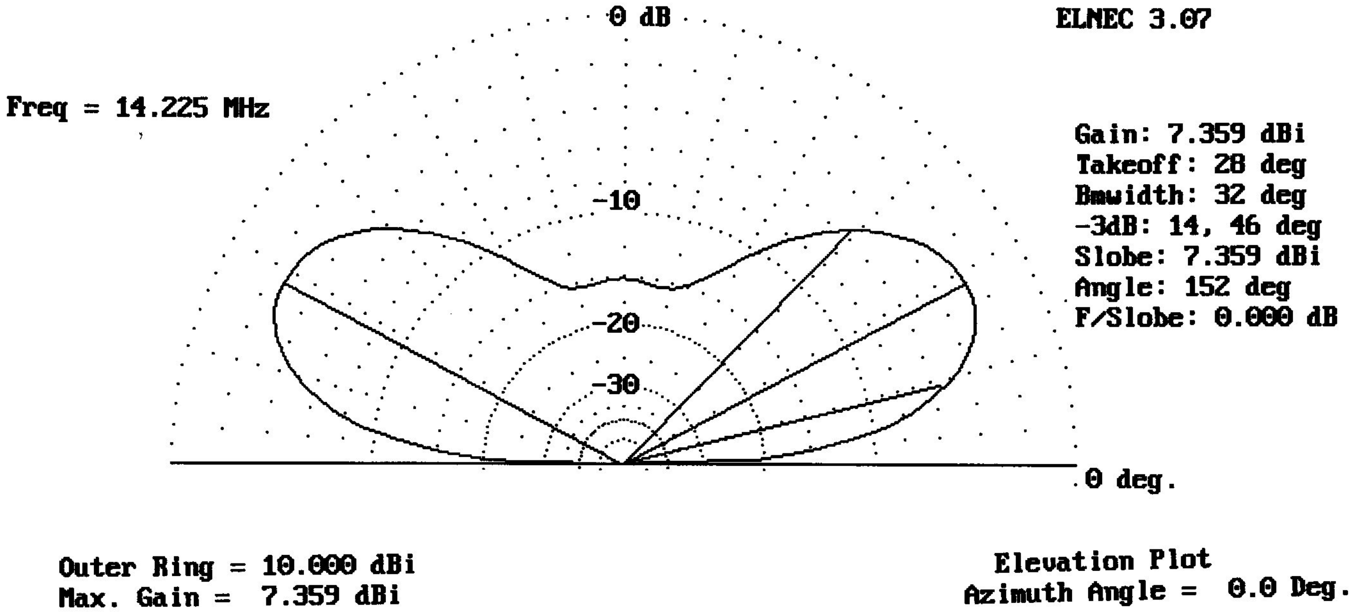

Figure 6. Elevation-plane radiation pattern for half-wave horizontal dipole at a height of 0.5λ.

than one antenna in order to provide maximum signal strength at ALL possible TOAs!)

A height of 0.5λ corresponds to approximately 34.7 feet on 20 meters, 69 feet on 40 meters, and 131 feet on 80 meters, assuming the center of the band in each case. It is not terribly difficult to put up a three-element 20-meter monobander at 35 feet, but the level of effort and expense required to erect a 3-element array on 40 or 80 becomes progressively higher as one moves downward in frequency. A full-size rotatable three-element 80-meter beam is truly huge, and the number of these beasts now in existence is extremely small. Since many hams use either a vertical monopole or a low (in terms of wavelength) inverted vee for operation on these two bands, it seems likely that the "next step up" from one of these "basic" antennas would be something much simpler than a full-size three-element yagi. Modeling with ELNEC indicates that a single half-wave horizontal dipole **also** seems to be a very good performer when mounted a half-wavelength above the ground (see figure 6). The HPBW in the elevation plane is 33°, and the antenna has more than 7.3 dBi of gain at a TOA of 28 degrees.

Several companies now manufacture reduced-size rotatable dipoles for the 40- and 80-meter amateur bands. Both the weight and the wind-loading of these antennas are relatively low, so they can be mounted on light-duty towers and turned by small rotators. Dipoles such as these, when placed at a height of one-half wavelength, may become viable choices for the operator who is seeking to upgrade the performance of his station on the "low" bands, but cannot go all the way to a multi-element beam. To illustrate this concept, figure 7 displays the elevation-plane radiation patterns for a ground-mounted quarter-wavelength vertical monopole, an inverted vee with its apex at a height of 0.25λ, and a horizontal dipole at a height of 0.5λ. When compared to the vertical, the "flat-top" dipole is better at all TOAs, in some cases by as much as an S-unit. The dipole is also superior to the inverted vee at all elevation angles below about 45°, although the reverse is true for TOAs above 45°. Again, we conclude that it might be nice to have **two** antennas from which to select: a "low" inverted vee for coverage of nearby stations and a "high" rotatable dipole (or yagi) for long-distance work.

Some of you are probably saying, "Wait a minute! A height of 0.5λ might be just fine for a three-element beam, but I've already got a big six-element monobander up at 100 feet. What about that?" OK, I'm glad you asked. Let's examine the elevation-plane radiation patterns for a W2PV-designed six-element array. The dimensions below are taken from his book [5]:

$$\begin{aligned} \text{reflector length} &= 0.49478\lambda \\ \text{driven element length} &= 0.48038\lambda \\ \text{all director lengths} &= 0.44766\lambda \end{aligned}$$

The boom length is 0.75λ, all element radii are 0.000526λ, and inter-element spacing is held constant at 0.15λ. In free space, ELNEC predicts a forward gain of 10.6 dBi and a front-to-back ratio of 35.5 dB for this antenna. Physically, the "PV6" yagi is more than twice as large as a "PV3," and provides an extra 2.3 dB of gain. Figures 8-11 display the elevation-plane radiation patterns for the PV6 when situated above ground at heights between 0.5 and 1.5 wavelength, in increments of 0.1λ. The range of heights used here is different than before, because a large array like this will usually be mounted on a substantial tower at an elevation well above that which would be contemplated by the typical purchaser of a three-element beam. (In the center of the 20-meter band, a height of 1.5λ is about 104 feet.)

How much better is the big antenna? When we compare a PV3 with a PV6 mounted at the **same height**, we find that the larger yagi has two distinct advantages. First, the PV6 has anywhere from 1.5 to 2.2 dB of additional gain; second, the peak value of forward gain for the PV6 occurs at a TOA which is 1 to 3 degrees lower than that for the PV3. The PV6 produces more gain at a lower TOA without increasing the height of the system, but its wind-load is much greater, so a more robust tower and rotator are required.

An analysis of figures 8-11 reveals that a PV6 at a height of 0.5λ has a very nice pattern. Nevertheless, it seems unlikely that anyone would place a six-element monobander only half a wavelength above the ground, because the mounting height would actually be less than the length of the boom.

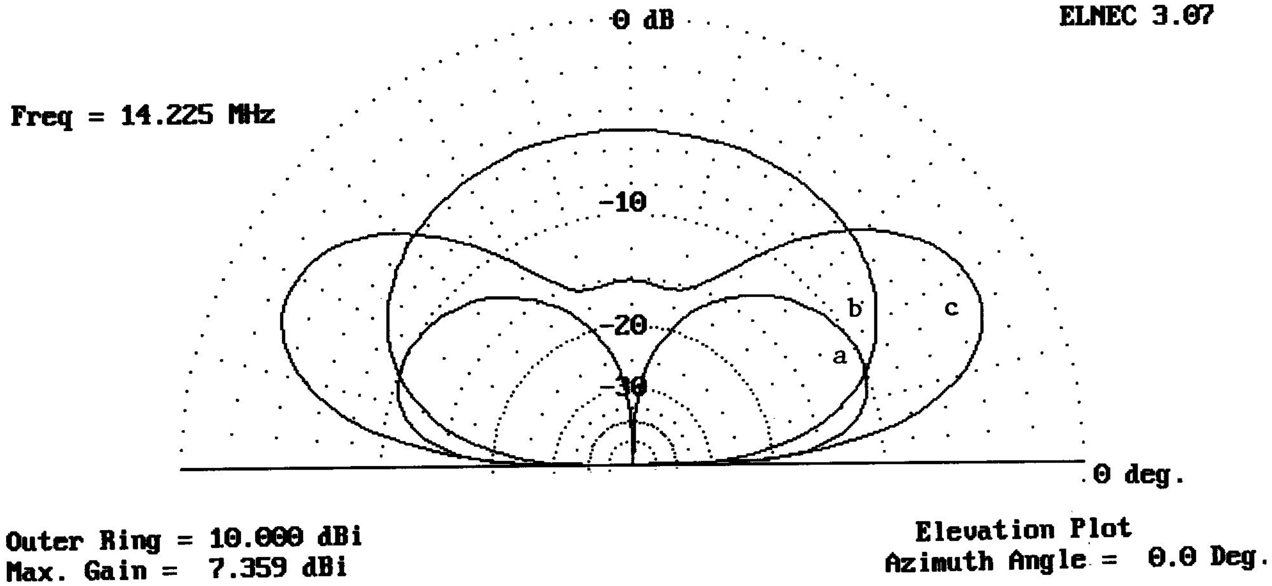

Figure 7. Comparison of elevation-plane radiation patterns for (a) ground-mounted quarter-wave vertical, (b) inverted-vee with apex at 0.25λ, and (c) horizontal dipole at H=0.5λ.

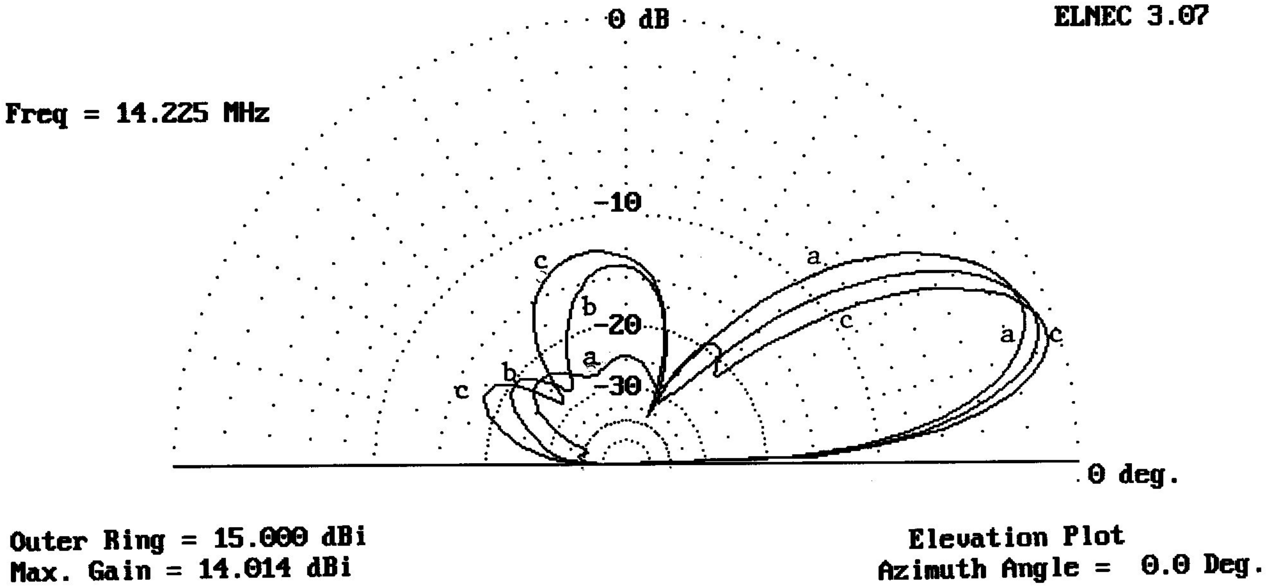

Figure 8. Elevation-plane radiation patterns for 6-element W2PV yagis at heights of (a) 0.5λ, (b) 0.6λ, and (c) 0.7λ.

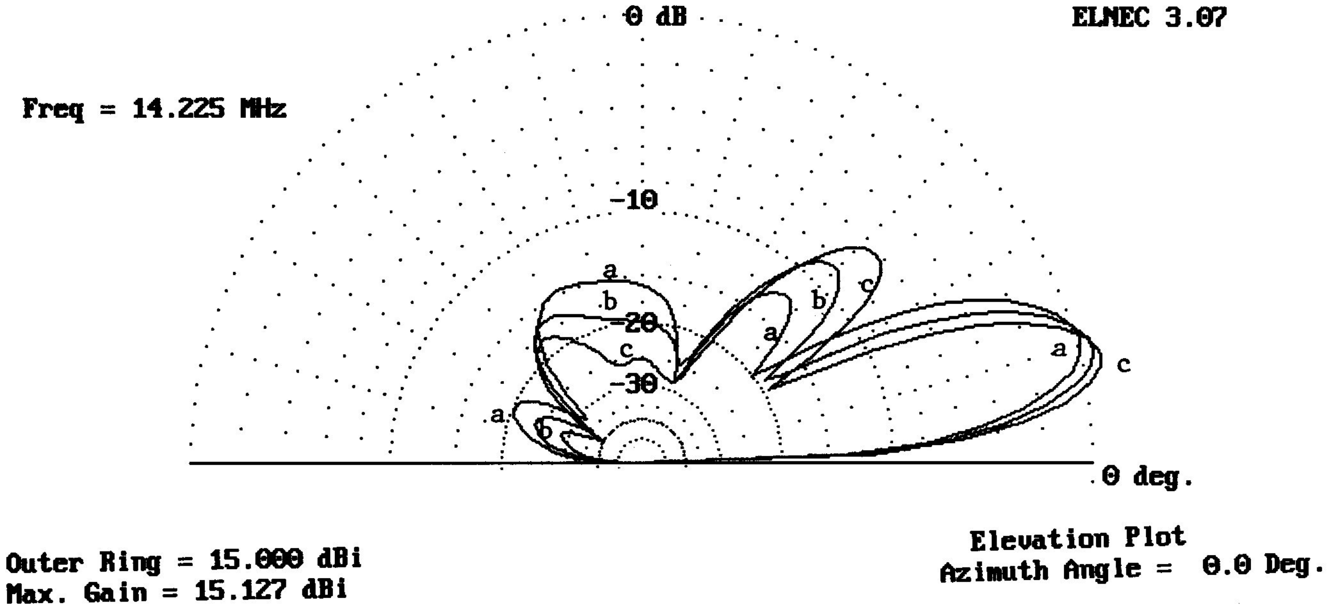

Figure 9. Elevation-plane radiation patterns for 6-element W2PV yagis at heights of (a) 0.8λ, (b) 0.9λ, and (c) 1.0λ.

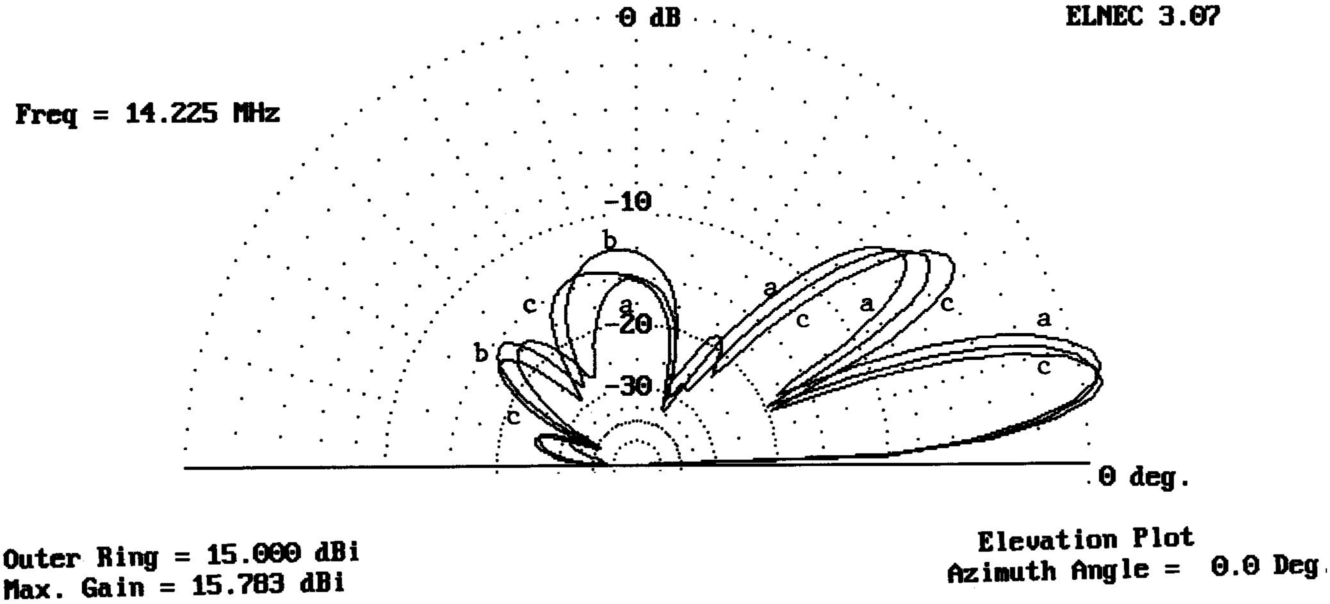

Figure 10. Elevation-plane radiation patterns for 6-element W2PV yagis at heights of (a) 1.1λ, (b) 1.2λ, and (c) 1.3λ.

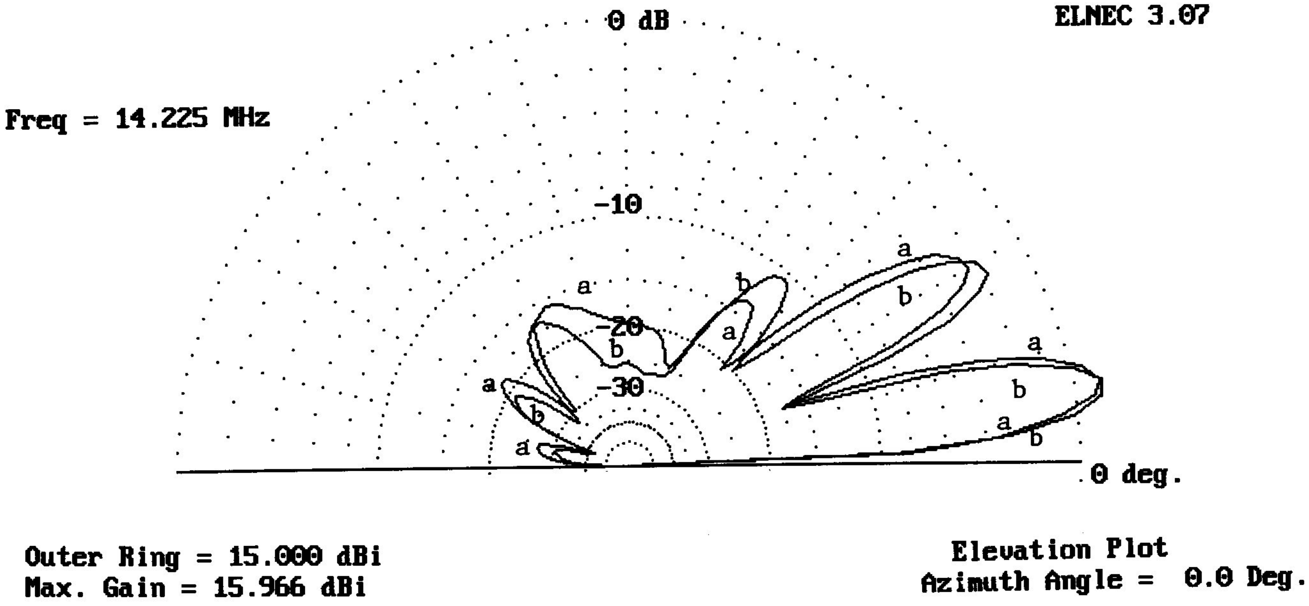

Figure 11. Elevation-plane radiation patterns for 6-element W2PV yagis at heights of (a) 1.4λ and (b) 1.5λ.

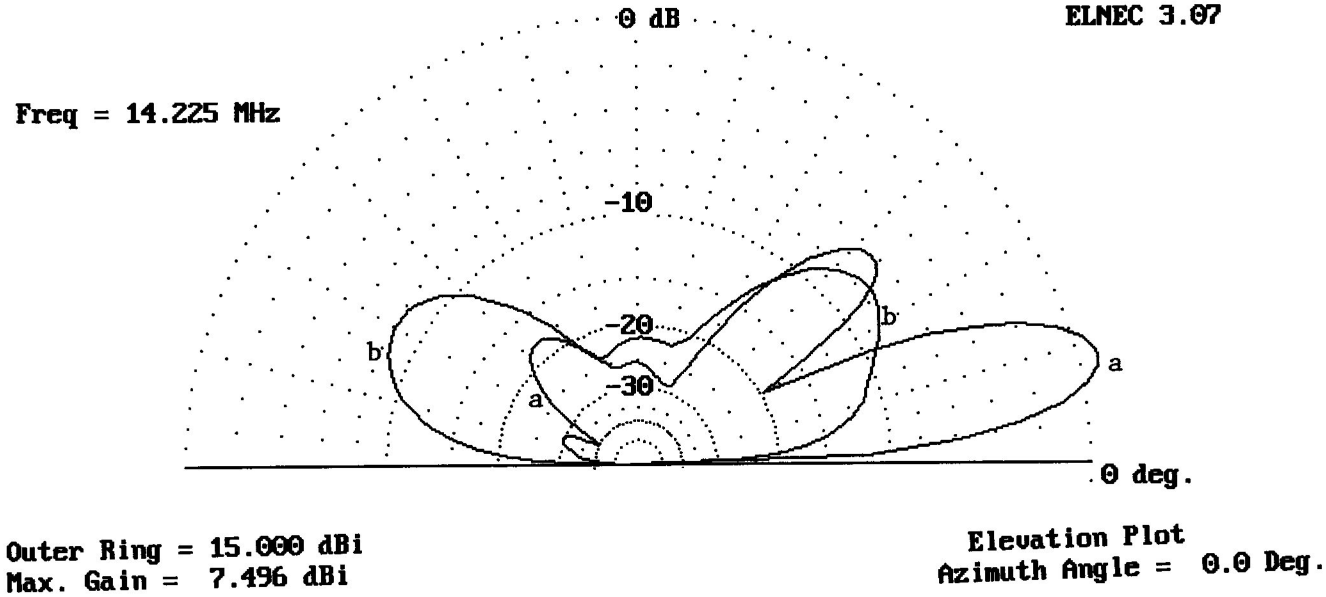

Figure 12. Elevation-plane radiation patterns for (a) 6-element W2PV yagi at H=1.0λ, when mounted on the same tower above (b) a horizontal dipole at H=0.5λ. In each case the unused antenna feed-point is open-circuited.

Instead, the owner would probably install such a yagi at an elevation of 1 to 1.5λ. However, an examination of the figures shows that there are pronounced minima or partial nulls (at certain TOAs) in the PV6 radiation patterns at these heights. Depending upon propagation conditions or operator needs, these particular elevation angles could be important.

One possible solution is to add a horizontal dipole located 0.5λ above the ground, and use this antenna to fill in the nulls mentioned above. Figure 12 shows what happens when a dipole is used in conjunction with a PV6 up at one wavelength, while figure 13 illustrates the same case when the PV6 is situated 1.5λ above the ground. It can be seen that the dipole adds as much as two S-units to the signal strength at those take-off angles where the big beam is deficient. (For those of you with a three-element array at a height of one wavelength above the ground, figure 14 indicates how a dipole at H = 0.5λ can be used to provide fill at TOAs around 30°.)

A horizontal dipole a half-wavelength above the ground has an **azimuthal** HPBW of about 86 degrees, so two fixed dipoles oriented at right angles to each other could provide switch-selectable coverage of all compass points. Alternatively, a single dipole could be mounted on a ring-rotor if perfect alignment with the high yagi was desired. When two antennas (such as a dipole and a beam) are tuned to the same band and placed on the same tower, there will usually be a certain amount of interaction, and the figures **do** show some distortion in the shape of the dipole's radiation pattern. However, modeling with ELNEC indicates that the mutual-impedance effects are actually rather small, no matter whether the unused antenna is open-circuited or short-circuited at its respective feed-point. (We mention here that even better performance may be obtained by using a small rotatable yagi, instead of just a simple dipole, as the "fill" antenna.)

V. STACKED ARRAYS

The previous discussion leads us directly to the topic of stacked arrays. If one-half wavelength is a desirable height for a horizontal dipole or a three-element yagi, what placement should be used when mounting **two or more** beams for the same band on a single tower? The author carried out several brief studies on stacked arrays using various spacings in order to determine if an "optimum" configuration could be found. Here, the number of possible combinations is **very large**, and the analysis which was conducted was certainly not exhaustive. However, once again it was found that half-wavelength spacing looks quite good. W2PV's book contains many other suggested values [6], but half-wavelength spacing seems to offer an excellent blend of performance features.

For a "two-stack" of three-element beams at heights of 0.5 and 1.0 wavelength, the six configurations which were examined included:

1. both antennas driven simultaneously (either in-phase or out-of-phase)
2. lower yagi driven alone (upper yagi either shorted or open-circuited at its feed-point)
3. upper yagi driven along (lower yagi either shorted or open-circuited at its feed-point).

Figure 15 illustrates that the best choices are

(a) both antennas fed (in phase)
(b) lower yagi fed alone, with upper beam shorted at its feed-point
(c) both antennas fed (out of phase).

These three combinations provide strong signals at all elevation angles up to about 55°. (A low inverted-vee could then be used to cover TOAs from 55° up to the zenith.)

As an example, a "single-tower seven-band HF system," based upon the analysis described above, might consist of 130 feet of Rohn 65 tower, guyed with Phillystran. The antennas could be a Mosley PRO-95 (on a ring-rotor) at 34.5 feet, a Mosley PRO-96 (on a ring-rotor) at 69 feet, and an M^2 80M3 (with a conventional rotator) at the top of the tower. With suitable switching and impedance-matching networks, this array provides "two-stack" performance (allowing the operator a choice of several take-off angles) on **all five** of the bands between 20 and 10 meters, although half-wavelength spacing between yagis is available only on 20. It also includes three-element beams for both 40 and 80 meters, with each one mounted at the favorable height of 0.5λ. A less-costly alternative would

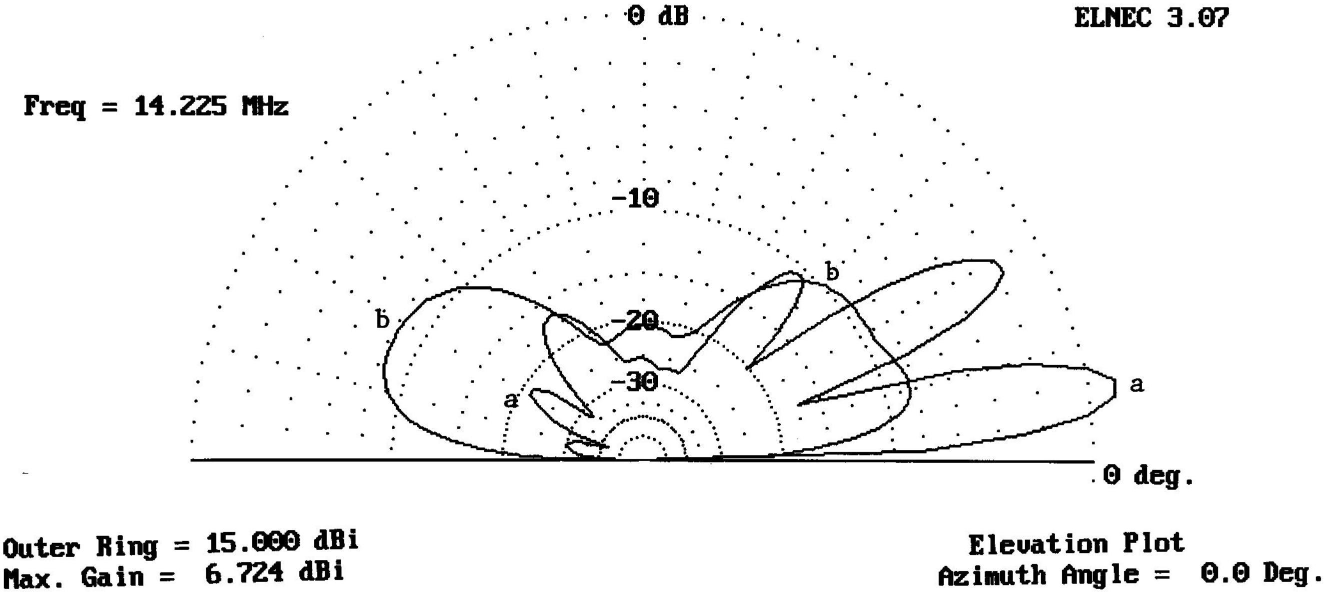

Figure 13. Elevation-plane radiation patterns for (a) 6-element W2PV yagi at H=1.5λ when mounted on the same tower above (b) a horizontal dipole at H=0.5λ. In each case the unused antenna feed-point is open-circuited.

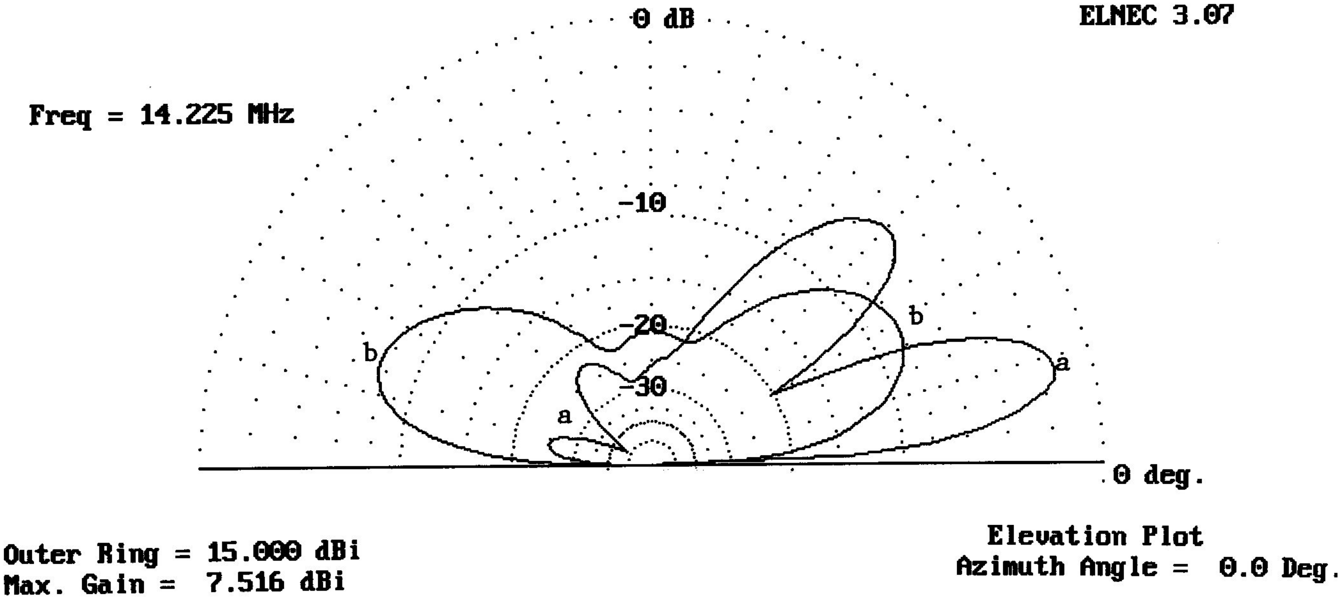

Figure 14. Elevation-plane radiation patterns for (a) 3-element W2PV yagi at H=1.0λ, when mounted on the same tower above (b) a horizontal dipole at H=0.5λ. In each case the unused antenna feed-point is open-circuited.

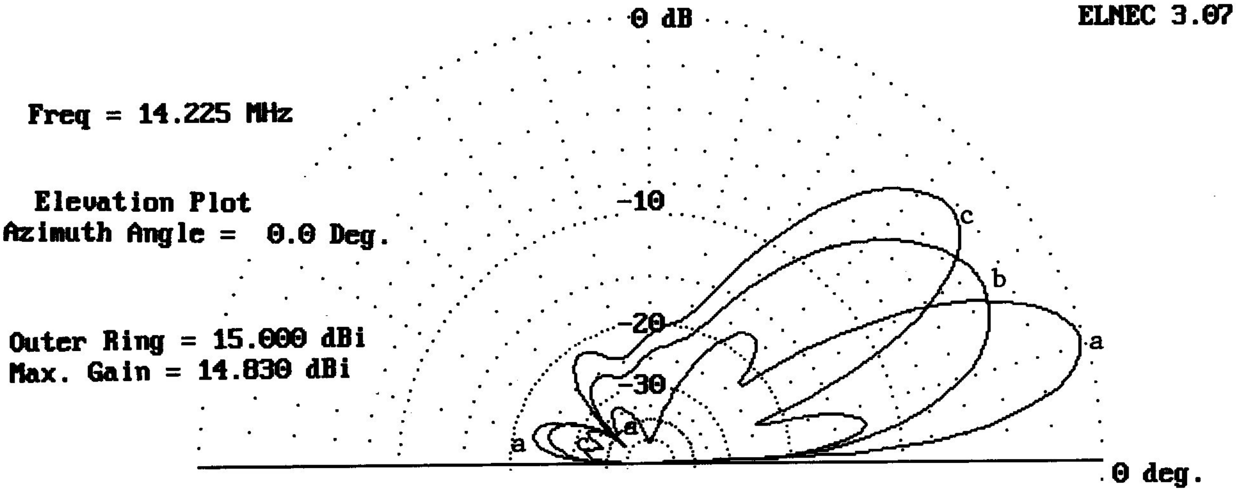

Figure 15. Using several feed combinations to obtain a variety of take-off angles with two 3-element yagis at H=0.5 and 1.0λ [lower antenna is #1, upper is #2]: (a) both fed in phase, $V_1 = V_2 = 1\angle 0°$, (b) lower fed, upper short-circuited, $V_1 = 1\angle 0°$ and $V_2 = 0$, and (c) both fed out-of-phase, $V_1 = 1\angle 0°$ and $V_2 = 1\angle 180°$.

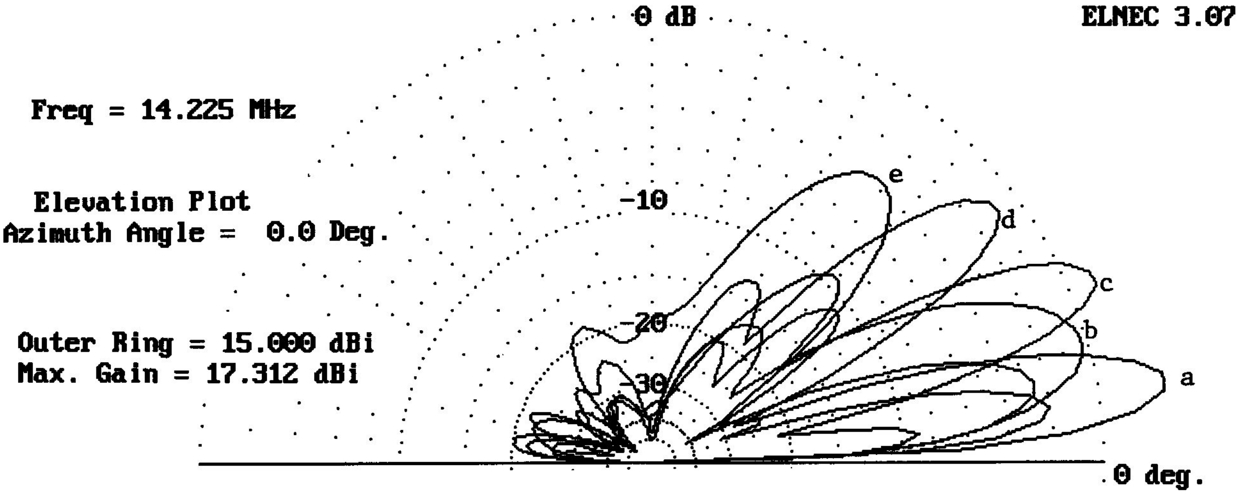

Figure 16. Using several feed combinations to obtain a variety of take-off angles with four 3-element yagis at H=0.5, 1.0, 1.5, and 2.0λ [lowest antenna is #1, highest is #4]: (a) all four fed in phase, $V_1 = V_2 = V_3 = V_4 = 1\angle 0°$, (b) lower pair fed in phase, upper pair open-circuited, $V_1 = V_2 = 1\angle 0°$ and $I_3 = I_4 = 0$, (c) lower pair fed together in phase, upper pair fed together out-of-phase, $V_1 = V_2 = 1\angle 0°$ and $V_3 = V_4 = 1\angle 180°$, (d) lowest and highest fed together in phase, middle pair short-circuited, $V_1 = V_4 = 1\angle 0°$ and $V_2 = V_3 = 0$, and (e) lowest and third fed together in phase, second and highest short-circuited, $V_1 = V_3 = 1\angle 0°$ and $V_2 = V_4 = 0$.

be to utilize 130 feet of Rohn 55 tower, replacing the PRO-95 with a PRO-57B, the PRO-96 with a PRO-67B, and the 80M3 with an 80M1 dipole. (This article is not intended to be an endorsement for any particular brand of tower or antenna. Towers are available from manufacturers such as Aluma, Glen Martin, Heights, Microflect, Rohn, Telex-Hygain, Tri-Ex, Trylon, Universal and US Tower. Rotatable single- and multiband beams can be purchased from companies like Antenna Mart, Create Design, Cubex, Cushcraft, Delta Loop, DX Engineering, Force 12, GEM-Quad, Ham-Pro, KLM-Mirage, Lightning Bolt, LTA, M^2, Mosley, RayCom, Summer, and Telex-Hygain.)

A quick study of "four-stack" arrays was also carried out, using 3-element W2PV yagis mounted at heights of 0.5, 1.0, 1.5, and 2.0 wavelengths above ground. A total of 15 different feed configurations were modeled, utilizing all four antennas driven (either all four together in phase, or upper pair out of phase with lower pair) as well as all possible combinations when feeding either one, two, or three of the four yagis, with the unused antenna(s) either open- or short-circuited at their feedpoint(s). Many of the results weren't especially useful, so they will not be presented.

Figure 16 illustrates the radiation patterns for a four-stack system which utilizes five different feed configurations to achieve excellent performance at all take-off angles below 60°. Four switch settings (a-b-c-d) can provide coverage of all elevation angles up to 45°, while TOAs below 30° can be attained with just three feed-point combinations (a-b-c). If desired, radiation pattern "b" may easily be omitted with only a slight loss in versatility. This would eliminate one setting from each of the arrangements described above, and thus simplify the switching requirements.

An example of a four-stack system might utilize 140 feet of guyed Rohn 65 tower; the beams could be Mosley PRO-95s at 34.5 and 103.5 feet, plus Mosley PRO-96s at 69 and 138 feet. This array includes "four-stack" performance on all bands from 20 to 10 meters (although half-wavelength spacing is available only on 20) **plus** a "two-stack" with half-wavelength spacing on 40 meters. Ring-rotors could be used to turn each yagi individually, or all four could be fixed to a rotating tower [7]. This antenna system does not cover 80 meters, so perhaps a two-stack of M^2 80M3s on 260 feet of Rohn 80 or 90 would appeal to those of you with **really big** aspirations! (A smaller "four-stack" could be constructed using Mosley PRO-57Bs and PRO-67Bs, respectively, instead of the PRO-95s and 96s.)

If desired, coverage of 40 meters can be deleted from the original "four-stack" above by replacing the two PRO-96s with PRO-95s. As a second option, the five bands between 20 and 10 meters may be covered by substituting Mosley PRO-57s (or log-periodic dipole arrays, or hybrids such as Telex/Hygain TH11DXs) for all four of the original beams. The resulting four-antenna system would then resemble the classic "TH-28" described several years ago by N5RM [8].

VI. CONCLUSION

It is the author's hope that this article has provided some food for thought to those hams who are contemplating their first beam (or their first stack?) and that it will stimulate further research into the fascinating realm of antennas.

VII. ACKNOWLEDGEMENT

The author wishes to express his appreciation to Jim Breakall, WA3FET, with whom he has had many long and interesting discussions regarding optimum antenna height and related topics.

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A NEW SIMULATED HUMAN BODY STANDARD FOR PAGER RECEIVER MEASUREMENTS

Lorenzo A. Ponce de Leon and Kazimierz Siwiak
Motorola Paging Products Group
1500 Gateway Blvd.
Boynton Beach, FL 33426 USA

Abstract - Simulated human body (SHB) devices are used in body mounted receiver testing to provide a stable, repeatable, and motion-free measurement environment. The performance of an IEC SHB and a new light-weight device (SHB-LW) is explored both analytically and experimentally. Good agreement between an analytic model and measured data using body mounted receivers is reported at VHF and UHF.

I. Introduction

The need to standardize measurements of body mounted pagers has led to the development of SHB devices. Devices such as the IEC [1] SHB-SALTY, depicted in Figure 1, are designed to operate as a substitute to a human body in the VHF and UHF range. A new lightweight device [2,3] (SHB-LW) is introduced which reduces the total weight of the SHB from 130 kg to 61.5 kg and is traceable to the existing SHB-SALTY standard. An analytic model is developed and validated by measurement in the VHF and UHF bands using a paging receiver as a magnetic field sensor.

II. Analysis

A model for a SHB at high frequencies is developed here via an analysis of an infinite stratified cylinder illuminated by an incident electromagnetic plane wave of arbitrary orientation [4]. A set of auxiliary potentials in cylindrical coordinates which satisfy Maxwell's equations, the Hertz potentials, are used. The electromagnetic field is decomposed into TM^z and TE^z type waves with respect to the axial direction. Both TM^z and TE^z solutions are used to match the boundary conditions between layers.

The vector equations for the electric and magnetic field equations, formulated in terms of the electric (Π_e) and magnetic (Π_m) Hertz vector potentials, are:

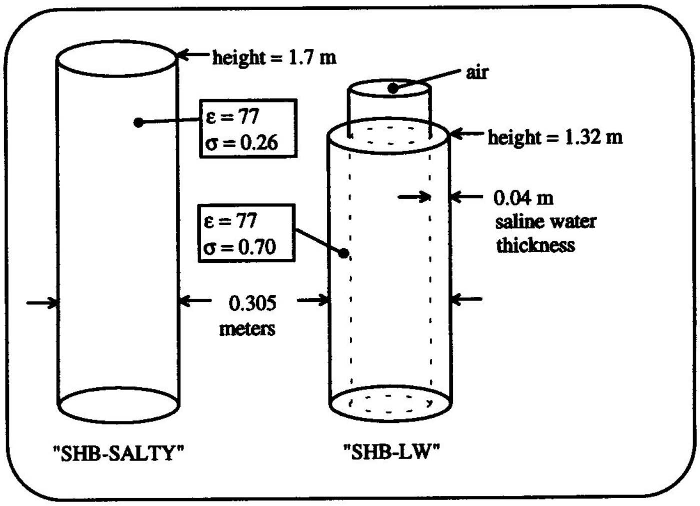

Figure 1. Simulated human body devices.
[from [5] © K. Siwiak]

$$\vec{E} = \nabla \times \nabla \times \vec{\Pi}_e - j\omega\mu \nabla \times \vec{\Pi}_m \qquad (1)$$

$$\vec{H} = \nabla \times \nabla \times \vec{\Pi}_m - j\omega\varepsilon \ \nabla \times \vec{\Pi}_e \qquad (2)$$

The coupled vector differential equations (1) and (2) are reduced by separation into a Helmholtz equation in cylindrical coordinates. The solution of the resulting equation is obtained via a set of scalar potentials for the TM^z and TE^z fields. In the present case π_e and π_m represent the electric and magnetic field Hertz scalar potentials, respectively :

$$\pi_{e,m}(\rho,\phi,z) = \sum_{n=-\infty}^{\infty} \{a_n J_n(k_\rho \rho) + b_n J_n(k_\rho \rho)\} \{c_n \cos(n\phi) + d_n \sin(n\phi)\} e^{jk_z z} \qquad (3)$$

Here k_ρ and k_z are the wave numbers.

A plane wave traveling in the minus z direction with arbitrary orientation is assumed. Arbitrary fields can be expressed as a superposition of TM^z and TE^z fields. For a TM^z field the expression for the incident electric field is given as:

$$\vec{E}^i = (\vec{u}_x \cos\theta_i + \vec{u}_z \sin\theta_i)\, E_o^i\, e^{jk_z z} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k_\rho \rho)\, e^{jn\phi} \tag{4}$$

whereas for a TE^z field the incident magnetic field expression is:

$$\vec{H}^i = (\vec{u}_x \cos\theta_i + \vec{u}_z \sin\theta_i)\, H_o^i e^{jk_z z} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k_\rho \rho) e^{jn\phi} \tag{5}$$

The total fields are formulated in terms of scalar potentials with unknown coefficients. The number of unknowns is reduced by selecting the Bessel functions which satisfy the form of the solution in each region. Incident waves are expressed in terms of Bessel functions of the first kind, scattered waves are expressed in terms of Hankel functions, and in the internal region of the cylinder, a general expression containing Bessel functions of the first and second kind is used. For example the, scalar potential π^s , used in representing the scattered field, is written in terms of Hankel and exponential functions.

$$\pi^s = \frac{1}{k_\rho^2} \sum_{n=-\infty}^{\infty} c_{on} H_n^{(2)}(k_\rho \rho) \sin(\theta_i)\, e^{j(k_z z + n\phi)} \tag{6}$$

Boundary conditions are satisfied by applying tangential field continuity between layers in stratified media (here designated as region "a" and region "b" by the subscript). They are:

$$H_{\phi,a}^{TE} + H_{\phi,a}^{TM} = H_{\phi,b}^{TE} + H_{\phi,b}^{TM} \tag{7}$$

$$H_{z,a}^{TE} + H_{z,a}^{TM} = H_{z,b}^{TE} + H_{z,b}^{TM} \tag{8}$$

$$E_{\phi,a}^{TE} + E_{\phi,a}^{TM} = E_{\phi,b}^{TE} + E_{\phi,b}^{TM} \tag{9}$$

$$E_{z,a}^{TE} + E_{z,a}^{TM} = E_{z,b}^{TE} + E_{z,b}^{TM} \tag{10}$$

The set of equations (7-10) is constructed from orthogonal infinite series (in this case cylindrical harmonic functions). For each index of the series, the solution to a N layered cylinder requires 4N equations with 4N unknowns.

Using a convention, the elements of the matrix are arranged in groups: TM^z fields due to TM^z potentials (TM^z), TM^z fields generated by TE^z potentials (TE^z->TM^z), TE^z fields due to TM^z potentials(TM^z->TE^z), and TE^z fields due to TE^z potentials (TE^z). The resulting matrix arranged with this convention and with the unknown coefficients (c_k,C_k), and the incident fields (E^i,H^i) is:

$$\begin{bmatrix} TM^z & TE^z -> TM^z \\ TM^z -> TE^z & TE^z \end{bmatrix} \begin{bmatrix} c_k \\ C_k \end{bmatrix} = \begin{bmatrix} E^i \\ H^i \end{bmatrix} \tag{11}$$

In the present investigation, the scattered azimuthal magnetic field (H_ϕ^s) is of particular interest. A significant reduction in computation effort is obtained by folding the series into single sided infinite summations. The field component H_ϕ^s expressed as a single sided infinite series for the TM^z case takes the form:

$$H_\phi^s = -\sin(\theta_i) e^{jk_z} \{ \frac{j\omega\varepsilon}{k_\rho} \sum_{n=0}^{\infty} \varepsilon_n c_{on} H_n^{(2)\prime} (k_\rho \rho) \cos(n\phi) + \frac{2k_z}{k_\rho^2 \rho} \sum_{n=1}^{\infty} n C_{on} H_n^{(2)}(k_\rho \rho) \cos(n\phi) \} \tag{12}$$

Here ε_n is Neumann's number, c_{on} and C_{on} are the unknown scattering coefficients associated with the electric and magnetic potentials. It is worth noting that the series associated with C_{on} in equation (12) arises from TM^z to TE^z field conversion. The mechanism for creating field conversion exist for all angles of incidence other than normal incidence. Finally, the total vector fields are obtained from scalar components.

$$\vec{E}^t = \vec{E}^i + \vec{E}^s = E_\rho^t \vec{u}_\rho + E_\phi^t \vec{u}_\phi + E_z^t \vec{u}_z \tag{13}$$

$$\vec{H}^t = \vec{H}^i + \vec{H}^s = H_\rho^t \vec{u}_\rho + H_\phi^t \vec{u}_\phi + H_z^t \vec{u}_z \tag{14}$$

III. Solution to a SHB

The solution to a two-layer SHB exited by a TM^z polarized plane wave is presented here. This model is applied to the study of SHB-SALTY. A four layer model used to represent SHB-LW is documented elsewhere [4]. Defining a new set of coefficients,

$$u_i = \frac{j\omega\mu_i}{k_{\rho_i}} \quad (15) \qquad e_i = \frac{j\omega\varepsilon_i}{k_{\rho_i}} \quad (16)$$

$$n_{ij} = \frac{nk_{z_i}}{k_{\rho_i}^2\rho_j} \quad (17) \qquad a_{on} = j^{-n}E_o^i \quad (18)$$

Here notation such as J'_{11} represents $J'_n(k_{\rho 1}\rho_1)$, the derivative taken with respect to the argument of the function, and the suffix indicating the wave number $k_{\rho 1}$ and radii ρ_1 in the argument of the function. Using this notation, the matrix of TM^z to TM^z elements is

$$\begin{bmatrix} e_1J'_{11} & -e_2J'_{21} & -e_2Y'_{21} & 0 \\ J_{11} & -J_{21} & -Y_{21} & 0 \\ 0 & e_2J'_{22} & e_2Y'_{22} & -e_oH'_{o2} \\ 0 & J_{22} & Y_{22} & -H_{o2} \end{bmatrix} \quad (19)$$

The matrix of TE^z to TE^z elements is

$$\begin{bmatrix} -n_{11}J_{11} & n_{21}J_{21} & n_{21}Y_{21} & 0 \\ 0 & 0 & 0 & 0 \\ 0 & -n_{22}J_{22} & -n_{22}Y_{22} & n_{o2}H_{o2} \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (20)$$

The matrix for TE^z to TE^z elements is

$$\begin{bmatrix} u_1J'_{11} & -u_2J'_{21} & -u_2Y'_{21} & 0 \\ J_{11} & -J_{21} & -Y_{21} & 0 \\ 0 & u_2J'_{22} & u_2Y'_{22} & -u_oH'_{o2} \\ 0 & J_{22} & Y_{22} & -H_{o2} \end{bmatrix} \quad (21)$$

The excitation vector for TM^z polarization is written as

$$\begin{bmatrix} E^i \\ H^i \end{bmatrix} = \begin{bmatrix} 0 & 0 & a_{on}e_oJ'_{o2} & a_{on}J_{o2} & 0 & 0 & -a_{on}n_{o2}J_{o2} & 0 \end{bmatrix}^T \quad (22)$$

Further details on the analysis and the convergence characteristics of the series are available [4]. In the next section a model for the dielectric properties of saline water solution used as fill for the SHB is presented, and computed and measured SHB field patterns are compared.

IV. Numerical and Measured Results

The complex relative permittivity of saline water is determined using a Debye equation for the complex dielectric constant $\varepsilon_r(\omega)$,

$$\varepsilon_r(\omega) = \varepsilon_{r\infty} + \frac{\varepsilon_{rs} - \varepsilon_{r\infty}}{1 - j\omega\tau} \quad (30)$$

where ε_{rs} and $\varepsilon_{r\infty}$ are static and high frequency relative permittivity respectively, and τ is the relaxation time constant. Accurate curve fit formulas have been developed [3,6] which account for the NaCl concentration, temperature, and frequency of saline water. The dielectric constants used in the analysis and in the actual SHB were that for saline water with a NaCl concentration of 1.5 g/L.

The measurements were performed on an open field antenna range, illustrated in Figure 2, operated by Motorola Paging Products Group located in Boynton Beach, Florida and also in an anechoic chamber operated by the Land Mobile Products Group located in Plantation, Florida. For the open field antenna site a range model was developed which incorporates surface wave effects and specular reflections from the ground [4,5,7].

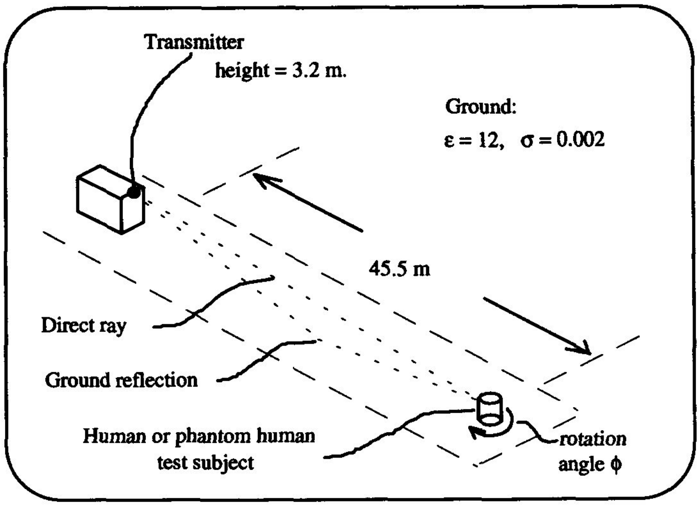

Figure 2. Receiver sensitivity test site.
[from [5] © K. Siwiak]

Paging receivers operating from VHF to UHF were used as measurement devices. The receivers incorporate an integral loop antenna which acts as a magnetic field sensor. Further details of the experimental methods and complementary set of data taken with both SHB and people is available [2].

In Figures 3-5 are plots of the pattern response, both measured data and computed, of the azimuthal magnetic field H_ϕ at a distance of 10 mm from the surface of the SHB. Measurements at three frequencies (168.725 MHz, 465.970 MHz, and 929.1125 MHz) are in agreement with the computed results. Some discrepancy was noted at nulls (180 deg. orientation) of the SHB pattern and are attributed to residual scattering in the antenna range not accounted for in the models.

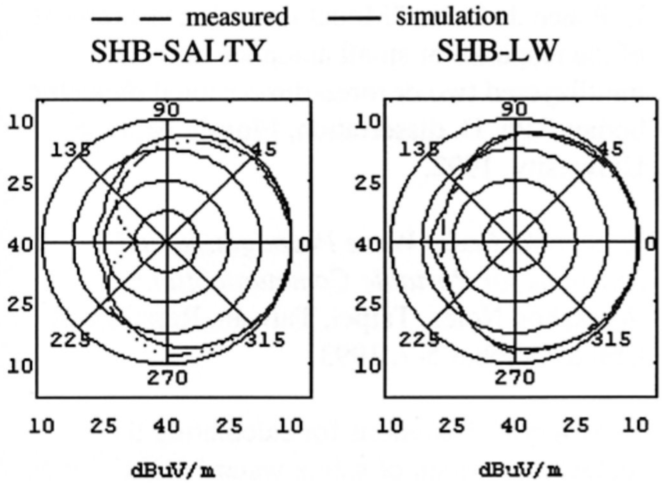

Figure 3. Azimuthal H-field pattern of SHB-SALTY and SHB-LW at f = 168.725 MHz.

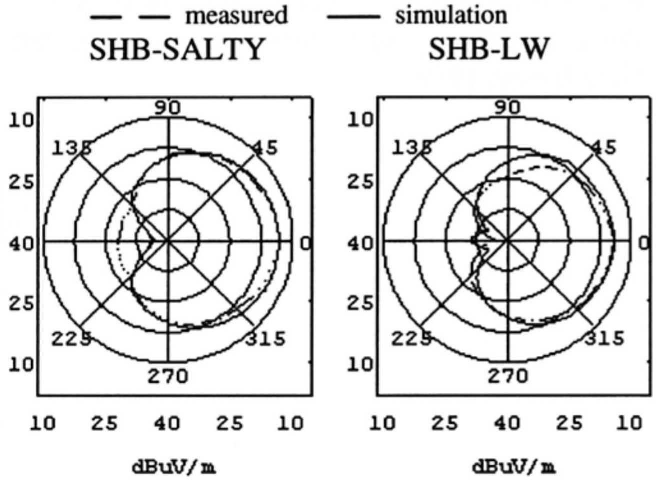

Figure 4. Azimuthal H-field pattern of SHB-SALTY and SHB-LW at f = 465.970 MHz.

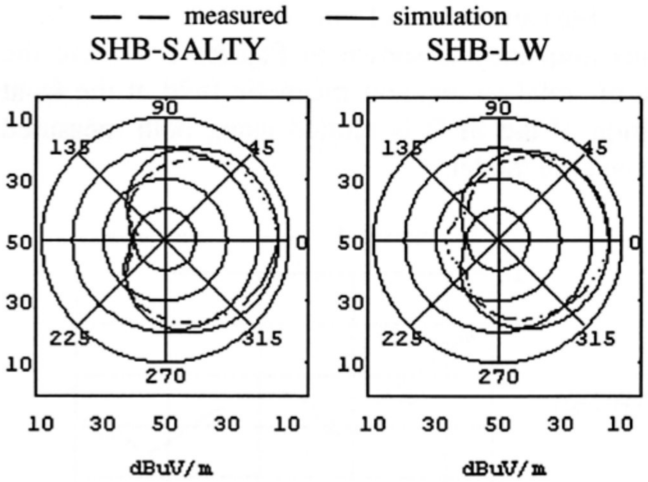

Figure 5. Azimuthal H-field pattern of SHB-SALTY and SHB-LW at f = 929.1125 MHz.

A key component in SHB design is attenuating the resonant modes of the cylinder structure. Use of distilled water without NaCl was investigated in SHB-LW. An anomaly in pager sensitivity was found near 168 MHz. Analysis reveals that a transverse resonance is supported by the structure at this frequency. Analysis versus frequency has also uncovered significant resonance's across the VHF to UHF band for both SHB's when the internal media is distilled water. Further study has revealed (measurement and analysis) that a salt concentration of at least 1.5 g/L is necessary to attenuate the resonance's of a SHB adequately. The recommended salt concentration for SHB-SALTY [1] is 1.5 g/L whereas for SHB-LW [3] the recommended concentration is 4.0 g/L.

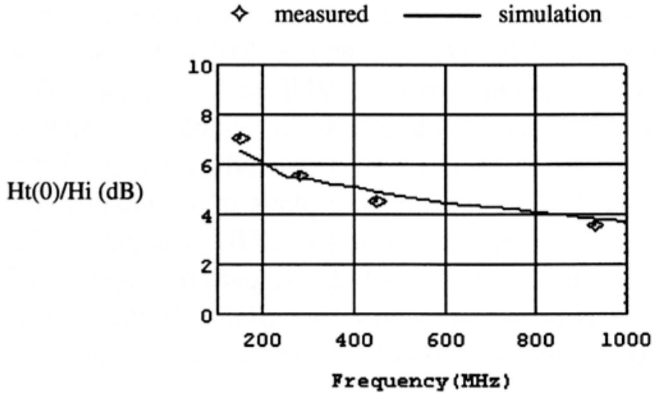

Figure 6. H-field enhancement: SHB-SALTY with saline water versus frequency.

Measurements of the response of the SHB versus frequency is shown in Figures 6-7. Here the ratio of total to incident magnetic field at the front position of the SHB is plotted using both measured data and the model.

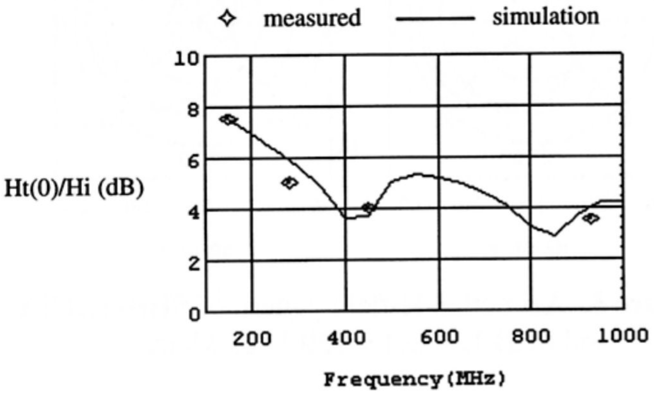

Figure 7. H-field enhancement: SHB-LW with saline water versus frequency.

A monatomic decline of the ratio of total to incident magnetic field versus frequency, an effect sometimes referred to as body enhancement, is observed in both SHB's. Other investigation have revealed that a resonant mode attributed to an axial resonance exists near 100 MHz. This phenomena imposes a limit to the use of the present model to frequencies above 150 MHz.

IV. Conclusions

A model to predict the fields scattered by a SHB illuminated by an oblique incidence plane wave was developed. The predicted and measured response of both a SHB-SALTY and a SHB-LW were in general agreement over the VHF to UHF band. The SHB-LW was validated as a viable alternative standard to SHB-SALTY. The study confirmed the role that NaCl concentration plays in attenuating the transverse resonance's found in SHB structures. The model is useful in predicting the pattern response of pager receivers tested on either SHB. Further work to model finite size effects of SHB are underway.

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Beamwaveguide Research at the Jet Propulsion Laboratory

Dr. William A. Imbriale
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109

1. Introduction to the Deep Space Network

JPL is responsible for the design and operation of the NASA Deep Space Network (DSN), which is the largest and most sensitive scientific telecommunications and radio navigation network in the world. Its principal responsibilities are to support unmanned interplanetary spacecraft missions and radio and radar astronomy observations. The network consists of three Deep Space Communications Complexes which are located on three continents: in the Southern California Mojave Desert, near Madrid, Spain, and near Canberra, Australia. Each of the three complexes consists of four operating stations equipped with ultra sensitive receiving systems and large paraboloidal reflector antennas. At each complex there are two 34-meter-diameter antennas, one 26-meter, and one 70-meter antenna. A centralized Signal Processing Center generates and transmits spacecraft commands and receives and processes the spacecraft telemetry.

The main features of the complex are the large antennas. Although diameters and mountings differ, all antennas employ a dual-reflector Cassegrainian feed system. The feed system is made up of a large horn, transmitter, and low-noise amplifier equipment, and is housed in a cone type structure mounted on the main reflector.

2. Motivation for Beamwaveguides

It was recognized that there are a number of advantages to feeding a large ground station antenna via a beamwaveguide (BWG) system rather than directly placing the feed at the focal point of a dual-reflector antenna. In a beamwaveguide system, the feedhorn and support equipment are placed in a stationary room below the antenna, and the energy is guided from the horn to the subreflector using a system of reflecting mirrors. Thus significant simplifications are possible in the design of high-power water-cooled transmitters and low-noise cryogenic amplifiers since these systems do not have to tilt as in a normally fed dual-reflector antenna. Furthermore, these systems and other components can be placed in a more accessible location enabling easier servicing and repair. In addition, the losses associated with rain on the feedhorn cover are eliminated because the feedhorn is sheltered from weather.

Consequently, the DSN undertook a comprehensive research program aimed at introducing BWG-fed antennas into the operational network. The research encompassed (1) new analytical techniques for predicting the performance of BWG, (2) a model test facility to experimentally verify the analytical tools, and (3) the design, construction, and test of a new 34-meter research and development antenna.

3. New Analytical Techniques

A BWG system consists of a number of conic section mirrors enclosed in a metal tube. There is a horn on the input, and the output irradiates the subreflector of the dual-reflector system. The commonly used analysis of this system ignores the presence of the metallic tube enclosing the beamwaveguide mirrors and uses either Physical Optics, Geometrical Theory of Diffraction, or Gaussian mode analysis of the diffracted field calculations. However, the basic weakness of these analyses is that they do not shed any light on the effect of the metal tube. Therefore a new and fundamentally more correct BWG analysis that considers the presence of the metal tube was developed. The basic concept is to use a Green's function appropriate to the circular waveguide geometry to compute the scattered field. With the new analysis, an accurate assessment of the effects of the tube, including noise temperature increase due to conduction losses in the tube, can be factored into the design.

4. New BWG Test Facility

In support of analytical and test activities, a flexible test facility was constructed to study BWG performance parameters. The objectives of the test facility were to (1) measure and characterize multiple mirror systems used in BWG antennas, (2) verify computer software and software models, (3) characterize BWG components not easily modeled by software, and (4) predict performance of BWG antenna designs.

The BWG test structure was installed in a microwave anechoic chamber 6-meters wide by 6-meters high and 18-meters long. The test facility setup consists of (1) a structure to hold the BWG elements under test, (2) a test probe mounted independent of the BWG structure support to provide the radiating patterning sampling device, and (3) an instrument control and its acquisition software. The test probe assembly consists of an open-ended circular waveguide feedhorn mounted at the end of a long radial arm that is rotated in a spherical arc by a 20-cm optical grade rotating table. The horn/arm/rotating table element is itself mounted in an azimuthal positioner. This design allows complete tangential field sampling over a hemispheric surface at a given radius from the center of the radial arm rotation point, thus producing a spherical near-field range measurement setup. A picture of the test facility is shown in Figure 1.

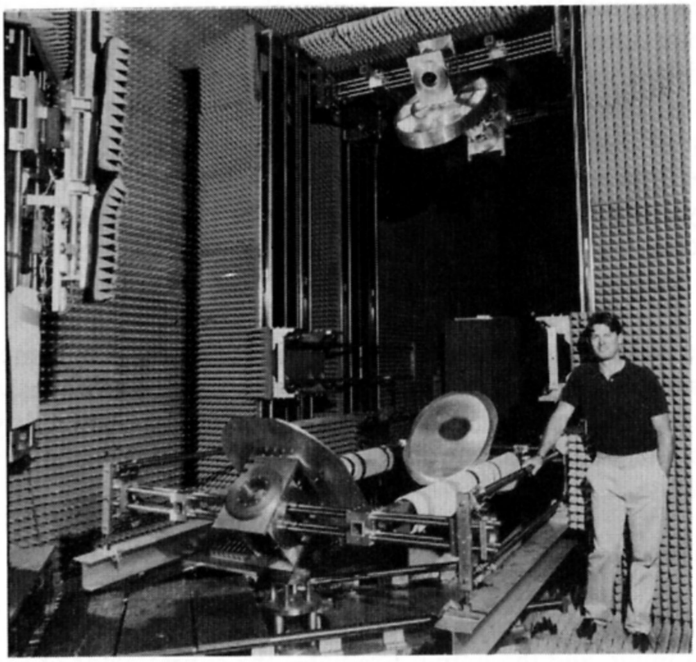

Figure 1. The JPL BWG Test Facility with a Two-Mirror Configuration

One-quarter size mirrors (of those used in the full-scale 34-meter BWG antenna) were machined from solid aluminum blocks and used in one-, two-, and three-mirror test configurations. The excellent correlation that was achieved between measured and predicted results enabled the full-scale 34-meter antenna system implementation to proceed with confidence.

5. New Research and Development Antenna

JPL maintains an experimental R&D station for testing new equipment prior to its installation into the operational network. To provide an upgraded antenna capable of Ka-band frequencies as well as to verify BWG technology before installation into the operational network, a new 34-meter BWG-fed antenna was built and tested.

The design of the new 34-meter BWG antenna (Figure 2) is based upon a Geometrical Optics criteria which optimizes high-frequency performance. Since it may also be desirable to retrofit

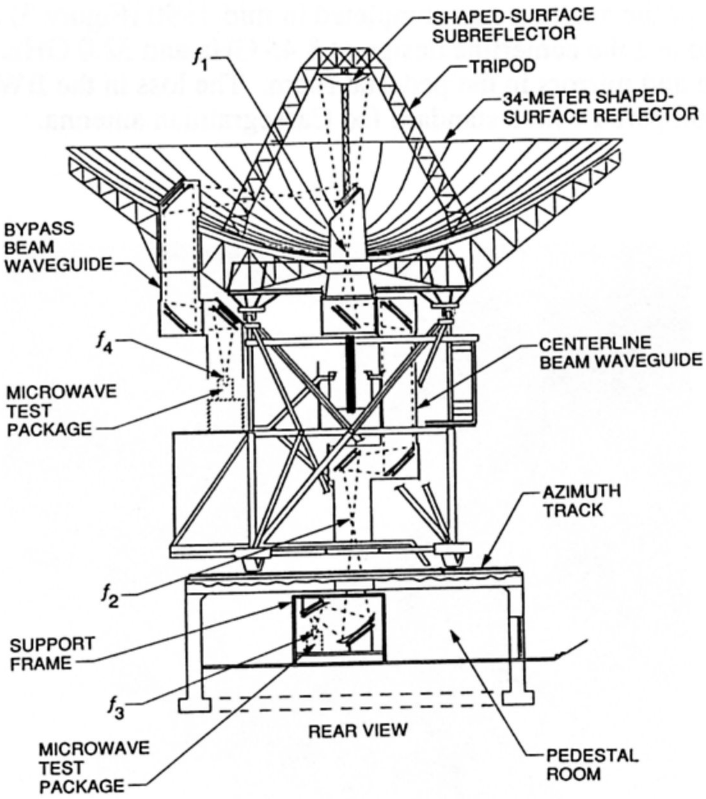

Figure 2. Layout of the Centerline and Bypass BWG Systems

existing antennas with a BWG in addition to constructing new antennas, there are two independent BWG designs built into the research and development antenna. The first, termed a bypass design, places the BWG outside one of the elevation bearings on the rotating azimuth platform, thereby retaining the existing elevation wheel and counterweight subassembly, which is suitable for retrofit applications. The second, a center design, places the BWG through the center of the main reflector, inside the elevation bearings and through the azimuth axis into a pedestal room located below the antenna. The centerline design is preferred for new construction. The bypass design uses two parabolic and two flat mirrors, whereas the center design uses the same four-mirror concept above the azimuth bearing with a flat plate and an ellipsoidal mirror that functions as a beam magnifier in the pedestal room. A beam magnifier is required since the pair of paraboloids requires a 29-dBi gain horn as input, whereas at the lower frequencies a 29-dBi gain horn would be too large to fit in the pedestal room. The ellipsoid design allows the use of smaller 22-dBi gain horns in the pedestal room. Observe that in the centerline design the feed doesn't move for any scan angle, while in the bypass design the feed rotates on the azimuth platform. The Japanese Usuda 64-m diameter antenna is an example of a BWG system where the feeds are mounted on the azimuth platform and thus only move in azimuth and do not tilt with the elevation motion.

The construction of the antenna was completed in mid-1990 (Figure 3) and the initial phase of the program was to test the centerline design at 8.45 GHz and 32.0 GHz. Figure 4 shows the 8.45-GHz test fixture and mirrors in the pedestal room. The loss in the BWG system measured less than 0.2 dB as compared with a standard fed Cassegrainian antenna.

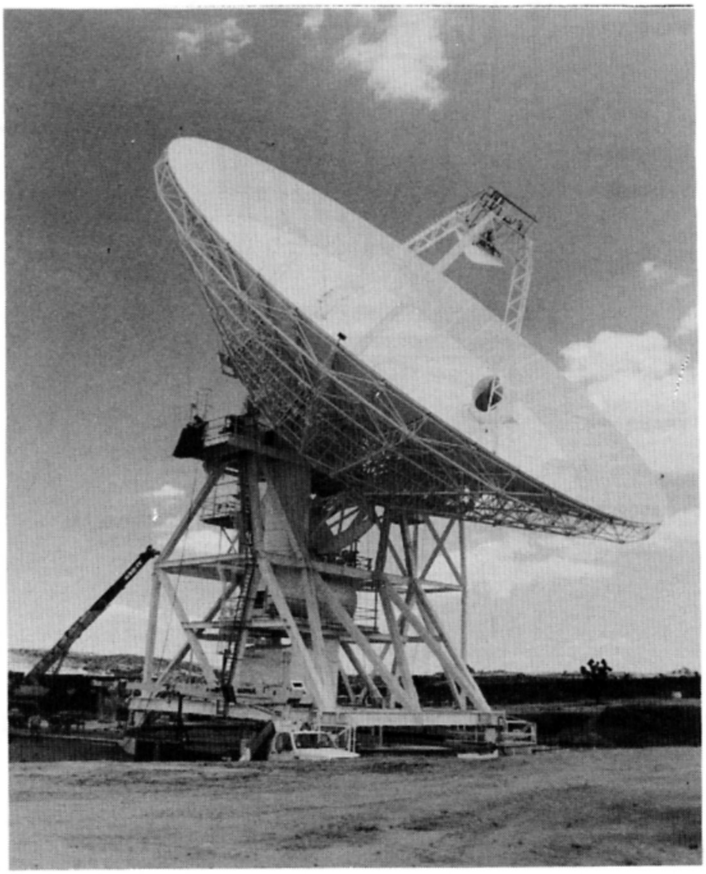

Figure 3. The New 34-m Research and Development Antenna

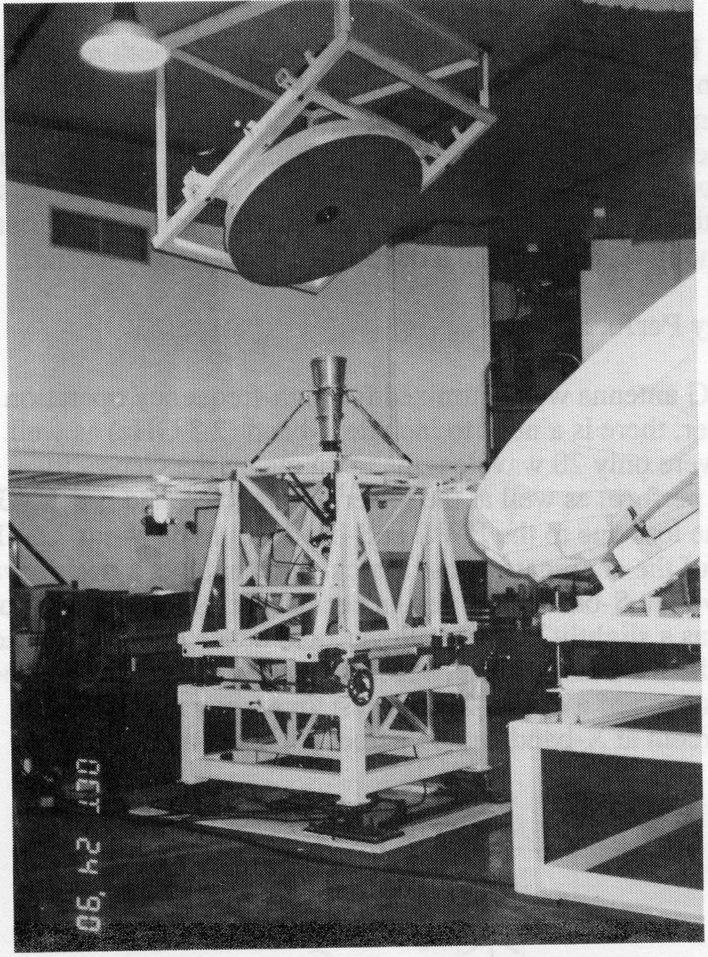
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Figure 4. Microwave Test Package in the Pedestal Room

6. Multifrequency Operation

Most planetary spacecraft utilize multiple frequencies for both radio science and reliability reasons. Simultaneous dual frequency is provided in the ground system through the use of a dichroic plate. A picture of the X/Ka-band system is shown in Figure 5. It uses an additional

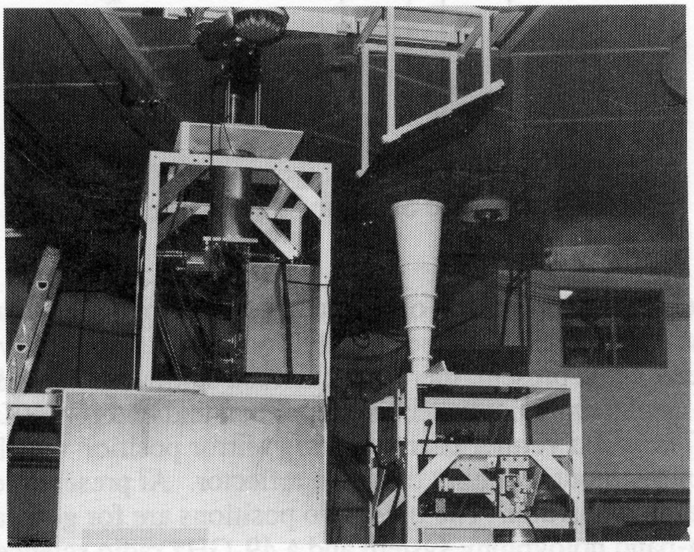

Figure 5. The X/Ka-band Feed System

elliptical mirror at Ka-band to provide sufficient room to fit both receive systems by putting the Ka-band focal point further from the main elliptical mirror than the X-band focal point. A 20-kW X-band transmitter at 7.7 GHz was also included as part of the X/Ka-band system. Tests were successfully conducted with X-band transmitting while simultaneously receiving X- and Ka-bands. There were no noise bursts or intermodulation product signals detected. Tests were also conducted with the Mars Observer spacecraft to demonstrate the first ever Ka-band (33.67-GHz) telemetry reception with a deep space planetary spacecraft.

7. Low Frequency Performance

The R&D BWG antenna was optimized for high-frequency operation (primarily X- and Ka-band). However, there is a need to include S-band (2.3 GHz) as well. It was recognized that since the mirrors were only 20 wavelengths in diameter, the Geometrical Optics design would not be expected to perform as well at the lower frequencies, and if a 22-GHz horn were placed at the BWG focus, the loss due to the BWG at S-band would be about 1.5 dB. However, due to a clever application of the conjugate-phase matching technique, a design was discovered that works extremely well at S-band. The design consists of using a 19-dB horn at the input to the BWG system. It has a slightly higher spillover (and hence a few kelvin additional noise temperature) past the basement ellipse, but significantly better spillover performance at the upper BWG mirrors. A sketch of a dual S-X feed system is shown in Figure 6. The measured efficiency is 70 percent at X-band and 63 percent at S-band.

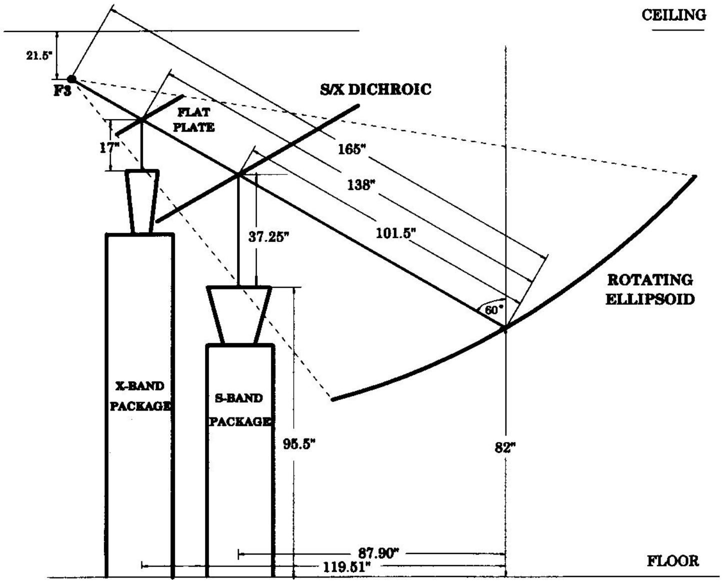

Figure 6. The S/X-band Feed System

The basement ellipsoid was placed on a rotating platform to allow easy switching between a number of feed stations assembled in the pedestal room. This versatility of the BWG antenna can be seen in Figure 7. At present, there are five feed stations in the R&D BWG antenna. One is utilized for S/X-band simultaneous receive operation and one for X/Ka-band receive and X-band transmit. There is a vernier beam-steering mirror position which enables conscan operation at Ka-band without scanning the main reflector. At present there is a seven-element array feed system at this position. The other two positions are for general R&D use and at present house a Ku-band holography system and a 49-GHz radio science receiver system.

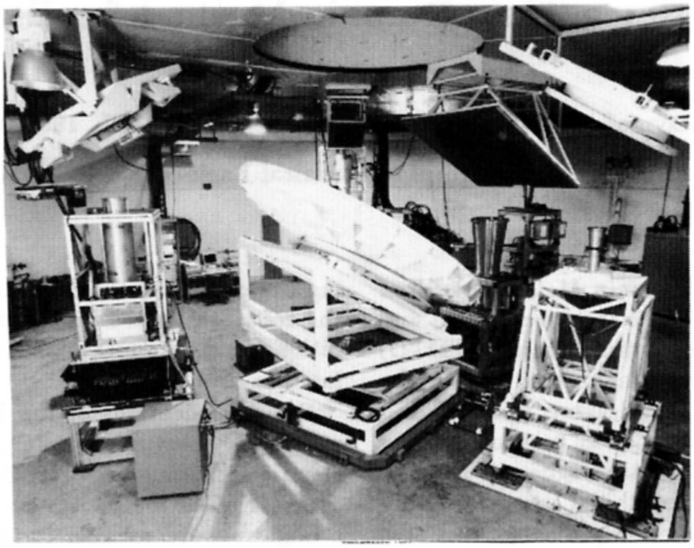

Figure 7. The Pedestal Room Feed Systems

9. New 34-m Antennas for the Operational Network

Based upon the success of the BWG research, the DSN is building four new 34-m antennas (three at the Southern California Goldstone site and one in Australia). These antennas will provide a simultaneous 2.295-GHz and 8.45-GHz receive system with a 20-kW, 2.115-GHz transmitting system. The new antennas will incorporate a centerline design.

The three new antennas at the Goldstone site will form part of a four element 34-m antenna array that will serve as a backup for the aging but extremely critical 70-m antenna.

The Finite Difference Time Domain Method for Electromagnetics

by

Karl S. Kunz and Raymond J. Luebbers, CRC Press, Boca Raton, FL, 1993, 448 pages, $79.95

Reviewed by: James L. Drewniak, Department of Electrical Engineering, University of Missouri–Rolla

The *Finite Difference Time Domain Method* is written by two of the leading contributors to the development and application of the finite-difference time-domain (FDTD) method for computational electromagnetics. With the advent of powerful and affordable desktop workstations, this computationally intensive numerical method is being widely applied in many areas of electromagnetics. Because of the great attention received by this method for application to electromagnetic interaction problems, this area is in a state of rapid development and application. The author's acknowledge in the preface that any text in this area is likely to be to some extent outdated as soon as it is published. However, while the FDTD method is theoretically quite straightforward, there are many details to successful application of this technique to any electromagnetic problem. Previously, these details were scattered throughout the literature. The authors have collected the central themes of these works, much of which is their own, and elaborate on some of the more subtle implementation details, recognizing that this is a rapidly advancing area.

The authors stated goals are broad and ambitious, striving to provide a presentation of the FDTD method which will fit the needs of undergraduate and graduate level courses, as well as those of an applications engineer attempting to assimilate and apply the method. The book is well organized to meet these goals. Specifically, the approach taken in the organization of the material is applications oriented, and is divided into five parts: 1) Fundamental Concepts, 2) Basic Applications, 3) Special Capabilities, 4) Advanced Applications, and 5) Mathematical Basis. Each section is divided into fairly short and concise chapters that treat a particular application or fundamental detail of the FDTD method.

The first section, Fundamental Concepts, devotes two chapters to the mechanics of the FDTD method. The authors employ primarily a scattered field formulation throughout the book. For many applications a total field formulation is desired; however, this can be obtained in a straightforward manner from the treatment presented. Chapter 2 discusses the development of the FDTD equations from Maxwell's equations. Practical details of the implementation of the method in FORTRAN are also discussed for perfect conductors and lossy dielectrics. Other practical considerations for actually implementing the FDTD method are presented in Chapter 3 including cell size, time-step size, source excitations, filling the computational domain with Yee cells, truncating the computational domain with absorbing boundary conditions, and computational resource requirements are related to problem size.

Basic applications of the FDTD method to shielding, waveguide aperture coupling, and dielectric and lossy dielectric scattering are presented in Part 2. The mechanics of the FDTD method given in Part 1 are applied in a straightforward manner to these problems. The application of the FDTD method to coupling effects of external fields to penetrable enclosures is discussed in Chapter 4. One of the author's early works in FDTD relating to the response of aircraft to EMP is described. Applying the FDTD method for investigation of coupling from an external field to the interior of an enclosure with an aperture is presented for apertures on the order of resonant dimensions, and for apertures smaller than resonant dimensions. Details of the modeling and computational intensity of these types of problems are given, as well as results that are not intuitive, which illustrate the power of numerical methods for providing insight and guiding design approaches.

Application of the FDTD method to more specific problems is discussed in Part 3 including obtaining the far-fields, FDTD for frequency-dependent materials, modeling impedance sheets, thin wires, voltage sources, lumped elements, nonlinear loads and materials, and visualization aspects. A method for obtaining the far electric and magnetic fields is developed in Chapter 7. The tangential electric and magnetic fields on a closed surface just inside the computational domain boundaries are related to the exterior fields, and a time-domain far field extrapolation is developed from which the time-harmonic fields can be obtained by FFT.

An FDTD algorithm for linear, dispersive materials is presented in Chapter 8. The algorithm is convolution based (relating the electric flux density to the electric field). The modified FDTD update equations are developed for first order Debye materials. A recursive evaluation of the resulting convolution integral is developed that renders the algorithm computationally efficient and can be realistically applied in three-dimensional problems with currently available workstations. Also given are algorithms for first order Drude dispersion, as well as more general second order dispersive materials. These algorithms are a straightforward extension of the first order development. Recursive evaluations of the convolution integrals are given for second order materials as well. Finally, a differential equation based modification of the FDTD equations are given. The convolution based, and differential equation based approaches are compared and contrasted. While the differential equation based approach is more direct, more storage is required in general, which may be a detriment in some cases, in particular in larger three-dimensional problems.

An FDTD implementation of surface impedance boundary conditions for good conductors is given in Chapter 9. In these cases, a small mesh dimension would be required in the good conductor, and an inordinately large number of cells could result without some modification to the basic FDTD algorithm. Since in many cases only the fields external to the conductor are desired, a frequency domain surface impedance boundary condition can be employed to modify the FDTD equation for tangential magnetic field components adjacent (one-half cell) to the boundary. The procedure is applied to one and two dimensional problems.

Chapter 10 discusses special algorithms for incorporating thin wires and lumped elements into the FDTD method. When the scatterers or elements to be modeled are small relative to the wavelength, an inordinately small cell dimension would be required to model the geometry. This in turn decreases the maximum time step dictated by the Courant limit, and the solution time can grow prohibitively large. In a number of cases, modifications based on a known or approximated field behavior can be introduced into the FDTD equations for those cells through which the small geometries pass. A larger mesh dimension can then be maintained while still being able to model (sometimes only approximately) the desired small elements. Subcellular algorithms have been developed for thin wires, lumped loads, and impedance sheets. In preparation for developing the thin wire FDTD equations, the basic FDTD equations and distribution of the field components over the unit cell are related to the integral form of Maxwell's equations. This relationship can provide significant insight into the basic algorithm for newcomers to the FDTD method, and is useful to read with introductory material in Part 1.

Incorporation of simple nonlinear lumped loads and nonlinear materials into the FDTD method is discussed in Chapter 11. Modifications of the FDTD equations modeling a diode are presented. The voltage-current relation for a diode is combined with the finite-differenced form of Ampere's law to yield a nonlinear system of equations that must be solved at each timestep for any unit cells that incorporate a diode. Details for modeling a nonlinear magnetic sheet are also given and the results compared with previous studies. Since the magnetic material is nonlinear and has a large conductivity, the timestep to ensure stability of the algorithm is significantly affected. A helpful discussion as well as tabulated values of conductivity, mesh dimensions, and time increment are given for a linear medium to ensure stability.

Three chapters of more advanced applications of the FDTD method to scattering, antennas and gyrotropic media are given in Part 4. The material presented on scattering and antennas applies previously developed methods, while special techniques for handling gyrotropic media are given in the final chapter of the section. Calculations of the radar cross section employing FDTD for impedance sheets and for a frequency dependent material are discussed in Chapter 13. Since the FDTD method is most typically applied using a rectangular mesh, the effects of approximating geometries that do not conform to rectangular boundaries, i.e. "stair-casing" errors, are also discussed and demonstrated through RCS calculations for conducting plates and dielectric spheres. Examples are also given and discussed regarding the distance of the absorbing boundaries from the scatterer geometry via RCS calculations.

The FDTD method applied to antenna problems is presented in Chapter 14. Antenna input impedance, efficiency, power gain, and mutual impedance are calculated from FDTD results for a two antenna array of dipoles, one of which is driven and the other a director. The accuracy of the FDTD method for these types of calculations is demonstrated by comparison with moment method results. Input impedance, radiation patterns and antenna gain are also computed for a monopole on a conducting box and each compared with experimental results. The good agreement demonstrates the power of the FDTD method for modeling complex geometries, and the potential for accurately computing input impedance, which is typically difficult and sensitive to feed-point modeling.

An FDTD formulation for application to gyrotropic media is presented in Chapter 15. Both a magnetized plasma in which the dispersion and anisotropies affect the update computations for the electric field, as well as a magnetized plasma in which the dispersion and anisotropies affect the magnetic field updates are considered. The recursive algorithms developed in Chapter 8 are applied for evaluating convolution integrals efficiently. The resulting algorithm is applied to normally incident plane wave scattering at the interface of free space and the gyrotropic medium.

Part 5, Mathematical Basis of FDTD and Alternate Methods, gives a brief presentation of the topics of finite-differencing schemes, stability, dispersion, and absorbing boundary conditions. The book is primarily applications oriented, and these developments are brief, but sufficient to give the reader an appreciation of the topics. A three-dimensional FDTD Fortran code is given in the appendix that is capable of handling perfect conductors and lossy dielectric materials. The code is liberally commented and easy to follow.

Overall I believe that this book is a very nice contribution to the electromagnetics community. For an individual attempting to assimilate and apply the FDTD method to a specific problem, the book provides a good treatment of the method, and does a particularly good job of relating FDTD implementation to the applicable physics. The progression of topics throughout the book, from FDTD basics to application for modeling more complex media, structures, and loads is also very well suited for learning and assimilating the FDTD method quickly. Finally, the authors provide insight and a means for approximating the computational resources required for a given size of problem, which is very helpful for three-dimensional problems given the computational intensity of the FDTD method. My criticisms of the book are based primarily upon personal preference, and in general are minor. First, I found the references not entirely complete at points. Important or helpful references to direct the reader to more specialised topics, or give another perspective could have been provided in several places. Also, no treatment of the FDTD method on unstructured meshes was given. However, even a brief but sufficient treatment would have added considerable length to the book. Finally, given the computational intensity of the FDTD method, a more detailed discussion of multigrid methods for reducing the number of cells in the computational domain would have been helpful.

Introduction to Computer Methods for Microwave Circuit Analysis and Design

by

Janus A. Dobrowolski, Artech House, Norwood MA, 02062, 1991, 427 pages, $79.00

Reviewed by: Ray Perez, ACES Newsletter Editor-in-Chief, Jet Propulsion Laboratory

The subject of microwave engineering is presently going through a fast transformation prompted by two major factors: a) the development of a variety of CAD/CAE tools over the last 10 years (e.g Supercompact, Touchstone, ACCAD, Microwave Harmonica,...etc), and b) the development of RFICs (RF Integrated Circuits) for all sorts of wireless communications. The demand for engineers knowledgeable in these latest technologies in the world of RF/MW communications is increasing at a very fast pace. RF/MW engineering which was once dedicated mostly to the development of systems for aircraft, satellites, spacecraft, radars, missiles, secured communications, ...etc is now experiencing a second revolution in the commercial world; from cellular phones to GPS and data transmission networks. Why do we want to review a book in computer methods for RF/MW circuit design in the ACES newsletter? Because it is becoming more obvious to the RF/MW CAD industry that Computational Electromagnetics (CEM) will become an essential ingredient not only in the design of microwave circuits but also in the development of more sophisticated CAD tools. I will dwell more on this subject at the end of this review.

This book basically describes the mathematics behind the algorithms used by CAD tools in the design and analysis of microwave circuits. Though the book is heavy in its mathematical approaches, the material is well organized and easy to follow by most readers. Another book that our readers may be interested in is the one titled "Algorithms for Computer Aided Design of Linear Microwave Circuits," (S.Rosloniec, Artech House) which describes the typical software in the algorithms used by many CAD tools. The book in this review contains 11 chapters and 3 appendices. The first 5 chapters contribute the basic mathematics used in CAD implementations. Chapters 6 through 8 emphasize the use of numerical techniques for the analysis of linear systems of differential equations with immediate application to CAD tools development. Chapters 9 through 11 cover methods for design optimization.

After a brief introduction in Chapter 1 describing the essential parts of most RF/MW CAD tools, Chapter 2 describes network topologies. Several matrix representations of microwave elements are discussed such as chain matrix, scattering matrix, transfer scattering matrix, and the admittance scattering matrix. The relationships among these matrices in multiport representation are also discussed. Chapter 3 addresses computer aided methods for linear microwave circuit analysis in the frequency domain. Several types of analyses are described: a) nodal admittance matrix for voltage and current analysis, and b) scattering matrices for normalized wave variables at the ports. Scattering matrices are popular because their parameters are easy to measure. Chapter 3 also covers the subject of matrix representations of large circuits by cascading multiple two-port scattering matrices of smaller circuits. Admittance matrices, chain matrices, scattering matrices, and transfer scattering matrices representation for elements commonly encountered in microwave circuits are represented in the tables of this chapter. Chapter 4 covers sensitivity analysis: the evaluation of variations in circuit function due to small changes in circuit element parameters or the presence of parasitics. The chapter presents the direct and adjoint network methods for sesitivity analysis. Methods for evaluating group delay of microwave transmission functions based on the network sensitivity analysis principle are also given. CAD noise analysis methods of microwave circuits are given in Chapter 5 not only for circuits composed of interconnected two-ports but also for circuits of arbitrary topology. Noise properties of circuit elements are described by noise correlation matrices and an algorithm for noise figure computation of two-port connected in cascade is also given. Noise correlation matrices for common elements of microwave circuits are presented for admittance and scattering matrix representations. Numerical techniques for solving linear equations in the frequency domain for microwave circuit sensitivity or noise analysis are covered in chapters 6 through 8. Chapter 6 concentrates on Gaussian elimination, LU decomposition, and bifactorization. Because many of such analyses contain sparse matrices, chapters 7 and 8 contain techniques for solving large sparse systems of equations. An sparse matrix equation solver and its source code are provided. Chapter 9 presents the subject of tolerance analysis: the effect of circuit parameter spreads on the performance of the circuit design. Both deterministic and statistical analysis approaches are discussed. Chapter 10 deals with computer aided methods for tolerance design, again two approaches are taken, the deterministic and the statistical exploration approach. In CAD, changing the element parameters and observing the results by again analyzing the circuit can be done automatically by means of optimization methods. Chapter 11 covers the fundamentals of optimization theory, including the description of several algorithms suitable for CAD of microwave circuits. Practical aspects in the implementation of optimization methods are discussed in Chapter 11.

Let us now answer specifically the question previously posed of how can CEM be of interest in the analysis of RF/MW circuits. At the heart of RF/MW CAD tools is their ability for representing circuits of any topology into a form that can expressed as a series of cascaded networks using the different types of matrix representations previously discussed. The parameters (or elements) of these matrices can be obtained by approximate analytical expressions. However, CEM can often provide highly accurate numerical results for such matrix elements. For example, TLM has often been used in the past for obtaining several types of parameters in microstrip design. It can be envisioned that future CAD tools for RF/MW circuit design will be making use of CEM as preprocessor in the design process. This book, though not of introductory nature, can be recommended for those with interest in RF/MW circuit design and who have an interest in developing/improving CAD tools.

INDEX TO COMPUTER CODE REFERENCES FOR VOL. 8 OF THE ACES JOURNAL AND THE ACES NEWSLETTER

This computer code index is updated annually in the second issue of each volume of the ACES Newsletter.

Legend:

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

NOTE: The inclusion of any computer code in this index does not guarantee that the code is available to the general ACES membership. Where the authors do not give their code a specific name, the computational method used is cited in the index. The codes in this index may not all be general purpose codes with extensive user-orientated features - some may only be suitable for specific applications.

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ABSTRACTS OF ACES JOURNAL PAPERS

VOLUME 8

This compilation of abstracts is updated annually in the second issue of each volume of the *ACES Newsletter*.

AN ASSESSMENT OF MININEC AND ITS USE IN THE TEACHING OF ANTENNA THEORY

B.A. AUSTIN
Department of Electrical Engineering and Electronics,
University of Liverpool,
P.O. Box 147, Liverpool, L69 3BX,
United Kingdom

MININEC is a compact, Method of Moments code, written specifically for the personal computer which has evolved considerably in the last decade. This paper presents an assessment of the program and discusses its use in the teaching of antenna theory to undergraduates. The results of a number of validation exercises on the code are included and the simulation of loaded wire antennas, using MININEC, is discussed. **[Vol. 8, No. 1 (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 7-28]**

ELECTROMAGNETIC COMPUTATIONAL METHODS IN THE TEACHING OF ELECTROMAGNETIC COMPATIBILITY

Reinaldo Perez
Jet Propulsion Laboratory
California Institute of Technology

The teaching of Electromagnetic Compatibility (EMC) is gaining acceptance as an important subject that needs to be taught in the Electrical Engineering curriculum at the undergraduate and graduate levels. It has become evident that EMC plays an important part in the design and manufacture of electronic components, subsystems and systems; hence, the need for its teaching. Traditional approaches for the teaching of EMC have focused on analytical methods for the study of diverse types of interference mechanisms. Recently, the use of computational electromagnetic methods in the analysis and solution of EMC problems has been introduced in the teaching of EMC. Students have shown great interest in an EMC course where the use of computer methods helps in their understanding of this, sometimes, difficult subject. **[Vol. 8, No. 1, (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 29-48]**

SIMPLE TECHNIQUES FOR THE DESK-TOP PRODUCTION OF COMPUTER MOVIES WHICH ILLUSTRATE FUNDAMENTAL CONCEPTS IN ELECTROMAGNETICS

F.E. Vermeulen, F.S. Chute, and E. Sumbar
Department of Electrical Engineering
University of Alberta
Edmonton, Alberta, Canada
T6G 2G7

Using Macintosh(R) computers and a selection of readily available commercial software, computer animations that effectively illustrate fundamental concepts in electromagnetics can be quickly and easily produced. The methodology, typical movie preparation, and the software and hardware requirements are discussed. **[Vol. 8, No. 1 (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 49-65]**

A GLOBAL APPROACH TO TEACHING NEAR-FIELD ANTENNA MEASUREMENTS

D. Picard[1], A. Rekiouak[2], M. Hélier[1]
A. Ziyyat[1], J.-Y. Gautier[3], J.Ch. Bolomey[1]

[1] Ecole supérieure d'Electricité & Laboratoire des Signaux et Systèmes
Plateau de Moulon. Gif sur Yvette. France
[2] Ecole supérieure d'Electricité. Plateau de Moulon. Gif sur Yvette. France
[3] Now with MOTHESIM. Le Plessis-Robinson. France.

A complete set of experiments on near-field antenna measurements is presented. This labwork serves two purposes: first, it introduces students to the difficulties associated with such a measurement technique, and second, they gain the confidence to work in high tech, elaborate environments. The technical goal in this labwork is to obtain the radiation pattern of an antenna through measurements of the near-field using a complete experimental set-up driven by a Macintosh computer, and performing a near-to-far field transformation using a combination of Helmholtz equation and the Fourier Transform. Actually, the knowledge students acquire in this labwork is built up in stages which are both independent and experiments in their own right: they are described in detail in the paper, along with the knowledge built up at each stage by students as they advance into the labwork, and the objectives achieved. **[Vol. 8, No. 1, (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 66-76]**

COMPUTER-BASED ELECTROMAGNETIC EDUCATION

Magdy F. Iskander
Electrical Engineering Department
University of Utah
Salt Lake City, UT 84112

Computers provide an exciting opportunity for boosting electromagnetic education and corporate training. Animated graphics of the wave propagation phenomenon, visualization of the abstract and highly mathematical subjects, one-on-one and self-paced tutoring, and the ability to mimic often unavailable and expensive laboratory experiments are among the often-cited benefits of a computer-based electromagnetic education. In this paper, we review the activities of the NSF/IEEE Center for Computer Applications in Electromagnetic Education (CAEME). This Center was established to stimulate and accelerate the use of computers and software tools in EM education. A reflection on the extensive software package developed and distributed by the CAEME Center is described and examples of the developed software are presented. To help integrate available EM software in classroom teaching and corporate training, CAEME developed four multimedia lessons for instruction. These interactive media lessons integrate and allow individuals to interactively manipulate information from multimedia sources such as video, software, and animated graphics and also include instructional information such as quizzes and tutorials to help evaluate the students' performance. Features of these lessons are presented, and future developments in the Center's activities are described. **[Vol. 8, No. 1, (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 77-107]**

MULTIMEDIA SELF-TRAINING PACKAGE FOR BASIC MICROWAVES LEARNING

M. Hochedez, J.F. Legier, M. Vindevoghel
I.E.M.N, U.M.R 9929
Department Hyperfrequences et Semiconducteurs, Bat P4
Universite des Sciences et Technologies de Lille
59655 Villeneuve d'Ascq Cedex

The purpose of this article is to present an original pedagogical product for teaching microwaves. It contains 9 lessons and is composed of 2 media:

- a handbook
- interactive educational software

It is a multimedia self-training product recommended for technicians and engineers working in conventional electronics and wishing to acquire advanced knowledge in microwaves in connection with their working structure. It can also be used in self access at the university by undergraduate students. In this last case, the authors will state in the conclusion, their observations following an experiment in computer aided learning (C.A.L.) carried out at the university of Lille. **[Vol. 8, No. 1, (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 108-115]**

EMAP: A 3-D, FINITE ELEMENT MODELING CODE FOR ANALYZING TIME-VARYING ELECTROMAGNETIC FIELDS

Todd Hubing, Mohammad Ali, and Girish Bhat
University of Missouri-Rolla
Rolla, Missouri 65401

No Abstract provided. **[Vol. 8, No. 1, (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 116-124]**

A ROMANIAN EXPERIENCE IN COMPUTER-AIDED ELECTROMAGNETIC EDUCATION

Mihaela Morega and Daniel Ioan
Electrical Engineering Department
Polytechnic Institute of Bucharest
Bucharest, Romania

The paper presents the actual interests in computer-aided electromagnetic education (CAEE) at the Electrical Engineering Department from Polytechnic Institute of Bucharest, Romania.

The actual state of computer use on different levels of undergraduate and graduate education is presented. Specifically, an overview of the undergraduate theoretical training and practical applications is described, and research topics for graduate reports and doctoral dissertations are discussed. Issues related to hardware utilities are reviewed, and future projects aimed at improving the CAEE capabilities in Romania are described.

The material is based on significant selected references. **[Vol. 8, No. 1, (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 125-137]**

CAL - ANTENNAS
COMPUTER-AIDED LEARNING OF ANTENNAS

Emmanuel TONYE (Associate, IEEE) and Olivier VIDEME BOSSOU
Ecole Nationale Superieure Polytechnique
B.P. 8390 Yaounde, CAMEROUN
Tel.: (237) 231226, Fax (237) 231841

CAL-ANTENNAS is a tool containing graphics (2D and 3D) and sounds coded in the Turbo Pascal 5.5 language, for the implementation of educational software on antennas. From the Units files, a data base (frequency bands, antenna forms, antenna dimensions, formulae, characterising radiation) and a repertory of numericals methods (integration, graphs plotting, etc...) have been developed, complying with speed constraints. The necessary fundamental principles are contained in text files. Thus, this is one of the first structured software packages developed on the computer in the domain of antennas that treats the fundamental principles and the methodology of design.

This version of CAL-ANTENNAS for the microcomputer based on the Intel 386 and 486 Microprocessors contains more than a hundred illustrations. **[Vol. 8, No. 1, (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 138-156]**

TEACHING COMPUTATIONAL ELECTROMAGNETICS AT NORTHEASTERN UNIVERSITY: FROM PCS TO SUPERCOMPUTERS

Carey M. Rappaport
Center for Electromagnetics Research
235 Forsyth Building
Northeastern University
Boston, MA 02115

As supercomputers become more accessible and as inexpensive personal computers become more powerful, the numerical modeling of electromagnetic fields in non-idealized geometries becomes increasingly practical. To enable graduate students to solve useful real-world problems, Northeastern University's course ECE 3347: *Computational Methods of Electromagnetics* teaches the important techniques of field and wave simulation, making use of a variety of programming languages, graphics packages, and computer systems which range from home computers to the most powerful supercomputers. Strong emphasis on algorithm design and computer testing helped motivate students to develop an understanding of the major issues involved in using computers to simulate electromagnetics problems. **[Vol. 8, No. 1, (1993), Special Issue on Computer Applications in Electromagnetics Education, pp 157-165]**

COMPUTATIONAL SIMULATION OF ELECTRIC FIELDS SURROUNDING POWER TRANSMISSION AND DISTRIBUTION LINES

J. Patrick Donohoe*, Min-Yee Jiang, Joe F. Thompson**, David B. Miller***

*Department of Electrical and Computer Engineering
Mississippi State University
P.0. Drawer EE
Mississippi State, MS 39762

**Engineering Research Center for Computational Field Simulation
Mississippi State University/National Science Foundation
P.O. Box 6176
Mississippi State, MS 39762

A numerical technique is presented for computing the potential distributions surrounding power transmission and distribution lines of complex geometry. The technique employs a finite difference solution using boundary-fitted coordinates. A newly developed finite difference solver code is coupled with the existing EAGLE grid generation code to yield a system capable of solving for the electric potential and field distributions surrounding complex configurations. A code validation example is presented which consists of a sphere-to-ground electrostatic solution. Sample results are also presented for a distribution line model. **[Vol. 8, No. 2 (1993), pp 4-16]**

COMPARISON OF ELECTROMAGNETIC RESPONSE IN TIME AND FREQUENCY DOMAINS

S. Kashyap and A. Louie
Electronics Division
Defence Research Establishment Ottawa
Ottawa, Ontario, Canada
K1A 0Z4

This paper is concerned with the use of time- and frequency-domain methods for computing the interaction of electromagnetic waves with simple and complex structures. An example chosen for this study is a cubic box with the top open. The Finite Difference Time Domain (FDTD) method is used for computing time-domain responses to an electromagnetic pulse (EMP), a Gaussian pulse, and a sine wave. Frequency-domain results are obtained by using a moment method solution of the electric field integral equation (EFIE). Comparison is then made, both in the frequency and time domains, on corresponding quantities using Fourier transforms. Effects of various factors - the shape of the incident waveform, discretization of the structure, and Fast Fourier Transformation - on the CPU time and the accuracy of the solution are demonstrated. Guidelines are established for obtaining an accurate response. **[Vol. 8, No. 2 (1993), pp 17-43]**

VALIDATION OF THE NUMERICAL ELECTROMAGNETICS CODE (NEC) FOR ANTENNA WIRE ELEMENTS IN PROXIMITY TO EARTH

M. M. Weiner
The MITRE Corporation
Bedford, MA 01730-1420

This paper summarizes recent MITRE efforts to validate the NEC-3 and NEC-GS versions of the Numerical Electromagnetics Code (NEC) developed by Lawrence Livermore National Laboratory for predicting the performance of antenna wire elements in close proximity to flat earth. In an early version (NEC-l), the effect of the air-ground interface was included by applying a plane-wave Fresnel reflection coefficient approximation to the field of a point source. The NEC-2 version, while still retaining the Fresnel reflection coefficient model as an option, provides a more accurate ground model by numerically evaluating Sommerfeld integrals. The version NEC-3 extends the NEC-2 version to cases for bare wire segments below the air-earth interface. Version NEC-GS utilizes rotational symmetry to provide a more efficient version of NEC-3 for the case of a monopole element with a uniform radial wire ground-screen (GS).

Results of the various versions are compared with each other and with other models. The input-output format of the NEC-GS version is discussed. It is concluded that the NEC-3 Sommerfeld integral option in the NEC-GS version is the best available model for monopole elements with electrically small radial-wire ground planes. **[Vol. 8, No. 2 (1993), pp 44-71]**

PROPAGATION OF VLF RADIATION IN THE EARTH-IONOSPHERE WAVEGUIDE EXCITED BY AN AIRBORNE DUAL TRAILING WIRE ANTENNA

D.H. Werner
The Applied Research Laboratory
The Pennsylvania State University
P. O. Box 30
State College, PA 16804

J.K. Breakall
Electrical and Computer Engineering
The Pennsylvania State University
University Park, PA 16802

R. J. Lunnen
The Applied Research Laboratory
The Pennsylvania State University
P. O. Box 30
State College, PA 16804

Field strength variations produced by an orbiting aircraft dual trailing wire VLF transmitting antenna are investigated. The towplane is assumed to be executing a circular orbit at a constant altitude and speed. A steady-state mechanical model is adopted for determination of the shape of the dual trailing wire antenna. The exact current distribution on this antenna is calculated using the Numerical Electromagnetics Code (NEC) which is based on a method of moments solution of the Electric Field Integral Equation (EFIE). A propagation code developed at the Naval Ocean Systems Center (NOSC) called TWIRE has been modified to be used in conjunction with NEC. This modified version of TWIRE has been called TWIRENEC. The TWIRENEC code uses the current distribution information provided by NEC to determine the dipole moments for a segmented antenna. The wire segmentation geometry and corresponding dipole moments are then used to calculate the electric field strength as a function of distance and azimuth in the earth-ionosphere waveguide. The waveguide can be considered as either horizontally homogeneous or inhomogeneous. It is demonstrated that the periodic variations in field intensity resulting from an orbiting transmitter are a function of receiver position. These periodic variations can range from a small fraction of a dB to several dB depending upon the location of the receiver with respect to the transmitter. A point dipole approximation of the dual trailing wire antenna is suggested for use in the study of VLF radiation excited by an orbiting antenna in the presence of wind shear. The point dipole approximation is applied to estimate the field strength variations caused by a yo-yo oscillation of the transmitting antenna as it orbits. These yo-yo oscillations are characterized in terms of the change in verticality of the point dipole which occurs over one complete orbit. **[Vol. 8, No. 2 (1993), pp 72-92]**

AN INVESTIGATION OF WIRE GRID AND SURFACE PATCH MODELING USING THE NUMERICAL ELECTROMAGNETICS CODE (NEC)

James K. Breakall
Electrical and Computer Engineering Department
The Pennsylvania State University
University Park, PA 16802

Richard W. Adler and Panos D. Elliniadis
Electrical and Computer Engineering Department
Naval Postgraduate School, Monterey, CA 93943

The Numerical Electromagnetics Code (NEC) was used to evaluate the admittance and the electric near and far fields of a monopole antenna mounted on a cubical box over a perfectly conducting ground plane. Two models of the box, employing surface patches and wire grids, were evaluated. The monopole was positioned at the center, the edge, and at a corner of the box's top surface. NEC admittance results were obtained and good agreement was found with experimental data and with results from PATCH, another independent electromagnetic modeling code. Results are presented in contour and 3-D formats for the near fields and polar format for the far field radiation patterns using surface patch and wire grid models in NEC. Excellent agreement was obtained for both approaches in NEC after finding the optimum number of patches and wire grid segmentation to obtain convergence. This paper provides guidelines for convergence for both modeling approaches and indicates a six-fold savings in run-time for the surface patch method. Furthermore, results are presented in modern graphical format for near field comparisons of the two NEC techniques. **[Vol. 8, No. 2 (1993), pp 93-113]**

AN INTEGRATED ENVIRONMENT FOR THE NUMERICAL MODELING OF COMMUNICATION ANTENNAS BASED ON RELATIONAL DATABASES

Virginia Stover
Department of Mathematics and Computer Science
University of San Diego
San Diego, CA

James C. Logan
Research and Development Division
Naval Command, Control and Ocean Surveillance Center
San Diego, CA

As modeling systems mature, they become larger, more complex, and more difficult to maintain. Modeling tools increase in number and complexity. Frequently they are written in different languages and require data in different formats. Databases also increase in size as modeling systems are applied to new and more complex problems. Engineers spend large amounts of money trying to integrate tools and data that are basically incompatible. Unfortunately, budgets do not grow at the same rate as the complexity of our modeling systems and databases. To maintain productivity, it is necessary to design modeling environments that can handle large amounts of data in flexible ways and are simple to maintain and upgrade.

This paper describes a new environment developed by the authors for the modeling of communication antennas based on a relational database management system. This approach simplifies the task of integrating a set of heterogeneous programs with incompatible data formats. The relational database provides a common store for all modeling objects including the antenna, platform, ground, electromagnetic sources, currents, charges, and fields, and model history. The database management system provides the organization, storage, and retrieval functions and some of the data input, validation and display functions for the antenna models. The main advantages of this approach are its ability to grow as new tools and capabilities are added, its portability to other machines and operating systems, and the ability it provides engineers to easily share data among themselves and with other modeling applications.

This work was conducted for the Naval Ocean Systems Center as part of the Navy Summer Faculty Research Program, a cooperative program with the American Association for Engineering Education (ASEE). **[Vol. 8, No. 2 (1993), pp 114-127]**

AN APPLICATION OF THE HYBRID MOMENT METHOD/GREEN'S FUNCTION TECHNIQUE TO THE OPTIMIZATION OF RESISTIVE STRIPS

R. Craig Baucke
GE Aircraft Engines M/D J185
1 Neumann Way
Cincinnati, OH 45215-6301

An automatic method of synthesizing resistive tapers is developed. This method embeds a hybrid moment method/Green's function inside a nonlinear optimization package. Using this technique, resistive tapers are rapidly synthesized for complex scatterers which can consist of multiple resistive strips, as well as large, arbitrary conducting regions. The method is applied to the optimization of resistive tapers that reduce the diffraction from conducting scatterers. **[Vol. 8, No. 2 (1993), pp 128-143]**

PARALLEL MATRIX SOLVERS FOR MOMENT METHOD CODES FOR MIMD COMPUTERS

David B. Davidson
Dept. of Electrical and Electronic Engineering
University of Stellenbosch
Stellenbosch 7600
South Africa.
E-mail:davidson@firga.sun.ac.za

Parallel algorithms are presented that are suitable for the solution of the system of linear equations generated by moment method problems on local memory Multiple Instruction, Multiple Data (MIMD) parallel computers. The two most widely used matrix solution algorithms in moment method codes are described, namely the conjugate gradient (CG) method and LU decomposition. The underlying philosophy of parallelism is briefly reviewed. Suitable parallel algorithms are then described, presented in pseudo-code, their timing behavior analyzed theoretically, and timing results measured on a particular MIMD computer--a transputer array --are presented and compared to the theoretical timing models. It is concluded that efficient parallel algorithms for both the CG and LU exist and that MIMD computers offer an attractive computational platform for the solution of moment method problems with large numbers of unknowns. **[Vol. 8, No. 2 (1993), pp 144-175]**

'A PRIORI' KNOWLEDGE, NON-ORTHOGONAL BASIS FUNCTIONS, AND ILL-CONDITIONED MATRICES IN NUMERICAL METHODS

Ch.Hafner
Swiss Federal Institute of Technology
Zurich

Many terms and ideas used in numerical methods have their origin in analytical mathematics. Despite the well-known discrepancies between number spaces of computers and those of good old mathematics, the consequences of applying mathematical theorems to numerical methods and the importance of physical reasoning are often underestimated. The objective of this paper is to demonstrate that introducing 'a priori' knowledge of a problem into a numerical code can lead to superior numerical techniques but it may violate analytic dogmas at the same time. **[Vol. 8, No. 2 (1993), pp 176-187]**

ON THE CONVERGENCE OF THE METHOD OF MOMENTS, THE BOUNDARY-RESIDUAL METHOD, AND THE POINT-MATCHING METHOD WITH A RIGOROUSLY CONVERGENT FORMULATION OF THE POINT-MATCHING METHOD

K.J. Bunch and R.W. Grow
Microwave Device and Physical Electronics Laboratory
Department of Electrical Engineering
University of Utah
Salt Lake City, Utah 84112

The method of moments reduces to the boundary-residual method or the point-matching method with a suitable weighting function. This paper shows another means by which these three methods can produce equivalent results. Arguments are given as to why point matching can fail to converge, while the other two methods rigorously converge. An example is given to support these arguments. **[Vol. 8, No. 2 (1993), pp 188-202]**

SOLUTION OF TEAM BENCHMARK PROBLEM #10 (STEEL PLATES AROUND A COIL)

O. Biro
Graz University of Technology, Kopernikusgasse 24, A-8010 Graz, Austria

Problem No. 10 of the TEAM Workshops is solved by three different finite-element formulations using a magnetic vector potential with the Coulomb gauge and an electric scalar potential. Allowing the normal component of the vector potential to jump at iron/air interfaces yields results in good agreement with measurement data. **[Vol. 8, No. 2 (1993), Special Section in Team Benchmark Problem Solutions, pp 203-215]**

SOLUTION OF TEAM BENCHMARK PROBLEM #13 (3-D NONLINEAR MAGNETOSTATIC MODEL)

O. Biro, Ch. Magele, G. Vrisk
Graz University of Technology, Kopernikusgasse 24, A-8010 Graz, Austria

Problem No.13 of the TEAM Workshops is solved by two scalar potential and one vector potential finite-element formulations. The results obtained by the different scalar potential methods are identical and their agreement with those yielded by the vector potential approach and also with measurement data is satisfactory. **[Vol. 8, No. 2 (1993), Special Section in Team Benchmark Problem Solutions, pp 216-225]**

SOLUTION OF TEAM BENCHMARK PROBLEM #13 (3-D nonlinear magnetostatic model)

Lauri Kettunen
Tampere University of Technology
P.0.Box 692
33101 Tampere 10
Finland

Larry R. Turner
Argonne National Laboratory
Advanced Photon Source
Argonne, Illinois 60439
U.S.A.

Four solutions for the TEAM magnetostatic benchmark #13 are presented. The problem was solved with the three dimensional volume integral code CORAL, formerly called GFUNET. A series of models were solved with increasing discretization in order to study the convergence and the charged CPU-time. **[Vol. 8, No. 2 (1993), Special Section in Team Benchmark Problem Solutions, pp 226-231]**

SOLUTION OF TEAM BENCHMARK PROBLEM #9 (Handling Velocity Effects with Variable Conductivity)

Kent Davey
School of Electrical Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0250

Users often raise the question of whether it is possible to analyze eddy current problems with velocity effects within codes that are not programmed to account for movement. This paper looks at a technique for applying a conventional boundary element technique to the analysis of a velocity induced eddy current by altering the conductivity of the conducting medium as a function of position. Results of the predicted B fields for v=0 m/s and v=10 m/s are compared to the analytical solution of a coil traveling axially down the center of a conducting tube. Good agreement is achieved; further refinement could be realized by iterating on conductivity if necessary. **[Vol. 8, No. 2 (1993), Special Section in Team Benchmark Problem Solutions, pp 232-243]**

ACKNOWLEDGEMENT

The assistance of Mrs. C. Freislich at the Department of Electrical and Electronic Engineering, University of Pretoria, Pretoria, South Africa in the preparation of these abstracts for publication, is gratefully acknowledged.

AUTHOR'S KIT FOR THE ACES JOURNAL

Information concerning the types of articles considered for publication by the ACES Journal are normally printed on the two back cover pages of the Journal. Papers submitted for consideration for publication may be in 12 point font size (or acceptable equivalent) and may be in one and a half or double line spacing for the convenience of the reviewers. It is requested that intending author(s) for the Journal send four copies of their article to the Editor-in-Chief of the Journal. Some additional information applicable to final camera-ready copies is also provided on the back pages of the Journal. However, in response to many enquiries from prospective authors it has been decided, for archival purposes, to publish copies of the material sent to authors whose papers have been accepted for publication in the Journal. The kit comprises the following:

1) ACES Copyright forms (these are regularly published in the Journal)
2) Page charge policy
3) A note concerning the preferred font sizes and lay-out for camera-ready Journal articles,
4) Specific requirements for camera-ready copies, and
5) Style requirements for Journal articles. The kit is subject to revision from time to time. Please note that these requirements apply only to the final camera-ready copy. It is important to note that once a paper has been accepted for publication, it will not be turned down because the author(s) is/are unable to meet the requirements for the preferred font sizes or lay-out. Where necessary, every effort is made to assist authors to produce acceptable camera-ready copy.

Duncan C. Baker
Editor-in-Chief, ACES Journal
EE Department, Univ of Pretoria
0002 Pretoria, South Africa.

16 May 1994

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W. Perry Wheless, Jr.
ACES Editor-in-Chief

PREFERRED FONT SIZES AND LAY-OUT FOR CAMERA-READY *ACES JOURNAL* ARTICLES

Duncan C Baker, ***ACES Journal*** **Editor-in-Chief**

ABSTRACT. This brief discussion for intending ACES Journal authors deals with the vexing question of fonts, point sizes and lay-out. It represents a first attempt at optimising the use of available printed pages in the ACES Journal to the benefit of all members and authors. The ultimate objective is to be able to publish more worthy papers in the allocated number of pages without affecting the actual length (word count) of the papers themselves. This should eventually lead to faster turnaround time, cost savings and/or a regular quarterly Journal. The guidelines proposed are just that - only guidelines. No author's work will be turned down because he/she is unable to adhere to the proposed formats.

1 INTRODUCTION

Desktop publishing has become a reality for many authors. There are a large number of word processing packages and printers such as laser or inkjet printers available. These make it possible for an author to produce a high quality camera-ready copy with minimal effort. In this brief discussion proposals are motivated for a number of preferred presentation formats for papers to be published in the *ACES Journal*. The pages saved in this way will be utilised to the benefit of *ACES* members and authors. More worthy papers can be published on the same number of printed pages and the *Journal* can more readily achieve its longterm objective of becoming at least a quarterly publication.

It is emphasised that, while the preferred formats will result in substantial savings of printed pages without shortening the actual text of a paper, **no author will be discriminated against because he or she does not have access to modern word processing and/or desktop publishing facilities.**

2 READABILITY AND LEGIBILITY

2.1 Introduction

Readability and legibility are sometimes considered to be synonymous. Of course, they are not. Legibility is the quality of a typeface that makes it possible to read it, whereas readability is the characteristic of a body of type which makes it comfortable to read. The ensuing discussion is based on information available in texts on printing [1,2,3].

Readability is affected ultimately by no less than 9 factors. These are:

(a) typeface, or font
(b) size of type, or point size
(c) length of line (and words per line)
(d) leading, or space between words
(e) page pattern (including margins)
(f) contrast of type of paper (including colour)
(g) texture of paper
(h) typographic relationships (heads, folios, etc), and
(i) suitability of content.

2.2 Point size

This document was produced using Wordperfect 5.1 along with an HP LaserJet 4P printer. It was originally printed on A4 (European standard) paper but with the margins and page length set to conform to US standard size. The margin width was set at 20 mm (about 3/4 inch), the column width at 85 mm (about 3 3/8 inches) and the inter-column space at 6 mm (about 1/4 inch). A variety of fonts in different point sizes were available for use with the printer. There are 72 points per inch. Unless otherwise stated this document was prepared in Times Roman (TR) font with proportional spacing and the following point sizes. The title and author lines are in TR 12 point. The body of the text is in TR 10 point.

By way of comparison this specific sentence is printed in TR 12 point.

In books intended for people over 60, the point size should not be smaller than 11 point. For adults with normal eyesight the "apparently larger" 10 point typefaces are adequate (some typefaces are more "open" than others). For reference, note that most hardcover books are set in 11 point, while paperbacks with their enormous popularity are set in 10 or 9 point, and sometimes even 8 point. As can be seen from this sentence set in 8 point TR, this point size is not nearly as comfortable to read as the 9 or 10 point sizes.

2.3 Pitch

Pitch refers to the spacing of words.

`Courier font with 10 characters per inch (cpi), as used in this sentence, certainly tends to spread the document.` Contrast the previous sentence with this one in Times Roman 12 point with proportional spacing. This sentence, on the other hand, is prepared in Prestige Elite with 12 characters per inch.

2.4 Serifs and sans-serif

Serifs refer to the little finishing strokes at the ends of letters in the typeface or font. These are in turn related to the "certainty of deciphering", and thus the legibility. They help to differentiate individual letters.

It is important to note the following

(a) sans-serif type (that without the serifs) such as the Helvetica 10 point used in this sentence, is intrinsically less legible than seriffed type,

(b) well-designed Roman upper or lower case seriffed type is easier to read than any of its variants, e.g. *italic,* **bold,** CAPITALS, or various expanded or condensed versions, and

(c) words should be set closer to each other (about as far apart as the width of the letter 'i'); and there should be more space between the lines than between the words.

3 RECOMMENDATIONS

While this has by no means been a comprehensive study of the vexing question of the ideal font type, point size and lay-out, some clear recommendations can be made. These recommendations must be seen against the background of trying to achieve maximum advantage in order to stretch the available printed page allocation to allow more worthy papers to be published. Another consideration is of course the desirable long term objective of producing at least a quarterly issue of the *ACES Journal.*

The recommendations are thus that provision should be made for at least three paper presentation formats with the following order of preference:

(a) Double column presentation with a 10 point seriffed type of font and proportional spacing; the heading should be in 12 or 14 point size. Margins and column width have been discussed elsewhere in these notes.

(b) Paste-ups with the body of the text in 14 point seriffed font, which after linear reduction to 71% becomes the equivalent of 10 point. The heading should be in about 18 point size, which reduces to about 13 point. Consideration should be given to providing the heading in suitably sized font in a space left at the top of the document for those authors lacking suitable facilities.

(c) For those who cannot accommodate either of the above formats, a 10 or 12 point seriffed font with proportional spacing is suggested. If proportional spacing is not available, suitable fonts with 10 or 12 characters per inch are suggested. The smaller font sizes should be given preference.

For comparison, the length of this note in different font styles is as follows:

Times Roman 12 point - 3 pages and about 1 inch of script,
Courier 10 cpi - 3 pages and about 2 inches of script,
Prestige Elite 12 cpi - 2 pages and about 7 inches of script, and
Helvetica 12 point - 3 pages and about 1 inch of script

It is important to reiterate that no author will be deprived of the possibility of publishing in the *ACES Journal* because of a lack of suitable typing and/or word processing facilities occasioned by adherence to the more stringent guidelines. The above guidelines are proposed in the face of continuing pressure for optimum usage of the available printed pages for the various issues. If an author is unable to meet the suggested criteria, every effort will be made to assist him or her to produce an acceptable camera-ready copy.

4 REFERENCES

[1] M. Lee, 'Bookmaking: The Illustrated Guide to Design/Production/Editing', R.R. Bowker Company, New York, 1979. ISBN 0-8352-1097-9.

[2] R. McLean, The Thames and Hudson Manual of Typography', Thames and Hudson, London, 1980. ISBN 0-500-68022-1.

[3] H. Williamson, 'Methods of Book Design', Yale University Press, New Haven and London, 1983. ISBN 0-300-02663-3.

<Revised - April 1994>

APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY JOURNAL

REQUIREMENTS FOR CAMERA-READY COPY FOR *ACES JOURNAL* ARTICLES

Congratulations! Your paper has been accepted for publication in the *ACES Journal.*

In order that we may publish your paper promptly, please prepare your final, camera-ready copy in accordance with the following instructions:

1. PRESENTATION FORMAT

Many authors have access to word processing facilities and laser-printers. This enables the preparation of high quality camera-ready copy. Where possible authors should capitalize on this capability to produce a camera-ready copy in the equivalent of Times Roman 10 point type face with proportional spacing such as that used in the body of these notes.

If the reduced font size is used, a double column presentation is preferred to go with it. An oversize paste-up (140% linear enlargement of a normal US standard sheet) using double columns and 14 point font is also acceptable, although a larger font will have to be used for the Title. The oversize sheets are photo-reduced by 71% linear dimension to provide standard size copy with the equivalent of 10 point font size if 14 point was originally used.

The use of these two options considerably reduces the number of printed pages compared to the normal font size of approximately 12 points by as much as a third. The resultant advantages for members and authors include more worthy papers per issue and faster turnaround time.

Where an author is not able to produce an original camera-ready copy in the reduced font size of 10 points, he/she may use the normal font size of approximately 12 points. Proportional spacing is preferred, but not mandatory.

Single line spacing is preferred. Where the use of subscripts and superscripts influences the readability of a document, one and a half spacing is recommended above or below the line so affected. Double spacing should only be used in the same way when one and a half spacing is not possible.

No author will have his/her work rejected after it has been accepted for publication because of an inability to meet the more stringent requirements in terms of font size and lay-out for camera-ready copy.
The Board of Directors has imposed an excess pages levy on papers greater than a pre-determined length. For more information see the page titled 'Excess Length Page Charge Policy'.

2. TYPES OF PAPER FOR THE DOCUMENT

Special materials such as mats, other special forms, India Ink, and glossy prints ARE GENERALLY NOT REQUIRED. Any plain white paper may be used. Note, however, the possible exception of oversized paper referred to in paragraph 1.

3. MARGINS

All top and bottom margins should be approximately 1 inch (2.54 cm), based on US standard page sizes of 8.5 in x 11.0 in. The side margins may not be less than 0.75 in (2.0 cm) or more than 1 in (2.54 cm). The approximate area of the text itself is then 6.5 in x 9.0 to 7 in x 9 in. The slightly larger area is recommended for double column use. In this case the space between the columns should be approximately 0.25 in (0.6 cm).

You must maintain this approximate area, even if you are using a different page size (other than 8.5 in x 11.0 in) such as the European standard A4 page.

4. THINGS TO AVOID

The following are to be avoided in the original camera-ready copy:

a. Faded or broken lines on figures - especially graph grids (use either a "good" grid or else no grid);

b. White streaks in text or figures, especially along fold lines. Do NOT fold your final, camera-ready manuscript when you mail it. Stiffen the envelope with a sheet of cardboard the same size as the paper itself;

c. Captions, coordinates, labels, or other text too small to read - especially in super- and subscripts, tables and on figures;

d. Blurred, smeared, smudged, or other low-contrast areas;

e. Spotty or smeared typeface;

f. Sloppy equations, or other sloppy handwriting or corrections;

g. Large numbers of streaks or dots resulting from poor quality photocopying, especially on figures;

h. Figures which are misaligned or not centered (see below); and

i. More than one layer of tape on top of any printing (see below).

Final Reminders

We have noticed that many "camera-ready" submissions are just that -- very clean and sharp original documents. Equally often, however, we receive non-original photocopies of original typed or laser-printed pages. These submissions are only on occasion clean and sharp. A majority of them suffer from non-optimal copy machine conditions. Dirty glass, streaky toner, and jittery light sources or print tables all contribute to low quality in the final printed pages.

We must adhere to our policy on what is acceptable in order to maintain quality standards. Your paper is at risk if you submit other than original typed or laser-printed pages. We will return any and all originals which you require. **If an article's print quality is poor, we will not publish it until it meets our camera-ready copy requirements.**

WE REPEAT - Do NOT fold final submissions! Use full-size envelopes with cardboard stiffeners.

5. FIGURES

Original figures -- even paste-ups -- are preferred. These original figures will be returned upon request. Do NOT send "nth generation" photocopies.

6. LAY-OUT OF PASTE-UP FIGURES AND CAPTIONS

Additional requirements and suggestions for lay-out of paste-up figures and captions are:

a. Line up all figures and captions parallel to the edges of the paper. (The use of a T-square and drafting table is recommended.)

b. Position (centre) small figures on a page to obtain an eye pleasing layout. Do NOT run all figures to one margin limit if this means that the remaining margins are large, such that the page lay-out is unbalanced.

c. The use of glue-stick or other transparent adhesive is acceptable. However, do NOT use more than one layer of "Frosty cellophane" tape - such as Scotch Magic Tape in the green box - on top of any printing. (By the time we photograph through two layers of frosty tape, the image fuzzes out, and two or more layers mean that we have to dissect the page and re-do it. In addition, we suggest that you use Scotch Removable Magic Tape, which is packaged in a blue box, instead of frosty tape. We find that the Removable Magic Tape simplifies re-positioning, is acceptable optically, and is otherwise convenient.)

d. We will gladly do the lay-out of your pages if you will provide the original to-be-pasted figures on captions, together with your instructions as **to how you want the pages to look**. However, if you choose to lay-out your own figures in final camera-ready form, then place the captions directly on the figures and NOT on a separate page.

To maintain our rapid turnaround policy and our quality standards, it is important that we do NOT waste time re-constructing unsatisfactory lay-outs.

7. OPTIONAL SUBMISSION OF PAPERS ON DISKETTE

You MAY submit an extra copy of your paper on diskette, in addition to the original camera-ready copy. **This is NOT A REQUIREMENT**, but it will enable us to correct typographical and other errors which might otherwise delay publication of your paper. If you choose to submit a diskette, send it to the Managing Editor, together with the original camera-ready copy. For further information regarding acceptable word processors, contact the Managing Editor.

IN SUMMARY - each page must be neat, legible, and photo-offset reproducible. This is most easily achieved if the document submitted is the original print copy and not a photocopy. If you have additional questions concerning this, please contact the Managing Editor, Dr. RW Adler, at:

Naval Postgraduate School,
ECE Dept. Code EC/AB
833 Dyer Road, Room 437
Monterey, CA 93943-5121
USA

Phone: 408-656-2352
Fax: 408-656-2955 or
408-649-0300
e-mail5541304@mcimail.com

<Revised - April 1994>

STYLE REQUIREMENTS FOR *ACES JOURNAL* ARTICLES

The *ACES Journal* is flexible, within reason, in regard to style. However, certain requirements are in effect:

1. The paper title should NOT be placed on a separate page. The title, author(s), abstract, and (space permitting) beginning of the paper itself should all be on the first page. The title, author(s), and author affiliations should be centered (centre-justified) on the first page.

2. An abstract is REQUIRED. The abstract should reflect the content of the paper and should be usable by technical abstracting and indexing services. If applicable, the computer codes and computational techniques (for example, moment method, finite difference time domain, transmission line method, finite element, or modal expansion) discussed in the paper should be stated in the abstract.

3. Either British English or American English spellings may be used, provided that each word is spelled consistently throughout the paper.

4. Any commonly-accepted format for referencing is permitted, provided that internal consistency of format is maintained. As a guideline for authors who have no other preference, we recommend that references be given by author(s) name and year in the body of the paper (with alphabetical listing of all references at the end of the paper). We prefer that names of journals, monographs, and similar publications be in boldface italic font or boldface font (or underlined if these fonts are not available). In addition, we prefer that names of papers and articles be in quotation marks.

5. Internal consistency shall also be maintained for other elements of style, such as equation numbering. As a guideline for authors who have no other preference, we suggest that equation numbers be placed in parentheses at the right column margin.

6. The intent and meaning of all text must be clear. For authors who are NOT masters of the English language, the ACES Editorial Staff will provide assistance with grammar (subject to clarity of intent and meaning).

7. It is RECOMMENDED that figures and tables be placed within the paper, and as close to the relevant text as possible -- especially if the paper is long. However, this is NOT A REQUIREMENT.

8. To economize on space, a section or subsection should NOT begin on a new page if this will result in several lines of unused space on the previous page. (If the previous page has only enough space to accommodate the section or subsection title, in part or in total, then the section or subsection may begin on a new page.)

9. For similar reasons, we prefer that lines be single-spaced (no blank lines between lines of text). However, double spacing should be used for equations, section headings, and section sub-headings, to place a blank line between adjacent lines of text. In addition, double spacing between paragraphs is recommended. If the use of single spacing will "crowd" subscripts and superscripts so that readability is difficult, then one and a half line spacing should be used if possible, to place a blank half-line between adjacent lines of text. Use double spacing only if necessary to maintain readability and one and a half line spacing is not available.

<Revised - April 1994>

COLOR PRINTING COSTS FOR THE ACES JOURNAL AND NEWSLETTER

1. Color Printing of ACES publications is a process involving four separate passes through a printing press with different ink colors; black, magenta (a red), yellow and cyan (a blue).

2. Originals that are in the "Final Form" (all colors present in the correct mix) must be prepared for the press as "Color Seps", meaning that four copies of the page must be prepared by a photographic "color separation" process, producing a black, a magenta, a yellow and a cyan page. These four color seps represent the four passes through the press. ACES' cost of preparing a set of color seps for various size images are:

3"X 4"	$ 65
4"X 6"	$ 80
5"X 8"	$ 95
7"X 9"	$100
9"X11"	$160

3. Additional printing costs, above the standard cost for black and white pages, are:

up to	4 pages	$250/ea.
	8 pages	$160/ea.
	12 pages	$180/ea.
	16 pages	$150/ea.

(The reason for the price variation is that a sheet of paper that is run through the press contains four pages on one side and four pages on the other side. Thus, 12 pages of color is priced at the cost of running one sheet through the color passes on one side (four pages) and running a second sheet through the color passes on both sides (8 more pages).

4. Since the costs for 8 pages are based on the front and back sides of a page in color, the *LAYOUT* of the publication with regard to where in the issue the color pages will be placed is critical. It *IS* possible that eight pages back-to-back will require two partial sheets at a higher cost than for a single sheet, depending on the publication layout sequence of pages.

5. It may be possible to provide a rough estimate of the cost of color pages, but an accurate prediction will require knowledge months before press-time, of nearly all of the papers to be published in a given issue and of the sequence of the papers within the publication, a very unlikely scenario.

6. There is a possibility of the binder folks adding color pages that have been preprinted and provided by the author, but the logistics of knowing exactly which page numbers to have printed on the color pages before the publication goes to press are very difficult to set up. Thus author-provided color page drop-ins are also a very unlikely scenario.

For further clarification, contact Richard W. Adler. Managing Editor, ACES Publications.

THE APPLIED COMPUTATIONAL ELECTROMAGNETIC SOCIETY

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TECHNICAL PROGRAM CHAIRMAN
Ray Luebbers
Department of Electrical Engineering
Pennsylvania State University
University Park, PA 16802
Phone: (814) 865-2362
FAX: (814) 865-7065
Email: lu4@psuvm.psu.edu

SYMPOSIUM ADMINISTRATOR
Richard W. Adler
ECE Dept./Code ECAB
Naval Postgraduate School
833 Dyer Rd. Room 437
Monterey, CA 93943-5121
Phone: (408) 646-1111
FAX: (408) 649-0300
Email: 554-1304@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
Email: eegordon@vm.cc.olemiss.edu

PUBLICITY CHAIRMAN
Paul M. Goggans
EE Dept. Univ. of Mississippi
Anderson Hall, Box 1
University, MS 38677
Phone: (601) 232-5954
FAX: (601) 232-7231
Email: eepmg@cotton.vislab.olemiss.edu

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THE APPLIED COMPUTATIONAL ELECTROMAGNETIC SOCIETY

CALL FOR PAPERS

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- Code validation
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- Computer hardware issues
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  - antennas
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  - shielding
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  - fiberoptics
  - communications systems
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  - wave propagation
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  - bioelectromagnetics
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  - propagation through plasmas
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- Partial list of techniques:
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  - integral equation & differential equation techniques
  - finite differences & finite element techniques
  - diffraction theories
  - modal expansions
  - hybrid methods
  - physical optics
  - perturbation methods
  - moment methods

INSTRUCTIONS FOR AUTHORS AND TIMETABLE

For both summary and final paper, please supply the following data for the principal author: name, address, Email address, FAX, and phone numbers for both work and home.

October 3, 1994: Submission deadline. Submit four copies of a 300-500 word summary to the Technical Program Chairman.
November 18, 1994: Authors notified of acceptance.
December 23, 1994: Submission deadline for camera-ready copy. The papers should not be more than 8 pages long including figures.

Registration fee per person for the Symposium will be approximately $235 for ACES members and $260 for non-ACES members. The exact fee will be announced later.

SHORT COURSE

Short courses will be offered in conjunction with Symposium covering numerical techniques, computational methods, surveys of EM analysis and code usage instruction. It is anticipated that short courses will be conducted principally on Monday March 20 and Friday March 24. Fee for a short course is expected to be approximately $90 per person for a half-day course and $140 for a full-day course, if booked before March 3, 1995. Full details of 1995 Symposium will be available by November 1994.

EXHIBITS

Vendor booths and demonstrations will feature commercial products, computer hardware and software demonstrations, and small company capabilities.

For information regarding ACES or to become a member in the Applied Computational Electromagnetics Society, contact Dr. Richard W. Adler, ECE Department, Code ECAB, Naval Postgraduate School, 833 Dyer Rd, Rm 437, Monterey, CA. 93943-5121, telephone (408) 646-1111, Fax: (408) 649-0300, E-mail:554-1304@mcimail.com. You can subscribe to the Journal and become a member of ACES by completing and returning the form below.

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