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NEWSLETTER

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ACES NEWSLETTER STAFF

EDITOR-IN-CHIEF, NEWSLETTER
Bruce Archambeault
IBM
3039 Cornwallis Road
B306 Dept 18 DA
Research Triangle Park, NC 27709
Phone: 919-486-0120
email:barch@us.ibm.com

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

EDITOR-IN-CHIEF, PUBLICATIONS
Andrew Peterson
Georgia Institute of Technology, ECE
777 Atlantic Drive
Atlanta, GA 30332-0250
Phone: 404-894-4697
Fax: 404-904-5935
email:peterson@ee.gatech.edu

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

EDITORS

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

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

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

PERSPECTIVES IN CEM
Manos M. Tentzeris
Georgia Institute of Technology
ECE Dept.
Atlanta, GA 30332-0250
Phone: (404) 385-0378
email:etentze@ece.gatech.edu

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

TUTORIAL
J. Alan Roden
IBM Microelectronics
Dept. OSXA
3039 Cornwallis Road
Research Triangle Park, NC 27709
Phone: (919) 543-8645
email:jaroden@us.ibm.com

ACES JOURNAL

EDITOR-IN-CHIEF
Atef Elsherbeni
EE Department, Anderson Hall
University of Mississippi
University, MS 38677 U.S.A.
Phone: (662) 915-5382
email:atef@olemiss.edu

NEWSLETTER ARTICLES AND VOLUNTEERS WELCOME

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

AUTHORSHIP AND BERNE COPYRIGHT CONVENTION

President's Post

During the past two decades, computer modeling and numerical methods have matured as problem-solving tools in real-world electromagnetics applications. ACES was formally chartered and incorporated as a non-profit organization in 1986 with the second annual review of progress held at NPS in Monterey, CA. Now, 18 years later, ACES is an international, inter-disciplinary, professional society, with a wide range of activities and services. The interdisciplinary scope of ACES is pivotal to maintaining "cross-fertilization" between the high-frequency and low-frequency applications.

ACES activities and services have expanded to include canonical problem solution workshops and code user groups, the newsletter, the journal, the annual symposium in addition to the software exchange and software performance standards activities. At the symposia, short courses and software demonstrations are offered. The ACES Journal is administered by an international editorial board with members from around the world.

ACES is not immune to the changes most companies and institutions face in times of accelerating technological and social shifts. Electronic dissemination of information is changing our interface with the society members and is changing the way we will distribute our products and services. This represents an opportunity for us to increase the value of ACES membership in general as well as to organizational groups such as industry and government institutions. We need to understand what member value is today and what it should be in the future to ensure that we continue to serve industry and the Computational Electromagnetics Community.

With more of our information coming from the Internet, we need to offer a full range of electronic products and services. ACES needs to be the first source for its members to go for information. We must help the member identify the right information and then provide appropriate access to it. On this front, some good things for ACES have been achieved, which will have a lasting beneficial effect for ACES members. The realization of a professional quality ACES Web site "ACES Online" is a significant accomplishment. This site represents an excellent information source and home to some powerful electronic publishing and software tools. We thank our colleague Dr. Atef Elsherbeni for his leadership in accomplishing this project.

During this year's annual ACES symposium held last March in Monterey CA, the ACES board of directors approved the creation of the Member Communications Committee. Our colleague Dr. Vicente Rodriguez accepted the nomination of being the Chair of this Committee. The objective of this Committee is to keep the members informed about the society's plans and goals, in a timely manner through monthly communication. This activity will keep ACES members updated via electronic mail through ACES web site. In this way it is expected that a more frequent channel of communication will be opened between ACES members and the board of directors. In the near future, additional e-mail alerting service will be generated automatically to inform members about new titles or software of interest with direct link to the source on the ACES website.

We also need to improve our focus on industry and government agencies and increase the relevancy of ACES to these organizations. This can take many forms such as publications and products that give practical information. We could also focus on professional networking by facilitating communications among practitioners in specialized technical areas in the applied electromagnetics field. Starting with upcoming ACES annual symposium to be held March 24-28, 2003 at NPS in Monterey, CA, panel sessions and invited paper sessions from industry will be organized. Also, the software exhibit will be expanded and the number of interactive presentations will be increased. Furthermore, social functions will be increased during the conference to give industrial participants and other attendees amble time for networking and discussions.

ACES also need to increase its continuing education focus. For industrial members and their managers, continuing education is very important to keep up to date and may be fill a need of acquiring professional development hours (PDH) required to maintaining licensure. ACES offer a number of short courses before and after the annual conference with a great deal of educational materials. Also, plenary presentations and record of panel sessions make valuable educational materials at our conferences. This material could be collected and presented online or in other format such as a CD and be made available as products. These continuing education initiatives, if implemented, will have the potential to be of major value to ACES members in the future and will help attract new members and industrial organizations.

The overall future of ACES is very bright and we can be valuable in our members. The key for us is to utilize the opportunities inherent in the dramatic changes in our world and our technology. Relevance to our members with products and services will increase membership and enhance attendance at the annual symposium. I will continue to promote ACES on all fronts and increase communication and cooperation with other organizations. We must all work together if we are to grow and prosper.

O. A. Mohammed

President, ACES

PERMANENT STANDING COMMITTEES OF ACES INC.

COMMITTEE	CHAIRMAN	ADDRESS
NOMINATIONS	Rene Allard	Penn State University 321 Oakley Drive State College, PA 16803
ELECTIONS	Rene Allard	Penn State University 321 Oakley Drive State College, PA 16803
FINANCE	Allen Glisson	University of Mississippi 20 Anderson Hall, Box 1848 University, MS 38677
PUBLICATIONS	Andrew Peterson	Georgia Institute of Technology School of ECE Atlanta, GA 30332-0250
CONFERENCE	Osama Mohammed	Florida International University Room EAS-3983 Miami, FL 33174
AWARDS	Pat Foster	MAAS 16 Peachfield Road Great Malvern, UK WR14 4AP

MEMBERSHIP ACTIVITY COMMITTEES OF ACES INC.

COMMITTEE	CHAIRMAN	ADDRESS
SOFTWARE VALIDATION	Bruce Archambeault	IBM barcj@us.ibm.com
HISTORICAL	Robert Bevensee	BOMA Enterprises rmbevensee@cs.com
INDUSTRIAL RELATIONS	Andrew Drozd	Andro Consulting a.1.drozd@ieee.org
MEMBERSHIP COMMUNICATIONS	Vicente Rodriguez	ETS rodriguez@ieee.org

Publications Committee Report

At the March conference, the Board of Directors spent quite a bit of time discussing the growing costs associated with our publications and ways to control those costs. As those of us in the United States know only too well, postage costs continue to grow by leaps and bounds. Overall, postage makes up at least half of the cost of providing publications to ACES members.

After a lengthy discussion, the Board voted to make some fundamental changes in the way that our publications operate. Beginning sometime this year, the ACES Newsletter will be distributed via web access. ACES members will be able to sign onto the ACES web page, and use their password to access the Newsletter (see your membership card for your member number/password!). Members who are unable to access the web page should contact Dick Adler to arrange for another mode of delivery. In any case, ACES will no longer publish a nicely-bound Newsletter in paper form.

Beginning in 2003, the default subscription for the ACES Journal will also become electronic, via CD-ROMs mailed to members three times per year. Paper copies will still be printed (and nicely bound) for our institutional members (libraries) and for those individual members willing to pay the actual cost for paper copies. However, the Board hopes to phase out paper copies for members over the next few years. It may be possible to move to a system where the Journal will also be web-based, reducing the need to mail multiple CD-ROMs to members each year.

These changes are expected to result in significant cost savings for ACES, and in return ACES members should expect to see a dues reduction effective in 2003.

I encourage each of you to continue to submit useful articles to both the ACES Newsletter and ACES Journal during this transition period, and please encourage others that you know to do the same.

Professor Andrew F. Peterson
School of Electrical & Computer Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0250
USA

(404)-894-4697 (office)
(770)-454-9557 (home)
(404)-894-4641 (shared department FAX)
peterson@ee.gatech.edu

Biographical Sketch of
Osama A. Mohammed

Dr. Osama A. Mohammed is the current president ACES since March 2002 and was ACES vice president last year. He has been on ACES BoD for the past three years. Dr. Mohammed has been a long time active member of ACES and its journal editorial board as well as a recipient of ACES service award. As president of ACES, he started new programs and activities to enhance the annual conference and membership services and make an effort to bring industry and government agencies into the ACES conference and its activities.

Dr. Mohammed is a Professor of electrical and computer engineering at Florida International University, Miami, Florida. He received his Master of Science and Ph.D. degrees in Electrical Engineering from Virginia Tech., Blacksburg, Virginia in 1980 and 1983, respectively. He has many years of teaching, curriculum development, research and industrial consulting experience. He authored and co-authored more than 175 technical papers in the archival literature as well as in National and International Conference records. In addition, he has several book chapters, edited volumes, numerous technical and project reports and monographs to his credit. He specializes in Electromagnetic Field Computations in Nonlinear Devices, Design Optimization of Electromagnetic Devices, Artificial Intelligence Techniques and their Applications to Electromagnetic Systems.

He received many awards for excellence in research, teaching and service to the profession. Dr. Mohammed is a Fellow of IEEE. Professor Mohammed was the General Chairman of the 1993 COMPUMAG, October 31- November 4, 1993, and was Vice-Chairman of COMPUMAG-RIO, November 3-7, 1997. He was also the General Chairman of the 1996 IEEE International Conference on Intelligent Systems Applications to Power Systems (ISAP'96), Orlando, Florida, January 28-February 2, 1996 as well as the General Chairman of the 1994 IEEE Southeastcon, Miami, Florida, April 10-13, 1994. He also was a member of the technical program committee for the 1996 IEEE/CEFC conference, Okayama, Japan, and a member of the International Steering Committee for the ISEM conferences, and the 1997 (IEEE-IEMDC), Milwaukee, Wisconsin. May 18-21, 1997. Dr. Mohammed was the editorial board chairman for the 2000 IEEE/CEFC conference, June 4-7, 2000 and the editor of the associated issue of the IEEE Transactions on Magnetics. In addition, Professor Mohammed is an editor of the IEEE Transactions on Energy Conversion and currently serves on several other technical programs and editorial boards. Furthermore, he chaired sessions and programs in numerous National and International Conferences and has delivered numerous invited lectures and tutorials at scientific organizations worldwide.

Professor Mohammed serves on several IEEE committees and boards. He is the Chairman of the Miami Section of IEEE as well as the past chairman of the Florida Council of IEEE. He was a member of the IEEE/PES Governing Board (1992-1996) and he is a currently on the board as chairman of the constitution and bylaws committee chair. He currently serves as chairman, officer or as an active member on several IEEE society committees, sub-committees and technical working groups.

2003 ELECTION FOR ACES BOARD OF DIRECTORS

CANDIDATE STATEMENTS

COLIN BRENCH

GENERAL BACKGROUND

Colin Brench is a Principal Member of the Technical Staff at Hewlett Packard Corporation, formerly Compaq Computer Corporation, formerly Digital Equipment Corporation, and has been responsible for EMC product design since first joining the company in 1986. Since 1995, he has lead the effort to develop Digital's (and Compaq's) computational electromagnetic compatibility modeling capability.

Colin is a co-author of the book, *EMI/EMC Computational Modeling Handbook*, (Kluwer Academic, 1st Edition 1998, and 2nd Edition 2001), and has authored over 20 technical papers and articles. In addition, he holds ten patents for various methods of EMI control. He is a NARTE certified EMC Engineer, a member of the IEEE EMC Society, and is active in the TC-9 and ANSI ASC63 SC-1 committees. In March of 2001, Colin was appointed a Distinguished Lecturer for the IEEE EMC Society.

At Digital / Compaq, Colin's involvement in EMC design has ranged from the microprocessor through to completed systems. His patents reflect this inclusive approach to EMC, and include VLSI packaging techniques for minimizing emissions at the source, isolation techniques, and practical methods of constructing shielded enclosures from suitably treated plastics. Specific products include small desktop workstations and servers, network products, and the much larger high-end servers and high performance technical computers that are currently his primary responsibilities.

Prior to this, Colin was with Applicon, Inc. for 6 years, where he was responsible for the formation and operation of the Compliance Engineering Department, and the compliance of all products to the regulatory standards including EMC design and testing, and UL compliance. He also formed his own consulting business, DJR Associates, where he provided EMC design and supported testing to FCC, VDE, and MIL-461, as well as providing analog circuit and power supply designs.

Colin has been active in the area of antennas and EMC since the early 1970's. From 1975 to 1979, at McMichael Ltd. and GTE Sylvania, he evaluated various antennas, waveguide structures, and designed power supplies with specialized EMC requirements.

In June 1975, he earned his B.Sc.(Hons) in Electronic Engineering at The City University in London, England. His thesis was entitled the "Design and Construction of a VHF SSB Transceiver". He was also active in amateur radio from 1967 to 1978, and had the call sign: G8DJR.

PAST SERVICE TO ACES

Colin first began presenting papers at the ACES Annual Reviews in 1990. He is an active member of the IEEE EMC Society, Technical Committee 9 (EMCS TC9). TC9 is a committee focused on all aspects of computational electromagnetics for EMI and EMC work. Colin's primary focus has been to help bridge the gap between those developing computational tools and the EMC engineering communities. In this role he has written columns for the IEEE EMC Society newsletter on CEM, and for the ACES newsletter on EMC. He has given a number of presentations at workshops on EMI modeling for the IEEE EMC symposia and at the 2002 ACES annual conference.

CANDIDATE'S PLATFORM

ACES continues to provide a focus for those with a wide range of skills in computational electromagnetics. At the annual conference it is clear that there are many application areas of interest. Today's engineers have unprecedented computational power available, if not in their brief cases then at the office. It would seem to be a natural extension of this capability that engineers would begin to utilize computational techniques; there is however still significant resistance to this. ACES is in a unique position to help with this situation, not only by emphasizing the "Applied" in ACES, but also by providing training.

As a member of the ACES BoD, I would drive to expand the visibility of ACES beyond those associated directly with EM theory, algorithms, and codes, to reach those who focus on measurement and experiment. Of particular interest is the area of EMC. I believe that the maturity of both CEM and personal computers are such that strides can now be taken to bring about significant changes in this field.

DR. CHARLES F. BUNTING

GENERAL BACKGROUND

Charles F. Bunting was employed at the Naval Aviation Depot in Norfolk, VA as an apprentice, an electronics mechanic, and an electronics measurement equipment mechanic from 1981-1989. He received his A.A.S. in Electronics Technology from Tidewater Community College in 1985, the B.S. degree in Engineering Technology with highest honors from Old Dominion University in 1989. He received the M.S. degree in Electrical Engineering from Virginia Polytechnic Institute and State University (Virginia Tech) in 1992. He participated in the development of a test fixture for temperature and humidity measurements for microwave characterization of stripline structures and investigated surface roughness effects on propagation in stripline structures. His thesis title: Issues Related to Finite Element Techniques for Two-Dimensional Transmission Structures. From 1991-1994 Dr. Bunting held a Bradley Fellowship and a DuPont Fellowship. He developed a robust functional to eliminate false solutions in full field formulations and developed a two-dimensional random mesh generator for numerical computations. In 1994 he was awarded the Ph.D. in Electrical Engineering from Virginia Tech. Dissertation title: Functionals in Electromagnetics - An Investigation into Methods to Eliminate Spurious Solutions in the Application of Finite Element Techniques.

From 1994 to 2001 Dr. Bunting was an assistant/associate professor at Old Dominion University in the Department of Engineering Technology where he worked closely with NASA Langley Research Center on electromagnetic field penetration in aircraft structures and reverberation chamber simulation using finite element techniques. The chief focus of the computational electromagnetics effort was in the development of finite element software to solve the large EM problem associated with reverberation chamber simulation for both deterministic and eigenvalue problems.

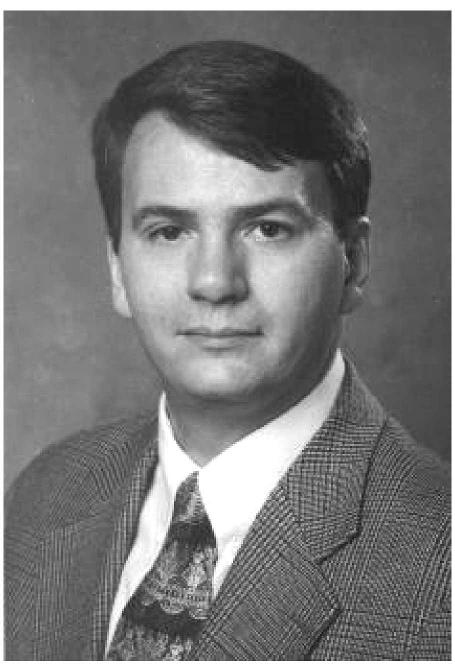
In the Fall of 2001 he joined the faculty of Oklahoma State University as an associate professor. His chief interests are fundamental variational principles and computational electromagnetics, statistical electromagnetics, electromagnetic characterization and application of reverberation chambers, and the analysis of optical and microwave structures using numerical methods including finite element techniques. He is applying moment methods for antenna interactions in the reactive reverberation chamber environment, finite difference time domain techniques for field penetration studies, and finite element methods for the statistical characterization of electromagnetic reverberation chambers.

CANDIDATE'S PLATFORM

The candidate has been assisting the ACES Newsletter Editor in the migration of the newsletter to an email/WEB based publication. The candidate is the Webmaster for the IEEE EMC Computational Electromagnetics Society and is responsible for EMI Modeling Web page link that is accessed from the ACES web site. Modernization of electronic resources and maintaining strong interactions with industry, government, and academia are the key to demystifying the role and capabilities of computational electromagnetics. Several mailing lists are available that promote the interchange of questions and solutions (SuperNEC and Sonnet both have listserve-like lists that help users with Q&A). Tighter integration of these communication resources with ACES resources would better serve the overall EM community.

A clear discrimination between the strengths and limitations of current EM techniques (integral equation based versus differential equation based for example) must go beyond personal preferences to the particular suitability of the method to the problem. A direct effort in unbiased comparisons must be made. Another important focus of applied computational EM is the connection of the simulation to the experimental observable (eg. scattering parameters). ACES is the venue that is best suited to address these practical issues in a manner that provides REAL answers to the questions: What am I simulating? How can I verify it? Is this the best way to approach this problem? Do I really need this tool, or would that one work better, and why?

DR. LEO KEMPEL



GENERAL BACKGROUND

Leo Kempel was born in Akron, OH, in October 1965. He earned his B.S.E.E. at the University of Cincinnati in 1989 and participated in the cooperative education program at General Dynamics/Fort Worth Division. He earned the M.S.E.E. and Ph.D. degrees at the University of Michigan in 1990 and 1994, respectively.

After a brief Post-Doctoral appointment at the University of Michigan, Dr. Kempel joined Mission Research Corporation in 1994 as a Senior Research Engineer. He led several projects involving the design of conformal antennas, computational electromagnetics, scattering analysis, and high power/ultrawideband microwaves. He joined Michigan State University as an Assistant Professor in 1998 where he is conducting research in computational electromagnetics and electromagnetic materials characterization, teaching undergraduate and graduate courses in electromagnetics, and supervising the research of several M.S. and Ph.D. students. Prof. Kempel's current research interests include computational electromagnetics, conformal antennas, microwave/millimeter wave materials, mixed-signal electromagnetic interference techniques, and measurement techniques. Prof. Kempel has been awarded a CAREER award by the National Science Foundation and the Teacher-Scholar award by Michigan State University in 2002. He also received the MSU College of Engineering's Withrow Distinguished Scholar (Junior Faculty) Award in 2001.

Dr. Kempel served as the Chapter IV Vice-Chair for the Southeast Michigan chapter of the IEEE as well as the technical chairperson for the 2001 ACES Conference. He has organized several sessions at recent URSI and ACES meetings. He is an active reviewer for several IEEE publications as well as JEWA and Radio Science. He co-authored *The Finite Element Method for Electromagnetics* published by IEEE Press. Dr. Kempel is a member of Tau Beta Pi, Eta Kappa Nu, ACES, Commission B of URSI, and is a Senior Member of IEEE.

PAST SERVICE TO ACES

Leo has been a member of ACES for a number of years. He has presented papers, organized sessions, served as Vendor Chairperson for the 2000 meeting, Technical Chairperson for the 2001 meeting, and Co-Chairperson for the 2002 meeting.

CANDIDATE'S PLATFORM

Leo is interested in evolving the society in to an organization with broader appeal. Over the past few years, the society has done very well at encouraging international participation in the meetings and at providing Internet-based information to the society and electromagnetic community as a whole. However, recent changes in the world have adversely impacted the annual meeting's attendance. In particular, over the years the number of military and Department of Defense industrial engineers and scientists has reduced. I am committed to working with the society and conference management to improve the appeal for DoD and industrial attendees. Specific ideas include recruiting DoD-based session organizers who will have the charter of creating sessions that review non-sensitive CEM-related research. For example, as session on High Performance Computing (HPC) results would be welcome. We need to make presentation and participation by military researchers (and their industrial support staff) at ACES a critical part of their research mission and career development.

I am also interested in increasing the number of students associated with ACES and participating in the annual meeting. This may include the establishment of student branches with periodic, ACES-endorsed seminars by and for students. The idea is that we want to excite every CEM student with ACES and keep them after they have graduated. Experience has shown that as we transition throughout our careers, we need to chose organizations to support if for nothing else as a time-management tool. ACES should strive to the first society for all CEM researchers beginning with their student days.

OTHER UNIQUE QUALIFICATIONS

Leo has touched on three of the four pillars of ACES membership (U.S. Government, industrial, academic, and international members). After graduating from Michigan, he worked for four years in a small DoD-sponsored research company. After that period, he returned to academia and has continued to support the DoD, industry, as well as NSF and other Federal research agencies. Hence, he understands the unique needs and capabilities of the military, industrial, and academic research and development communities and is prepared to tap all of them to strengthen ACES for the future. He also looks forward to meeting more international members, understanding their concerns and talents, and hence fostering an environment of excitement amongst all four pillars of ACES.

DR. OSAMA A. MOHAMMED

GENERAL BACKGROUND

Dr. Osama A. Mohammed is the current President of ACES since March 2002 and is a Fellow of IEEE. Dr. Mohammed is a Professor of electrical and computer engineering at Florida International University, Miami, Florida. He received his Master of Science and Ph.D. degrees in Electrical Engineering from Virginia Tech., Blacksburg, Virginia in 1980 and 1983, respectively. He has many years of teaching, curriculum development, research and industrial consulting experience. He authored and co-authored more than 175 technical papers in the archival literature as well as in National and International Conference records. In addition, he has several book chapters, edited volumes, numerous technical and project reports and monographs to his credit. He specializes in Electromagnetic Field Computations in Nonlinear Devices, Design Optimization of Electromagnetic Devices, Artificial Intelligence Techniques and their Applications to Electromagnetic and Energy Systems. He is also interested in low power design considerations for Digital Mobile Telecommunication Applications

He received many awards for excellence in research, teaching and service to the profession. Dr. Mohammed is a Fellow of IEEE. He has extensive experience in organizing major national and international conferences. Professor Mohammed was the General Chairman of the 1993 COMPUMAG, October 31- November 4, 1993, and was Vice-Chairman of COMPUMAG-RIO, November 3-7, 1997. He was also the General Chairman of the 1996 IEEE International Conference on Intelligent Systems Applications to Power Systems (ISAP'96), Orlando, Florida, January 28-February 2, 1996 as well as the General Chairman of the 1994 IEEE Southeastcon, Miami, Florida, April 10-13, 1994. He also was a member of the technical program committee for the 1996 IEEE/CEFC conference, Okayama, Japan, and a member of the International Steering Committee for the ISEM conferences, and the 1997 (IEEE-IEMDC), Milwaukee, Wisconsin. May 18-21, 1997. Dr. Mohammed was the editorial board chairman for the 2000 IEEE/CEFC conference, June 4-7, 2000 and the editor of the associated issue of the IEEE Transactions on Magnetics. In addition, Professor Mohammed is an editor of the IEEE Transactions on Energy Conversion and currently serves on several other technical programs and editorial boards.

Furthermore, he chaired sessions and programs in numerous National and International Conferences and has delivered numerous invited lectures and tutorials at scientific organizations worldwide.

Professor Mohammed serves on several IEEE committees and boards. He is the Chairman of the Miami Section of IEEE as well as the past chairman of the Florida Council of IEEE. He was a member of the IEEE/PES Governing Board (1992-1996) and he is a currently on the board as chairman of the constitution and bylaws committee. He currently serves as chairman, officer or as an active member on several IEEE society committees, sub-committees and technical working groups.

PAST SERVICE to ACES

Dr. Mohammed is the current President of ACES since his election by the ACES BoD in March 2002. He was ACES vice president last year and he started a study on how ACES could get involved in short courses and tutorials that could be offered in electronic and web-based format. He is currently concentrating on enhancing the ACES annual conference and increasing industrial and government activities and participation in ACES. He is also concentrating on increasing the value of membership in ACES by enhancing services, communication with members as well as the conference format. He has already introduced several changes to the ACES conference format and its publicity as well as member communications. Dr. Mohammed has been on ACES BoD for the past three years. He has organized sessions and presented papers at many of the ACES conferences. Dr. Mohammed has been a long time active member of ACES and its journal editorial board as well as a recipient of ACES service award.

CANDIDATE'S PLATFORM

As the current president of ACES, for only the past two month, I have developed a vision statement that simply say "*ACES will strive to be the main venue for the CEM community that is best suited for theorists, experimentalists and practitioners*". During the past two decades, computer modeling and numerical methods have matured as problem-solving tools in real-world electromagnetics applications. The interdisciplinary scope of ACES is pivotal and should be directed towards maintaining "cross-fertilization" between the high-frequency and low-frequency applications as well as to experimentation and practice.

In addition to the services that ACES now offer its members, we must introduce modifications that would enhance member services and improve attendance and format of the ACES annual conference. The ACES Journal should become widely distributed, referenced and utilized by the CEM community worldwide.

In times of accelerating technological and social shifts, ACES services should be modified to deal with these changes. Electronic dissemination of information is changing our interface with the society members and is changing the way we will distribute our products and services. This represents an opportunity for us to increase the value of ACES membership in general as well as to organizational groups such as industry and government institutions in particular. We need to understand what member value is today and what it should be in the future to ensure that we continue to serve industry and the CEM community. With more of our information coming from the Internet, we need to offer a full range of electronic products and services. ACES needs to be the first source for its members to go for information. We must help the member identify the right information and then provide appropriate access to it.

We also need to improve our focus on industry and government agencies and increase the relevancy of ACES to these organizations. This can take many forms such as publications and products that give practical information such as standards. We could also focus on professional networking by facilitating communications among practitioners and experimentalists in specialized technical areas in the applied electromagnetics field.

ACES also need to increase its continuing education focus. For industrial members and their managers, continuing education is very important to keep up to date and may fill a need of acquiring professional development hours (PDH) required to maintaining licensure as well as it could be a source of income for the society.

The overall future of ACES is very bright and we can be valuable in our members. ACES can be extremely relevant if we work hard and execute the above items in our vision. The key for us is to utilize the opportunities inherent in the dramatic changes in our world and our technology. Relevance to our members with products and services will increase membership and enhance attendance at the annual symposium. As ACES president and BoD member I will continue to promote ACES on all fronts; work towards tasks outlined in our vision and increase communication and cooperation with other organizations.

DR. OMAR RAMAHI

GENERAL BACKGROUND

Omar M. Ramahi received the BS degrees in Mathematics and Electrical and Computer Engineering, with highest honors, from Oregon State University, Corvallis, OR in 1984. He received his M.S. and Ph.D. in Electrical and Computer Engineering in 1986 and 1990 respectively from the University of Illinois at Urbana-Champaign. From 1990-1993, he held a visiting fellowship position at the University of Illinois at Urbana-Champaign including a one-year appointment as a Postdoctoral Fellow working with the Professor Y. T. Lo on microstrip antenna problems. In 1993, he joined Digital Equipment Corporation as a member of the Technology Development Group. In 1994 he became a member of the alpha server product development group at the same company. In August of 2000, he joined the faculty of the A. James Clark School of Engineering at the University of Maryland at College Park, where he presently holds a faculty appointment in the Mechanical Engineering Department and an affiliate appointment in the Electrical and Computer Engineering Department. Professor Ramahi is also a faculty member of CALCE Electronics Products and Systems Center at the University of Maryland.

Dr. Ramahi served as a consultant to several companies. He was instrumental in developing computational techniques to solve a wide range of electromagnetic radiation problems in the fields of antennas, high-speed devices and circuits and EMI/EMC. He has developed computational electromagnetic codes based on the Method of Moments, the Finite Element method, the Finite-Difference Time-Domain method, amongst others. His interests include theoretical, experimental and computational EMI/EMC studies, high-speed devices and interconnects, biomedical applications of electromagnetics, novel optimization techniques, interdisciplinary studies linking electromagnetic application with new materials. He has authored and co-authored over 110 journal and conference papers and presentations. He is a co-author of the book *EMI/EMC Computational Modeling Handbook,* 2nd Ed., (Kluwer Academic, 2001). Dr. Ramahi is a member of Eta

Kappa Nu and Tau Beta Pi honor societies. He is also a Senior Member of IEEE and a member of the Electromagnetics Academy.

PAST SERVICE TO ACES

The candidate's past service to ACES includes presentation of numerous papers, organization of special sessions for the ACES Symposia and participation as short course instructor.

CANDIDATE'S PLATFORM

The field of electromagnetism (EM) is probably one of the very few fields in applied science that has reached a high level of maturity. Computational electromagnetism, which is considered the applied side of electromagnetism, has witnessed an explosive growth in the past fifteen years. Today, we have numerical algorithms that can characterize wave-matter electromagnetic interaction with a high degree of accuracy and with sufficient speed. Despite the maturity in both theoretical and computational electromagnetism, the application of computational EM to new technological frontiers remain in its infancy. For instance, in the emerging field of nanotechnology, sensors, biomedical devices, amongst others, electromagnetism is expected to play a significant role. For computational EM practitioners, the primary challenge is in the fact that these new technologies are driven by strong interdisciplinary research teams that are typically devoid of computational EM experts. Interestingly enough, the classical EM practitioner paradigm has changed. Instead of using computational EM to solve known problems, we need to look at applications that can be designed by harvesting the power of EM with the aid of computational EM.

Having the vintage point of working with mechanical, electrical, and aerospace engineers in the emerging technologies, I have the advantage of identifying new and significant applications of computational EM and bring these applications to the EM community through ACES. Furthermore, bringing a strong focus to ACES activities and seminars would be a priority. Despite the plethora of symposia and technical societies involved in electromagnetics, there is a distinct place for a society, such as ACES, which is devoted exclusively to practical computational electromagnetics. For this reason, ACES needs to have a strong focus through symposia and published media that reinforces its distinct thrust. The ACES annual meeting has been suffering in the past few years from lower attendance than in the earlier years. This phenomenon needs to be addressed and structural changes might become necessary to maintain the vitality, strength and relevance of ACES. These are some of the issues that I like to address if I become a Board Member.

DR. TAPAN SARKAR

GENERAL BACKGROUND

Tapan Kumar Sarkar received the B. Tech. degree from the Indian Institute of Technology, Kharagpur, India, in 1969, the M.Sc.E. degree from the University of New Brunswick, Fredericton, Canada, in 1971, and the M.S. and Ph.D. degrees from Syracuse University; Syracuse, New York in 1975.

From 1975 to 1976 he was with the TACO Division of the General Instruments Corporation. He was with the Rochester Institute of Technology, Rochester, NY, from 1976 to 1985. He was a Research Fellow at the Gordon McKay Laboratory, Harvard University, Cambridge, MA, from 1977 to 1978. He is now a Professor in the Department of Electrical Engineering and Computer Science, Syracuse University; Syracuse, NY. His current research interests deal with numerical solutions of operator equations arising in electromagnetics and signal processing with application to system design. He obtained one of the "best solution" awards in May 1977 at the Rome Air Development Center (RADC) Spectral Estimation Workshop. He has authored or co-authored innumerable journal articles and numerous conference papers and has written chapters in ten books including the latest one "Iterative and Self Adaptive Finite-Elements in Electromagnetic Modeling" which was published in 1998 by Artech House. He has published eight general purpose computer programs through Artech House which deal with various aspects of radiation and scattering analysis from composite structures, analysis of printed circuits, transient and steady state responses of nonlinearly loaded transmission lines and so on. He is a distinguished lecturer (2000-2002) for the IEEE Antennas and Propagation Society.

Dr. Sarkar is a registered professional engineer in the State of New York. He received the Best Paper Award of the IEEE Transactions on Electromagnetic Compatibility in 1979 and in the 1997 National Radar Conference. He was an Associate Editor for feature articles of the IEEE Antennas and Propagation Society Newsletter, and he was the Technical Program Chairman for the 1988 IEEE Antennas and Propagation Society International Symposium and URSI Radio Science Meeting. He is on the editorial board of Journal of Electromagnetic Waves and Applications and Microwave and Optical Technology Letters. He has been appointed U.S. Research Council Representative to many URSI General Assemblies and was the Chairman of the Intercommission Working Group of International URSI on Time Domain Metrology (1990-1996). He has served on the ACES board of directors from (2000-2003). Dr. Sarkar is a member of Sigma Xi and International Union of Radio Science Commissions A and B. He received the title Doctor Honoris Causa from Universite Blaise Pascal, Clermont Ferrand, France in 1998.

PAST SERVICES TO ACES

The candidate has contributed to both invited and survey papers to the ACES conference, journal, on the board of directors (2000-2003) and has actively supported exhibit booth at the ACES conferences. In addition, sessions were also organized in the last two ACES conferences.

CANDIDATE'S PLATFORM

The strength of ACES lies in the following areas:

1. Providing a more pragmatic and user-oriented approach to computational electromagnetics thereby providing a strong coupling between the code users and the code developers.

2. Providing focussed articles, which are more practical and more meaningful to the users.

3. Providing an open forum with an extended summary of the presentations, which make it very convenient for a reader to understand what the speaker talked about in the conference long after the conference, is over.

Therefore to continue along the niche areas of strengths of ACES, my participation in the past had been to organize technical sessions along these themes, particularly on use of electromagnetic simulation codes. An attempt was made to delineate pros and cons of some of the commonly used codes so that light can be generated without heat. If selected again, I shall continue my efforts in this direction and might increase the technical scope in generating tutorial articles on this topic from experienced scientists belonging to this community.

In summary, the strength of ACES lies in building a stronger connection between the code developers and the users and that should be further enhanced. This is what I propose to strengthen further.

OTHER UNIQUE QUALIFICATIONS

I believe I can create a stronger link between the CEM theoreticians and the users by making an attempt to reorient the theoreticians into looking at the solution of a CEM applications from a practical pragmatic standpoint. In addition valuable information can be gained from such interactions between researchers of such diverse background as we have tried to follow the same philosophy during the last decades by not only developing computer codes but also making them user friendly for researchers who are not familiar with them.

Two-Dimensional TM and TE FDTD Codes with Visualization

Allen W. Glisson[1] aglisson@olemiss.edu

Atef Z. Elsherbeni[1] atef@olemiss.edu

Chun-Wen P. Huang[2] cwhuang@anadigics.com

[1]Dept. of Electrical Engineering
University of Mississippi
University, MS 38677

[2]Anadigics, Inc.
35 Technology Drive
Warren, NJ 07059

Introduction

This paper describes the use of two available two-dimensional Finite Difference Time Domain (FDTD) codes with visualization capabilities that have been developed primarily for educational use. The programs animate time domain scattering by a two-dimensional material geometry excited either by a *z*-directed electric current line source in the TM case (*tmpml*) or by a *z*-directed magnetic current line source in the TE case (*tepml*). A fairly general scattering geometry can be described by defining various regions with different isotropic constitutive parameters. The perfectly matched layer (PML) absorbing boundary condition is applied at the computational boundaries. The codes are available from the ACES web site http:/aces.olemiss.edu.

Code Components and System Requirements

The two programs and their associated example input data files comprise the following ten files:

tmpml.exe	tepml.exe
tmpml.dim	tepml.dim
tmpml.geo	tepml.geo
tmpml.vwc	tepml.vwc
tmpml.ind	tepml.ind

The codes were compiled with Compaq Visual Fortran version 6.6 and use the Compaq Array Viewer version 1.6. They have been tested under Windows 2000. In addition, if the machine on which the programs are to run does not have the Compaq Array Viewer installed, the user must obtain and install the Compaq Array Viewer Demo program. This “demo” is available on the web at http://www.compaq.com/fortran/

If the user already has the Compaq Array Viewer installed, he should verify that the DLL file aview160.dll is in the Windows System directory.

Program Usage

The programs *tmpml.exe* and *tepml.exe* are "Fortran Console Applications" that run in a Command Prompt window. The user interacts with the FDTD program through keyboard input to the Command Prompt window. However, when so instructed by appropriate input data, the program invokes the Compaq Array Viewer for visualization of the solution. The Array Viewer program is a native Windows program. The user can interact with the Array Viewer program as with most Windows programs to change viewing angle, display method, plot parameters, etc.

The programs *tmpml.exe* and *tepml.exe* can be run by any of the usual methods for executing Windows programs.

Input Data Description

The descriptions of the input data files below are given explicitly for the TM program *tmpml.exe*. The data files for the TE program *tepml.exe* are identical except that they begin with the letters "te" rather than "tm" and except for a few minor differences in the data definitions, which are identified in the descriptions when appropriate.

Filename: *tmpml.dim* — dynamic dimensioning parameters

Data required for dynamic dimensioning of the program arrays must be present in this data file in the form shown in Figure 1 (free format):

```
Ngx          Ngy
NPMLlayers   PMLpower
Nax          Nay
```

Figure 1. Data format for the file *tmpml.dim.*

`Ngx` and `Ngy` represent the numbers of "grid points" in the *x* and *y* dimensions of the computational grid in the TM case. These grid points are defined to be the points at which the *z* component of the electric field is computed. In the TE case, `Ngx` and `Ngy` represent the numbers of rectangular "cells" in the *x* and *y* dimensions of the computational grid. The center points of these rectangular cells are the points at which the *z* component of the magnetic field is computed in the TE case. All non-free-space materials of the scattering geometry reside within this computational grid. There is always one layer of free-space material surrounding the computational grid in addition to the PML region. `Nax` and `Nay` are the numbers of additional free-space layers to include between the computational grid and the PML region. `NPMLlayers` is the number of PML layers to be used to absorb the outgoing waves. `PMLpower` is the exponent in the expression for the rate of increase of σ as a function of distance from the air-PML interface within the PML region, typically 1, 2, 3, or 4. `PMLpower` is a real number; all other quantities in this file are integers.

Filename: *tmpml.vwc* — Array Viewer control parameters

Data required for initial control of the Array Viewer program must be present in this data file in the form shown in Figure 2 (free format):

```
IGeomDraw
IFieldDraw
IPlotStep
IPlotPause
PlotPeak
IFldComp
```

Figure 2. Data format for the file *tmpml.vwc.*

`IGeomDraw` controls whether or not the Array Viewer is used to display a schematic representation of the geometry before computation begins. A value of 1 turns geometry visualization on, and a value of 0 turns it off. `IFieldDraw` controls whether or not the Array Viewer is used to display the value of a field component during execution. A value of 1 turns field visualization on, and a value of 0 turns it off. If field visualization is on, the remaining values will control the initial visualization parameters.

`IPlotStep` controls the plot update frequency. If `IPlotStep` is set to a value of *n*, the field plot will be updated every n^{th} time step. The more often the field plot is updated, the slower the simulation will run. `IPlotPause` controls the number of time steps before execution is paused. If `IPlotPause` is set to a value of *n*, the simulation will be paused at every n^{th} time step. `IPlotPause` is useful to allow the user to interact with the FDTD program (instead of the Array Viewer program). When the FDTD program is paused in this manner, the user can take time to view the field plot more carefully, or can interact with the FDTD program to change the current values of `IPlotStep` and/or `IPlotPause`. To interact with the FDTD program, or even to continue execution from the paused state, however, the Command Prompt window must be the "active window."

The variable `PlotPeak` is used to set the maximum magnitudes of the field values to be displayed by the Array Viewer program.

The variable `IFldComp` is used to choose which field component is to be displayed. For the TM case the choices are 1 for E_z, 2 for H_x, or 3 for H_y. The peak value variable `PlotPeak` is then used to determine the peak value of E_z that would be displayed. If H_x or H_y is chosen for display instead, the value of `PlotPeak` is automatically adjusted by the free-space impedance value η_0. For the TE case the values of `IFldComp` for the various component choices are 1 for E_x, 2 for E_y, or 3 for H_z. The peak value variable `PlotPeak` in this case is used to determine the peak value of H_z that would be displayed. If E_x or E_y is chosen for display instead, the value of `PlotPeak` is automatically adjusted by η_0. `PlotPeak` is a real variable; all other variables in this file are integers.

Filename: *tmpml.geo* — scatterer geometry data

Data required to describe the scatterer geometry must be present in this data file in the form shown in Figure 3 (free format):

```
NumMatDefs
MatID        epsr      mur     sigmae    sigmam
MatID        epsr      mur     sigmae    sigmam
      :
      :
      :
MatID        epsr      mur     sigmae    sigmam
ID           nxstart   nxend   nystart   nyend
ID           nxstart   nxend   nystart   nyend
      :
      :
      :
ID           nxstart   nxend   nystart   nyend
-1           0         0       0         0
```

Figure 3. Data format for the file *tmpml.geo.*

The first line of this data file identifies the number of different materials (`NumMatDefs`) to be defined to the program in subsequent lines of the data file. `NumMatDefs` must be between 1 and 50, allowing for use of 50 different materials as part of the scatterer geometry. Following the first line there must be `NumMatDefs` lines of data describing the materials. These subsequent data lines must specify the integer material identification number (`MatID`), the relative permittivity ε_r (`epsr`), the relative permeability μ_r (`mur`), the electric conductivity σ^e (`sigmae`), and the magnetic conductivity σ^m (`sigmam`). Thus, the first `NumMatDefs+1` lines of this data file represent material definition data available to the program. Note that these are just material definitions; it is not necessary for each material defined here to be used in the scatterer geometry to be simulated.

In addition to the definitions noted in the preceding paragraph, the free-space material type is predefined with a material ID of 0, while the perfect electric conductor (PEC) material type is predefined with a material ID of 51. These two material types can be used in the definition of the scatterer along with the other material types provided by the user. Any or all of the defined material types can be used in a particular scatterer geometry.

The user must define the scatterer geometry starting in line `NumMatDefs+2` of this data file. The geometry is defined in rectangular blocks by specifying a material ID (`ID`) and the range occupied by the material in the *x* and *y* dimensions in terms of the computational grid indices `nxstart`, `nxend`, `nystart`, and `nyend`. For the TM case, note that these quantities represent *node* or *grid point* values where the *z* component of the electric field is computed. Thus, in the TM case, the materials are specified to fill the spatial region with the corners defined by the four specified nodes. For the TE case, the quantities `nxstart`, `nxend`, `nystart`, and `nyend` represent *cell* number values where the *z* component of the magnetic field is computed. Thus, in the TE case, the materials are specified to fill the entire spatial region with the corners defined by the outermost corners of the four specified cells.

Each successive geometry specification line overwrites any material type previously specified for the indicated region. Thus, for example, one can create a hollow, rectangular dielectric cylinder by first creating a solid dielectric cylinder with the exterior dimensions desired, and then specifying the interior hollow region to have material ID 0. The interior region that was originally specified as dielectric material will be replaced with the new material type of free space.

Scatterer geometry input is terminated by specifying a material type of –1 (negative one; the computation grid ranges must still be present as suggested by the data file form shown in Figure 3, but they are not used). When the material type of –1 is encountered, no further data lines are read by the program.

Filename: *tmpml.ind* — other input data

Other input data required to describe the number of time steps to use, the spatial increments, the excitation, the saved field values, the output data file names, etc., must be present in this data file in the form shown in Figure 4 (free format):

The descriptions of the input variables in this file follow:

`Nstop` Final time step number to use.

`JzAmp` For the TM case this value represents the excitation electric current line source (Real, signed) amplitude. For the TE case this is instead `MzAmp` – the excitation magnetic current line source amplitude.

```
Nstop      JzAmp
dx          dy
Nsourcex    Nsourcey
ExciteType
MDecayFactor
SineFreq
PMLsxMax
PMLsyMax
DiagFilename
NoutFiles                                   _________
Outfilename                                          |   This section is repeated
Header                                               |     NoutFiles times
NTestPts                                             |   (once for each output file)
NPx         NPy       NfldType                       |
NPx         NPy       NfldType                       |
      :                                              |
      :                                              |
      :                                              |
NPx         NPy       NfldType  _________|
```

Figure 4. Data format for the file *tmpml.ind.*

`dx,dy` Spatial increment values (Real) in x and y in meters.

`Nsourcex,`
`Nsourcey` For the TM case these values represent the *node* indices in the x and y directions within the computational grid of the electric current line source J_z. For the TE case they represent the *cell* indices in the x and y directions

within the computational grid of the magnetic current line source M_z. The magnetic current line source is located at the center of the specified cell.

`ExciteType` Excitation type (Character): there are two allowed current source excitation types that must be entered starting in column 1 *exactly* as shown in one of the following forms:

`sine` A sine wave starting at t=0
`Gaussian` A Gaussian pulse

`MDecayFactor` Integer M that controls the decay rate of the Gaussian pulse. It is used to compute the inverse Gaussian decay constant $\tau = M \max(\Delta x, \Delta y)/(2c\sqrt{3})$. A value must appear in the data file for this variable in all cases, but is used only for the "Gaussian" excitation. M should be chosen such that $M \simeq \sqrt{3}n_c$, where n_c is the number of cells to be used per wavelength at the maximum usable frequency.

`SineFreq` Sine wave frequency in GHz. A value must appear in the data file for this variable in all cases, but is used only for the "sine" excitation.

`PMLsxMax`, `PMLsyMax` The maximum values of the electric conductivity to be used in the PML region in the x and y directions.

`DiagFilename` The name (character*16) of the diagnostic output file.

`NoutFiles` Number of output data files (maximum of 10).

`Outfilename` The name (character*16) of the data output file.

`Header` The header string (character*70) to appear in the data output files.

`NTestPts` The number of test points at which to save and print the field values (maximum of 500).

`NPx`, `NPy`, `NFldType` For the TM case `NPx` and `NPy` specify the *node* indices in the x and y directions within the computational grid at which the field value is to be saved for printing. `NFldType` specifies which field component to save: 1 for E_z, 2 for H_x, or 3 for H_y. For H_x and H_y, which are located between "nodes," the value saved is the next value encountered in the increasing index direction from the node (`NPx, NPy`). For H_y, for example, this will be the value of H_y at the point represented by (`NPx+1/2, NPy`). For the TE case `NPx` and `NPy` specify the *cell* indices in the *x* and *y* directions within the computational grid at which the field value is to be saved for printing. `NFldType` specifies which field component to save: 1 for E_x, 2 for E_y, or 3 for H_z. For E_x and E_y, which are located between "cells," the value saved is the next value encountered in the increasing index direction from the center of cell (`NPx, NPy`). For E_y, for example, this will be the value of E_y at the point represented by (`NPx+1/2, NPy`).

Code Execution

When the code begins execution, a Command Prompt window similar to that shown in Figure 5 will appear. If `IGeomDraw` has been set to a value of one in the data file *tmpml.vwc* (*tepml.vwc* for the TE case), the geometry view window will also appear (Figure 6) and will be the active window. In the geometry window in Figure 6 the material ID number is plotted as a function of *x* and *y*. The sample geometry shows a 3-sided PEC box (material ID 51) that is filled with a material medium (material ID 10), and the remainder of the space is filled with homogeneous free space (material ID 0).

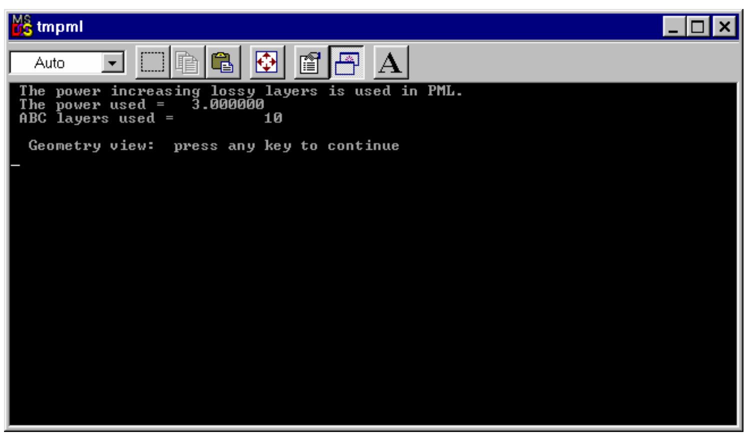


Figure 5. The *tmpml* Command Prompt window.

With the geometry window open, the user may rotate the schematic geometry view interactively with the mouse to obtain different views. The user may also interact with the menu items and tool bars of the Array Viewer program to zoom in to view a smaller region of space (i.e., the material ID array), change the plot scale, change to an image map view of the array as shown in Figure 7, or change other Array Viewer options.

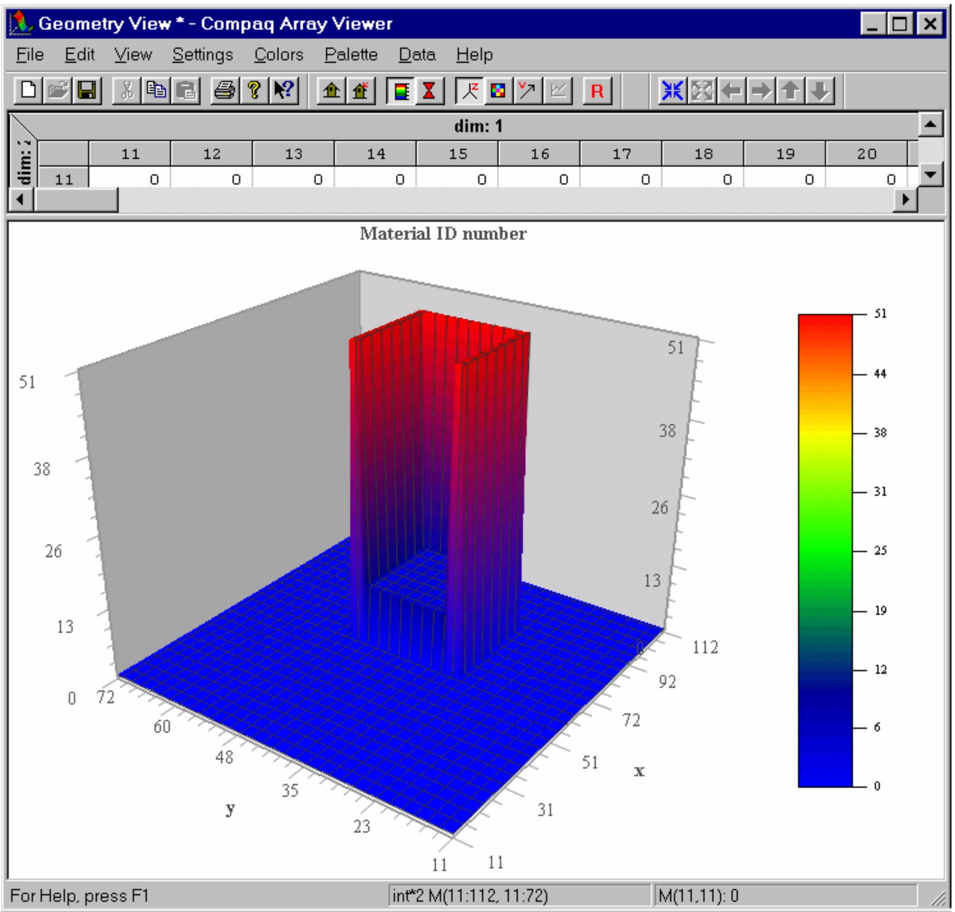


Figure 6. The Array Viewer geometry view window of the program *tmpml* showing a 3D schematic representation of the geometry.

One should note that the indexing scheme shown on the *x* and *y* axes includes the space required for the PML implementation. Thus, in the example above for which 10 PML layers were used, the indexing scheme begins with 11. The non-free space geometry, which was specified in the input data file to begin at node 50, shows up in the array as beginning at 61. By letting the mouse hover over a point in the image map of Figure 7 one can obtain quick (approximate) information on the particular array index and its value via a "tooltip-type" box, but the resolution is somewhat crude. Exact data can be obtained by using the array data window above the plot. The size of the data window can be increased as necessary.

To continue execution the user must first make the Command Prompt window the active window and then press any key to continue. The geometry view window will then close and execution of the FDTD simulation will begin. Since the Command Prompt window must be the active window to continue execution after a pause, it may be convenient to reduce the font size of the Command Prompt window and allow it to remain as the top window once execution starts. Depending on the value of `IPlotPause` in the input data file *tmpml.vwc*, execution may continue until completion, or it may pause after a certain number of time steps. If execution pauses, the Command Prompt window will appear similar to that shown in Figure 8.

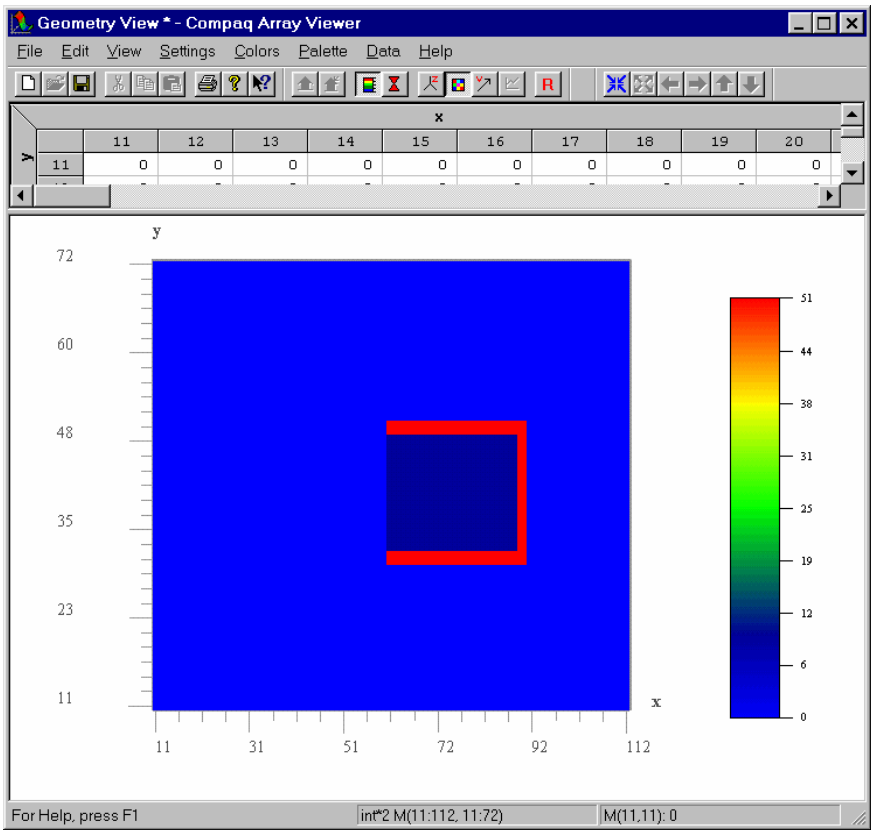


Figure 7. The Array Viewer geometry view window of the program *tmpml* showing an image map schematic representation of the geometry.

In the window shown in Figure 8 execution has been paused once at 100 time steps, then continued, and has been paused again at 200 time steps. While the program is in this paused state, if the user presses the “m” key a menu will appear as shown in Figure 9.

At this point the user can choose to abort the simulation immediately, to change the plot time spacing (i.e, change the current value of `IPlotStep`), or to change the pause time step spacing (change the current value of `IPlotPause`).

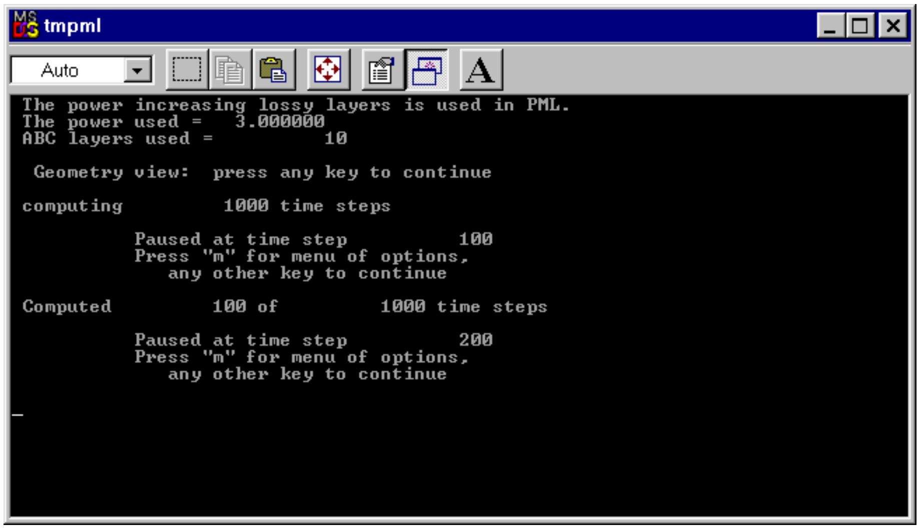


Figure 8. The *tmpml* Command Prompt window after execution has paused at a time step.

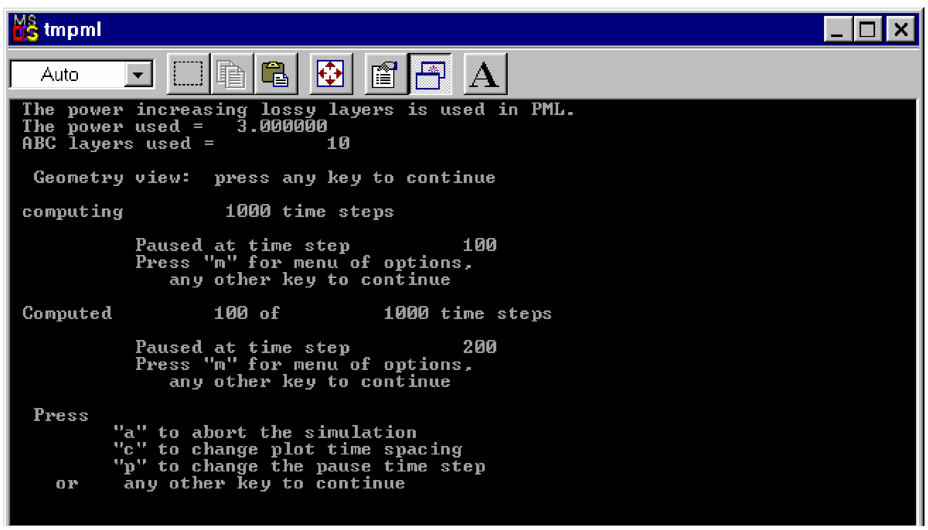


Figure 9. The *tmpml* Command Prompt window after the user has pressed “m” to get a menu of options.

For the TM case example data, when execution is paused at time step number 200 the Array Viewer window will appear similar to that shown in Figure 10. Note that the PML region surrounding the computational grid is also displayed in the simulation window.

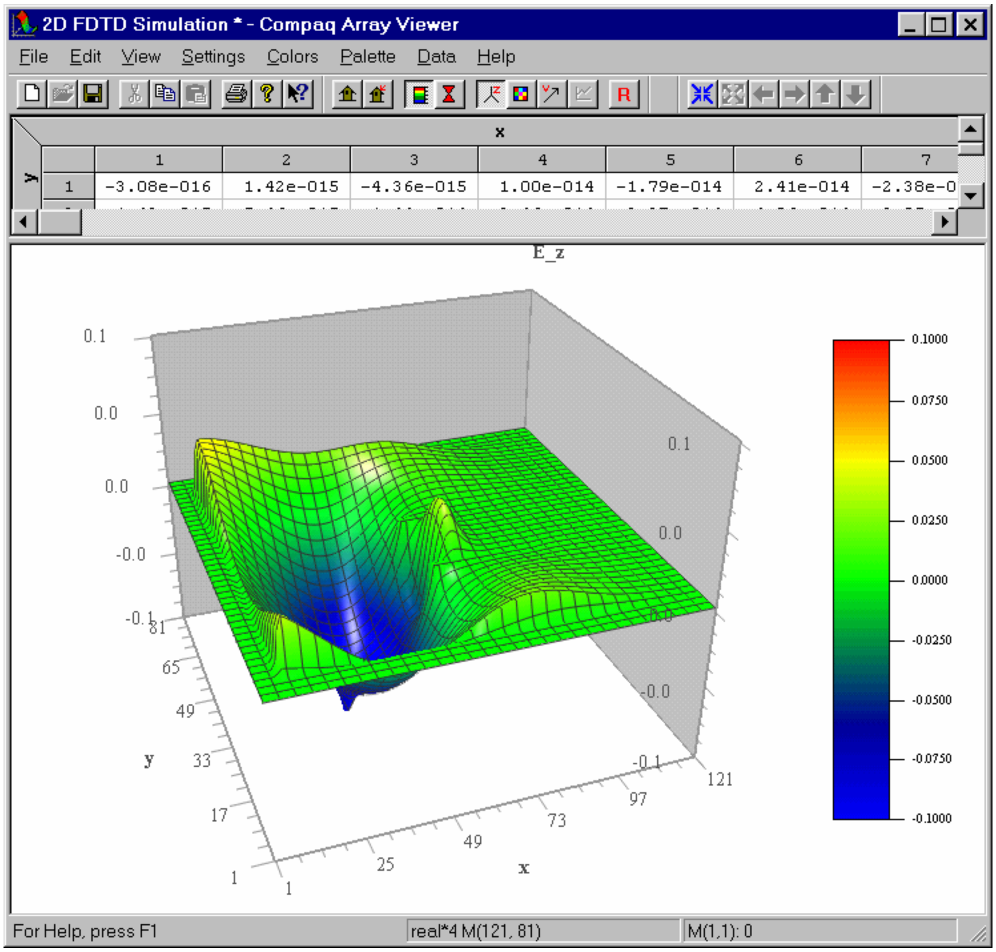


Figure 10. The Array Viewer simulation window of the program *tmpml* showing a 3D view of the electric field distribution.

As with the geometry window, the user may rotate the view in the simulation window interactively with the mouse to obtain different views. The user may also interact with the menu items and tool bars of the Array Viewer program to zoom in to view a smaller region of space, change the plot scale, change to an image map view of the electric field distribution array as shown in Figure 11, or change other Array Viewer options.

The user can also find the current time step value and the current time value in picoseconds by using the Array View menu. To see this information select Data, then Annotation… The Annotation will appear as shown in Figure 12.

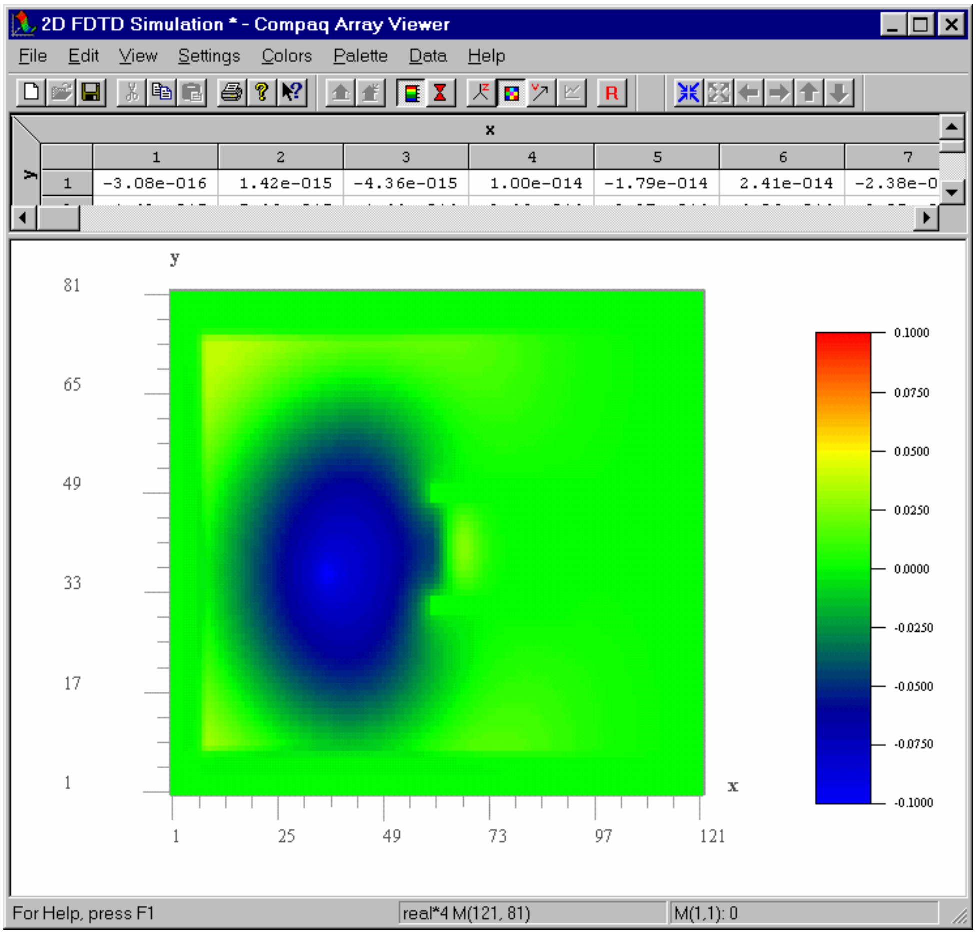


Figure 11. The Array Viewer simulation window of the program *tmpml* showing image map view of the electric field distribution.

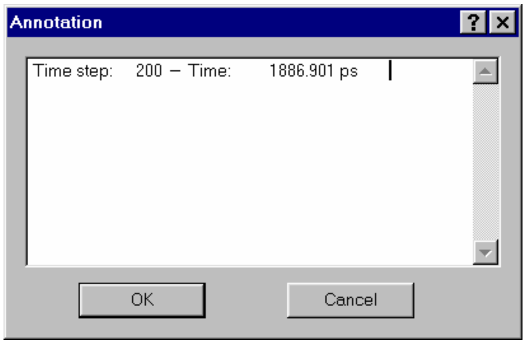


Figure 12. The Array Viewer Annotation window.

Execution of the TE program *tepml.exe* proceeds in exactly the same manner. Example screens for the TE simulation case are shown in Figures 13 and 14, when execution is paused at time step number 200 for the sample data case.

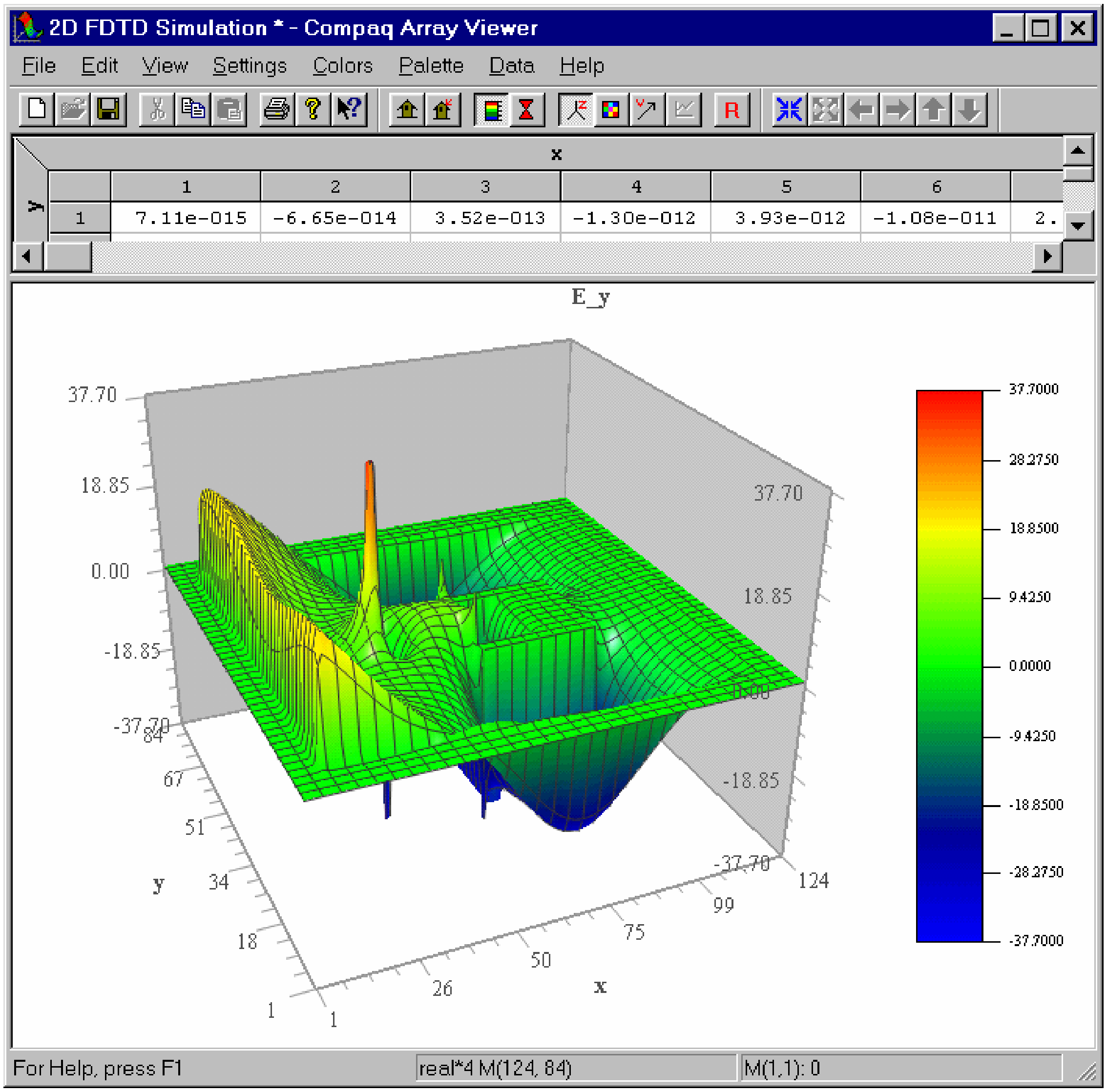


Figure 13. The Array Viewer simulation window of the program *tepml* showing a 3D view of the *y* component of the electric field distribution.

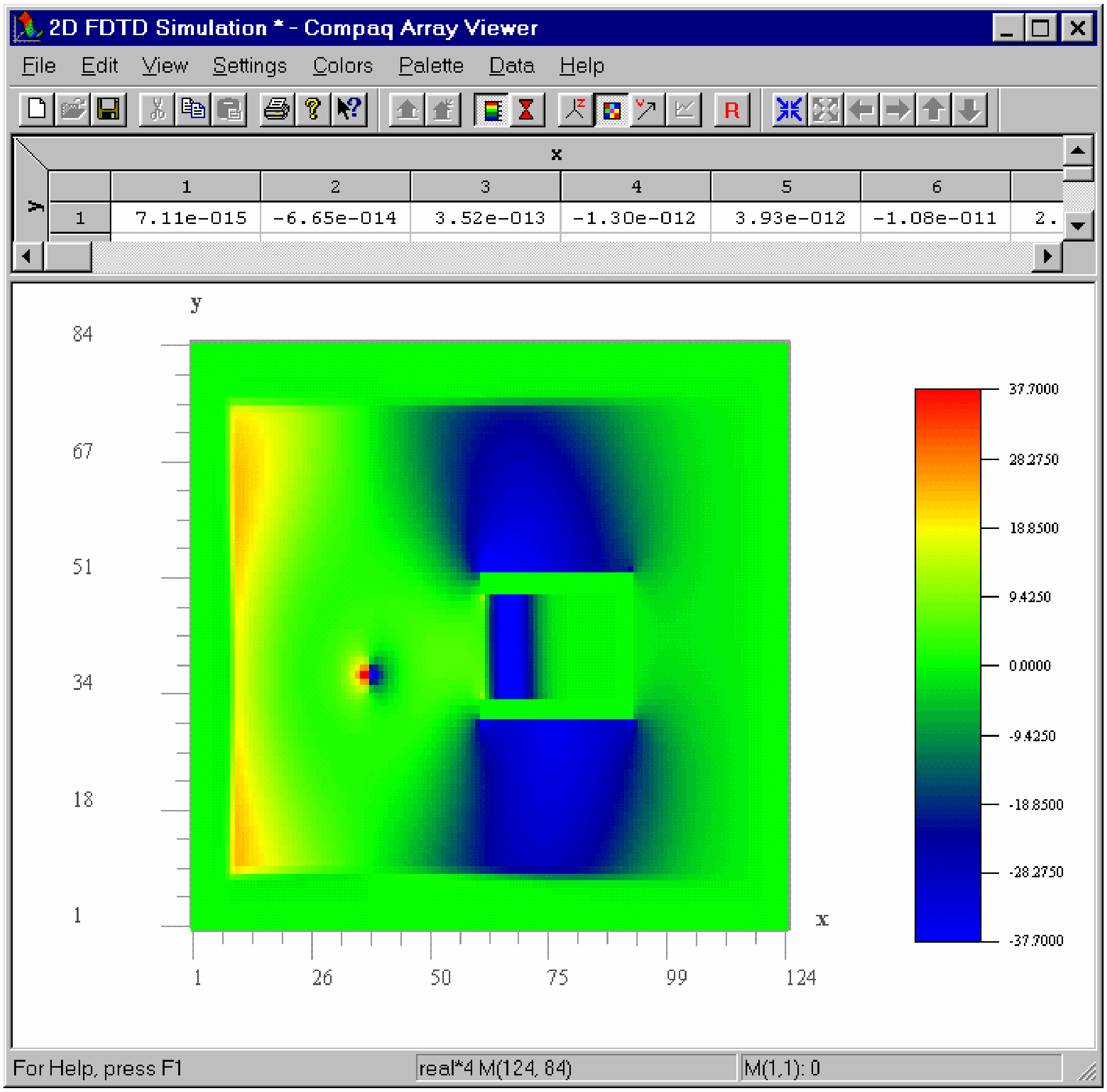


Figure 14. **The Array Viewer simulation window of the program *tepml* showing image map view of the *y* component of the electric field distribution.**

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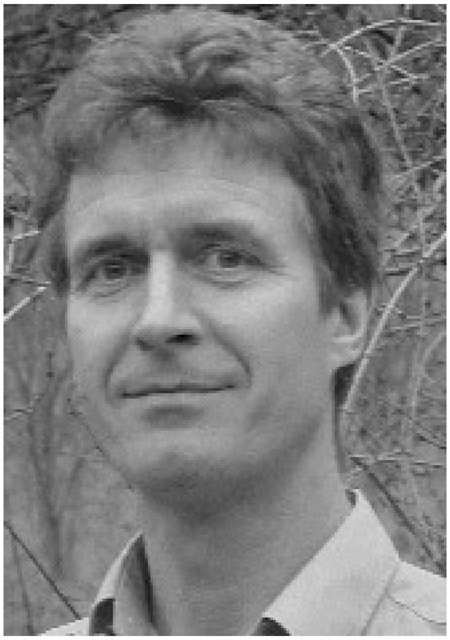

GENERAL BACKGROUND

Simon Walker received his Bachelor's degree from Imperial College, London, in 1977, and his PhD, also from Imperial, in 1980.He was employed by the United Kingdom Atomic Energy Authority from 1977 to 1980, engaged on fast reactor safety analysis and nuclear fuel modelling studies. In 1980 he joined Shell International, and worked in The Netherlands and Canada, as an engineer engaged on the construction and operation of sour gas processing plants. In 1984 he returned to the UK, and joined the faculty of Imperial College. He is presently reader in the Computational Mechanics Section of the Mechanical Engineering Department. His group is involved in the development and application of computational methods for electromagnetic wave propagation, in particular the development of time domain integral equation and time domain finite element methods for scattering and RCS problems. He is a Chartered Electrical Engineer (MIEE), and a member of the IEEE.

PAST SERVICE TO ACES

He was one of the founding members of the UK Chapter of ACES, and is a Member of its Management Committee. The UK Chapter provides a mechanism for UK based workers to join ACES, and helps to promote interactions between UK practitioners and researchers in the area of applied CEM. Simon Walker has been the Chair and organiser of the ACES (UK) Annual Meetings for the last six years. We use these meetings also to try to foster links with other parts of ACES, and each year bring over a speaker to present a Short Course, either from mainland Europe, or more commonly the USA.

PLATFORM

We like to feel that the spread of ACES membership outside the US is mutually beneficial, both strengthening ACES, and facilitating access to a larger community for what are generally much smaller groups of workers outside the US. The UK is the largest non-North American group of ACES members, and whilst geographically remote, we try to play as active a part as distance allows! We hope that having one of our number on the Board of ACES (as indeed has been the case for some years) will be valuable, both generally, and additionally in providing input from a different perspective, and trying to encourage the growth of non-North American participation in ACES.

CEM TECHNIQUES FOR ANALYZING ELECTRONIC BATTLESPACE ENVIRONMENT PLATFORM-ANTENNA COUPLING INTERACTIONS

Andrew L. Drozd†
ANDRO Computational Solutions
Beeches Technical Campus
Rome, NY 13440
andro1@aol.com

Abstract

This article discusses the application of an integrated, multi-fidelity CEM modeling and simulation approach for analyzing EM interactions for complex electronic battlespace environment (EBE) scenarios. A postulated RF EBE simulation model is generated consisting of multiple antenna-mounted air and ground vehicle platforms. The effects of EM environments produced by external RF systems on other distributed platforms are analyzed. Included in the simulation model are radars, RF communications systems, multi-spectral sensors, and other types of intentional as well as deliberate jamming sources. The approach involves modeling the total environment and isolating selected platforms from within the overall scene to analyze mutual coupling, antenna-platform interactions, scattering, and intersystem electromagnetic interference (EMI). Methods are used to automatically generate detailed CEM models of the selected physical systems and their antenna radiators from CAD or other types of data sources. Future directions in antenna analysis and the application of design software for antenna-platform simulations will be discussed.

INTRODUCTION

An EBE scenario can be defined as a digital model of a complex arrangement of multiple RF systems and platforms. The scenario arrangements or configurations can contain both static elements (tanks under trees) and dynamic components (airborne systems). Regardless, the potential for intersystem EMI and mutual EM environment-to-platform coupling interactions exists. One of the basic concerns of EBE strategists and planners is to assure RF communications, command, control, and computing (C^4) system operability in EM-rich environments. Also, the potential self or co-site interference effects among local (onboard) RF systems is also of concern. For instance, self interference can drastically change the radiated emissions and susceptibility states of onboard transceivers, which in turn may contribute to the overall intersystem EMI problem or lead to additional vulnerabilities in the presence of external EM fluences. In general, the RF EBE scenario typically involves the deployment of multiple systems and platforms in the battlespace volume. Hostile elements (e.g., nearby deliberate jammers) may also be part of the scenario.

In the process of discussing the EBE modeling and simulation approach, several key technology areas will be highlighted. These include: (a) self/mutual antenna coupling and radiation modeling (antenna design and performance, antenna coupling and isolation, sensor siting and interference/jamming mitigation); (b) CAD pre-processing; (c) automated techniques for generating grid models from CAD data; (d) CEM design environment for creating mesh and asymptotic high-frequency ray tracing models; (e) illustrating how computed data can be presented in different ways depending on the needs of the analyst; (f) fidelity issues in modeling the effects of multi-spectral sources or environments (radar, high energy microwaves); and (g) common modeling frameworks for multi-disciplinary engineering applications.

Background

A basis for the RF battlespace scenario is the Open Systems Interconnection (OSI) Reference Model, which deals with the connection of open systems (i.e., systems that are ready to communicate with other systems in a

† ANDRO Computational Solutions, Beeches Technical Campus, Bldg. 3, Suite 4, Route 26N, Turin Road, Rome, NY 13440, Tel. (315) 334-1163 or (877) 334-1188, Fax: 315.334.1397, andro1@aol.com or androcs@borg.com.

prescribed manner) and Mobile Ad Hoc Networking, which involves route maintenance, disconnect, and so forth. The OSI architecture has seven layers starting at the base with the *physical layer* and upwards, in order, to include the *data link* and *network layers* followed by the *transport*, *session*, *presentation*, and *application protocols*. The present concern is on the first three layers i.e., the *physical*, *data link*, and *network layers* which comprise the *communications subnet boundary* of the OSI model.

There are three perspectives or views on this architecture concept: (1) operational view, which identifies sensor to shooter warfighter relationships and information needs; (2) systems view, which relates capabilities and characteristics to operational requirements for network-centric and multi-echelon connectivity; and (3) technical view, which prescribes standards and conventions. The near and midterm architectures applicable to this concept, for example, include: intelligence, surveillance and reconnaissance (ISR) including SIGINT, HUMINT, and electronic or synthetic aperture radar (SAR) mapping of hostile RF emitters, sensor to shooter, and aerial common sensors and control nodes. The architecture concepts have transitioned from platform-centric to a Global Information Grid (GIG) network centric to maintain the philosophy that the best sensors plus robust networks equals information dominance. What is the relevance here to CEM? The answer lies in the need to reasonably model the EBE "big picture" and characterize the various EM interactions in a multi-fidelity way focusing on critical network nodes. The modeling and simulation approach to accomplish this is described herein.

In the general OSI-based model, RF communications must be assured or maintained to coordinate the transfer of data/information across the OSI Reference Model topology layers, starting with the physical layer and up to the data link and network layers. Nodes and information pathways in the 3-D communications grid represent the connectivity among critical assets in the RF battlespace. These must be able to operate through the EM-rich environment. One way of determining this is through EMI modeling and simulation starting at the physical layer where the systems and platforms operate.

The efficient management of the intersystem EMI problem for *systems of systems* scenarios can be quite tedious and daunting. The analysis procedure requires the application of several different tools and techniques in order to obtain meaningful solutions. Further, top-down and bottom-up modeling are often required implementing an iterative, building block, or step-wise approach to the problem-solving task. The first step, however, is to develop an effective method of performing interference analysis culls to eliminate non-problems from the interaction sample space and to focus on likely or certain interference problems using a high-fidelity approach. This will be demonstrated qualitatively using the *E^3EXPERT*[*] technology.

E^3EXPERT Technology

E^3EXPERT is a computer tool that is used to predict intrasystem or co-site EMI for co-located onboard systems as well as intersystem or mutual EM coupling between external or offboard RF systems and sensors [1-9]. The tool can also analyze the effects of externally-produced multi-spectral EM environments on systems. The program computes the composite EM environment due to multiple sources by integrating the power spectrum across frequency. Both intentional as well as inadvertent (i.e., hostile jammers, enemy radar, ultra wideband, fratricide) sources can be modeled for in-band and out-of-band frequencies (dc to 50 GHz). Environmental sources can be characterized as fixed-tuned (CW tone), variably-tuned (multiple tones), frequency-agile (hopping), pulsed radar (chirp and other forms), and wideband (stochastic or modulated signals).

E^3EXPERT can compute the mutual coupling among distributed aerospace, land, and sea systems deployed within the EBE volume that have source and receiver antennas mounted on their structures. The approach involves conservative *physical layer* modeling of reconfigurable *systems of systems* scenarios. The immediate interest is in simulating the EBE problem to analyze the various electromagnetic environment effects (E^3) and distributed system EM interactions at the *physical layer*. This includes analyzing the effects of multiple radar jamming sources on RF communications grids and information/network systems, which addresses the assured RF communications, information systems and network integrity, and tactical information warfare problem.

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[*] Developed by the Air Force Research Laboratory, Rome Research Site under Contract F30602-98-C-0034.

At this layer, E^3*EXPERT* models individual radars, communications assets and information systems as nodes. The nodes are analyzed to compute mutual EM coupling interactions as well as to calculate the susceptibility/vulnerability response of the nodes to incident energies from external sources. Intentional radar and communications signals, and information pathways for conventional and more complex signal sources (e.g., mobile spread spectrum radios), as well as fratricide and unintentional or hostile sources can be modeled. Both linear and nonlinear (intermodulation) coupling modes are considered.

EBE scenarios are imported as digital satellite or aerial imagery resulting from multi-sensor fusion processes combined with system platform CAD descriptions as shown in Figure 1. Selected portions of the scene can be extracted and automatically converted into a generalized CEM model as illustrated in the nodal network grid of Figure 2. In this example, the intersystem coupling between a radar mounted ground vehicle and selected airborne systems is to be simulated and analyzed. The induced surface currents and scattered fields due to onboard radiators and ground vehicle radar illumination can be computed to identify potential hot spots or interference situations.

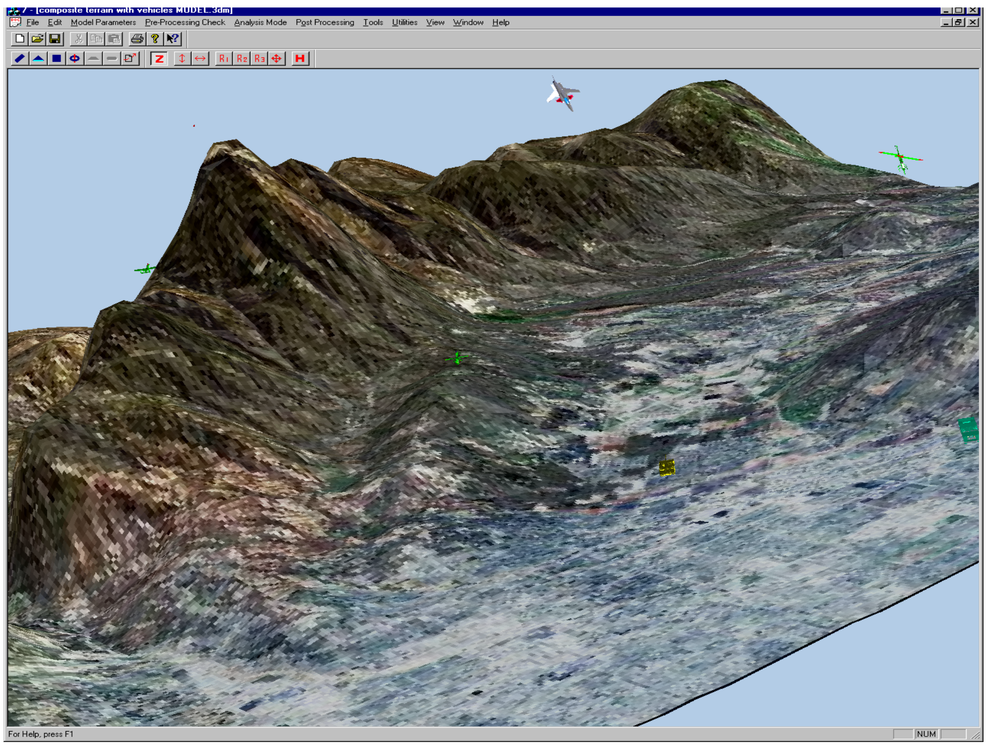


Figure 1. A "Snapshot" of the RF Battlespace Used to Analyze Intersystem EM Interactions

E^3*EXPERT* provides the necessary capability to analyze complex systems and scenarios using multi-resolution modeling techniques. This means that models can be analyzed using coarse-fidelity, phase coherent (i.e., conservative) techniques or by applying accurate, high-fidelity CEM techniques, both in the frequency and time domains. One of the codes used to accomplish this is the *General Electromagnetic Model for the Analysis of Complex Systems (GEMACS V6)* [10]. The *GEMACS* code employs high-fidelity physics and numerical solvers to predict mutual coupling, antenna isolation, and scattering. Another computational engine, *SystemView*™, adds a time-domain signal modeling capability to complement the resident frequency-domain techniques [11].

E^3*EXPERT* applies a knowledge-based expert system modeling and simulation approach to generate valid computational models and orchestrate the analysis procedures [12] to compute EM scattering and frequency-domain coupling parameters based on an automated system-level methodology. It ranks computed results and automatically specifies an initial set of recommendations to mitigate undesired EM effects in the frequency domain. Detailed mitigation requirements in the time domain can then be deduced.

Computer simulations have been conducted to study the effectiveness of this approach for various complex system scenarios involving externally-mounted fixed- and variably-tuned RF radiating antennas, coherent frequency-hopped and direct sequence spread spectrum radios, and incident radar sources producing both incident CW and wideband pulses. The results of these simulations are qualitatively described below.

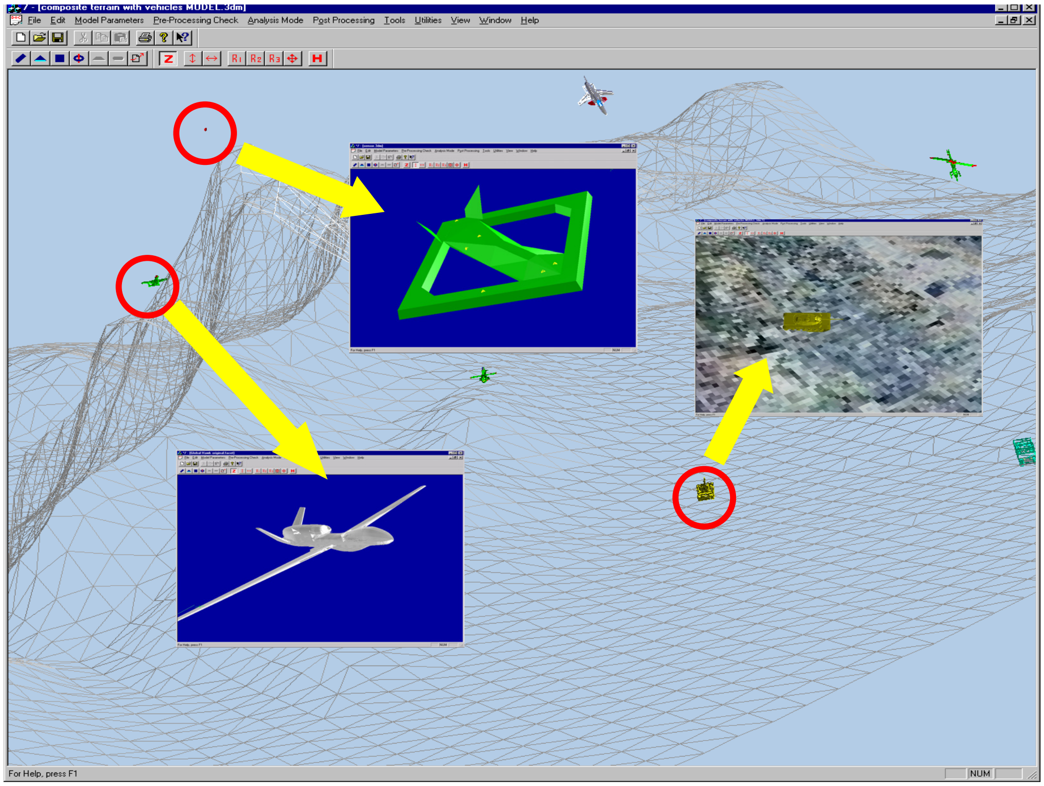


Figure 2. Selecting "Targets" for Intersystem EM Analysis

SCENARIO MODELING

E^3*EXPERT*'s integrated framework provides a suite of tools to design a scenario consisting of: physical systems, platforms or structures; networks; node models of intentional transmitters and receivers; EM jammers or other interference sources; and EM environments. A physical modeling approach is used to describe an OSI-based EBE scenario where assets are modeled with varying levels of fidelity in accordance with problem-driven constraints and accuracy requirements. E^3*EXPERT* provides capabilities to model air-air, air-ground, as well as ground-ground scenarios. In the case of antenna radiators, both terrain and intravehicle coupling models are used to compute propagation path losses.

Frequency and time-domain parameters are used to characterize multi-spectral, multi-sensor system operational states and signal modulations. This defines the operation of high-power radars, mobile wireless spread spectrum radios, and signal/information processing systems. These include systems that utilize low-band technology for dynamically exploiting complex RF environments, high-band technology for dynamically exploiting microwave frequencies and above, RF/microwave transceiver and directional antenna technologies, and a variety of modulation, coding, and information processing schemes.

For the general EBE problem, a *physical layer* model of the OSI network architecture is developed consisting of multi-sensor and multi-function host platforms, RF communications and information processing systems, and EM radiators. The results of the *physical layer* simulation can be interfaced with *network layer* prediction codes in order to perform end-to-end simulations against specific and reconfigurable combat system scenarios. This approach assists in analytically evaluating the life cycle performance of combat system networks and C^4 systems that may be exposed to a broad range of EM environments or threats. The results of the analyses can be used to increase the interference and jamming immunity of friendly systems as well as further develop ways of reducing EM signatures to minimize detection and identification, and to exploit the weaknesses of hostile systems.

ANALYSIS PROCEDURE

The EBE computational model is generated from mutually registered and digitized aerial or satellite imagery and terrain elevation data as was shown in Figure 1. CAD model data corresponding to system platforms and targets in the EBE scenario are "linked" to the digitized scene. This was illustrated in Figure 2. The model is then analyzed in the frequency domain to compute EM interactions (scattering, propagation/path loss, coupling, and interference) between all components in the model. Method of moments (MoM) and high-frequency asymptotic uniform theory of diffraction (UTD) ray tracing techniques are used to compute vehicle and ground propagation coupling losses. Computed results for selected CEM structure models and their radiators are ranked according to the type and severity of coupled interference. Corrective measures can then be determined to mitigate or cancel the interference. The *E^3EXPERT* knowledge base is designed to assist in determining mitigation solutions. In particular, the knowledge base is used to "monitor" the signal environment in the time domain and select mitigation scheme(s) to excise or suppress undesired EM effects.

The modeling and simulation procedure consists of the following steps:

1) Import the digitized battlespace scene and linked CAD models.
2) Defeature and discretize the scene to generate a meshed model view to rapidly identify targets and set up the problem to compute intersystem EM propagation/coupling parameters.
3) Apply coarse-fidelity, phase coherent simulation techniques to isolate certain or probable intersystem interference cases.
4) Based on the results of step 3, select one or more specific platform-antenna structures to analyze the cumulative, incident energy effects and/or to study co-site EM interactions using both coarse- and high-fidelity modeling techniques.
5) Using high-fidelity techniques, compute platform propagation path loss, scattering, or isolation for an MoM mesh, UTD surface, or hybrid model based on frequency, desired accuracy, and other "ensemble" parameters.
6) Compute and map the predicted surface currents and/or field intensities on the CEM model(s).
7) Compute near and far field antenna patterns and antenna input impedances.
8) Apply time-domain signal modeling and analysis techniques to study waveform distortion in antenna receiver front ends.
9) Evaluate system performance.
10) Apply expert system based mitigation solutions, as necessary.

Steps 3 and 4 above are critical transition steps in that they establish the initial EM interaction sample space, which will be further analyzed and reduced using high-fidelity computational techniques at the system level. The effects of cumulative EM environments on selected platforms and onboard receivers can also be computed in these steps. An example of the cumulative EM environment compared to a receiver's susceptibility of immunity level is shown in Figure 3.

Selecting Model(s) for CEM Analysis

E^3EXPERT gives the analyst a capability to rapidly generate valid EM scenario and structure models from selected CAD data, existing CEM model information, and by employing a few basic modeling assumptions. In our example, we have computed all possible EM interactions for all nodes in the model. We are now at the point of analyzing the effect of incident energies from one or more sources in the problem on a given platform and its

receivers. To accomplish this, the analyst can zoom in and select one or more of the targets in the digital battlespace scene and retrieve the corresponding CAD file description(s) of the platform(s) of interest (step 4 in the procedure). This was illustrated for the case of a tank and a postulated unmanned aerial vehicle (UAV) in Figure 2. CAD and rendering formats currently supported by E^3*EXPERT* include *IGES*, *DXF*, *facet*, and *VRML* entities.

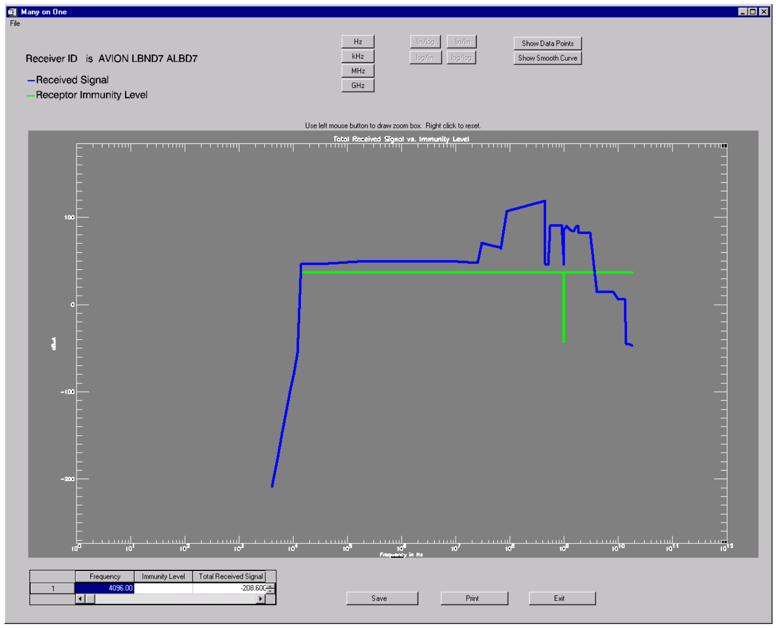


Figure 3. Computation of Cumulative EM Environment to a Victim Receiver

At this point, a CAD or existing CEM model is read in, converted, and stored in an internal 3-D metafile (native) format. The CAD models are converted into CEM models to accommodate one or more of the CEM codes and computational modes supported by E^3*EXPERT*. The native file format and internal database structure represent a common modeling environment in which computational models are stored and used in a generic way for various code applications. E^3*EXPERT* also performs certain CAD and CEM model preprocessing to identify and "heal" anomalies in the imported model. The role of the metafile and intelligent preprocessor are illustrated in Figures 4 and 5. The present metafile design supports MoM, UTD, and SBR/PO/PTD formalisms related to geometry generation for codes like *GEMACS*, *NEC-MOM*, *NEC-BSC*, *Xpatch* and *Carlos-3D*. It has the potential for supporting other physics formalisms such as finite difference time domain (FDTD), finite element modeling (FEM), multi-level fast multipole algorithm (MLFMA), and volume integral equation (VIE) techniques for selected CEM codes.

Generating CEM Models

For all platform structure models that have been imported or created, the associated multi-sensor and RF communications system antennas are also specified. This includes the specification of the relevant performance measures and EM parameters (excitations, frequencies, operational levels, loads, etc.). Again, the first task is to analyze intersystem coupling interactions and the effects of incident energies on systems in the frequency domain for given structures in the model. This involves the computation of certain EM figures of merit such as mutual coupling or interference margins and isolation. Intrasystem or self interference can also be calculated in terms of local platform scattering effects and mutual coupling between onboard antennas. For instance, antenna performance can be affected by the presence of the platform structure, materials, excitation waveforms, and the operation of other onboard antennas.

Once the structure, performance and EM measures have been defined, multi-fidelity CEM models are generated as a function of frequency and other problem parameters. For example, CAD models can be converted into equivalent canonical smooth surface structures which are useful in analyzing coupling, scattering, and interference at high frequencies using asymptotic UTD ray tracing methods, in particular, when the structure is electrically large. Alternatively, at lower frequencies where the model is electrically small, the model can be parameterized using a built-in *autogridder* to generate a MoM patch model.

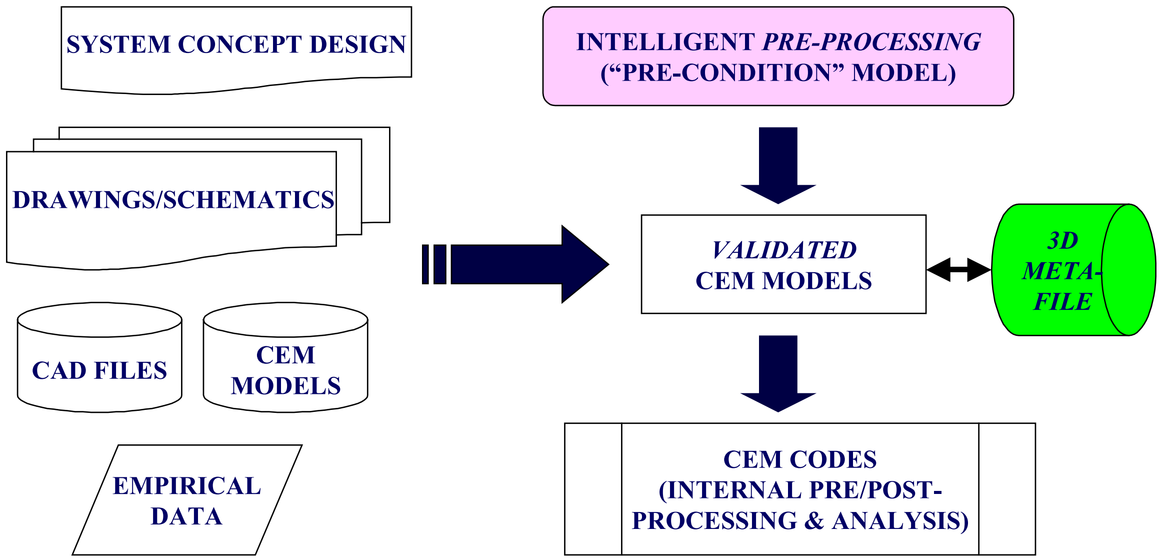


Figure 4. Preprocessing and Database Scheme

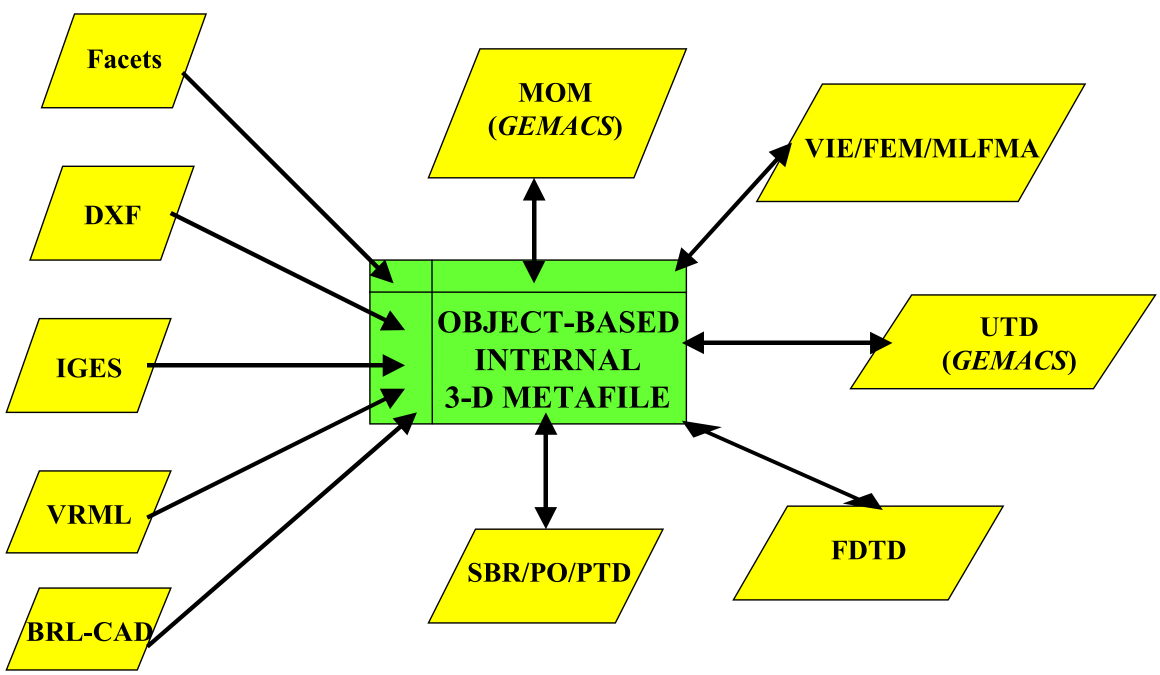
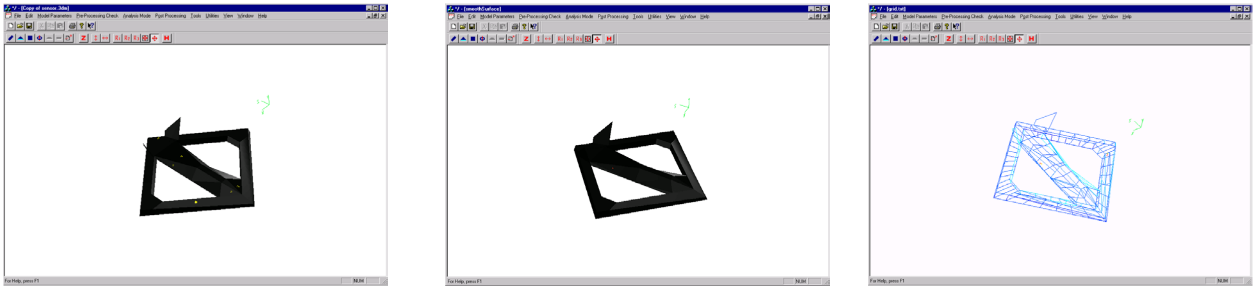


Figure 5. Common Modeling Environment Concept

The general multi-fidelity scheme is illustrated in Figure 6 for the postulated UAV structure. Figures 7 and 8 show models of the UAV generated for high frequencies based on the UTD modeling method. In these figures, coarse and higher fidelity UTD models were generated and comparisons are made of the computed isolation for the models. As expected, a significant improvement in the isolation is computed at the sample frequency using the more refined models. This illustrates the importance of considering model fidelity in assuring reasonable computational accuracy. Another aspect of the multi-resolution approach based on the autogridding scheme for different mesh resolutions and frequencies is shown in Figures 9.



(a) CAD Model **(b) UTD Model** **(c) MoM Mesh Model**

Figure 6. Progression of UAV Models in Multi-Fidelity Scheme

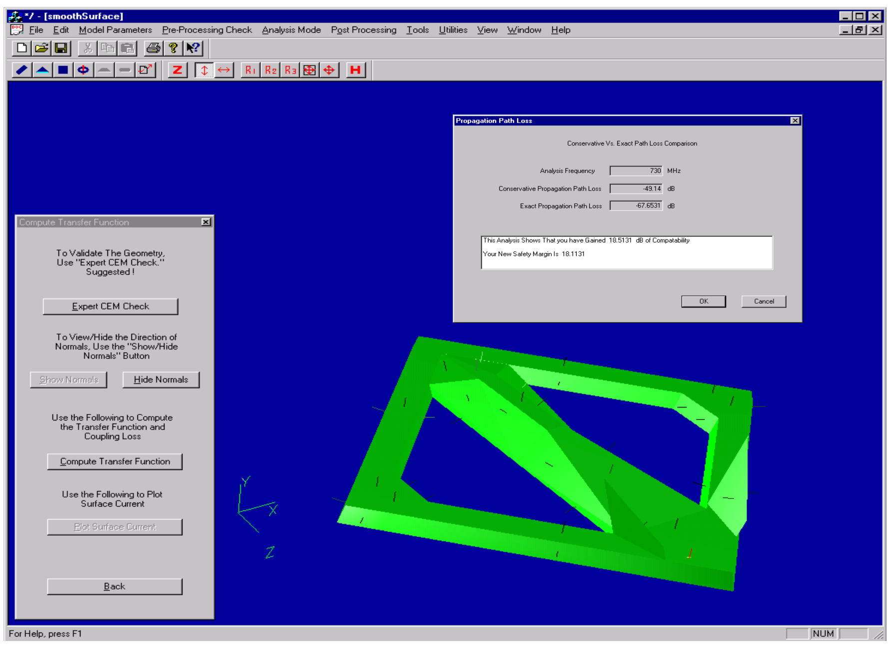


Figure 7. Comparison of Computed Isolation for Coarse and High Fidelity UTD Model at 730 MHz

Figures 10 - 12 show how the autogridding process has been used for other system platforms to produce models of varying fidelity and accuracy for the purpose of analyzing intersystem and intrasystem EM coupling for EBE-type scenarios.

Depending on the desired analysis fidelity, the models may be used "as is" or modified to suite the computational accuracy requirements. For example, E^3*EXPERT* is used to convert the detailed facet model into a UTD canonical model and then into a MoM mesh model to compute vehicle scattering losses and EM coupling due to incident energies. Again, this is accomplished in terms of frequency and other ensemble problem drivers.

The code also allows the analyst to defeature or modify a CAD or CEM model. This can be used to simplify or augment a model depending upon the type of analysis, sampling frequency, and the desired accuracy. These factors influence the level of detail needed in the structure model for a given simulation. For example, at lower frequencies, or for situations where high accuracy is unnecessary, or when computational resources are limited, or where certain scatterers do not affect the simulation, the analyst may opt to simplify the model by generating a coarser representation. This leads to a more computationally feasible model.

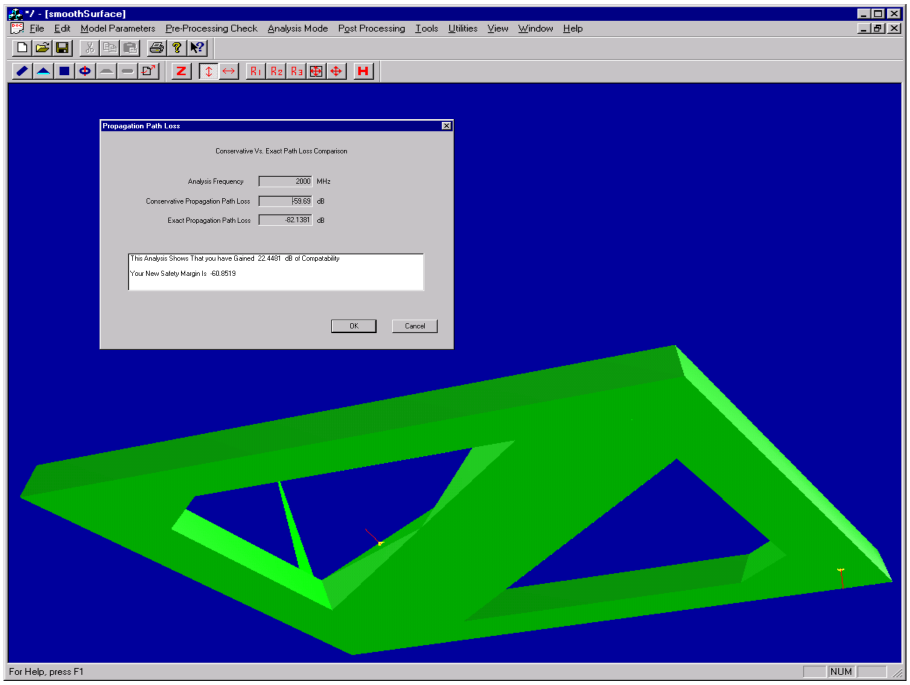
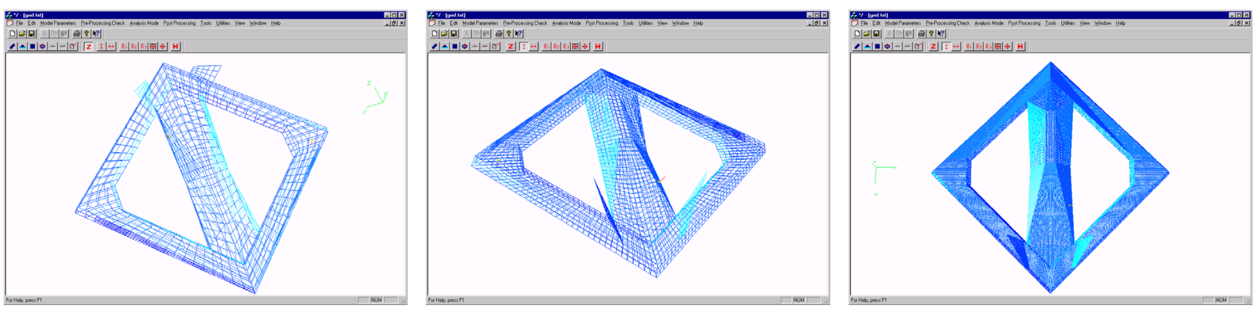


Figure 8. Comparison of Computed Isolation for Coarse and High Fidelity UTD Model at 2 GHz



(a) 25,000 Unknowns at 100 MHz **(b) 37,000 Unknowns at 200 MHz** **(c) 100,000 Unknowns at 633 MHz**

Figure 9. Illustration of Multi-Resolution Autogridding Scheme

Computing CEM Observables

Figures 13-15 show examples of the scattered field contour plots that can be produced based on computed surface current densities for several structure models as a function of frequency. The *GEMACS V6.0* code was used as the CEM engine in E^3*EXPERT* to calculate these quantities. In Figure 13 for example, the original CAD facet model of the postulated UAV platform was automatically converted into a canonical smooth surface structure and then meshed to predict the hot spots. Source and receiver RF antennas are included in the simulation. The contour plot shown in Figure 13 indicates the location of hot spots (in the near field of radiating antennas and/or where energy adds constructively as the aircraft is illuminated by the ground radar) and cold spots where the energy levels decay. This information can be used to assist in sensor siting for optimized performance and to develop robust mitigation schemes for reducing antenna jamming potential.

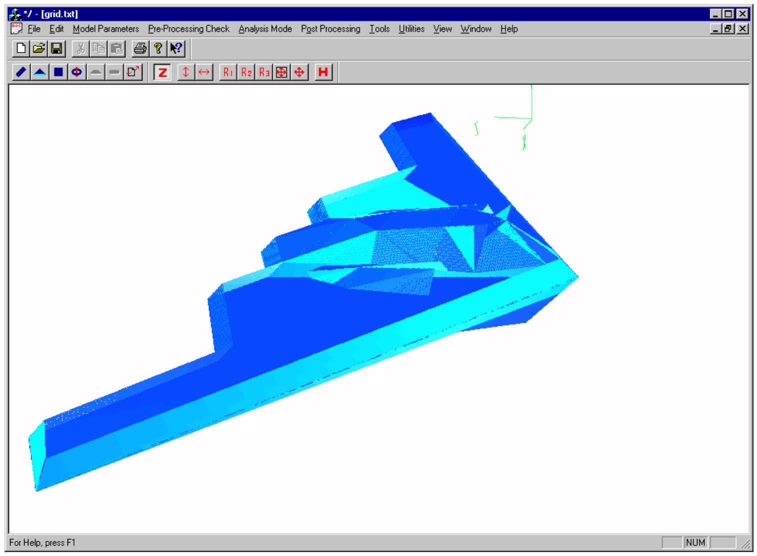
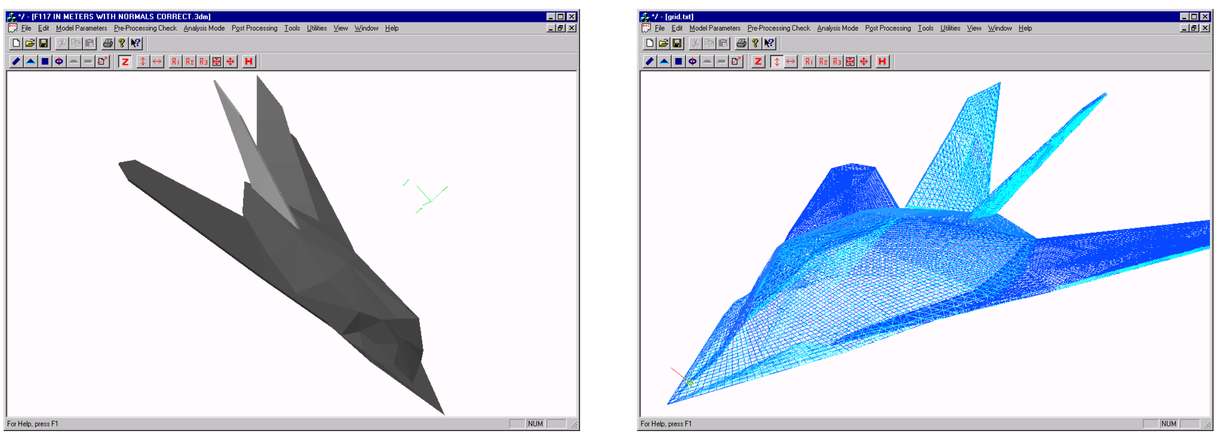


Figure 10. Aircraft Model With 1,185,000 Unknowns at 750 MHz Generated by Autogridder



(a) CAD Model **(b) MoM Mesh Model**

Figure 11. Aircraft Model With 820,000 Unknowns at 500 MHz Generated by Autogridder

Antenna patterns for on-structure radiators can also be computed. An example of a 3-D antenna pattern plot using *GEMACS*' pre/post-processing utility called *XGAUGE* is shown in Figure 16 [10]. A similar 3-D plot capability is also being developed for *E^3EXPERT*. This will allow an analyst to visualize frequency-dependent gain patterns for antenna-mounted platforms selected from within an EBE scene. In this way, mutual and self antenna coupling via sidelobes can be visually analyzed. Sidelobe reduction can also be directly evaluated as a function of frequency, waveform parametric adjustments, antenna location, near field platform scattering, polarization, and other system influences or perturbations.

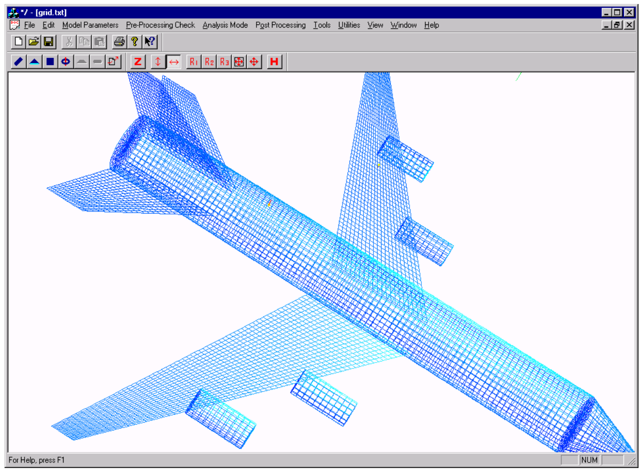


Figure 12. Aircraft Model With 150,000 Unknowns at 200 MHz Generated by Autogridder

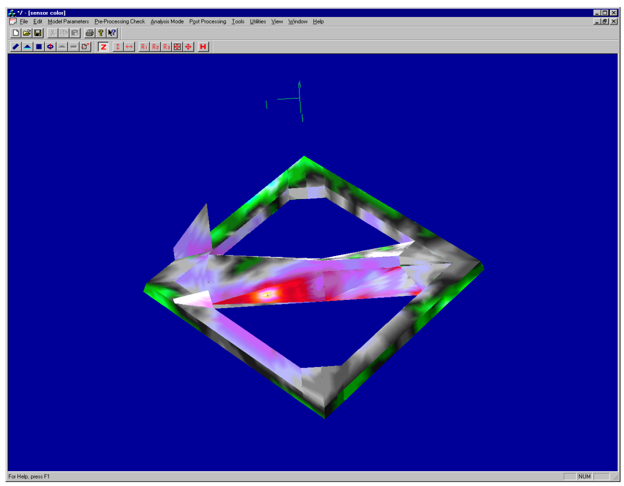


Figure 13. Hot Spots Arising from Surface Currents for UAV Radiators and Incident Fields

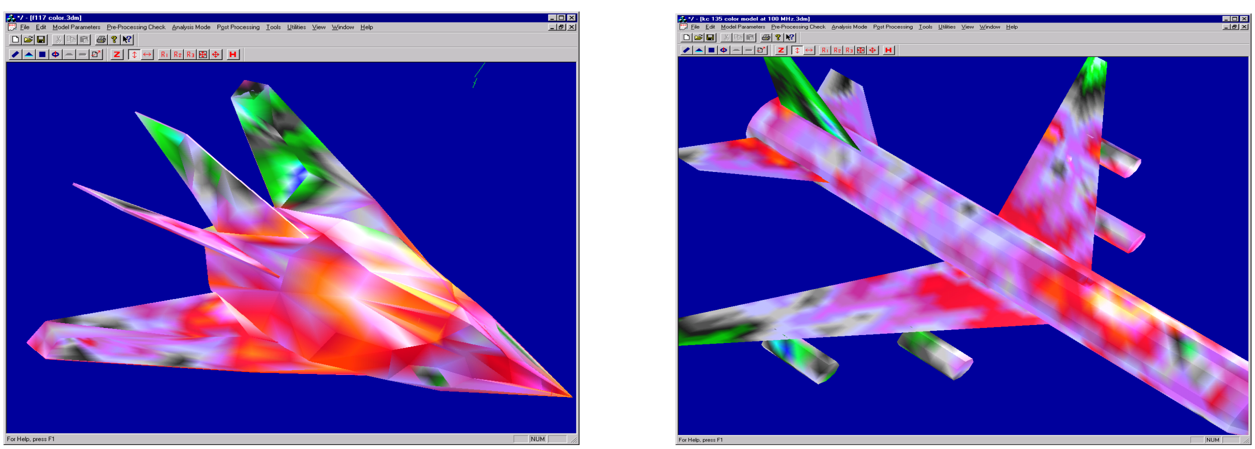


Figure 14. Contour Plots Showing Hot Spots Due to Surface Currents on Airframes

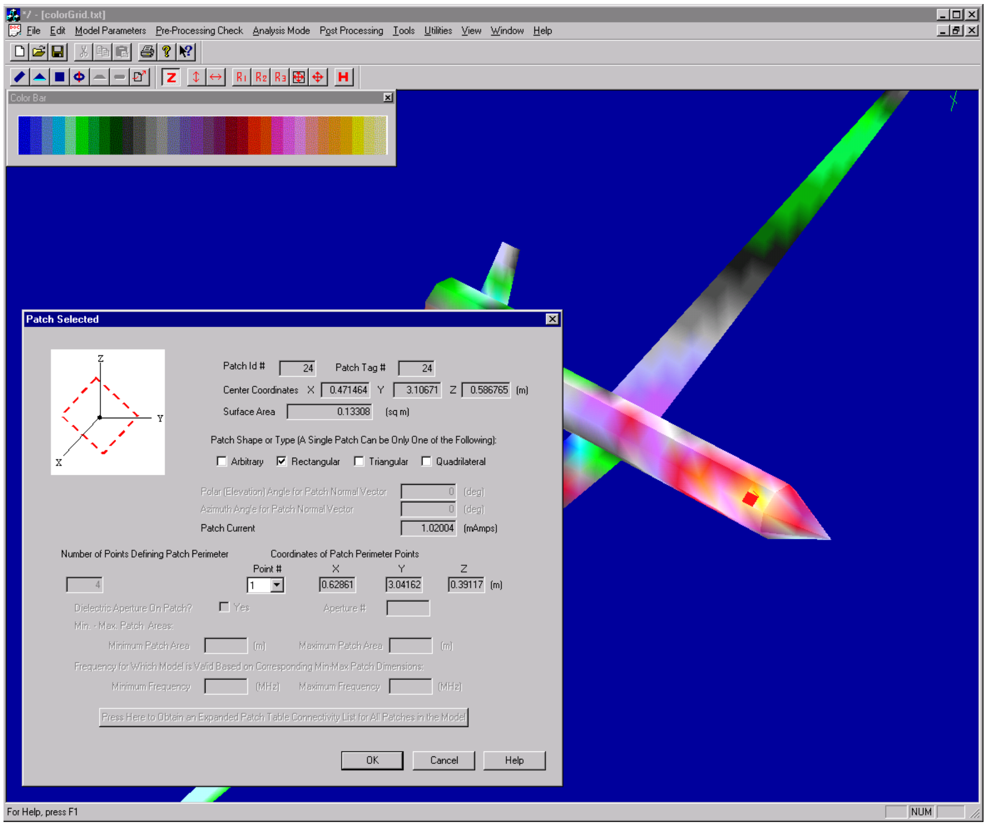


Figure 15. Picking on the Model to Obtain Surface Current Values and Patch Information

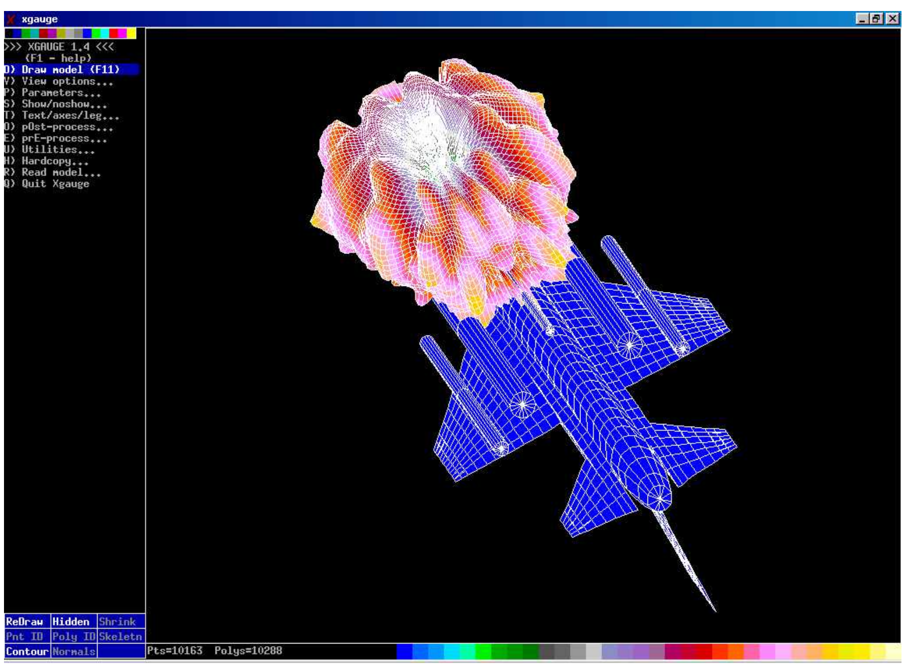


Figure 16. Sculpted Far-Field Pattern on an Aircraft Structure Model [10]

Time-Domain Signal Modeling Simulations

An additional capability is resident within E^3*EXPERT* to model individual EM ports (RF antenna front ends, electronic equipments and cable-connector interfaces) to analyze the coupling and leakage effects due to creeping signals arising from induced surface currents. The *SystemView*™ module of E^3*EXPERT* provides a time-domain capability to model and analyze such components and coupling paths in a block-step fashion [11]. *SystemView™* incorporates a wide variety of digital signal processing, communications, and modulation signal libraries. An example of a *SystemView™* simulation workspace for the case of a direct sequence spread spectrum systems is shown in Figure 17. This figure shows an intended transmitter coupling to a receiver in the presence of an interferer. It is clear from this figure that some waveform distortion exists due to the interference. The path loss and excitation levels calculated in the frequency domain stage are used in the time-domain simulation.

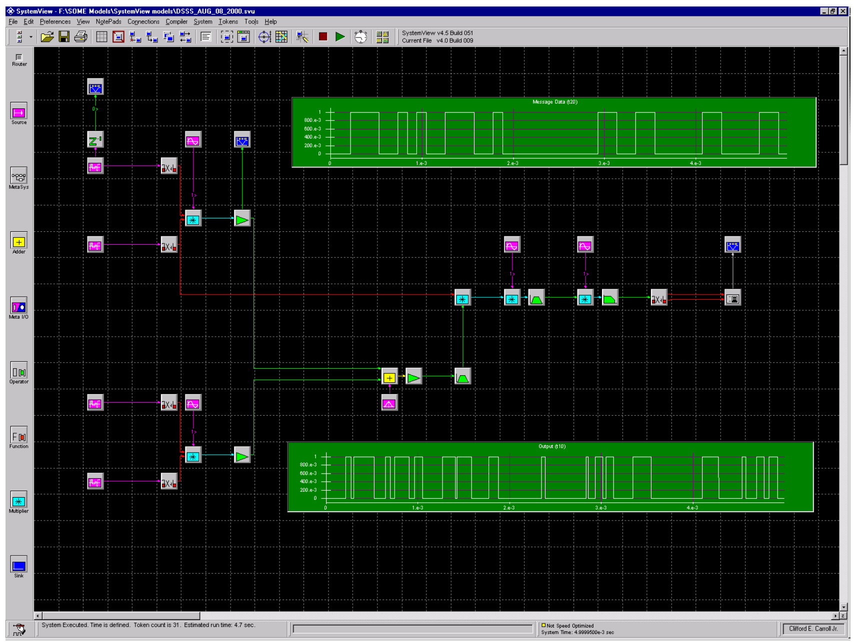


Figure 17. *SystemView*™ Direct Sequence Spread Spectrum Analysis Model

The analysis considers both linear coupling and intermodulation interference. The intermodulation products arise from inherent nonlinearities in the victim receiver due to presence of amplifiers, mixers, and other nonlinear devices. When incident signals from multiple transmitting sources arrive at the receiver and interact with the nonlinear elements in the receiver front-end path, intermodulation frequency products are produced which may fall within the receiver's RF and IF bandwidths. This is illustrated in Figure 18. Nonlinear interference may occur depending on the receiver's RF and IF filtering capacity and the power levels of the intermodulation products. Typically, one is primarily interested in the 3rd-order intermodulation products. However, other orders can be considered in accordance with established techniques based on weakly nonlinear systems theory [13-16].

Expert System Mitigation Solutions

E^3*EXPERT* applies a knowledge-based approach to recommend basic interference mitigation solutions. For an EBE scenario, the solutions for mitigating interference or the effects of jamming would be based on, but not limited to the following schemes:

- Employing tactical avoidance measures.
- Automatically switching systems to available high isolation modes.
- Specifying frequency or waveform adjustments to reduce sidelobe coupling potential.
- Applying adaptive filtering and other methods to increase antenna isolation.

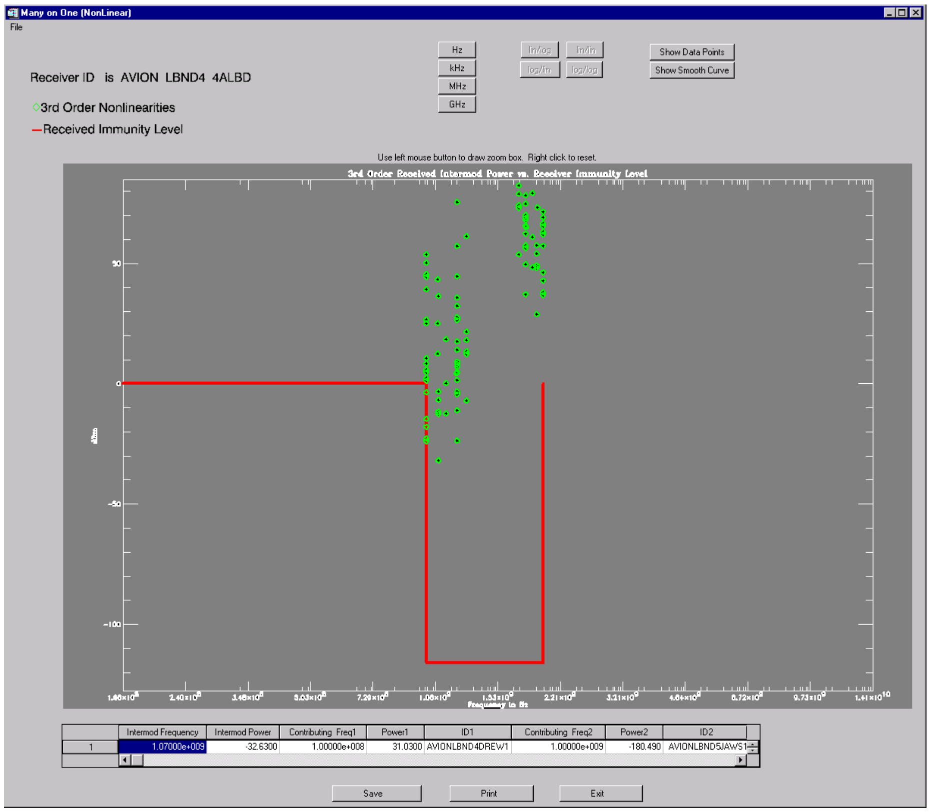


Figure 18. Results of Nonlinear Many-On-One Interference Analysis to a Victim Receiver

SUMMARY

This article discussed a method for modeling RF battlespace scenarios and analyzing complex platform-antenna EM interactions using the E^3*EXPERT* technology. This includes analyzing the performance of antennas and systems immersed in EM-rich environments. A system-level (*physical layer*) analysis methodology is applied to the intersystem EBE problem to address antenna design, siting, and performance issues and to determine necessary vulnerability/jamming mitigation solutions.

Digital EBE modeling using E^3*EXPERT* addresses the following technical areas: (a) use of hybrid CEM techniques to study individual platform-antenna EM interactions and antenna isolation; (b) solutions for CAD preprocessing and effective approaches for gridding/meshing large, complex systems; and (c) methods for developing multi-fidelity simulation models for different frequencies, accuracy requirements, and problem-solving categories. The EM spectrum models, physics and solution methods within E^3*EXPERT* are useful in analyzing and predicting scattering, coupling, interference, and jamming via antenna main and side lobes. The approach also assists in specifying adaptive interference cancellation based on frequency excision schemes as well as basic requirements for frequency management.

Future research will investigate the further definition of performance-validation benchmarks, incorporation of new physics and solution methods (e.g., FDTD and MLFMA), and the utilization of high-performance parallel processing technologies. The latter will assist in optimizing the utility of rigorous CEM modeling, simulation, and analysis techniques to handle electrically large problems accurately and efficiently. Some other areas to be investigated include:

- Adapting existing EM environment databases.
- Incorporating more accurate ground propagation models.
- Enhancing materials modeling techniques.
- Expanding antenna model libraries (arrays, cavity-backed spirals, etc.) for sharing and reuse.
- Extending present methods for graphically post-processing computed results.

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Optimization of Transmission Line Discontinuities using the Genetic Algorithm

J. Alan Roden
Electromagnetic Consultant Engineer

Raleigh, NC 27614
Email: Alan.Roden@IEEE.ORG

Abstract. In this paper, a genetic algorithm based optimization procedure is applied to the equivalent circuit optimization of a microstrip via. A new form of equivalent circuit is introduced which more accurately characterizes the vias' performance. Spice results are presented which demonstrate the impact of various via topologies on transmission line signal integrity.

I. Introduction

Accurate three-dimensional electromagnetic analysis of complex systems oftentimes exceeds the analysis capabilities of modern-day computer systems. Subsequently, the signal integrity or packaging engineer must rely on intelligent simplifications of the problem scenario in order to minimize the computational requirements. One such scenario is the modeling of uniform transmission lines using one-dimensional transmission line techniques such as those in Spice. In the regions where a uniform transmission line exists, TEM assumptions are valid, and simple transmission line analysis methods may be applied accurately. It is in such a manner that most complex systems are modeled today.

When discontinuities are encountered along a transmission line, TEM field assumptions are no longer valid and a pure transmission line modeling approach can lead to significant error. In such a scenario, a full-wave approach is needed to accurately characterize the electromagnetic effects of the anomaly. Full wave analysis of an entire PCB design is typically not practical due to computational and time demands. Furthermore, device libraries for the various active components which exist on a printed circuit board are typically only available in a Spice-like environment.

A good compromise approach entails the incorporation of lumped-parameter equivalent circuit models to capture the three-dimensional effects of the discontinuity. In such an approach, the full wave analysis engine is *only* applied to the discontinuity whereas a Spice equipped circuit solver is applied to the majority of the problem domain where TEM field assumptions are valid, ie the uniform regions of the system's transmission lines. Such an approach yields an accurate and efficient solution to many complex modeling problems.

Equivalent circuit design does not provide an exact solution. The discontinuities which are to be modeled typically do not have an exact analytic solution. Therefore, an optimal solution over a desired frequency band must be the goal. Numerous optimization techniques may be employed.

Here, the genetic algorithm is employed due to its robust capabilities and its ease of use. It does not typically suffer the most typical problem of getting trapped in non-optimal local minima.

In this paper, the genetic algorithm is applied along with the FDTD technique in order to derive an accurate broadband equivalent circuit for a microstrip via. In section II, a design and optimization procedure will be presented. In Section III, results are demonstrated for two commonly occurring microstrip via topologies. Finally, the paper is concluded in section IV.

II. Equivalent Circuit Extraction Using the FDTD Technique

The equivalent circuit generation procedure used here is similar to that reported by Werner and Mittra[1]. Initially, the n-port scattering matrix is extracted from the discontinuity over the frequency domain of interest. Here the scattering parameters are computed from a full-wave solution using the finite-difference time-domain technique (FDTD) . Subsequently, an equivalent circuit form is chosen to represent the discontinuity. It is essential that the circuit has adequate complexity to fully characterize the discontinuity over the frequency band of interest. Next, the scattering parameter matrix of the proposed equivalent circuit is developed analytically. Finally the genetic algorithm is applied to optimize the R, L, and C parameter values of the proposed equivalent circuit so as to match the characteristics of the measured scattering parameters.

The FDTD technique is uniquely qualified to determine scattering parameters from discontinuities for several reasons. First, the FDTD solution is a broadband solution, therefore all necessary frequency components are computed from one simulation. Second, a most unique characteristic of the FDTD technique as opposed to other integral equation based techniques such as the method of moments, is its use of absorbing boundaries. Specifically, absorbing boundaries are used to terminate the problem domain.

For the present case, the PML absorbing boundary condition was employed which has very robust absorption performance over a wide frequency band [2],[3]. At normal incidence, less than -100dB of reflection error can be expected. This excellent ABC performance allows the computational domain to be truncated very close to the discontinuity, thus limiting the problem size. Additionally, for printed circuit board geometries, the PCB may be extended through the PML region. The effect is to emulate an infinite reference plane in each dimension. Thus, the problem solution is immune from resonant effects which finite reference planes will introduce. For discontinuities which produce very small perturbations, such resonances can completey invalidate the scattering parameters computed.

Recently, much research has been directed at producing accurate broadband equivalent circuits using purely analytic methods in an automated manner[4]. In some cases, a simple cascading of ‘pi’ or ‘T’ networks may be adequate. Currently, however, choosing an accurate and efficient equivalent circuit topologies still requires good engineering insight. The success of this procedure is highly dependent on how well a circuit topology can match the discontinuity behavior over the frequency band of interest.

The optimization procedure accomplishes a minimization of the distance between the actual measured or simulated S parameters and the S parameters of the equivalent circuit posed. Mathematically, this is stated as

$$C = \sum_{n=1}^{nfreqs} \sum_{i=1}^{N} \sum_{j=1}^{N} \left| S_{ij}^{meas}\left(f_n\right) - S_{ij}^{equiv}\left(f_n\right) \right|^2 . \qquad (1)$$

The function C is referred to as the cost function. The minimization of this function is the duty of the genetic algorithm. The genetic algorithm[5] is an optimization procedure based on the 'survival of the fittest'. Each circuit parameter is represented by n-bit string called a *gene*. Groups of *genes* are referred to as a chromosome, where a chromosome represents one individual design within the population. Initially, a parameter value range is chosen for each gene (circuit element). The genetic algorithm starts with an initial population of designs. Subsequently, chromosomes(designs) are mated and mutated providing new populations at subsequent generations. The designs in each generation are graded against the cost function, and the most robust design characteristics are carried to future generations. Through such an evolutionary process, after a fixed set of generations, an optimal design is achieved.

It is important to note that the design resulting from this design process is an *optimal* design given the circuit topology and parameter range supplied. If the circuit topology does not adequately describe the frequency behavior of the discontinuity, the resulting optimized circuit will not accurately represent the problem. Therefore, it is crucial that a proper equivalent circuit topology be posed.

III. Example: The Microstrip Via

The microstrip via is a common and crucial design element in most modern-day printed circuit board designs. It is also common within chip packages where numerous voltage and reference planes exist. A via provides an electrical path for a signal to transverse between various wiring planes within a PCB or package substrate. The via can extend entirely through the board regardless of the layer of the signal and reference layers, or can simply exist between the two layers where the signals is transversing (blind via). The first of these is studied here although a similar analysis and model can be applied to the blind via as well.

The via is characterized by its barrel size, annular ring size, and clearance dimension on each layer. The barrel is cylindrical and extends the through the height of the board, the annular ring exists at the top and bottom of the via minimally, but also at each layer where a signal line is connected. The clearance area is a cylindrically drilled hole which creates an isolation area around the via from adjacent materials.

All vias are not the same from an electrical standpoint. The two major classifications of vias are the simple via and the through-board via. The simple via electrically connects signal traces on the opposing layers of a common reference plane. For such a via, the return current has a continuous current path through the clearance hole in the reference plane to the opposite side of the reference plane, where the completion of the signal circuit exists. The through-board via traverses numerous reference layers moving from one initial reference plane to a final different one.

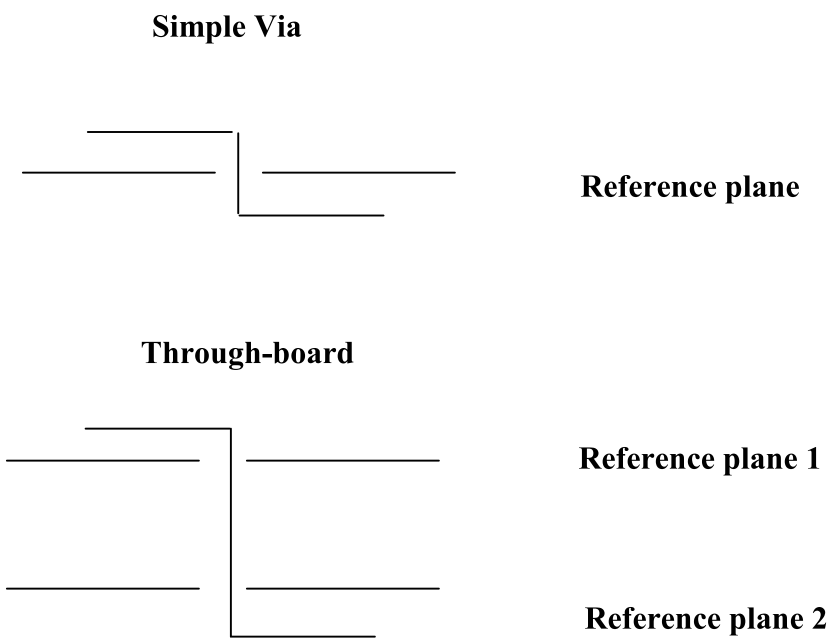

Figure 1 Common via topologies for printed circuit boards.

Initially, a full-wave analysis of the via is accomplished using the FDTD technique in order to determine its scattering parameters. The first geometry analyzed consists of a 50 ohm trace, a through-board via (barrel=10mil diameter, annular ring 20mil diameter), followed by another 50 ohm trace on the opposite sidee of the board. The trace is doubly terminated into the PML absorbing boundary. The board core is 60 mils thick. Two ground vias of equivalent dimension are placed 100 mils from the signal via on either side of it. These represent decoupling capacitors which would be present in a real design. It is important to note that decoupling capacitors are not typically placed this close to every signal line, therefore the performance here is a bit ideal.

The discretization is 2 mils in each dimension. The problem dimension is 80 x 200 x 50. The microstrip is excited by a gaussian pulse with a bandwidth of 5 GHz. Port 1 is defined 50 mils from the via on the top layer, port two is defined 50 mils from the via on the bottom layer. Time domain voltages are measured at each reference plane with and without the via present. Subsequently, scattering parameters are computed effectively with reference plane shifts to give parameters of the vias alone.

Figure 2 illustrates the time domain waveforms at port 2. Clearly some time shift does occur as well as some signal amplitude distortion. Looking closely, we see some loss. This is primarily due to the radial wave launched internal to the board, but also to the return loss. An equivalent circuit was derived based on previous work as well as the insight gained from simulations and viewing subsequent field animations. The initial circuit chosen was a multi-stage 'pi' circuit where the number of stages could be varied. The circuit was similar to that used by Harms in [6]. It was determined that this model could be modified slightly to give better performance for the through board via. The additions accounted for the plane-to-plane capacitance and inner plane loss through components R3 and C3. This modified T circuit is shown in Figure 2.

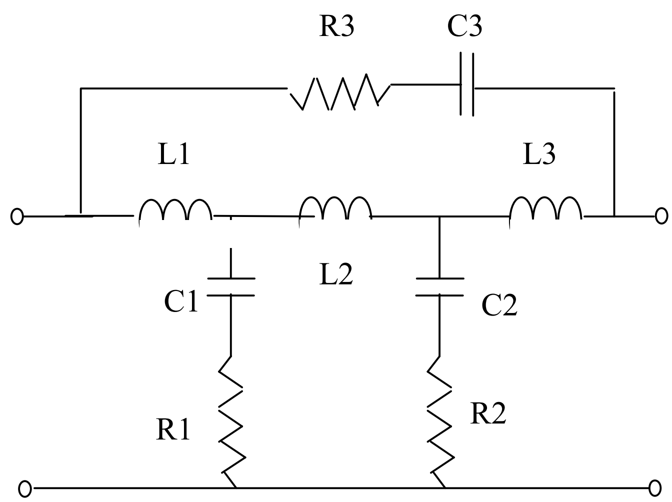

Figure 2 Equivalent circuit for PCB via; modified 'T' design.

Figure 3 illustrates the time domain voltage waveform at port 2 for the through board via. Clearly, the most significant effect is the phase shift which will be board thickness dependent.

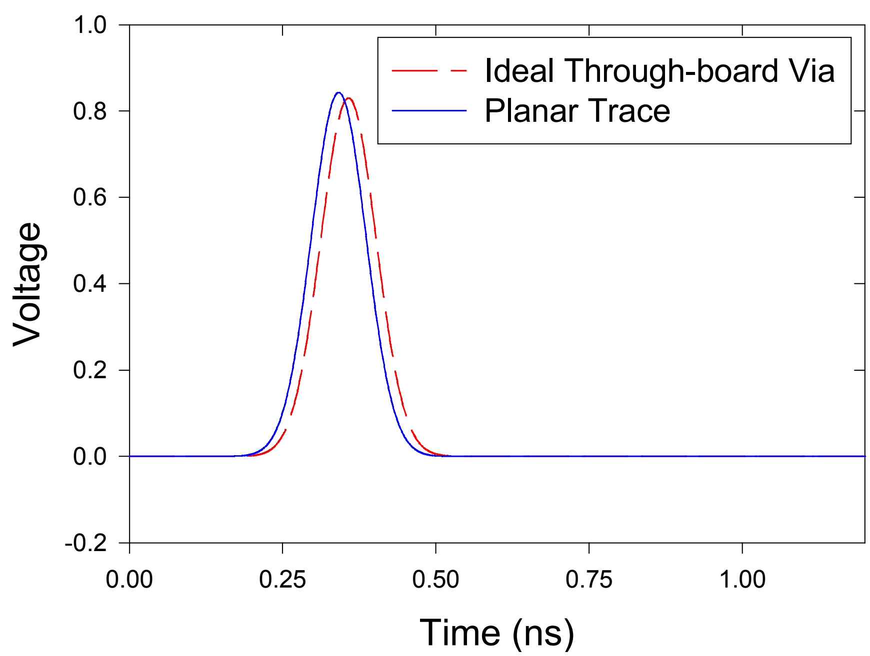

Figure 3 Time domain FDTD waveform at port 2 for a through board via.

In Figure 4 the scattering parameters S_{11} and S_{21} are illustrated. Here the initial two-stage 'pi' design, the modified 'T' design, and the measured results are shown. Clearly, good agreement

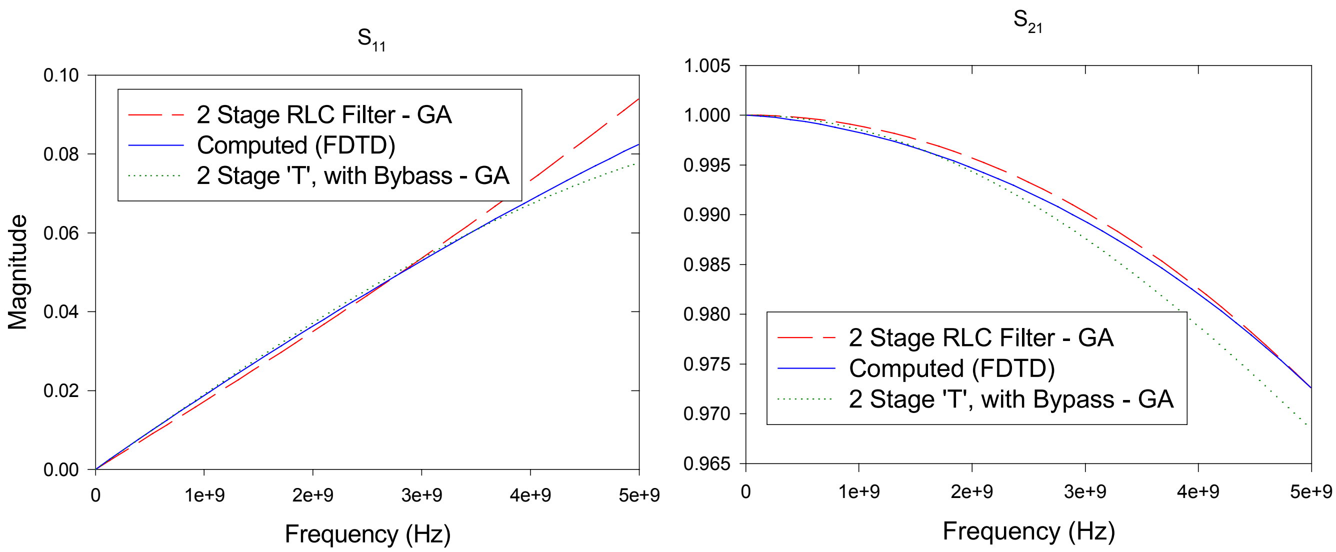

Figure 4 Magnitude of Scattering parameters for through board via. (unitless)

exists across the entire band with some deviation by the simple two stage 'pi' above 3 GHz. Similarly, the phase is shown in Figure 5. Here, we see again that the S_{11} phase performance for the new modified 'T' design is excellent with some error from the 2 stage 'pi' design. The phase of S_{21} showed good agreement for either model. It is important to note that the complexity of the 'pi' circuit was increased to as large as eight stages in an attempt to get better broad band performance. Such efforts led to no further improvement.

Figures 5 and 6 represent the culmination of the equivalent circuit design. Here the genetic algorithm generated equivalent circuits are included in a Spice simulation of an ideally terminated transmission line. Also included in these plots is a simple and commonly used model for a via, a 1 pF capacitor. This trusted model has been used for years due to its simplicity.

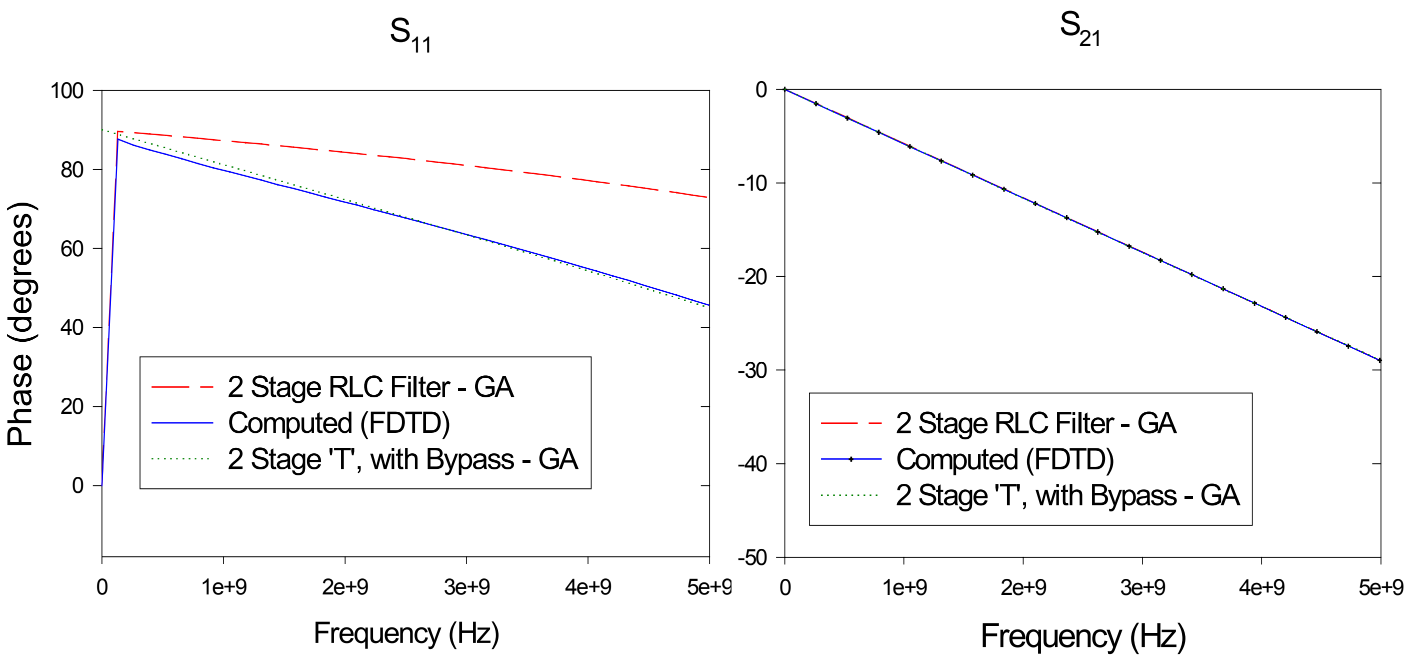

Figure 5 Scattering parameter phase for through board via.

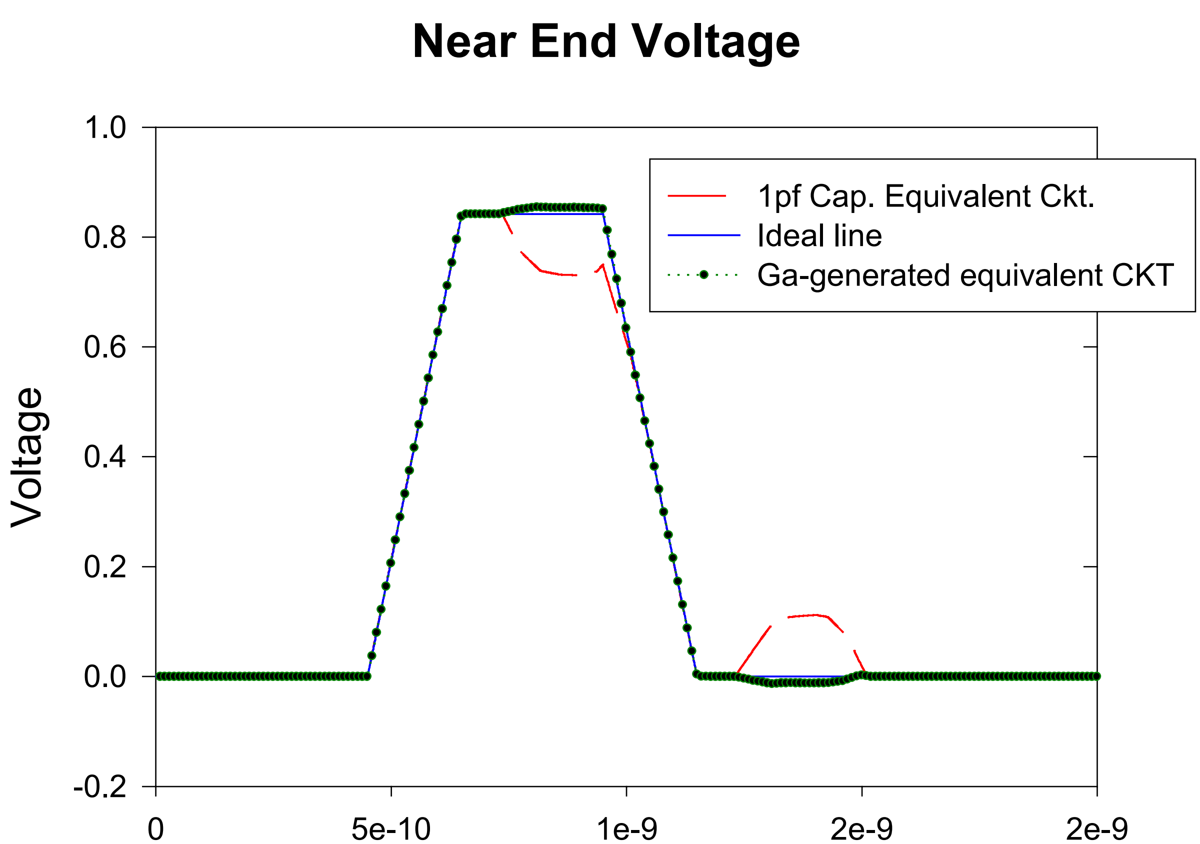

Figure 6 Spice simulated near-end voltage including genetically designed equivalent circuit for a through-board via and a simple 1 pF model for via.

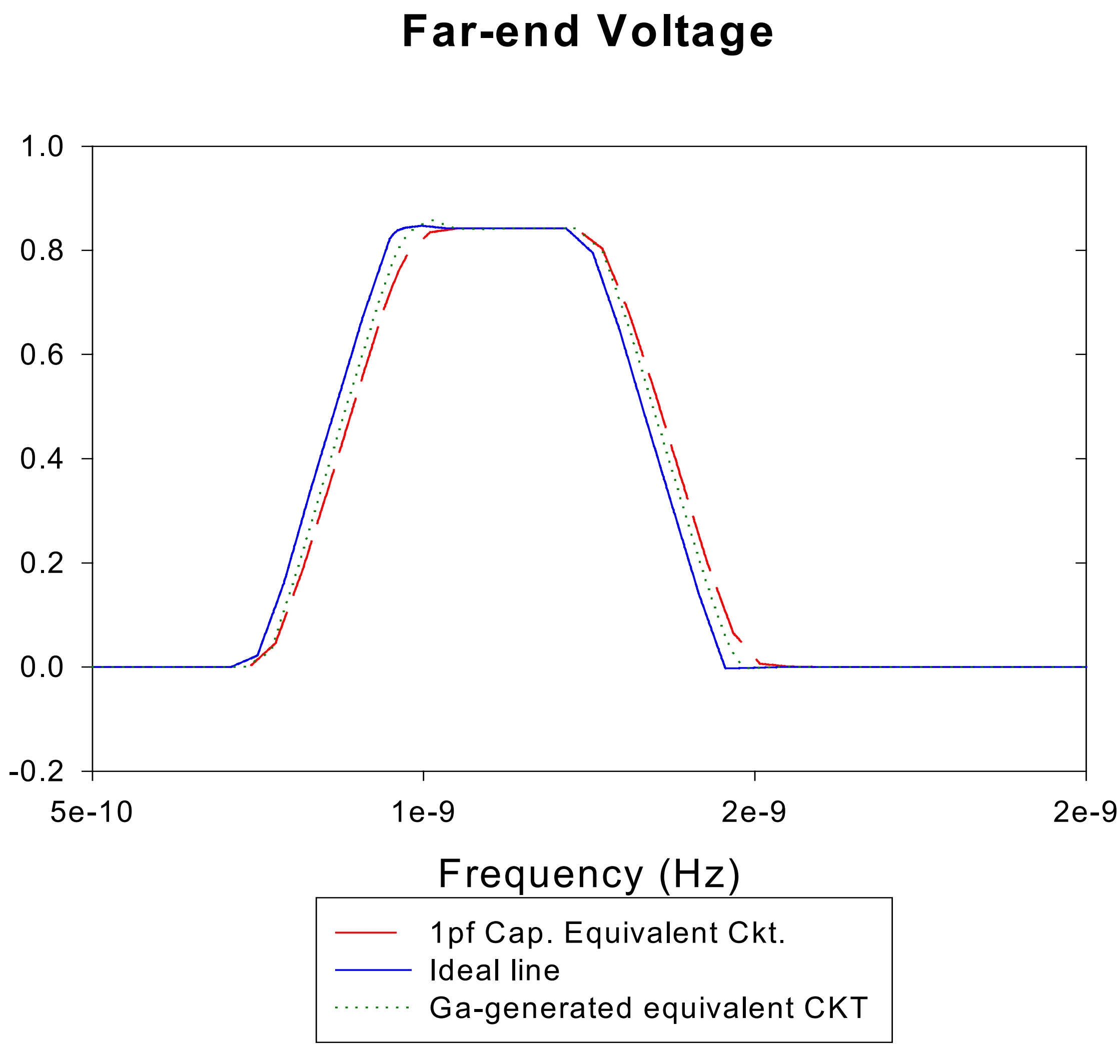

Figure 7 Spice result for far-end voltage for genetically designed equivalent circuit for a through-board via and a simple 1 pF via model.

Figure 5 illustrates that the via does cause a noticeable distortion to the time domain waveform. Interestingly, the actual via model shows much less return loss than the simple 1 pF model of the via. Figure 6 illustrates the primary impact of the microstrip via; delay. Here we see that a delay of about 16 ps is caused by the via. This is a small but significant delay for modern-day designs. Also note that the simple 1 pF cap demonstrated very similar performance to the equivalent circuit with respect to delay, suggesting that this has not been such a bad choice for this most crucial figure of merit.

The simple via was also examined using the current technique. It was found that the simple via produced much less distortion and delay than the through-board via. This is due to the fact that the return current path is not discontinued completely, just rerouted. The genetic algorithm proved to be even more robust for equivalent circuit optimization in this case. The time-domain spice waveform is shown in Figure 7 for the simple via. As is demonstrated here, the delay is greatly reduced over the through-board via (6 ps). Also, the simple capacitor model continues to portray a delay of about 22 ps which is far greater than actual.

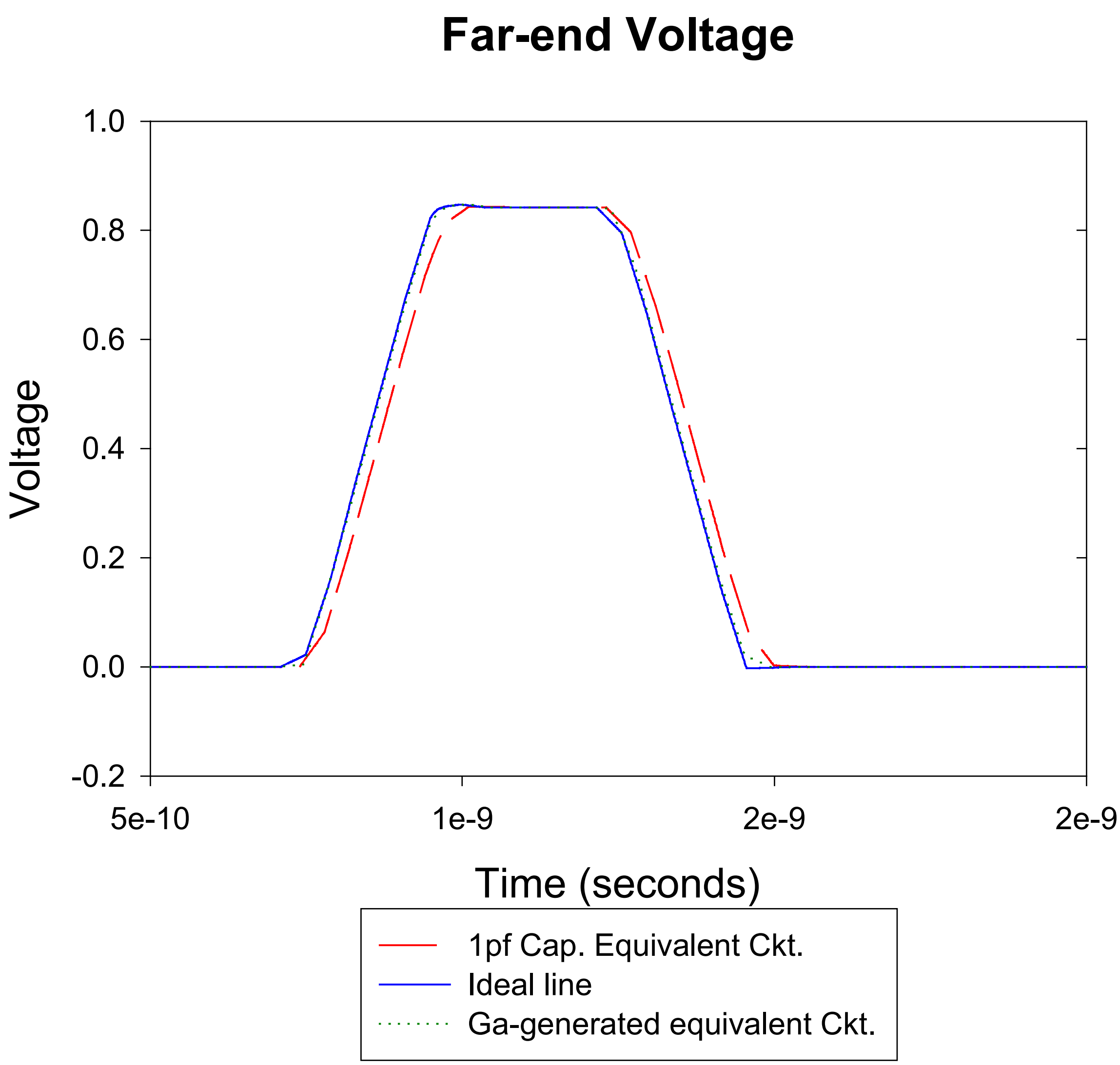

Figure 8 Far-end Hspice voltage for simple via and 1pf capacitor model.

IV. Conclusion

In this paper, the genetic algorithm was applied to the equivalent circuit design and analysis of a via. The results presented showed that the genetic algorithm is indeed a very robust tool for equivalent circuit optimization. Successful equivalent circuit optimization requires an accurate choice of circuit topology. In this work, a new circuit topology was introduced for the microstrip via which proved more accurate than those previous presented. This method may be applied to a variety of geometries where the features are small with respect to a wavelength. Further research is needed to find a systematic method to determine equivalent circuit topologies.

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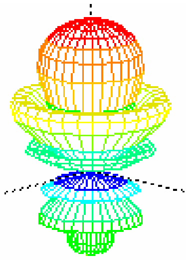

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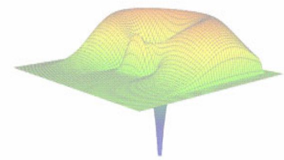

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AREA	INDIVIDUAL SURFACE MAIL	INDIVIDUAL AIRMAIL	ORGANIZATIONAL (AIRMAIL ONLY)
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☐ CHECK (PAYABLE TO ACES) ☐ TRAVELER'S CHECKS ☐ INTERNATIONAL MONEY ORDER

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CREDIT CARD ACCOUNT # ☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐ 2002

DEADLINE FOR THE SUBMISSION OF ARTICLES

Issue	Copy Deadline
March	January 13
July	May 25
November	September 25

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