APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY (ACES)

NEWSLETTER

Vol. 16 No. 3 November 2001

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NEWSLETTER ARTICLES AND VOLUNTEERS WELCOME

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

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OFFICER'S REPORTS

PRESIDENT'S POST

by Perry Wheless
20 September 2001

The Annual ACES conference is still almost six months away, but you should be aware that the 2002 conference may be affected by the attack of 11 September 2001 on the United States. Plan your conference trip accordingly.

The Naval Postgraduate School (NPS) in Monterey, California, has been a terrific partner and gracious host for the ACES Annual Review of Progress in Applied Computational Electromagnetics series. Except for the first and tenth anniversary conferences, held at Lawrence Livermore National Laboratory and the DoubleTree Hotel Monterey, respectively, NPS has been our home. We, as a society, have chosen to base our conference activity at NPS, a government facility, and the arrangement has been very beneficial to ACES over an extended period of time. However, as ACES oldtimers know, access to NPS can depend on military alerts and security concerns. Last year there were no guards at the gates, and access was unrestricted. In prior years, most of us can remember guards and having to produce picture identification in order to gain access.

As a result of the extraordinary events of September 11, more stringent security measures are now in effect at NPS. With conference so far in the future, why bother you with these matters now? The reasons are twofold: (1) unlike past alerts, which arose and dissipated rather quickly, there is a general expectation that this situation is different and heightened security is likely to remain in place for an extended period of time, and (2) because a protracted condition of high security at NPS could seriously hurt our conference participation level and revenues, the ACES Board of Directors will need to consider contingency planning for future conferences.

The Most significant security procedure now in place at NPS is a requirement that the name of *any visitor* to the facility must be submitted for screening and approval at least 24 hours in advance. This may be relaxed or changed in some other way between now and March. At the moment, however, the most prudent path for planning purposes is to assume the current conditions will continue to apply at conference time. A person appearing for on-site registration at, for example, 8:30 am on Monday, would not be allowed access to NPS before 8:30 am Tuesday, at the earliest. This means we need to get the word out, in a big way, that **advance registration is critically important** this year! Clearly, there is the additional issue that our usual registration area inside the NPS compound may not be available for last minute walk-in registrants. Because these issues have just arisen, it will take some more time to identify an acceptable "on-site" registration area outside the NPS perimeter.

For future conferences, the recent developments may actually prove to be constructive. In earlier years, proposals to move the conference location annually were rejected by the Board of Directors because the Monterey location was a perennial hit, plus Dick and Pat Adler could minimize the considerable work of local arrangements for conference by staying at NPS. On the other hand, the decision to base at NPS has probably hurt our recruitment of conference chairs, as potential chairs could garner more support from their employer/institution for conducting a local, versus remote, conference. The Board of Directors will discuss this matter in their next meeting, an October teleconference, and a more substantial report on the status of these considerations should be available for the next ACES Newsletter. In the immediate future, for 2002, we presently believe our best response is to stay the course at NPS and operate as close to "traditionally normal" as possible. At the same time, recent events will cause us to re-think our conference priorities and procedures - a potentially positive development for the long term.

Register early for ACES 2002. Spread the word about the importance of advance registration to your CEM acquaintances who are potential registrants! Updates and news of significance will be posted under the Conference link on the ACES Web site, **http:///aces.ee.olemiss.edu**. We expect another outstanding conference, and I look forward to seeing you there.

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MODELER'S NOTES

Gerald J. Burke

On a continuing theme, we have an update on NEC–4 performance on P-4 systems, including a contribution from Larry Laitinen on a low cost clone P-4 system. But first an embarrassing "woops". The changes that I recommended in the July 2000 and March 2001 Newsletters turned out to have some adverse side effects. A hopefully better fix is given below.

This issue first came up when Mike Morgan at the Naval Postgraduate School encountered problems with extraneous spikes in the near magnetic field over a Sommerfeld ground. NEC–4 evaluates the magnetic field from finite differences of electric field values. Such "glitches" were a known problem at points where the electric field evaluation is switched from interpolation to least-squares approximations and to asymptotic approximations, since the differences magnify small discontinuities in E. The spikes are very localized, but can be a serious problem if you are looking for peak field values. At that time I looked at the code and found that the largest spike coincided with a switch to using single-point integration on the segments to save time when the interaction distance was sufficiently large. Disabling this switch, so that the code always integrated over the segments, eliminated the worst spike in H. What I did not notice is that this change also locked out the asymptotic approximation for E, so that the least-squares approximation was used outside of its intended range. The L.S. approximation does allow extrapolation, but the error grows with increasing distance, and is not acceptable beyond a few wavelengths. In April of this year John Grebenkemper reported inaccurate impedance values as a short vertical dipole passed through a height of $\lambda/2$. This problem also appeared to be fixed by disabling the switch to single-point integration.

Instructions for disabling the switch to single point integration were included in Modeler's Notes in the July 2000 and March 2001 Newsletters. If you have made those changes, undo them by reactivating the four lines of code. Fortunately this problem did not affect the ground wave obtained with the RP1 command, so that may limit the damage.

Fixing the problems is a little more complicated. The error in the impedance of a vertical dipole with height around $\lambda/2$ is probably the most important, since it affects near field interactions. The problem is due to the treatment of point charges on the segment ends. An isolated segment has point charges at its ends that contribute to the electric field. In NEC the basis functions ensure continuity of current over the structure, so the fields due to point charges would cancel and are not evaluated. For the Sommerfeld-ground field at distances less than the limits for integration NEC integrates numerically for $(E_{\text{Sommerfeld}} - E_{\text{quasistatic}})$ and adds the analytic integral over the current for $E_{\text{quasistatic}}$. The quasistatic term has the same form as the free space field, and the evaluation omits the point charges for each segment. When the code switches to single-point integration it evaluates only $E_{\text{Sommerfeld}}$ with point charges (for a hertzian dipole) included. Hence there is a mismatched charge at the transition point.

There are a couple of ways that this problem might be fixed. I chose to turn on the evaluation of point charges before switching to single-point integration. The switch must be done for all segments at a junction, so it is necessary to compute the location of the segment ends rather than just the center. The modification to subroutine EFLD is shown below. The bold text is added code, and the call to subroutine EFLDSG has been modified.

```
C
C     FOR SOMMERFELD GROUND EVALUATION, TEST IF DISTANCE IS GREAT ENOUGH
C     TO USE POINT SOURCE APPROXIMATION.  IF SO THE TOTAL REFLECTED
```

```
C    FIELD IS EVALUATED BY SOMMERFELD-INTERPOLATION CODE.
C
      IF(IPERF.EQ.2)THEN
        IMAGF=1
        RHO=SQRT(XIJ*XIJ+YIJ*YIJ)*GSCAL
        ZIJS=ZIJ*GSCAL
        IF((ZIJS.GT.ZZMX1).OR.(-ZIJS.GT.ZPMX1).OR.(RHO.GT.RHMX1))THEN
          IMAGF=2
          GO TO 17
        END IF
C    Include point charges on segment ends within 0.1 of the boundary
C    for switching to one-point integration.
        SLENH=.5*SLENJ
        XDST1=XI-(XJ-DXJ*SLENH)
        YDST1=YI-(YJ-DYJ*SLENH)
        ZDST1=ZI+(ZJ-DZJ*SLENH)*GSCAL
        RHOD1=SQRT(XDST1**2+YDST1**2)*GSCAL
        XDST2=XI-(XJ+DXJ*SLENH)
        YDST2=YI-(YJ+DYJ*SLENH)
        ZDST2=ZI+(ZJ+DZJ*SLENH)*GSCAL
        RHOD2=SQRT(XDST2**2+YDST2**2)*GSCAL
        IF(ZDST1.GT.ZZMX1-.1.OR.-ZDST1.GT.ZPMX1-.1.OR.
     &     RHOD1.GT.RHMX1-.1)THEN
          INDX1=60000
        ELSE
          INDX1=IND1
        END IF
        IF(ZDST2.GT.ZZMX1-.1.OR.-ZDST2.GT.ZPMX1-.1.OR.
     &     RHOD2.GT.RHMX1-.1)THEN
          INDX2=60000
        ELSE
          INDX2=IND2
        END IF
      ELSE
        INDX1=IND1
        INDX2=IND2
      END IF
C
C    EVALUATE IMAGE FIELD
C
      CALL EFLDSG(XIJ,YIJ,ZIJ,DXJ,DYJ,DZJR,SLENJ,ARADJ,ZPEDS,XK,ETX,
     &XKSJ,INDX1,INDX2,TXK,TYK,TZK,TXS,TYS,TZS,TXC,TYC,TZC)        ←Change
                                                                 IND1 to INDX1
                                                                 IND2 to INDX2
```

Note that it is assumed above that the flag for evaluating the point charge is the value 60000. I have modified our codes to use 60000 for the point charge flag and 30000 to flag connection to a patch. Earlier copies of NEC–4 used 20000 and 10000, respectively, and people who have run into the limit of 10000 segments may have changed their codes to other values. In any case, set the correct flag value for INDX1 and INDX2 in the modified code.

The above correction fixed the problem that John Grebenkemper found in the impedance of a vertical dipole when the ends bracket $z = \lambda/2$. A similar error occurred in the electric field of a segment when the horizontal distance was one wavelength, and that is also fixed by the above change. Fixing the point charge treatment removed some spikes in the near H, but others remained where the code switched from interpolation to least-squares approximation and to the asymptotic approximation. I fixed the spike on switching to the asymptotic approximation by locking the evaluation method. On the first evaluation of the six-point central difference approximation for $\nabla \times E$ the code determines, based on the source and evaluation point locations, whether to use interpolation, least-squares or asymptotic. For the latter two the modified code sets a flag to lock the method for the remaining five evaluations of E. The same could not be done easily for the switch from interpolation to least-squares, since the interpolation cannot be extrapolated by much, and there is already a smoothing applied at this transition.

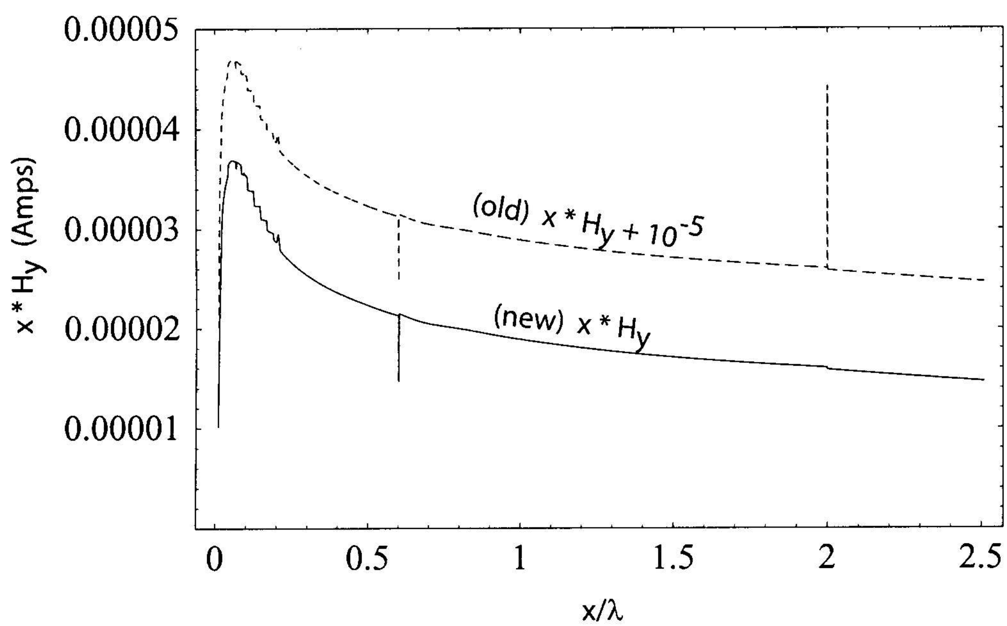

Fig. 1 Near magnetic field H_y times distance x due to a vertical 0.1λ dipole just above the ground. The complex ground permittivity was $\tilde{\epsilon}_r = 20 - j10$.

The near H fields before and after making these changes are shown in Figure 1 for a vertical 0.1λ dipole above a ground with complex permittivity of $\tilde{\epsilon}_r = 20 - j10$. The quantity $x \times H_y$ is plotted so that the singularity for small x does not dominate the plot. The remaining spike at about 0.6λ is due to the switch from interpolation to least squares. The curve for small x looks a little ragged. I have not looked for the source of this, but it is not noticeable if you plot H_y rather than $x \times H_y$. The best solution would be to write new code for interpolation and least-squares evaluation of H rather than numerically evaluating $\nabla \times E$. This would be reasonable to do now, with the advances in computer memory and speed since when NEC–4 was written. However, it would take a considerable amount of time to work out the details.

The changes to lock the evaluation method during the evaluation of $\nabla \times E$ are simple, but involve several areas of the code. I have not included them here to save space. Anyone who has NEC–4 and wants to make this change can contact me by email and I will send the changes, or can send new files for the code if they do not want to make the changes and recompile the code.

If anyone using NEC–4 would like a new code with these changes, they can let me know and I will send it out. I did get a call about eight to ten months ago from someone who reported that the field did not fall off correctly at large distances over ground, but I assumed that they were going so far that the near field evaluation was breaking down. It was probably a result of this problem, but I did not take a close enough look.

On a new topic, last May, just after the deadline for the last Newsletter, I got a Dell 8100 PC with 1.7 GHz P-4 processor and 1 GB of RAM for use at work. The cost at the "higher education" rate was just under $3000 with a 60 GB disk, CD-RW and DVD drives. Of course, a test of NEC running times was one of the first items of business, and the results were fairly impressive, as shown in the table below.

	CVF V. 6.5A compiler				CVF V. 6.6 compiler			
No. seg.	Fill (sec)	Factor (sec)	Total (sec)	Estimated MFLOPS	Fill (sec)	Factor (sec)	Total (sec)	Estimated MFLOPS
1200	5.49	7.80	13.90	590.8	6.21	7.36	14.23	626.2
2400	21.48	60.47	84.47	609.6	24.27	57.34	84.15	642.9
3600	48.39	202.29	256.28	615.0	54.81	192.13	252.55	647.5
7500	249.85	2413.04	2689.37	466.2	322.13	2135.46	2484.22	526.8

Times are given for NEC4D compiled with both the Compaq Visual Fortran V. 6.5A compiler and the new V. 6.6 compiler. I upgraded to V. 6.6 about three weeks ago, since V. 6.5A was generating bad code in compiling the EIGER program in debug mode. The reply from Compaq support was to get V. 6.6 from their ftp site as a free upgrade from V. 6.5A. At the time V. 6.6 was not mentioned on the Compaq website, but that may have changed by now. It is a main line, well documented release that adds some new features and fixes some bugs, including the one we encountered with EIGER. It also made some differences in the speed of NEC-4, as shown in the above table. The fill time went up and the factor time went down. The V. 6.6 compiler has a setting to optimize for a P-4 processor, but I could find no significant difference in speed with that setting over the default to optimize for a blend of processors. NEC-4 was compiled for "Maximum optimization", which did produce faster code than the default of "Full optimization", but changing the loop unrolling from the default of 4 to 8 did not have a significant effect. The NEC4D code that Larry Laitinen used for the results in the article that follows this were compiled with V. 6.5A.

In the above table it is seen that the speed in factoring the matrix has increased by about 6x for a 2x increase in clock speed over the 850 MHz P-III in the data that Larry Laitinen supplied in the July Newsletter. The increase in matrix fill speed falls a little short of the clock speed factor. Compiling the code for 7500 segments produced the message "Image size of 905,990,144 exceeds the maximum of 268,435,456, image may not run". It did run, but a little slower than scaling by N^3 from the smaller problems. The single processor 1.7 GHz P-4 is still about 25% slower in running EIGER than an older DEC Alpha with dual 533 MHz processors, which shows the advantage of a 64-bit system. It will be interesting to see how much faster the code runs on the P-4 with the Intel optimized LAPACK routine. If it shows the same factor of improvement as with the P-III it would really be impressive.

A recent check of the Dell website showed a 2 GHz P-4 available with 1 GB or RAM and DVD and CD-RW drives and no monitor for $2535 at the "higher education" rate. Filling it up to 2 GB of RAM cost another $1200. Larry Laitinen discusses a still more economical option in the following article.

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

PENTIUM-4 RAMBUS PC PERFORMANCE WITH NEC-4.1

Larry Laitinen, University of Oregon

Four 1.4-GHz Pentium-4 "clone" PCs were recently purchased and tested. These PCs are based on the Intel D850GBAL motherboard with 512-MB of ECC RamBus RDRAM memory. One of the four PCs was loaded with Windows-NT and performance tested for floating point, network and disk I/O speed. Double-precision floating point performance was evaluated using NEC-4.1's matrix factor timing data, as shown in Table-1 below. Table-2 compares the P-4 RamBus based PC performance with that of the earlier P-3 SDRAM based PCs. Table-3 shows basic disk performance for the P-4 test PC using the HDTACH disk performance test program.

P-4 PCs with RamBus RDRAM memory provide significant 5X to 6X performance improvements over older P-3 based systems with PCC-133/100 SDRAM memory. However, GNEC's FPU code optimizations and multiple CPU support provided similar performance improvement in matrix factorization for the 550-MHz Dell dual-P3 system. It will be interesting to see how well this carries over to multiple CPU P-4 RamBus based systems.

The P-4 test PC's network speed with an Intel Pro/100 S Desktop IPsec 3DES PCI bus Ethernet adapter was measured at 7.88-MBytes/sec for the COPY command and 7.46-MBytes/sec for the FTP GET command. The test server was running Netware-5.1. Note that the Intel D850GBAL motherboard has an onboard Ethernet adapter that provided transfer rates in the 6.2 to 6.8-MBytes/sec region.

This is very impressive performance for a baseline PC in the $1200 price range (w/o monitor, keyboard, mouse). Further, it provided 94% of the 1.7-GHz Dell Dimension-8100's NEC factorization performance at roughly 60 to 75% of the Dell's cost, after adjusting for differences in memory and other accessory/option items. The sluggish PC (and especially the memory) markets have made fast P-4 RamBus based PC systems very affordable for desktop office, scientific and engineering applications. As usual, your EPA mileage may vary...

Finally, this workstation PC boots Windows-NT in 15-seconds flat from the Windows-NT boot menu to the Ctrl-Alt-Del login splash screen. This is the fastest Windows-NT boot I've ever experienced with an IDE/UDMA boot disk drive based PC.

Table 1. 1.4-GHz P-4 RamBus PC Performance for NEC-4.1 under Windows-NT V4 SP6A.

No. seg.	Fill (sec)	Factor (sec)	Total	Pagefile size	Estimated MFLOPS*
600	1.652	1.092	2.924 sec		n/a
1200	6.459	8.302	15.352 sec		555.0
2400	25.597	66.004	1.557 min		558.5
3600	57.653	222.30	4.731 min		559.7
4800	183.273	1126.60	23.316 min	1.7-GB	261.8**
7500	453.172	4628.63	1.469 hr	2.9-GB	243.1**
10000	780.162	13336.62	4.024 hr	6.6-GB	200.0**

* Estimated MFLOPS/sec based on [8/3 * (# Segments)^3] / [Factor Time] for 1,000 or more segments.

** Swaps to disk – not enough RAM. For this compiled version of NEC-4.1, the maximum RAM used was about 283-MB including the OS.

Table 2. Some comparisons for 1200-segments with other recent PCs.

Machine	Fill (sec)	Factor (sec)	Total (sec)	Estimated MFLOPS
550-MHz P-3 dual-cpu Dell 610 with 2-GB RAM	10.21	6.65	n/a	692.9
1.7-GHz P-4 Dell Dimension-8100 with 1-GB RDRAM	5.49	7.800	13.900	590.8
1.4-GHz P-4 Intel D850GBAL motherboard with 512-MB RDRAM	6.459	8.302	15.352	555.0
850-MHz P-3 Gigabyte GA-BX2000 motherboard with 512-MB PC-100	7.881	47.408	56.120	97.2
933-MHz P-3 Gigabyte GA-6VXD7 motherboard with 1-GB PC-133	7.250	49.453	57.453	93.2

Notes:

a) 550-MHz P-3 data provided by Keith Lysiak of SwRI. Data from GNEC code execution using the Intel MKL/Lapack libraries with dual-CPU support and Pentium FPU optimization. GNEC is an enhanced NEC-4.1 from Nittany-Scientific.

b) 1.7-GHz P-4 NEC-4.1 data provided by Jerry Burke of LLNL, the author of NEC.

c) Except for the 550-MHz P-3, all data came from NEC-4.1 code compiled by Compaq (previously DEC) Visual Fortran compiler.

Table 3. The P-4 test PC's disk I/O performance measured by HDTACH between the outer and inner cylinders. The disk drive is a 30-GB IBM Deskstar, 7200-rpm, 2-MB cache/buffer, 8.5-msec seek time drive.

Maximum sequential disk I/O rate:	41.62-MB/sec
Minimum sequential disk I/O rate:	8.80-MB/sec
Average sequential disk I/O rate:	32.01-MB/sec
Random access time:	13.4-msec

Numerical Formulations and Applications of the ADI-FDTD Method

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Abstract – In this paper, the ADI-FDTD (Alternating-Direction-Implicit Finite-Difference Time-Domain) method is presented. As the algorithm of the method is unconditionally stable and free from the Courant-Friedrich-Levy (CFL) stability condition restraint, a time-step size larger than the CFL limit can be set and computation time can be saved for some problems. Numerical formulations are explained and simulation results are compared with those of the conventional FDTD method.

1. Introduction

The finite-difference time-domain (FDTD) method [1][2] has been applied to various problems related to electromagnetism. As the traditional FDTD method is based on an explicit finite difference algorithm, the numerical formulations are quit simple and its computation is very efficient. However, the Courant-Friedrich-Levy (CFL) stability condition must be satisfied when this method is used. Therefore, the maximum time-step size is limited by minimum cell size in the computational domain. As a result, if an object of analysis has fine scale dimensions compared with wavelength, the small time-step size creates a significant increase in calculation time.

To eliminate the CFL stability condition, applying implicit techniques to the FDTD scheme is required. In 1984, Holland reported an implicit FDTD method [3] but it was not completely stable. There have been few works on the implicit approaches since. Thus, no one had succeeded in constructing unconditionally stable FDTD schemes until 1998. We first reported the unconditionally stable FDTD method in two- and three-dimensions [4][5] in 1998. Because they are based on the alternating-direction-implicit (ADI) method [6], we called them the ADI-FDTD method. Our approaches were also published in IEEE transactions [7][8]. Soon after having published our findings, Zheng et al. reported the same approach [9] and theoretically proved the stability of the scheme in three-dimensions [10].

The ADI method is known as the implicit finite-difference algorithm, which has the advantage of ensuring a more efficient formulation and calculation than other implicit methods in the case of multidimensional problems. The ADI method has been widely applied to parabolic equations for solving heat transfer problems [6].

In this paper, numerical formulations of the ADI-FDTD method are explained and simulation results are compared with those of the conventional FDTD method.

2. Numerical Formulations

2.1 Fundamental Equations [8]

The numerical formulations of the ADI-FDTD method for a full three-dimensional wave are presented in (1)-(12). The electromagnetic field components are arranged on the cells in the same manner as the conventional FDTD method. These formulations are applicable to inhomogeneous lossy medium as well as to nonuniform cells. The calculation for one discrete time step is performed using two procedures. The first procedure is based on (1)-(6) and the second procedure is based on (7)-(12) as follows:

<First procedure>

$$E_{x(i+1/2,j,k)}^{n+1/2} = C_{a(i+1/2,j,k)} \cdot E_{x(i+1/2,j,k)}^{n} + C_{b(i+1/2,j,k)} \cdot \left[\{H_{z(i+1/2,j+1/2,k)}^{n} - H_{z(i+1/2,j-1/2,k)}^{n}\}/\Delta y(j) - \{H_{y(i+1/2,j,k+1/2)}^{n+1/2} - H_{y(i+1/2,j,k-1/2)}^{n+1/2}\}/\Delta z(k)\right] \tag{1}$$

$$E_{y(i,j+1/2,k)}^{n+1/2} = C_{a(i,j+1/2,k)} \cdot E_{y(i,j+1/2,k)}^{n} + C_{b(i,j+1/2,k)} \cdot \left[\{H_{x(i,j+1/2,k+1/2)}^{n} - H_{x(i,j+1/2,k-1/2)}^{n}\}/\Delta z(k) - \{H_{z(i+1/2,j+1/2,k)}^{n+1/2} - H_{z(i-1/2,j+1/2,k)}^{n+1/2}\}/\Delta x(i)\right] \tag{2}$$

$$E_{z(i,j,k+1/2)}^{n+1/2} = C_{a(i,j,k+1/2)} \cdot E_{z(i,j,k+1/2)}^{n} + C_{b(i,j,k+1/2)} \cdot \left[\{H_{y(i+1/2,j,k+1/2)}^{n} - H_{y(i-1/2,j,k+1/2)}^{n}\}/\Delta x(i) - \{H_{x(i,j+1/2,k+1/2)}^{n+1/2} - H_{x(i,j-1/2,k+1/2)}^{n+1/2}\}/\Delta y(j)\right] \tag{3}$$

$$H_{x(i,j+1/2,k+1/2)}^{n+1/2} = H_{x(i,j+1/2,k+1/2)}^{n} + D_{b(i,j+1/2,k+1/2)} \cdot \left[\{E_{y(i,j+1/2,k+1)}^{n} - E_{y(i,j+1/2,k)}^{n}\}/\Delta z(k) - \{E_{z(i,j+1,k+1/2)}^{n+1/2} - E_{z(i,j,k+1/2)}^{n+1/2}\}/\Delta y(j)\right] \tag{4}$$

$$H_{y(i+1/2,j,k+1/2)}^{n+1/2} = H_{y(i+1/2,j,k+1/2)}^{n} + D_{b(i+1/2,j,k+1/2)} \cdot \left[\{E_{z(i+1,j,k+1/2)}^{n} - E_{z(i,j,k+1/2)}^{n}\}/\Delta x(i) - \{E_{x(i+1/2,j,k+1)}^{n+1/2} - E_{x(i+1/2,j,k)}^{n+1/2}\}/\Delta z(k)\right] \tag{5}$$

$$H_{z(i+1/2,j+1/2,k)}^{n+1/2} = H_{z(i+1/2,j+1/2,k)}^{n} + D_{b(i+1/2,j+1/2,k)} \cdot \left[\{E_{x(i+1/2,j+1,k)}^{n} - E_{x(i+1/2,j,k)}^{n}\}/\Delta y(j) - \{E_{y(i+1,j+1/2,k)}^{n+1/2} - E_{y(i,j+1/2,k)}^{n+1/2}\}/\Delta x(i)\right] \tag{6}$$

<Second procedure>

$$E_{x(i+1/2,j,k)}^{n+1} = C_{a(i+1/2,j,k)} \cdot E_{x(i+1/2,j,k)}^{n+1/2} + C_{b(i+1/2,j,k)} \cdot \left[\{H_{z(i+1/2,j+1/2,k)}^{n+1} - H_{z(i+1/2,j-1/2,k)}^{n+1}\}/\Delta y(j) - \{H_{y(i+1/2,j,k+1/2)}^{n+1/2} - H_{y(i+1/2,j,k-1/2)}^{n+1/2}\}/\Delta z(k)\right] \tag{7}$$

$$E_{y(i,j+1/2,k)}^{n+1} = C_{a(i,j+1/2,k)} \cdot E_{y(i,j+1/2,k)}^{n+1/2} + C_{b(i,j+1/2,k)} \cdot \left[\{H_{x(i,j+1/2,k+1/2)}^{n+1} - H_{x(i,j+1/2,k-1/2)}^{n+1}\}/\Delta z(k) - \{H_{z(i+1/2,j+1/2,k)}^{n+1/2} - H_{z(i-1/2,j+1/2,k)}^{n+1/2}\}/\Delta x(i)\right] \tag{8}$$

$$E_{z(i,j,k+1/2)}^{n+1} = C_{a(i,j,k+1/2)} \cdot E_{z(i,j,k+1/2)}^{n+1/2} + C_{b(i,j,k+1/2)} \cdot \left[\{H_{y(i+1/2,j,k+1/2)}^{n+1} - H_{y(i-1/2,j,k+1/2)}^{n+1}\}/\Delta x(i) - \{H_{x(i,j+1/2,k+1/2)}^{n+1/2} - H_{x(i,j-1/2,k+1/2)}^{n+1/2}\}/\Delta y(j)\right] \tag{9}$$

$$H_{x(i,j+1/2,k+1/2)}^{n+1} = H_{x(i,j+1/2,k+1/2)}^{n+1/2} + D_{b(i,j+1/2,k+1/2)} \cdot \left[\{E_{y(i,j+1/2,k+1)}^{n+1} - E_{y(i,j+1/2,k)}^{n+1}\}/\Delta z(k) - \{E_{z(i,j+1,k+1/2)}^{n+1/2} - E_{z(i,j,k+1/2)}^{n+1/2}\}/\Delta y(j)\right] \tag{10}$$

$$H_{y(i+1/2,j,k+1/2)}^{n+1} = H_{y(i+1/2,j,k+1/2)}^{n+1/2} + D_{b(i+1/2,j,k+1/2)} \cdot \left[\{E_{z(i+1,j,k+1/2)}^{n+1} - E_{z(i,j,k+1/2)}^{n+1}\}/\Delta x(i) - \{E_{x(i+1/2,j,k+1)}^{n+1/2} - E_{x(i+1/2,j,k)}^{n+1/2}\}/\Delta z(k)\right] \tag{11}$$

$$H_{z(i+1/2,j+1/2,k)}^{n+1} = H_{z(i+1/2,j+1/2,k)}^{n+1/2} + D_{b(i+1/2,j+1/2,k)} \cdot \left[\{E_{x(i+1/2,j+1,k)}^{n+1} - E_{x(i+1/2,j,k)}^{n+1}\}/\Delta y(j) - \{E_{y(i+1,j+1/2,k)}^{n+1/2} - E_{y(i,j+1/2,k)}^{n+1/2}\}/\Delta x(i)\right] \tag{12}$$

The coefficients are defined in the same manner as the conventional FDTD method and they are as follows:

$$C_a(i,j,k) = \frac{2\varepsilon(i,j,k) - \sigma(i,j,k)\Delta t}{2\varepsilon(i,j,k) + \sigma(i,j,k)\Delta t}$$

$$C_b(i,j,k) = \frac{2\Delta t}{2\varepsilon(i,j,k) + \sigma(i,j,k)\Delta t}$$

$$D_b(i,j,k) = \frac{\Delta t}{\mu(i,j,k)}$$

2.2 Tridiagonal Systems of Equations

Equations (1)-(12) can not be applied directly for numerical calculation because they include the components defined as synchronous variables on both the left- and right-hand side, so modified equations are derived from the original equations.

In the first procedure, the E_x component on the left-hand side and the H_y components on the right-hand side are defined as synchronous variables in (1), thus, a modified (1') for the E_x component is derived from (1) and (5) by eliminating the $H_y^{n+1/2}$ components. The suffix k in (1') spans all values in z and indicates the maximum number of simultaneous linear equations which are involved in the implicit update of E_x. This is called the z-directional scan of E_x.

$$-\alpha_1 E_{x(i+1/2,j,k-1)}^{n+1/2} + \beta_1 E_{x(i+1/2,j,k)}^{n+1/2} - \gamma_1 E_{x(i+1/2,j,k+1)}^{n+1/2} = \mathrm{T1}_{(i,j,k)}^{n} \qquad (1')$$

where

$$\alpha_1 = D_{b(i+1/2,j,k-1/2)} / \Delta z(k)^2$$

$$\beta_1 = 1 / C_{b(i+1/2,j,k)} + \alpha_1 + \gamma_1$$

$$\gamma_1 = D_{b(i+1/2,j,k+1/2)} / \Delta z(k)^2$$

$$\begin{aligned}\mathrm{T1}_{(i,j,k)}^{n} = {} & p_1 E_{x(i+1/2,j,k)}^{n} \\ & + \{H_{z(i+1/2,j+1/2,k)}^{n} - H_{z(i+1/2,j-1/2,k)}^{n}\} / \Delta y(j) \\ & - \{H_{y(i+1/2,j,k+1/2)}^{n} - H_{y(i+1/2,j,k-1/2)}^{n}\} / \Delta z(k) \\ & + q_1 \{E_{z(i+1,j,k-1/2)}^{n} - E_{z(i,j,k-1/2)}^{n}\} / \{\Delta x(i) \Delta z(k)\} \\ & - r_1 \{E_{z(i+1,j,k+1/2)}^{n} - E_{z(i,j,k+1/2)}^{n}\} / \{\Delta x(i) \Delta z(k)\}\end{aligned}$$

$$p_1 = C_{a(i+1/2,j,k)} / C_{b(i+1/2,j,k)}$$

$$q_1 = D_{b(i+1/2,j,k-1/2)}$$

$$r_1 = D_{b(i+1/2,j,k+1/2)}$$

In the same way, the implicit equations for the $E_y^{n+1/2}$ and $E_z^{n+1/2}$ components are derived from (2), (6) and (3), (4), respectively. These update expressions involved all index value of x and y, respectively. By solving these simultaneous linear equations, we can get the values of the electric field components at the time of $n+1/2$. Thereafter, we can get the values of the magnetic field components at the time of $n+1/2$ directly by (4)-(6).

In the second procedure, the E_x component on the left-hand side and the H_z components on the right-hand side are defined as synchronous variables in (7), thus, a modified (7') for the E_x component is derived from (7) and (12) by eliminating the H_z^{n+1} components. The suffix j in (7') spans all values in y and indicates the maximum number of simultaneous linear equations which are involved in the implicit update of E_x. This is called the y-directional scan of E_x.

$$-\alpha_2 E_{x(i+1/2,j-1,k)}^{n+1} + \beta_2 E_{x(i+1/2,j,k)}^{n+1} - \gamma_2 E_{x(i+1/2,j+1,k)}^{n+1} = \mathrm{T2}_{(i,j,k)}^{n+1/2} \qquad (7')$$

where

$$\alpha_2 = D_{b(i+1/2,j-1/2,k)} / \Delta y(j)^2$$

$$\beta_2 = 1 / C_{b(i+1/2,j,k)} + \alpha_2 + \gamma_2$$

$$\gamma_2 = D_{b(i+1/2,j+1/2,k)} / \Delta y(j)^2$$

$$\begin{aligned}\mathrm{T2}_{(i,j,k)}^{n+1/2} = {} & p_2 E_{x(i+1/2,j,k)}^{n+1/2} \\ & + \{H_{z(i+1/2,j+1/2,k)}^{n+1/2} - H_{z(i+1/2,j-1/2,k)}^{n+1/2}\} / \Delta y(j) \\ & - \{H_{y(i+1/2,j,k+1/2)}^{n+1/2} - H_{y(i+1/2,j,k-1/2)}^{n+1/2}\} / \Delta z(k) \\ & + q_2 \{E_{y(i+1,j-1/2,k)}^{n+1/2} - E_{y(i,j-1/2,k)}^{n+1/2}\} / \{\Delta x(i) \Delta y(j)\} \\ & - r_2 \{E_{y(i+1,j+1/2,k)}^{n+1/2} - E_{y(i,j+1/2,k)}^{n+1/2}\} / \{\Delta x(i) \Delta y(j)\}\end{aligned}$$

$$p_2 = C_{a(i+1/2,j,k)} / C_{b(i+1/2,j,k)}$$

$$q_2 = D_{b(i+1/2,j-1/2,k)}$$

$$r_2 = D_{b(i+1/2,j+1/2,k)}$$

In the same way, the implicit equations for the E_y^{n+1} and E_z^{n+1} components are derived from (8), (10) and (9), (11), respectively. These update expressions involved all index value of z and x, respectively. By solving these simultaneous linear equations, we can get the values of the electric field components at the time of $n+1$. Thereafter, we can get the values of the magnetic field components at the time of $n+1$ directly by (10)-(12).

The simultaneous equations can be written in tridiagonal matrix form and (1') is expressed as follows:

$$\begin{pmatrix} \beta_{(1)} & \gamma_{(1)} & & & 0 \\ \alpha_{(2)} & \beta_{(2)} & \gamma_{(2)} & & \\ & & \ddots & & \\ & & \alpha_{(nk-1)} & \beta_{(nk-1)} & \gamma_{(nk-1)} \\ 0 & & & \alpha_{(nk)} & \beta_{(nk)} \end{pmatrix} \begin{pmatrix} E_{x(1)} \\ E_{x(2)} \\ \vdots \\ E_{x(nk-1)} \\ E_{x(nk)} \end{pmatrix}^{n+1/2} = \begin{pmatrix} \mathrm{T}_{(1)} \\ \mathrm{T}_{(2)} \\ \vdots \\ \mathrm{T}_{(nk-1)} \\ \mathrm{T}_{(nk)} \end{pmatrix}^{n} \quad (1")$$

For the tridiagonal systems of equations, the procedures of *LU* decomposition, forward- and backward-substitution each take only *O(N)* operations, and the whole solution can be encoded very concisely [11].

2.3 Treatment of Boundary Conditions

In the case of the ADI-FDTD method, we must add special treatment in the matrix form for the boundary conditions of the electric-field components. The first and last rows in (1") indicate formulations for calculating the E_x components at the *z*-directional terminals. Absorbing boundary conditions (ABCs) are commonly set on the outer surfaces of the computational domain, so they must be formulated in the rows. For the implementation, ABCs based on the one-way wave equation is applied. Mur's first-order ABC [12] is as follows:

$$E_{x(k=1)}^{n+1/2} - E_{x(k=2)}^{n} = s\left[E_{x(k=2)}^{n+1/2} - E_{x(k=1)}^{n}\right]$$

$$E_{x(k=kn)}^{n+1/2} - E_{x(k=kn-1)}^{n} = s\left[E_{x(k=kn-1)}^{n+1/2} - E_{x(k=kn)}^{n}\right]$$

where

$$s = \frac{c(\Delta t/2) - \Delta z}{c(\Delta t/2) + \Delta z}$$

By applying them into (1"), we have

$$\beta_{(1)} = 1.0,\quad \gamma_{(1)} = -s,\quad \mathrm{T}_{(1)}^{n} = E_{x(2)}^{n} - sE_{x(1)}^{n}$$

$$\beta_{(nk)} = 1.0,\quad \alpha_{(nk)} = -s,\quad \mathrm{T}_{(nk)}^{n} = E_{x(nk-1)}^{n} - sE_{x(nk)}^{n}$$

In the first procedure, E_x components at the *y*-directional terminals are calculated in the same way as the conventional method. Other ABCs are also applicable to the ADI-FDTD method. In fact, Berenger's PML [13] has successfully been applied to this scheme [14][15].

Perfect electric conductor (PEC) boundary conditions are also often used in the FDTD method. At the surface of the PEC, tangential electric field must be zero. For example, if the condition

$$E_{x(k)}^{n} = 0$$

is required, the following must be held:

$$\alpha_{(k)} = 0,\quad \beta_{(k)} = 1,\quad \gamma_{(k)} = 0,\quad \mathrm{T}_{(k)}^{n} = 0$$

Source conditions are applied similarly. If the hard-source excitation

$$E_{x(k)}^{n+1/2} = E_0 \sin[2\pi f_0 (n+1/2)\Delta t]$$

is required, the following must be set:

$$\alpha_{(k)} = 0, \beta_{(k)} = 1, \gamma_{(k)} = 0, \mathrm{T}_{(k)}^{n} = \sin[2\pi f_0 (n+1/2)\Delta t]$$

However, the soft-source excitation is performed in a different way [16].

As mentioned above, the implicit formulation should be used to implement boundary conditions of the electric fields.

3. Numerical Examples

3.1 Microstrip Linear Resonator [17]

Fig.1 shows the horizontal structure of the microstrip linear resonator and it is characterized as follows. The substrate is 810 μm thick with relative permittivity of 3.25. The width and thickness of the strip is 1.842 mm and 18 μm, respectively, thereby rendering the thickness negligible for numerical modeling. There are two gaps with widths of 80 μm. The length of the internal strip is 22 mm. We use nonuniform cells in order to treat the narrow gaps and the long microstrip lines. The spatial modeling is shown in detail in fig.2. The substrate region is divided into 6 cells in the *x*-direction and the strip region is divided into 12 cells in the y-direction. The 80-μm-wide gap region is divided into 4 cells in the *z*-direction, in which the minimum cells, which are 153.5 × 135 × 20 μm^3, are placed. The CFL stability condition of this model is derived from the minimum cells and is $\Delta t \leq 65.4059$ fs. The total number of cells is 22 × 44 × 78 = 75504. PEC boundary conditions are applied at the strips and at the ground plane. Mur's first-order ABCs are applied on all outer surfaces except the bottom ground plane. A Gaussian pulse is excited at one terminal and the output voltage is observed at the other terminal. By applying a Fourier transformation to the incident and output pulses, the insertion loss of the resonator can be calculated.

The time-step size for the conventional FDTD method is set so as to satisfy the CFL stability condition, and the time-step size for the ADI-FDTD method is set to 5, 10, or 20 times as large as the previous size. A physical time of each simulation is required about 12 ns for the oscillation of the output pulse to converge.

The calculated and measured insertion losses of the resonator are shown in fig.3. The time-step size and the required CPU time for each calculation are shown in table 1. The required memory size for the ADI-FDTD method is about 1.9 times as large as that for the conventional FDTD method because of the necessity of using extra electromagnetic component and coefficient array storage, which is common to all examples. The calculated insertion loss of the FDTD is quite similar to the measured data although the level of the FDTD is a little high and its response is shifted downward slightly in terms of frequency. Comparing the results of the ADI-FDTD method with those of the conventional FDTD method, we can see that there are differences depending on the time-step size. The resonant frequencies extracted from the insertion losses are shown in table 2, which also shows the relative errors of the calculated results with respect to the measured data. It can be seen, quantitatively, that the increase in time-step size resulted in a reduction of the resonant frequency.

As mentioned above, the tradeoff resulting from an increase in time-step size, which effects a reduction in CPU time, is an increase in numerical errors. This is a sample indicating that the ADI-FDTD method can be as accurate and efficient as the conventional FDTD method. However, the ADI-FDTD method will have an advantage over the conventional FDTD method if a similar model includes smaller minimum cells in the computational domain.

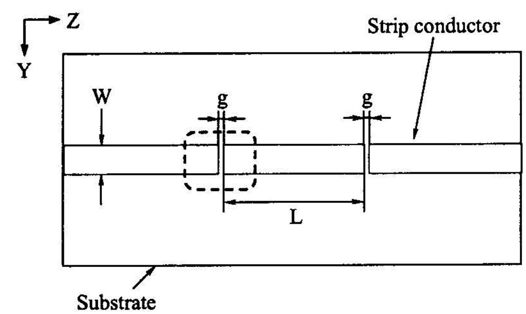

Fig. 1. Microstrip linear resonator (horizontal plane).

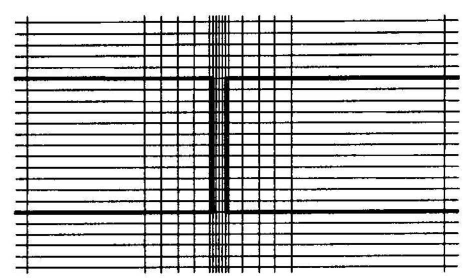

Fig. 2. Spatial discretization around the gap.

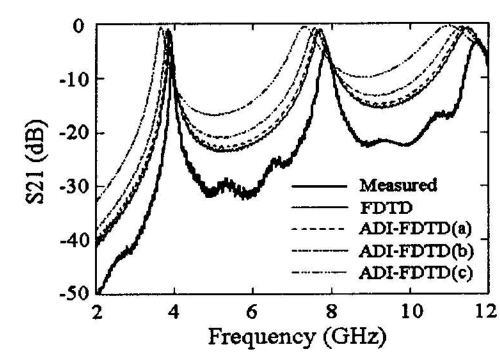

Fig. 3. Insertion loss of the microstrip linear resonator.

Table 1 Time-step size and CPU time

	Time-step size		CPU time	
	fs	ratio	min	ratio
FDTD	65.0	1.0	68.1	1.00
ADI-FDTD (a)	325.0	5.0	72.7	1.07
ADI-FDTD (b)	650.0	10.0	33.4	0.49
ADI-FDTD (c)	1300.0	20.0	16.8	0.25

Table 2 Resonant frequencies

	First mode		Second mode		Third mode	
	Resonant frequency	Relative error	Resonant frequency	Relative error	Resonant frequency	Relative error
Measured	3.95GHz	—	7.85GHz	—	11.76GHz	—
FDTD	3.90GHz	1.3%	7.72GHz	1.7%	11.48GHz	2.4%
ADI-FDTD (a)	3.87GHz	2.0%	7.68GHz	2.2%	11.46GHz	2.6%
ADI-FDTD (b)	3.83GHz	3.0%	7.58GHz	3.4%	11.31GHz	3.8%
ADI-FDTD (c)	3.66GHz	7.3%	7.32GHz	6.8%	10.99GHz	6.5%

3.2 Thin Conductive Enclosure [18]

Figs.4 and 5 show a model for estimating shielding effectiveness (SE). It consists of a half-cubic conductive shell on a ground plane. The shell is 56 × 56 × 25 mm^3 and is composed of 24-μm-thick conductive material with relative permittivity of 1.0, relative permeability of 1.0, and conductivity of 2400 S/m. Nonuniform cells are used to treat both the thin sheets of the shell and a wide computational region. A partial Gaussian pulse is applied at the excitation point, and the field at the observation point is output. Numerical calculations are carried out two times, with and without the shell. The SE values are calculated by applying a Fourier transformation to each output field. To estimate the electric field SE, vertical electric field components are used. Mur's ABCs are applied at all outer surfaces of the computational domain except the bottom ground plane. The SE values are calculated for the shell using the ADI-FDTD method and the conventional FDTD method. These results are compared with experimental data and analytical solutions.

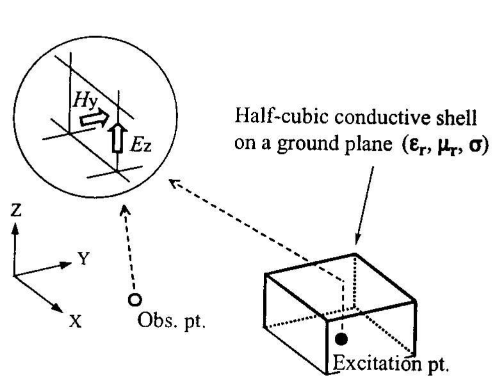

Fig. 4. Half-cubic conductive shell on a ground plane.

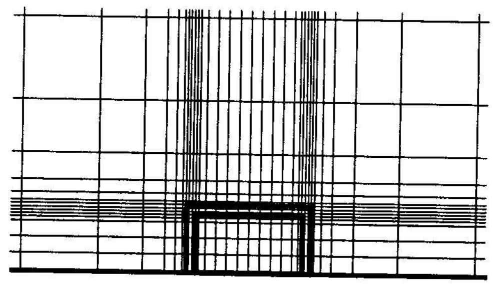

Fig. 5. Spatial discretization of the shell model.

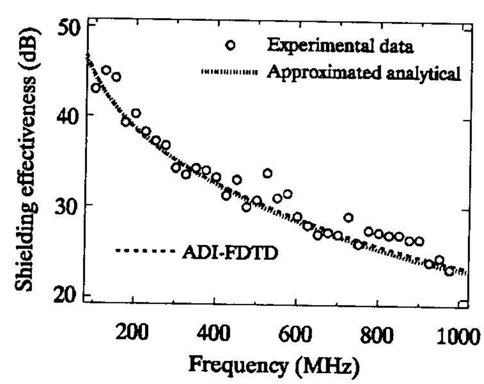

Fig. 6. Shielding effectiveness for electric field.

Fig.6 shows the SE values for fields for the shell. The numerical results for the ADI-FDTD method and the approximated analytical solution agree quite well. Moreover, they are quite similar to the experimental data.

There are no results for the conventional FDTD method here due to the extreme computational costs. Although numerical results cannot be obtained by the conventional FDTD method, table 3 lists the estimated computational effort for the two methods. The time-step size for the ADI-FDTD method is set 62 times larger than that for the conventional FDTD method. Consequently, the required CPU time for the ADI-FDTD method is reduced to 6.2% of that for the conventional FDTD method.

Table 3 Time-step size and CPU time

	Time-step size		CPU time	
	fs	ratio	s	ratio
FDTD	15.38	1.0	60060	1.0
ADI-FDTD	960.0	62.4	3749	0.062

4. Conclusion

The ADI-FDTD method is unconditionally stable, so the limitation of the maximum time-step size does not depend on the CFL stability condition but rather on numerical errors. The tradeoff resulting from an increase in time-step size, which effects a reduction in CPU time, is an increase in numerical errors. What limits the maximum time-step size depends on what kinds of problems or models are calculated. There is no guideline to decide a most appropriate time-step size for a problem. However, if the size of the local minimum cell in the computational domain is much smaller than the wavelength, the error limitation of the time-step size may be larger than the CFL limitation. In this case, the ADI-FDTD method is more efficient than the conventional FDTD method.

We have two subsequent works on the ADI-FDTD method. One is applying the method to many kinds of realistic problem and finding numerical models in which the method has the advantages compared with the conventional FDTD method. The other is developing advanced techniques on the method to improve the calculation accuracy when a large time-step size is used.

Acknowledgment

The author would like to thank Dr. J. Alan Roden, IBM Microelectronics, USA, for his usefull suggestions and great help to publish this article.

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Computational Electro-Magnetics in Commercial EMC Design

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In preparation for this article I looked back at my first involvement with ACES. In 1989 I attended my first ACES conference; and, as an EMC engineer, the idea of actually using computational methods to help in product design efforts seemed remote but intriguing. The following year I presented my first paper at ACES with the goal of highlighting the needs of commercial EMC designers in the hope that some of the available expertise could be focused in this direction. While there have been significant strides in this direction, there is still a way to go, and today we have the benefit of faster and more readily available computers. In light of the needs of the EMC engineer and today's updated techniques and technologies, I am again bringing this question to the ACES community.

In radar cross section, antenna calculations, and other applications of CEM, very precise answers are sought and an error of 0.1dB can have significance. EMC engineers, on the other hand, would have been, and still are, ecstatic to get an answer within 6dB. As stated in my 1990 ACES paper, 6dB, that is +100% / -50%, ***is*** accuracy to an EMC engineer. This was not my first technical presentation but it was probably the one that produced the most curious results in those attending. While there were some understanding nods, there were a lot more surprised faces, and I got the impression I was almost considered heretic by some.

Modeling is not used regularly by most EMC engineers. Rather, it is reserved only for the cases where established design rules fall short, and to address specific, well-defined problems. One difficulty resulting from occasional use is the trouble in becoming comfortable and competent in using what can be very complex computational tools.

EMC regulations cover the frequency range of 9 kHz to 40 GHz; however, only a portion of this range really requires help through modeling. Below 100 MHz, while some specific questions will be raised, modeling is usually in the form of circuit simulations and parameter extraction. EMC design rules and past experience both work well at these lower frequencies. The upper frequency bound is constantly rising due to increasing switching rates, and today it is rare for an EMC engineer to have serious concerns above 10 GHz. This leaves just a two-decade region where the need for modeling is greatest. EMC concerns are often broadband in nature, and so time-domain techniques can be most revealing, showing resonance and coupling effects over the frequency range of interest.

Another key consideration is to understand what EMC engineers are trying to model and why. Partly, models are done to determine specific parameters such as radiated emission levels or coupling coefficients. One area where the use of modeling really is helpful is in the evaluation of multiple "what if" scenarios, comparing apertures in shields and comparing emissions based on location of a particular component. While comparison models are usually aimed at solving a particular task, they also have a more general use, namely they enable the engineer to gain a better insight into the physics of the problem.

A great many EMC engineers did not select their careers based on their excellence in electromagnetic theory. Rather, EMC engineers are drawn from widely varying fields and so may not have training with any particular emphasis on EMC or even RF in general. It is a relatively recent step forward to have engineers actually trained as EMC engineers at college. Over the past decade or so, the use of CEM has grown greatly in the area of EMC, and this is in great part due to the training activities provided by ACES and the IEEE. Refinement of the computation techniques and ever increasing CPU power has also played a role.

Given the state of our computer resources and the developments in CEM, are better ways now possible for EMC modeling? Not being one to break with tradition, I would again like to challenge the ACES community to think about some of these situations that are unique to commercial EMC design engineers. Are there techniques that can, at the expense of some accuracy, provide solutions using less computer resources or in much less time? Can simplifications be made to an implementation, making a technique easier to use? Along the way, can these tools help provide engineers with EM or CEM training so that their skills can grow? If you have insight to any of these questions, the EMC community looks forward to hearing from you.

STANDARDS AND RECOMMENDED PRACTICES FOR CEM COMPUTER MODELING AND SIMULATION

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Abstract

The development of appropriate standards and guidelines for computational electromagnetics (CEM) computer modeling and simulation tasks has been a topic of much discussion within the electromagnetics community in recent years. This encompasses a broad range of applications such as the analysis of printed circuit board radiated and conducted emissions/immunity, assessing system-level EMC, predicting the radar cross section (RCS) of complex structures, and performing automated target recognition (ATR) and imaging simulations. In particular, there are concerns regarding the lack of well-defined methodologies to achieve code-to-code or even simulation-to-measurement validations within a consistent level of accuracy. This has been prompted by the development and use of new CEM computer codes mainly over the past twenty years. This article describes a project that is underway to guide the validation of CEM application models. The proposed standard is intended to address these concerns and provide a method for validating CEM codes and models.

INTRODUCTION

After hearing the concerns expressed by certain sectors of the electromagnetics community, the IEEE EMC Society's Standards Development Committee recently accepted to take the lead in sponsoring the development of a formal standard and recommended practice applied to CEM computer modeling and simulation. Although this is new territory for the Standards Development Committee and there is a great deal of support within the community to take serious steps in this direction, the idea of a "CEM standard" as such is not a new one. In fact, the need for a standard was realized over thirty years ago at a time when the development and use of computer tools for electromagnetics applications was emerging and just beginning to gain momentum. This was influenced by several factors: (a) the growing complexity and sophistication of military and commercial systems designs; (b) achieving requirements for a balanced, cost-effective electromagnetic environment effects (E^3) program in which computer analysis could effectively complement measurements; and (c) providing a means of developing consistent models and benchmarks to support life-cycle EMC code and measurement validations of actual systems. Important technological advancements in computer hardware and use of structured code only accelerated the arrival of CEM technologies and applications, as we know them today. The fast track CEM modeling and simulation trend continues today and will continue to grow as we further enter the age of high performance computing.

Fundamental Validation Issues

Practically speaking, there are both overt and subtle differences that CEM codes exhibit as a function of their underlying physics, mathematical basis functions, numerical solution methods, associated precision, and the building blocks (primitives) that are used to create models and analyze them. Although all CEM codes have their basis in Maxwell's equations of one form or another, their rate of convergence (relatively speaking) and "accuracy" depend on how the physics equations are cast (e.g., method of moments, uniform theory of diffraction, finite differences, or some other representation), what numerical solver approach is used (full or partial wave, non-matrix, etc.), inherent modeling limitations, built-in approximations, and so forth. The physics formalism, available modeling primitives (canonical surface objects, wires, patches, facets, etc.), analysis frequency, and time or mesh discretization further conspire to affect accuracy, solution convergence, and overall validity of the computer model. Here, we have just scratched the surface for there are even subtler, inocuous issues that affect the way the codes operate and how or even if they can be validly compared.

What has not been fully appreciated is the extent of the issue regarding model accuracy, convergence, and code validity. Simply put, concerns were raised when it was observed that the results of predictions using one type of CEM code did not agree favorably or consistently with the results of other codes of comparable type including measurement benchmarks. In some cases, noticable differences among analytically-based results over certain regions and for certain simulation states have been observed. Significant deviations between the analytical and empirical methods have been recorded as well. Differences are not unexpected, but the degree of disparity in certain cases cannot be readily explained nor easily discounted which leads to the question, "*...which result is correct?*"

While analysts may argue in favor of a given modeling approach, simulation technique or use of a particular CEM code there is no consistent methodology for comparing results among codes or against empirically-based methods in a truly valid, objective way. If a methodology exists, it does not appear to be universally practiced.

Furthermore, it is often difficult if not impractical to compare the results of certain codes even though they are based on Maxwell's equations. Of course, some exceptions to this can be cited, in particular, when one considers grouping and comparing the results of "similar" codes determined by their physics, solution methods, and modeling element domains. However, disparities even among "similar" codes have been observed, so oftentimes we are forced to go back to square one regarding the fundamental question.

Art Versus Science

Oftentimes the question has been asked "*Is CEM an art or a science*? By today's standards, one can make the case that it is nearly an even mix of both. The objective should be to emphasize the scientific aspects of modeling and simulation to ensure objectivity as a function of the overarching approach (modeling primitives, physics, problem to be solved) and the underlying scheme (physics, solver method, computation of observables). Obviously, the types of physics and solution method we use for a given problem and the desired observables are central to the issue.

No one will dispute the scientific basis and technical merit of CEM for solving complex problems. However, CEM is also something of an art from the perspective of the (expert) analyst. In practice, the expert is familiar with the code and the physics (i.e., the "canvas") and is proficient in applying the modeling tools and simulation/processing techniques (i.e., the brushes and colors). Unfortunately, this is also the root of the problem in that the process can introduce a certain degree of subjectivism and uncertainty. What seems appropriate to one expert analyst may be inconsistent or inappropriate to another, yet both may claim to be "correct" based on their preferred tools and applied techniques. Even though both approaches may be generally correct for a given problem, differences in results may arise. This again begs the question, "*...which result is correct?*"

In effect, we need to eliminate (or at least significantly reduce) potential uncertainty in the modeling and simulation process. The electromagnetic community clearly needs a benchmark methodology i.e., a *CEM standard* that can be used to assure consistency for objective modeling and simulation validations.

To achieve this we must rely on CEM experts as well as today's software savvy engineers and computer scientists familiar with the latest computerized simulation and hardware technologies. One of the goals should be to determine how generalized computer models are represented or generated, and how they can be effectively converted into efficient CEM models. One application that the DoD's High Performance Computing Modernization Program has investigated involves deriving high-fidelity CEM models from CAD databases. This implies an understanding of the typical ways to represent models possibly using a common language or via a universal set of descriptors, and then specifying methods to assure model and code validation utilizing these data.

Standards/Recommended Practices

To develop the standard and recommended practices, a balanced cross section of the CEM community must be being tapped. This includes the ACES community, the IEEE EMC Society's TC-9 Committee on CEM (co-sponsors of the proposed standard), the IEEE's Antennas and Propagation and Microwave Theory and Techniques Societies, ACES), Electromagnetic Code Consortium, and other international groups concerned with advancing and applying CEM technologies, for example, to RCS and ATR applications. Thinking somewhat "outside the box", we can also learn a great deal about relevant modeling and simulation technologies and techniques from the world of consumer video games.

There are two separate projects established to achieve the above concerns, issues, and goals. These are described next.

Project 1597.1: IEEE Standard for Validation of CEM Computer Modeling and Simulation

The scope of this four-year project is to develop a standard for the validation of CEM computer modeling and simulation codes in differing applications. The standard will provide a basis for analytical and empirical validation of CEM codes and configurations. Several key areas will be addressed, including:

- Validation by use of canonical models – This refers to the specification of canonical modeling elements (primitives) as a function of ensemble parameters (frequency, desired accuracy or fidelity, physics and numerical solution method, etc.). This is illustrated in Figure 1.
- Validation by simulation versus measurement - Included in the validations will be associated model-based parameter estimation (model- versus measurement-driven uncertainty estimates).

The purpose of this project is to guide the validation of CEM application models. The proposed standard is intended to address concerns over the lack of well-defined methodologies to achieve code-to-code or simulation-to-measurement validations within a consistent level of accuracy, and provide a method for validating CEM codes and models. An additional aspect of computer modeling and simulation for CEM considered here is aimed at studying radiation hazards and related safety issues.

Comparable work has been accomplished and continues to mature on behalf of other collaborative engineering disciplines such as computational fluid dynamics, thermal and structural/mechanical engineering. These will also be looked at for guidance and the development of a draft standard for CEM.

Project 1597.2: IEEE Recommended Practice for CEM Computer M&S Applications

The scope of this four-year project is to develop a recommended practice for use in CEM computer M&S applications to guide the EMC design of printed circuit boards to large, complex systems. Areas to be addressed include:

- General guidelines for creating CEM models.
- Development of modeling methodologies for small-to-large scale "canonical" systems, platforms or composite models.
- Methodologies for developing and applying collaborative, multi-disciplinary engineering modeling schemes.
- Computation of uncertainty for modeling applications.

This recommended practice will aid modelers and analysts in the selection and application of appropriate modeling and simulation methodologies, physics, and solution techniques to achieve accurate results and to complement measurements and EMC design tasks for a wide range of problems. As with its counterpart standard, a significant aspect of CEM computer modeling and simulation for electromagentic effects analyses will target the study of radiation hazards and related safety issues.

RELEVANT RESEARCH

This work will build upon prior analytical studies and research conducted by academic, government, commercial, and professional institutions and consortia [1, 2]. These include studies on the modeling and simulation of multi-disciplinary engineering problems pertaining to fluid dynamics, laminar flow, structural and thermal engineering applications [3]. Another key area of study is the development and use of analytical and measurement benchmarks.

SUMMARY

This paper discussed the development of appropriate standards and guidelines for CEM computer modeling and simulation A broad range of applications are considered ranging from the modeling of printed circuit board radiated and conducted emissions/immunity to analyzing large, complex system electromagnetic effects. Concerns have been raised regarding the lack of well-defined methodologies to achieve code-to-code or simulation-to-measurement validations within a consistent level of accuracy. To address these concerns, two IEEE projects are underway to guide the validation of CEM application models. The proposed standard and recommended practices to be developed under these projects are expected to provide a useful method for validating CEM codes and models. The progress on the development of these standards and guidelines will be reported upon periodically.

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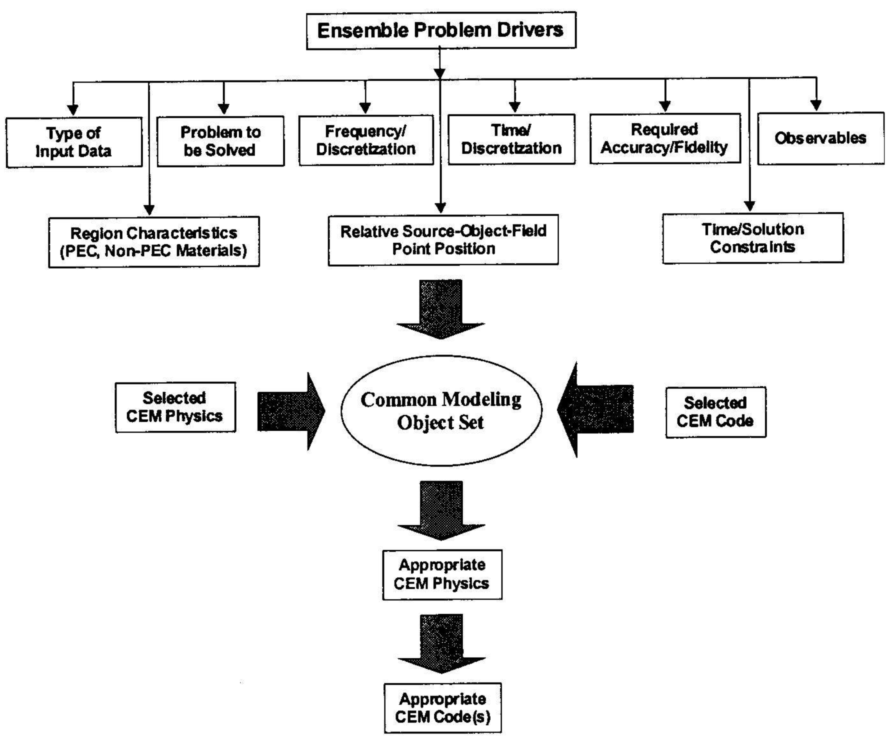

Figure 1. Ensemble Problem Drivers and Their Influence on the Selection of Appropriate CEM Physics and Codes for Validation Purposes

Book Review

Title: Handbook of Electrostatic Processes

Publisher: Marcel Dekker, 1995, pp.776

Editors: Jen-Shih Chang, Arnold J. Kelly, and Joseph M. Crawley

This is a very sizable book concerning the study of Electrostatic Discharge (ESD) processes. The book covers fundamentals of ESD and many other subjects related to ESD. The handbook is made up of thirty-three (33) chapters, but in reality it can be said the book contains thirty-three papers from a variety of sources (authors). As is customary each paper has an abundant number of references for further consultations if necessary.

The first chapter in the book is known as Electrostatic Fundamentals. Electrostatic is used in a wide range of applications ranging from the calculation of atomic forces to wrapping of leftover food items. All of these applications can be understood by the application of a few principles based on numerous observations. This chapter describes these principles and gives the formulas used to calculate the magnitude of the effects. The ideas presented here will be used repeatedly in the later chapters to discuss particular aspects of electrostatics. Chapter 2 discusses the Electrification of Solid Materials. It provides a brief over view of physical aspects related to the electrification mechanism of solid materials. With the exception of lightning, frictional electrification of material objects is probably the earliest electrophysical phenomenon known to people from their direct experience. This chapter emphasizes the present development of new and important links between electrification phenomena and certain fundamental aspects of quantum physics and other key areas of modern science, technology, and engineering. Chapter 3 covers Electrostatic Charging of Particles. When particles flow through an ionized zone, some ions will be deposited to the particle's surface and become charged particles. The amount of ion deposition on the particle surface depends on resident time, particle radius and shape, external electric and magnetic fields, particle velocity, etc. In this chapter, the effect of these parameters is discussed in detail. Chapter 4 is known as Electrical Phenomena of Dielectric Materials. If we exclude all metals, all remaining material are dielectric, whatever the state of the matter in question (solid, liquid, gas), and a permittivity can be ascribed to any substance, with vacuum as the reference dielectric. Dielectric can be employed either as passive devices (capacitors, cables) or in active devices (electrets, electrostatic motors), and they are required to function in our near or far environment (air seawater, soil, and space). Generally, materials are subjected to a voltage (dc, ac, and impulse), and, in exceptional cases, to an electromagnetic field produced by, for example, an intense laser beam. The spatiotemporal distribution of the field inside the matter not only is imposed by the geometry of the electrodes and the shape of the voltage wave but also depends on space charges: charge carriers can be generated or blocked at interfaces when different dielectric substances come into contact with each other. Chapter 5 is titled: Flow Electrification of Liquids. When a dielectric liquid flows through a pipe from one vessel to another, the potential difference that appears in the collecting vessel is due to the accumulation of charges. These charges result from the convection of a part of the electric double layer existing in the tube at the contact between the liquid and the inner wall. Indeed, at the liquid/solid interface, the electrochemical reaction induces an electrical double layer composed of two layers in the liquid: the compact layer very close to the wall (unaffected by the flow), and a diffuse layer that can be convected. Then the space charge density Q convected in a pipe by a flow is given by the ratio of the charge convected to the flow rate.

In Chapter 8 we see the subject of Injection Induced Electrohydrodynamic Flows. Electrohydrodynamic (EHD) is the study of the motion of liquids subjected to electric fields. The forces that are exerted by an electric field on free or polarization charges present in a liquid are transmitted by collisions on the neutral molecules. Typically, the liquid will be set in motion, thus changing the distribution of charges that in turn modify the electric field. This coupling makes EHD a difficult subject. The liquid state is chemically very reactive compared to the gas or solid state. Trace impurities undergo chemical reactions giving as end products ionic pairs. This chapter is organized as follows. In Sections II and III the equations of electrodynamics are deduced and then cast in nondimensional form to put in evidence the scales that appear frequently in EHD. Sections IV and V are dedicated to the problems of unipolar injection induced instability and convection. Chapter 9 addresses Gas Discharge Phenomena. The object of this chapter is to provide a brief overview of the fundamental aspects governing plasmas found in gas discharges, with particular emphasis on glow, arc, corona, and spark discharges. Gas discharge phenomena can generally be divided into those that occur at low pressures (<100 torr) such as glow discharges and those that occur at high pressure (< 760 torr) such as corona or spark discharges. Although arc discharges can occur under both low and high-pressure conditions, they have been included under discharges that occur at high pressure in this case. High voltage generation is addressed in Chapter 10. High voltage is widely used in equipment and in the testing of power apparatus. The types of high voltage in used can be classified as AC, DC and pulses. Some examples discussed in this chapter such as single transformer, cascade transformer, series resonance circuit, and Tesla coils (for AC) and half/full wave rectifier, voltage doubler, voltage multiplier, deltatron, and Van de Graff generator (for DC). Measurements of Electrostatic Fields, voltages and charges are described in Chapter 11. Examples of electrostatic environments in which measurements are important include electrostatic precipitators, static control systems for manufacturing, electrophotography, electrostatic flow systems, electrostatic spraying, atmospheric studies, and EOS/ESD hazard identification. This chapter outlines the basic principles and techniques of electrostatic measurement. The reader is assumed to have a working knowledge of field theory fundamentals as outlined in Chapter 1. Chapter 12 discusses the measurements of wind velocity using electrostatic flow measurement techniques.

The study of multiphase gas-liquid-solid flow requires accurate measurement of each phase velocity and phase fraction. Electrostatic multiphase flow measurement techniques are discussed in Chapter 13. Electrostatic principles can be used in the detection of multiphase flow measurement techniques. For example, piezoelectric transducers can be used to measure ultrasonic waveforms that have interacted with multiphase flow. Another example uses ionization (charge) chambers for the detection of radiation attenuation. The various techniques for measurements of two-phase flow parameters such as void fraction, phase distribution, and phase velocity will be discussed for gas-liquid and gas-solid two-phase flow applications. Several techniques are mentioned to ensure a fairly complete list with particular strengths and weaknesses addressed. In chapter 14 printer technology is discussed. Modern printing systems for computer output and office applications are generally divided into impact and nonimpact technologies. Most nonimpact printing technologies either were developed from the electrophotographic process or use one of many varieties of in jet printing. Hence electrostatic plays an important role in modern nonimpact printing systems. This chapter reviews the fundamental performance issues in document and graphics printers. Chapter 15 covers electrophotography. Copiers and laser printers, which use the electrophotography technology, represent one of the successful commercial applications of electrostatic phenomena. These devices, unknown to the general public, before 1959, have become indispensable office equipment today. Electrophotography is one of the most successful commercial applications of electrostatic phenomena. In most embodiments it requires six process steps to produce a copy: charge, expose, develop, transfer, fuse and clean. Electrostatic plays key roles in almost all these steps. Discussed in this chapter are the role of electrostatic in the charge, expose, develop, and transfer steps. During charge and transfer, the photoreceptor and the back of the paper, respectively, are uniform charged by extracting ions with an electric field from a gas breakdown, initiated by applying a high potential on this wire. Chapter 16 covers Electrostatics in Flat Panel Displays. Electrostatics plays a vital role in a variety of display technologies. These include the cathode ray tube (CRT), plasma displays (PD), liquid crystal displays (LCD), and high field electroluminescent displays (HFEL). This chapter will focus on display technologies that have application for flat panels, which are expected to make significant inroads into CRT dominated areas. The use of electric fields in PD, LCD, and HFEL will be described in conjunction with device operation and materials used in the active region of the device. However, another potential candidate for flat panels is a flat CRT. Chapter 17 addresses the Application of the Electrostatic Separation Technique. Separation and classification are very important manufacturing processes in many industries such as the mining and chemical industries. Equipment using many different methods of separation is applied in these processes. Electrostatic separation (including electrostatic classification) in one separation method. This method, relying on the differences of electrostatic characteristics inherent in different materials, has a long history. After an initial overview of the electrostatic technique, this chapter discusses a number of interesting applications of the techniques in the fields of ore, coal, food, and scrap processing. Finally, a few new applications are discussed. Chapter 18 considers Electrostatic Coalescence in Liquid-Liquid Systems. Phase coalescence may be defined as the aggregation of dispersed droplets that are suspended in another immiscible or partially miscible liquid, to form a heterogeneous dense packed zone at the main interface between the two bulk liquid phases. The coalescence phenomenon is associated with and important to some processing industrial operations, e.g. in the liquid-liquid extraction process. Indeed, liquid-liquid separation is not only restricted to extraction processes; it is also of considerable importance in effluent treatment plants and in any processes where liquid-liquid dispersions are present. Electrorheology is the title of Chapter 19. The electrorheological effect is a phenomenon in which the resistance to flow or to deformation of certain types of fluid can be changed by the application of an electric field. Chapter 20 is interested in Electrostatic Atomization and spraying. Electrostatic atomization and spraying in agriculture has found widest usage as the basis for incorporating electric force fields into the application of crop protection pesticides. Twofold improvements of droplets mass transfer efficiency onto plant surfaces are routinely achieved with corresponding environmental and economic benefits. Electrostatic induction has proven most satisfactory for charging water based sprays in the field, while electrohydrodynamic serves well for charging low conductivity, non aqueous liquids. Electrostatic Precipitation is outlined in Chapter 21. The electrostatic precipitator is a device for removing particulate pollutants in the form of either a solid (dust or fumes) or a liquid (mist) from a gas using an electrostatic force. Electrostatic precipitation (ESP) has been widely used for cleaning gas from almost all industrial processes with a medium to large gas volume (> 2000 m3/mim), including utility boilers, blast furnaces, and cement kilns. ESP is also in wide use for air cleaning in living environments and work places. ESP has large advantages over other particulate control devices: a lower operating cost, because of its low corona power and the low power needed in its blower due to a low pressure drop; a high collection performance even for submicron particles; and ease of maintenance.

The electrostatic precipitator (ESP) is a real challenge to the modeler. It requires knowledge of many fields: electrostatic, physics, fluid mechanics, mechanical and electrical engineering, adhesion, cohesion, and aerosol behavior. A model can be simple enough to describe with a few equations but can also require the capacity of a large computer to in details. The ESP is primarily an electrical device and must be characterized by its electrical parameters first. It is designed to collect aerosol particles, that is, particles small enough to remain suspended in a still gas for up to ten seconds. The characteristics of the aerosol are next most important. The removal of the particles from a flowing gas must be accomplished in a relatively short treatment time to minimize the size and cost of the ESP. Chapter 23 covers transducers. A transducer is a device that changes certain physical values to other physical values. There are many kinds of transducers related to electrostatics. They include electrostatic sensors, electric energy converters, and electric actuators. Typical examples are acoustic transducers made of electrets. One of which is called an electret microphone and is widely used in the compact cassette tape recorder. Other transducers include electromechanical converters, electrostatic sensors, and capacitive converters. Chapter 24 reviews EHD Enhanced Mass Transfer Operations and Chemical Reactions. The majority of conventional chemical processing operations applies mechanical or thermal energy in combination with pressure and gravity forces. The ability to superimpose electric fields to improve several separation processes has been well known and widely used for many years. The familiar industrial applications range from solid-liquid separation in the beneficiation of ores in the mining industry and cleaning of exhaust gases from solid particles in the energy and other industries. Chapter 25 (Heat Engineering) outlines the characteristics of active heat transfer enhancement techniques by applying electric fields.

Chapter 26 considers the usage of passing air or oxygen through a special s special electrical gas discharge to produce ozone. Ozone has any applications outlined in the chapter. Chapter 27 lists several methodologies for removing gaseous noxious emissions with a pulse electrostatic technology. Chapter 28 covers the very interesting subject of atmospheric electricity. The atmosphere is ionized by radioactivity, mainly alpha rays from the earth's crust, and by cosmic rays from space. Both electrons and primary positive ions thus produced react with atmospheric gases. The reactions continue until reaching the terminal negative and positive ions, respectively, within a few microseconds. Biomedical Engineering and electrostatic is discussed in Chapter 29. There are needs in biotechnology for the manipulation of small objects, such as cells, chromosomes, biological membranes, and nucleic acid and protein molecules. Biological cells range in size from less than a micrometer to several hundred micrometers, and molecules are even smaller, measured in nanometers Electrical forces are highly suitable for handling, characterization, and separation of these find particles. With the use of electrostatic effects , these objects can be manipulated collectively or even individually. In addition, because electrostatic force is "surface force" distributed around the surfaces of objects, it enables gentle manipulation, without applying too much stress to the objects. Finally chapters 30 through 33 addresses the negative aspects (or hazards) of electrostatic discharges.

NEW BOARD OF DIRECTORS WINNERS

Candidate statements appeared in the July ACES Newsletter.

Congratulations go to Allen W. Glisson, Jr., Keith Lysiak, and Eric Michielssen.

These three newly elected Directors will be installed in office at the next Annual Meeting of Members which occurs at the annual conference.

Among other benefits, these changes will allow incoming new Directors to participate in the Fall Board of Directors meeting, which has been occurring in October by telephone conference call. Although they will not be voting members at that time, their participation should be informative and useful to them when they actively begin their three year term.

Rene Allard, Elections Committee Chairman

ACES NEWSLETTER EDITOR'S ANNOUNCEMENT

ATTENTION ACES members: The ACES Board of Directors is considering converting the ACES newsletter to electronic distribution to better serve the membership. This change would allow faster distribution of the newsletter to the members as well as reduce printing costs. While a number of options are under consideration, we would like to hear your thoughts. Please take a moment to e-mail me at barch@us.ibm.com with any suggestions, thoughts, or concerns. Options include e-mail distribution, web page secure download, or a combination of hard copy and soft copy distribution. I encourage you to make you opinions known as soon as possible! Thanks!

Bruce Archambeault, ACES Newsletter Editor-in-Chief

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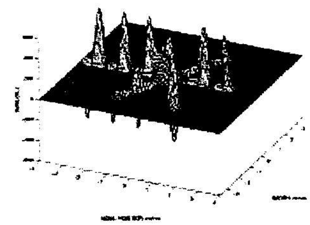

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THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY

The 18TH Annual Review of Progress in Applied Computational Electromagnetics

March 18 - 22, 2002

Naval Postgraduate School, Monterey, California

Classical electromagnetic field theory is already a mature branch of Theoretical Physics. Quite to the contrary, the relatively new engineering discipline of Applied Computational Electromagnetics (CEM) is a very dynamic and evolving field. Indeed, research in CEM is continuously generating practical and efficient new solutions for the analysis, design, development and measurement problems posed by increasingly complex systems. The pace of evolution in applied computational electromagnetics is monotonically escalating, driven by the ever-increasing and unrelenting requirements of new applications in such fields as global *EM* communications, radar, remote sensing, high-power microwaves *(HPM)*, high-speed computers, and large-scale nuclear physics facilities.

The annual *ACES* Symposium has been also continuously evolving from its rather modest origins, and is now recognized as the most influential and authoritative international forum in the field of CEM, where leading scientists and engineers convene annually to present the results of their most recent research efforts, and to share those results with their peers worldwide.

The annual *ACES* Symposium combines high scientific level and practical engineering emphasis to present a review of the most recent developments. International participation by non-members is welcome and strongly encouraged. The annual *ACES* Symposium is indeed *the premier* forum where the dynamic, vibrant progress in Applied Computational Electromagnetics is extensively reviewed, reported, and documented for archival reference.

The following matrix of hot topics, applications, methods and computational tools is merely intended to exemplify the extent of ACES interests by listing some of the most popular session subjects:

Typical Hot Topics	Applications	Methods	Computational Tools
Fast Hybrid Methods	Antennas	FDFD	New Codes or Languages
Modal Expansions	Phased Arrays	FEFD	New Computers/WorkStations
Domain Decomposition Methods	Adaptive Arrays	FDTD	High-Speed Computer Clusters
Symmetry Analysis & Applications	Beam Forming Networks	FETD	Graphic Domain-Definition
High Performance Computing	Radar Tracking	Modal Expansions	Output Data Post-Processing
Unstructured Meshes	Radar Imaging	TLM/Wavelets	Parallel Processing
Multiple Parallel Processors	Radar cross section	Symplectic Integr.	Diff. Equation Techniques
Large Scale Microwave Structures	Microwave components	Diakoptics	Moment Methods
Generalized Scattering Matrix *(GSM)*	Communications systems	GTD	Object-Oriented Programming
Multi-Mode Analysis	Satellite Communications	Physical Optics	Visualizations
Inverse Scattering	Wireless Communications	Integral Eqns.	Virtual Reality in Elec. Mag.
Non-Commutative Symbolic Comp.	High Power Sources	EFIE/MFIE	Differential Algebra
High Power Microwave Sources	Particle Accelerators	Perturb. methods	Inv. of Structured Matrices
MIMIC Interconnect Technologies	Fiber Optics	Hybrid methods	Code Validation
Susceptibility & Survivability	Bio-Electromagnetics	Numerical Optim.	High Order Taylor Maps

SYMPOSIUM STRUCTURE: The annual ACES Symposium traditionally takes place during the third week of March, and includes, in addition to formal sessions for oral presentation of submitted papers: (1) a poster session, (2) a student paper competition, (3) numerous short courses (both *full-day* and *half-day*), (4) an awards banquet, (5) vendor exhibits, and (6) a wine and cheese social. The ACES Symposium also includes three Plenary Sessions, where illustrious invited speakers deliver original essay-like reviews of hot topics of their own choice.

EARLY REGISTRATION FEES

(for registration prior to March 1, 2002)

ACES member	$310	Student/Retired/Unemployed	$130 (no proceedings)
Non-member	$365	Student/Retired/Unemployed	$165 (includes proceedings)

Each conference registrant is entitled to publish two papers in the proceedings free of charge. Excess pages over the limit of eight (8) pages for each paper will be charged $25/page.

PAPER FORMATTING REQUIREMENTS

The recommended paper length is 6 pages, with 8 pages as a free maximum, including figures. The paper should be camera-ready (good resolution, clearly readable when later photo-reduced to the final proceedings format of 6x9-inch paper). The submitted papers should be formatted for printing on 8.5x11-inch U.S. standard paper, with 13/16 inch side margins, 1-1/16 inch top margin, and 1 inch margin at the bottom. On the first page, the title should be 1-1/2 inches from top with authors, affiliations, and e-mail addresses beneath the title. Use single line spacing, with 10-12 point font size. The entire text should be fully justified (flush left and flush right). No typed page numbers, but sequential page numbers must be inserted as *non printing Acrobat Annotations*. Electronic submission of full photo-ready finished papers is required, in Acrobat 4.0 or 5.0 format only (*.pdf). All papers must strictly conform at the time of submission to the detailed electronic format specifications described on the ACES Web Site.

SUBMISSION DEADLINE

Submission deadline is **November 16, 2001.** The signed ACES copyright-transfer form, and a payment covering the registration for at least the corresponding author must be provided at the time of paper submission. Authors of rejected papers, who choose not to attend the conference, will receive a refund of their registration fee. **Authors will be notified of acceptance on or about December 15, 2001.**

$500 BEST-PAPER PRIZE

A $500 prize will be awarded to the authors of the best non-student paper accepted for the 18^{TH} *Annual Review.* Papers will be judged by a special ACES prize-paper committee, considering the following criteria:

1. EM/CEM theory and technical content correctness.
2. Reliable data.
3. Computational EM component and results.
4. Practical applications value.
5. Estimates of computational errors.
6. Significant new conclusions.

$300 BEST STUDENT PAPER CONTEST

This will be for the best student paper accepted for the 18^{TH} *Annual Review*. Student presentation at conference is required. Submissions will be judged by three (3) members of the ACES Board of Directors. Prizes for the best student paper include: (1) one free *Annual Review* registration for the following year; (2) one full-day, or two half-day, free short course(s) taken during the 2002 or 2003 *Annual Review,* and (3) $300 cash.

Ross A. Speciale - Technical Program Chairman

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Personal Home Page: http://home.socal.rr.com/thedrross/

2002 ACES Symposium Sponsored by: ACES, Naval Postgraduate School, Iowa State University, University of Mississippi, Michigan State University, Georgia Institute of Technology and South West Research Institute, in cooperation with: The IEEE Antennas and Propagation Society, IEEE Electromagnetic Compatibility Society, and the United States National Committee of URSI.

Symposium Co-Chairs	Electronic Publication Chair	Symposium Administrator	Short Course Chair	Exhibits Chair	Publicity Chair
Leo C. Kempel Michigan State University	**Atef Elsherbeni** University of Mississippi	**Richard W. Adler** Naval Postgraduate School	**John Schaeffer** Marietta Scientific	**S. Balasubramaniam** Iowa State University	**Keith A. Lysiak** Southwest Research Institute
Andrew F. Peterson Georgia Institute of Technology					

STUDENT BEST PAPER CONTEST

This will be for the "Best Paper"

submitted for publication in the 2002,

18th Annual Review of Progress.

(Student must be presenter on the paper chosen).

Submissions will be judged by three (3)

members of the ACES BoD during the 18th

Annual Review presentations.

The prizes for the Student presenter will

consist of: (1) $300 cash; (2) free Annual

Review registration for the following year;

and (3) one free Annual Review short

course for the following year.

MOTELS / HOTEL LIST FOR MARCH 2002 ACES SYMPOSIUM

18-22 MARCH 2002

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

NOTE! THERE IS NO CONTRACTS AT THIS TIME BETWEEN ACES AND THE HOTELS/MOTELS. THESE PRICES MIGHT POSSIBLY CHANGE!

FIRESIDE LODGE (**) (1 star)
1131 10th St. Monterey, CA 93940
Phone: (831) 373-4172 FAX: (831) 655-5640
Rates: **Govt** and **Conf.** $89 + tax

STAGECOACH MOTEL (**) (1 Star)
1111 10th St. Monterey, CA 93940
Phone: (831) 373-3632 FAX: (831) 648-1734
Rates: **Govt.** $74.- **Conf.** $79 + tax

MONTEREY BAY LODGE (**) (2 Star)
55 Camino Aguajito, Monterey, CA 93940
Phone: (831) 372-8057 FAX: (831) 655-2933
Rates: **Govt.** and **Conf.** $44.10 + tax

MONTEREY HILTON (**) (3 Star)
1000 Aguajito Rd. Monterey, CA 93940
(831) 373-6141 FAX: (831) 375-2367
Rates: **Conf.** $139 + tax (**no govt price**)

HYATT HOTEL & RESORT (**) (4 Star)
1 Old Golf Course Rd. Monterey, CA 93940
Phone: (831) 372-1234 FAX: 375-6985
Rates: **Govt.** $75.- 146; **Conf.** $159 + tax

most rates apply for Mon thru Thursday

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

IMPORTANT INFORMATION FOR ACES ATTENDEES, PLEASE READ

Hotel room tax exemption requires all of the following documents: (1) Travel Orders, (2) Payment by government issued AMEX/VISA card; (3) Govt./Military identification. Regarding Govt orders: prevailing perdiem lodging rate at time of arrival will be honored. Attendees on Govt. orders do NOT pay city tax; every other attendee pays city tax! When you book a room, mention that you are attending the "ACES" Conference, at NPS, and ask for either Government, or Conference rates.

There is NO PARKING at the Naval Postgraduate School or on nearby streets, so we advise you to book a room within walking distance, or plan to use a taxi. The GATES ARE GUARDED. To enter the base you must have two forms of govt. approved ID; have PRE-REGISTERED FOR THE CONFERENCE, by at least 1 day; before conference commences, so your name can appear on an approved list 24 hours before you may enter the base. Your vehicle will probably be inspected, due to the heightened security due to the 9/11/01 terrorism attacks. Please refer to the ACES Presidents Message on page 4 of this Newsletter **for further information.**

AIRLINE INFORMATION

The following airlines make connections from Los Angeles/San Francisco, to Monterey, CA: United Express, and American Eagle. Both fly a 30-35 passenger Prop. Jet Airplane. American Eagle, serves Los Angeles to Monterey, but not San Francisco to Monterey. United Express serves Monterey from both LA and SFO. There is no airline connection directly from San Jose, CA to Monterey, CA.

FLYING FROM SAN JOSE OR SAN FRANCISCO? MONTEREY/SALINAS AIRBUS

Departs every two hours from San Francisco for San Jose Airport, Salinas, and Monterey. Rate is $30.00 per person, one way. Reservations recommended. Cash/Credit Card accepted. Departs as early as 7 am from SFO. For more information, phone 831-883-2871

THINGS TO DO AND SEE IN THE MONTEREY BAY AREA

There are many activities for children and adults not attending the Conference. The colorful blue Monterey Bay is a vision of historic Monterey, rich with natural beauty and many attractions from Fisherman's Wharf, (be sure to try the seafood cocktails), to Cannery Row; the Monterey Adobes and city parks; the Monterey Bay Aquarium, (did you know that there is a deep canyon in the Monterey Bay? Check it out!);

APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY
RICHARD W. ADLER, EXECUTIVE OFFICER, ECE DEPARTMENT, CODE ECAB, NAVAL POSTGRADUATE SCHOOL, 833 DYER ROAD, RM 437, MONTEREY, CA 93943-5121, PHONE: 831-646-1111 FAX: 831-649-0300 EMAIL: RWA@ATTGLOBAL.NET

please print

LAST NAME FIRST NAME MIDDLE INITIAL

COMPANY/ORGANIZATION/UNIVERSITY DEPARTMENT/MAIL STATION
(PLEASE LIST THE ADDRESS YOU WANT USED FOR PUBLICATIONS BELOW)

MAILING ADDRESS

CITY PROVINCE/STATE COUNTRY ZIP/POSTAL CODE

TELEPHONE FAX AMATEUR RADIO CALL SIGN

E-MAIL ADDRESS E-MAIL ADDRESS CAN BE INCLUDED IN ACES DATABASE YES ☐ NO ☐
PERMISSION IS GRANTED TO HAVE MY NAME PLACED ON MAILING LISTS WHICH MAY BE SOLD YES ☐ NO ☐

CURRENT SUBSCRIPTION PRICES

AREA	INDIVIDUAL SURFACE MAIL	INDIVIDUAL AIRMAIL	ORGANIZATIONAL (AIRMAIL ONLY)
U.S., CANADA, MEXICO	( ) $60	( ) $60	( ) $110
W. EUROPE, ISRAEL, SCANDINAVIA, GREECE	( ) $63	( ) $73	( ) $110
ASIA, AFRICA, MIDDLE EAST, PACIFIC RIM, FORMER USSR, E EUROPE, BALKANS, CENTRAL & SO. AMERICA, TURKEY	( ) $63	( ) $80	( ) $110

FULL-TIME STUDENT/RETIRED/UNEMPLOYED RATE IS $25 FOR ALL COUNTRIES

Non-USA participants: Prices are in U.S. dollars. All currencies must be converted to U.S. dollars payable by banks with U.S. affiliates. (1) Bank Checks, must have U.S. address of bank; (2) Traveler's Checks (in U.S. $$); (3) U.S./International Money Order drawn in U.S. funds, payable in U.S. $$, (4) Credit Cards: Visa, MasterCard, Amex and Discover.

PAYMENT METHOD: ALL CHECKS/TRAVELER'S CHECKS/MONEY ORDERS ARE PAYABLE TO "ACES"

☐ CHECK (PAYABLE TO ACES) ☐ TRAVELER'S CHECKS ☐ INTERNATIONAL MONEY ORDER

☐ CREDIT CARD ☐ VISA ☐ MASTERCARD ☐ AMEX ☐ DISCOVER

CREDIT CARD USERS

SIGNATURE AND ADDRESS OF CARD HOLDER IS MANDATORY.

IF YOU ARE PAYING VIA ANOTHER PERSONS CARD, HE/SHE MUST PRINT AND SIGN NAME AND ADDRESS.

PRINT CARD HOLDER NAME: ______________________

CREDIT CARD HOLDER SIGNATURE: ______________________

CREDIT CARD EXPIRATION DATE: ____/____

CREDIT CARD HOLDER ADDRESS: ______________________

CREDIT CARD ACCOUNT # ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ 2001-2002

ADVERTISING RATES

	FEE	PRINTED SIZE
Full page	$200.	7.5" x 10.0"
1/2 page	$100.	7.5" x 4.7" or 3.5" x 10.0"
1/4 page	$ 50	3.5" x 4.7"

All ads must be camera ready copy.

Ad deadlines are same as Newsletter copy deadlines.

Place ads with Ray Perez, Newsletter Editor, Martin Marietta Astronautics, MS 58700, PO Box 179, Denver, CO 80201, USA. The editor reserves the right to reject ads.

DEADLINE FOR THE SUBMISSION OF ARTICLES

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

For the ***ACES NEWSLETTER*** send copy to Bruce Archambeault in the following formats:

1. A hardcopy.
2. Camera-ready hardcopy of any figures.
3. If possible also send the full document; if not, send the text on a floppy disk. We can read any version of MICROSOFT WORD, PageMaker and PDF files on IBM disks. On IBM disks we can also read LATEX files but contact us first concerning the LATEX version. If any software other than MICROSOFT WORD has been used, contact the Managing Editor, Richard W. Adler **before** submitting a diskette.