APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY (ACES)

NEWSLETTER

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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 COMMENTS

Recently I spoke with the director of nondestructive evaluation (NDE) for a large aircraft manufacturer. I was trying to sell him on the idea of purchasing VIC-3D, our company's volume-integral code for solving problems in eddy-current NDE. I began by introducing myself, and he said that he knew who I was from hearing me at various conferences.

"You're the fellow who keeps talking about Green's functions," he said, and I agreed that he had me pegged correctly.

He continued, "If I knew that you could make money by solving Maxwell's equations, I would have paid more attention in my undergraduate E and M courses."

I laughed and said that we were certainly trying to make a living by solving Maxwell's equations. I still haven't sold him a copy of VIC-3D, but that's not the point of this piece.

Those of you who work in antennas and scattering, have customers who know that they are paying you to solve Maxwell's equations, but NDE is an industry that is only now realizing the value of sophisticated modeling. Even then, eddy-currents, though a very common mode of doing NDE, are still considered quite mysterious by many of the practitioners in the industry. Therefore, it is absolutely essential that the software that we produce is easily useable by the average engineer, and that the data are easily interpreted. If the interface is snazzy enough, various shortcomings of the code might be overlooked. These are all issues that may make the idea of doing modeling (instead of simply doing things emirically) more palatable to the average user.

Beyond all of this, however, is the realization that we are, indeed, commercializing one of the most beautiful things in all of God's creation--the electromagnetic Green's function. This is a heady feeling, ladies and gentlemen, and causes us to do our daily work with reverence and fear.

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COMMITTEE REPORTS

AWARDS COMMITTEE

Awards presented at the 13th Annual Review of Progress were:

THE 1997 VALUED SERVICE AWARD was presented to Richard K. Gordon, for his dedicated leadership as Chairman of the 12th Annual Review of Progress.

THE 1997 MAINSTAY AWARD was presented to Keith W. Whites for his outstanding service to the ACES Journal and the Annual Review of Progress.

THE 1997 EXEMPLARY SERVICE AWARD was presented to J.P.A. Bastos for his outstanding service to the ACES Journal.

THE 1997 OUTSTANDING PAPER AWARD was presented to F. Rivas, L. Valle, and M.F. Catedra for their paper published in the July 1996 ACES Journal.

The above awards were presented at the Awards Banquet on Tuesday evening. In addition, a **BEST STUDENT PAPER PRIZE** was later awarded to Eric A. Jones and William T. Joines, for their paper "Improved Computational Efficiency by Using Sub-regions in FDTD Formulations."

The Board of Directors may wish to discuss whether the Awards Banquet in 1998 can be held one day later (on Wednesday), which may allow the awarding of the Best Student Paper Prize during the banquet.

Respectfully submitted
John R. Brauer

CONFERENCE COMMITTEE

This Committee has formulated the following policy for the ACES '98 Annual Review:

1. Method of selecting and limiting the number of Review papers.

To limit the number of papers for the Review and the Proceedings, and thereby limit the number of parallel sessions to 3 or fewer, the Annual Review Committee (Jianming Jin, Chairman) should cull--if necessary--the number of papers "behind the scenes". That is, reject after the deadline the number of papers necessary to adhere to a predetermined number of sessions. That number should determine closely enough the targeted Proceedings length.

We shouldn't have to coax papers from authors if we follow this policy. However, we should solicit timely papers and only reject them for gross grammatical and/or technical errors.

2. Paper Review Procedure

The Annual Review Committee will simplify this by eliminating the Summary Submissions and request authors to submit full-length, camera-ready copies.

3. A Pre-formatted Skeleton Agenda

The Conference Committee has devoted considerable thought to this matter, and the Annual Review Committee will decide on the number of days for papers, based on submissions and the limitation of 3 parallel sessions maximum. Short courses will be given on two separate days.

4. A CD-ROM for the Proceedings?

This is a possibility, but the Proceedings would continue to be available in book form.

The Call for Papers in this issue outlines the various aspects of the ACES '98 Annual Review.

Regarding the Penn State University (PSU) Symposium of short courses and workshops planned for September '97, we regretfully informed, in late July, the instructors of 13 submissions, that the Symposium would have to be postponed to 1998. This was because the PSU Committee was unable to prepare the advanced flyers for timely mailings, in spite of diligent and prompt efforts by Executive Officer R. Adler, ACES PSU Chairman J. Breakall, and your Conference Committee Chairman.

Currently we three are working with the PSU Committee to plan for a September or October '98 meeting. The instructors have been polled for their availability and hotel reservations will be made in the near future. The flyers are prepared, minus some details, and we anticipate early mailings next February or March.

Respectfully submitted,
Robert M. Bevensee, Conference Committee Chairman

NOMINATIONS COMMITTEE

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

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

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

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

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

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

DIRECTORS-AT-LARGE

Pat Foster	1998	John Brauer	1999	Andreas Cangellaris	2000
Todd Hubing	1998	Harold Sabbagh	1999	Ray Perez	2000
Adalbert Konrad	1998	Perry Wheless, Jr.	1999	Norio Taskahashi	2000

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PUBLICATIONS COMMITTEE

The ACES Board of Directors has a meeting scheduled during the month of October. Several Publications matters are actively under discussion now, and some may be acted on by the Board, so a report on the final disposition of these considerations is not possible just yet.

However, it is possible to report the major topics under active discussion in ACES Publications at this time. These include: (a) advertising policy and rates, both for paid advertising in the ACES Newsletter and for drop-in promotional mailers that go out with bundled Journal/Newsletter mailings, (b) policy on inclusion of, and charges for, color figure printing, (c) identification and conversion of meritorious papers from the ACES "Annual Review of Progress" Symposium into ACES Journal contributions, (d) expectations for paper submissions by members of the ACES Journal editorial board, (e) planning for changes in ACES Publications and ACES Journal staffing which will become effective in the spring of 1998, (f) the suggestion of A. Elsherbeni that ACES make software developed by ACES authors available for distribution, either by means of the ACES University of Missouri - Rolla computer site, or otherwise, and (g) an assessment of the member service rendered by the recent ACES Journal Special Issues guest-edited by J.P. Bastos, A. Konrad, and J. Brauer in the first case, and by K.R. Richter, D.A. Lowther, and G. Molinari in the second case.

The list above is not in order of significance. Indeed, item (g) is particularly important. It deserves elaboration here, and feedback from the ACES membership on this point is solicited. The papers in ACES Journal Vol. 12, no. 1, originated with presentations at the Brazilian Conference on Electromagnetics; those in Vol. 12, no. 2 similarly originated from the 7th International IGTE Symposium on Numerical Field Calculation held in Graz, Austria. ACES Publications decided to embark on these two Special Issue projects to bring new information and work results from outside ACES, and also North America, to the ACES membership. In both cases, the guest editors did an outstanding job, and the technical quality of both issues is something that we can be proud of. Whether the topics and techniques presented in these issues serve the widespread interests and needs of ACES members is another matter, and the question which now requires some careful assessment. Members who would care to contribute an evaluation of these Special Issues and/or offer comments on the merit of these sources for future ACES Journal material, are invited to send their remarks to Perry Wheless, Duncan Baker (duncan.baker@ee.up.ac.za), or Adalbert Konrad (konrad@power.ele.toronto.edu). If you wish for your remarks to be considered confidential for use only within ACES Publications, please indicate this in your correspondence.

Finally, a note to ACES '98 conference authors: as you prepare your conference paper, work from the outset with the intention of also making your submission into an ACES Journal contributed paper. Usually a Journal paper will require the inclusion of some new, additional material, and must satisfy a somewhat higher standard of quality. However, the potential of having your paper archived in a recognized peer-review Journal should be a strong motivation for all conference authors to also aspire to journal publication. The ACES Journal staff is available to encourage and assist you, and we seriously intend to use the 1998 conference as a source for some good Journal papers!

Submitted by
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MODELER'S NOTES

Gerald J. Burke

For this column we have some new NEC PC benchmarks from Larry Laitinen, updating his data from the July Newsletter. Also, I have finally given in to the overwhelming tide and bought a Pentium PC to supplement my Mac, so can provide some additional timing data. In the last issue we were a little unfair to HP in noting the seemingly slow performance of the 200 MHz Pentium Pro Vectra, since other Pentium Pro computers seem to show similar performance in filling the NEC matrix, and they do substantially beat the plain Pentiums and MMXs in the matrix factor time for larger problems, as shown below. The reasons for this difference, and the relatively fast performance of Power Macintoshes remain a mystery. There are no new NEC-4 patches to report, but a perplexing difference between NEC–4 and 2 in the reflection-coefficient approximation for ground is explained.

As usual, if anyone can contribute modeling-related material for future newsletters, they are encouraged to contact our editor Ray Perez or Jerry Burke, Lawrence Livermore National Lab., P.O. Box 808, L-154, Livermore, CA 94550, phone: 510-422-8414, FAX: 510-423-3144, e-mail: burke2@llnl.gov.

Benchmark update from Larry Laitinen, WA6JYJ, University of Oregon, laitinen@ oregon.uoregon.edu.

Larry is still finding most of his time taken up in moving to a new house, and has not been able to run all of the tests that he would have liked. He has gotten moved into the new house, but is now busy fixing up the old one to sell. However, he got a Pentium-II system to test, and wanted to get the results in this issue of the Newsletter. His system includes a Pentium-II processor operating at 266 MHz, 64-MB of ECC RAM, 9-msec 2.5-GB Hard disk, 16X CD-ROM drive, fast E/N card, etc. for a price of $1750 without monitor. Guess that is for the University of Oregon, and an individual might have to pay more, but it certainly seems like a lot of computer for the money, and the prices for the rest of us will probably come down soon.

The performance of the Pentium-II on the 299 segment test problem is shown in Table 1, along with other 200 MHz Pentium systems that Larry has tested. The benchmark times of Pentiums with slower clock speed, as well as the input data used in the test can be found in the July Newsletter. The Pentium-II times seem to scale about by the clock speed from the Pentium Pro times as shown in Table 2. Both Pentium-II and Pro are slower than a Pentium MMX in filling the matrix, and we do not understand the reason at this time. The time to fill the matrix is mainly taken up by evaluations of SIN and COS functions and complex exponentials, so it is less dependent on cache access speed than the matrix factoring operation. This may be a compiler issue, since the speed difference is smaller for NEC4D compiled with the Microsoft Fortran Powerstation compiler, and NEC4S is a little faster in filling on the Pentium Pro, as will be seen in Table 3. The time to L/U factor the matrix is faster with the Pentium Pro and II than on the MMX, and that is what counts for large models. The results in the July Newsletter showed that the MMX is faster than the plain Pentium (both 166 MHz) due to the MMX having 32 KB of L1 cache compared to 16 KB on the standard Pentium. The Pentium Pro has a 256 KB L2 cache on the chip carrier, where it

Table 1. Execution times in seconds for the TEST299.NEC input file run in double-precision NEC4.1 on various processors.

	CPU/Motherboard	L2 Cache	RAM	Matrix Fill	Matrix Factor	Total Exec.
1.	Pentium-II 266-MHz Gigabyte GA-686KX	512KB pburst	64MB FPM	8.576	2.053	10.93
2.	Pentium 200-MHz MMX Gigabyte 586HX	512KB pburst	64MB FPM	8.430	4.342	13.07
3.	Pentium 200-MHz MMX Asus 430TX	512KB pburst	64MB EDO	8.430	4.297	13.13
4.	Pentium-Pro 200-MHz Gateway P6-200 XL	256KB CPU	128MB ??	11.120	2.753	14.17
5.	Pentium-Pro 200-MHz HP Vectra XU 6/200	256KB CPU	64MB EDO	11.530	2.843	14.67

Notes: FPM = Fast Page Mode; pburst = Pipeline Burst cache; EDO = Extended Data Output.

Table 2. Comparison of performance ratios for NEC4.1 on various CPU chip and motherboard configurations.

	CPU/Motherboard	Clock Ratio	M-Fill Ratio	M-Fact Ratio	Exec Ratio	Norm. by CPU clock		
						M-Fill	M-Fact	T-Exec
1.	Pentium-II 266-MHz Gigabyte GA-686KX	2.96	2.192	5.163	2.766	0.742	1.747	0.936
2.	Pentium 200-MHz MMX Gigabyte 586HX	2.22	2.230	2.440	2.313	1.004	1.099	1.041
3.	Pentium 200-MHz MMX Asus 430TX	2.22	2.230	2.466	2.303	1.004	1.110	1.036
4.	Pentium-Pro 200-MHz Gateway P6-200 XL	2.22	1.691	3.850	2.133	0.761	1.733	0.960
5.	Pentium-Pro 200-MHz HP Vectra XU 6/200	2.22	1.631	3.728	2.061	0.735	1.679	0.928

can be accessed without going through the system bus, and this apparently accounts for the faster factor time. The difference is even larger on larger models, so it does seem worthwhile to get a Pentium Pro or II if you expect to run large problems. Larry is planning to test his systems on larger models, and also compile the code with a new Lahey compiler once the house work is out of the way. At this point his conclusion was that it does not look like any major architectural improvements for NEC users in the Pentium-II over the Pentium-Pro, but that could change with new compilers.

As I mentioned before, I finally bought a Pentium PC for home use, although I still prefer the Mac for convenience of use. Maybe that is a matter of getting used to the differences between Windows-95 and the Mac OS. I got it from a local PC shop, since that route was recommended to have good access to service and advice on configuring the system. I have not needed any service yet, and probably could have saved a couple of hundred dollars by getting it from a mail-order place. I got a 200 MHz Pentium MMX with Asus 430TX board, 64 MB of RAM and 512 KB L2 cache. Also bought the Microsoft Fortran Powerstation V. 4 compiler, since it was available at a good price, although a discontinued product now that DEC has taken it over from Microsoft. It seems to have a nice user interface, and it was relatively easy to get NEC to compile. The only problem was the READ into an internal file with a "*" format in subroutine PARSIT, which has been reported on nec-list.ee.ubc.ca and elsewhere. I have not seen this problem on other compilers for UNIX, Mac or DEC systems, and it is bad that the Powerstation compiler gives no warning, but just sets the values to zero. It was relatively easy, compared to the Mac, to get DIGLIB running for plotting, so we now have NECPLOT, ZPLOT and PATPLOT plotting programs for Windows-95 or NT. These programs, which were described in the July 1992 ACES Newsletter, plot the wire and patch structure with currents (NECPLOT), impedance versus frequency with rational-function interpolation (ZPLOT), and radiation patterns (PATPLOT).

Once it was running, the next question was how fast, so I tried Larry's compiled DNEC4 on the 299 segment case. Larry has included the results as line 3 of Tables 1 and 2. The NEC4D compiled on the Powerstation compiler gave times of 5.43 seconds to fill, 5.72 seconds to factor and 11.43 total, which are somewhat faster than Larry's code, but it was not clear whether his was optimized for the Pentium. Larry now has a new Lahey compiler, and plans to recompile the code when his work on the house is permitts. The Powerstation code was compiled with full optimization, but with the default option for a blend of Pentium and 486 optimizations. Compiling for Pentium-only optimization produced code that was about five percent faster, but I used the "blend" results since I did not want to re-run all the tests.

To time the code for somewhat larger problems I used the multiple, parallel wire tests of 300, 600 and 1200 segments that have been used in the past in this column. The input data for 1200 segments follows, and for 300 segments the second GM command was `GMO,2,...` while for 600 segments it was `GMO,5,...`

```
CE Timing test - Multiple parallel wires,  1200 segments
GWO,10,0.,0.,0.,0.,0.,1.,.001,
GMO,9,0.,0.,0.,.2,0.,0.,
GMO,11,0.,0.,0.,0.,.2,0.,
GE
EXO,0,5,0,1.,
XQ
EN
```

The results of running NEC4S and NEC4D for 300, 600 and 1200 segments are shown in Table 3 for my Pentium MMX, a Gateway Pentium Pro down the hall and a PowerMac 8600. The columns "fill ratio" and "factor ratio" give the ratio of time to that of the previous smaller case, so fill ratio should be 4 and factor ratio 8 when the number of segments N is doubled. The ratio may be smaller, since there are terms proportional to N, or for factoring N^2, that are significant for small N. When the ratios are larger than their ideal value it

Table 3. Execution times in seconds for the 300, 600 and 1200 segments in single and double precision.

CPU/MB or Model	N	Prec.	Matrix Fill	Fill Ratio	Matrix Factor	Factor Ratio	Total Exec.
Pentium MMX, 200 MHz	300	S	3.51		3.41		7.53
Asus 430TX	600	S	12.96	3.69	28.28	8.29	42.84
	1200	S	49.54	3.82	281.72	9.96	336.03
	300	D	4.67		4.28		9.61
	600	D	18.73	4.01	42.07	9.83	62.56
	1200	D	69.98	3.74	516.85	12.28	592.65
Pentium Pro, 200 MHz	300	S	3.13		2.64		6.26
Gateway P6-200 XL	600	S	11.92	3.81	21.80	8.25	35.04
	1200	S	46.08	3.87	175.71	8.06	225.91
	300	D	5.33		4.72		10.93
	600	D	20.60	3.86	38.28	8.11	60.69
	1200	D	81.67	3.96	307.31	8.02	394.21
PowerMac 8600, 200 MHz	300	S	2.547		1.453		4.688
PPC 604e Processor	600	S	8.766	3.44	12.133	8.35	22.469
	1200	S	32.680	3.73	96.039	7.92	134.102
	300	D	2.969		2.148		5.945
	600	D	10.555	3.56	17.164	7.99	29.516
	1200	D	40.320	3.82	153.148	8.92	200.516
Mac 8100, 80 MHz	300	S	6.67		2.75		10.93
PPC 601 Processor	600	S	24.00	3.60	22.98	8.36	49.42
	1200	S	75.05	3.13	184.18	8.01	264.68
	300	D	7.40		4.07		12.92
	600	D	26.03	3.52	33.17	8.15	61.62
	1200	D	81.67	3.14	285.58	8.61	372.87

seems like a likely cause is the cache becoming less effective, and that appears to be the case with the Pentium MMX. Larry's benchmarks showed the effect of the smaller L1 cache on the standard Pentium versus the MMX, and it would be interesting to see that comparison for larger problems.

The results in Table 3 show the 200 MHz PowerMac 8600 to be about a factor of two faster than the Pentium Pro of the same clock speed, and we are not sure why this is. The July issue of MacWorld reported on a comparison of fast PowerMacs and Pentiums running commercial video and image processing programs. The Macs won in speed and the Pentiums in price, but they were comparing the fastest Mac (225 MHz) and Pentium MMX or Pro (200 MHz) available at the time. They pointed out two factors that should put the Mac at a disadvantage. The Mac system bus, at that time, was operating at between 40 and 50 MHz, while the Pentium Pro was at 66 MHz. This could be significant, since access to the L2 cache is through the system bus on the Mac. The Pentium Pro uses the system bus to access main memory, but not its cache on the chip carrier. Also, much of the Mac operating system is still 680x0 code running under emulation on the PPC, but that should not matter once the matrix factoring code takes over. One possibility is that the Absoft MacFortran II compiler for the Mac may produce more efficient code than the Powerstation compiler for the Pentium. We have heard some reports that the Lahey compiler may produce substantially more efficient code than Powerstation, but have not seen any hard evidence. That will be answered when Larry gets his Lahey compiler running. Times on an old 80 MHz Mac 8100 with 601 PPC are also included in Table 3. Although the Mac code was compiled for 604 optimizations, the times for the 604e PPC are faster than the 601 by less than the ratio of clock speeds so the new architecture does not seem to offer an advantage for NEC.

I tried these tests on a 200 MHz SGI down the hall, and the SGI was about 22% slower than the Mac 8600. The owner was surprised, since he expected the SGI to win in cache and bus speed, but he also guessed that the difference may be in the Fortran compilers. Fortunately he has just bought a new SGI that is three times faster. If any readers have an explanation for the Mac being so much faster than the Pentium Pro, or can provide running times for another Mac compiler such as MacFortran, it would be interesting to hear from them.

There are no new NEC-4 patches to report, although Roy Lewallen uncovered a perplexing case in which NEC-4 gives near fields over an order of magnitude larger than NEC-2 for a reflection coefficient ground problem. This turned out not to be a bug, but just a result of the differences in the NEC–2 and 4 algorithms and the limitations of the reflection-coefficient approximation (RCA). It is a subtle thing to track down, so seems worth describing here for anyone else who may encounter it. His antenna was a vertical wire about 0.013 λ above ground, with near field computed at the same height at a distance of 0.6λ. The problem is in the treatment of the point charges on the ends of segments. The sources on a single segment can be thought of as -C+, where the - and + represent point charges where the current drops abruptly to zero at the segment ends, and C represents the continuous current and charge along the segment. When segments are put together in a continuous wire the sources look like -C+-C+-C+-C+-C+-C+, and the coincident + and - point charges exactly cancel out, since continuity of current is enforced in the basis functions. In NEC-4 the fields of these point charges are not evaluated at all to avoid the numerical cancellation and consequent loss of precision, while in NEC-2 the point-charge fields are evaluated and allowed to cancel. In the reflection coefficient approximation the field due to each segment is multiplied by a reflection coefficient for the angle of incidence of the reflected ray to the center of the segment. As a result, in NEC-2 the fields of coincident + and - charges on adjacent segments get multiplied by different factors and do not cancel, while cancellation is automatic in NEC-4 since the fields are not evaluated. It is hard to say which solution is "better." The Sommerfeld solution was between the NEC–2 and NEC–4 RCA results and both codes agree with the Sommerfeld treatment. With the increased speed of computers available now it is probably good to use the Sommerfeld ground model except in cases where the antenna is clearly far enough above the ground relative to wavelength (0.1 to 0.2 λ) and segment length so that the reflection coefficient approximation is safe.

APPROXIMATE CAPACITANCE FORMULAS FOR ELECTRICALLY SMALL TUBULAR MONOPOLE ANTENNAS

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ABSTRACT

Approximate expressions have been developed that can be used to calculate the capacitance of electrically small tubular monopole antennas. The approximations are sufficiently accurate to make them useful as tools for the design of electrically short cylindrical monopoles over a wide range of heights, lengths, and diameters.

1. BACKGROUND

A monopole antenna is said to be electrically small when its largest physical dimension is much smaller than the wavelength at which it operates. These antennas are commonly found in the portion of the radio frequency spectrum spanning from VLF to MF (3 - 3000 kHz). At these frequencies, such antennas are employed in maritime communications, air and coastal navigation, as well as local broadcasting [1-3]. For example, an active antenna that is atmospherically noise-limited may require the use of a thick monopole element (i.e., with length/diameter $\cong$ 1) whenever space constraints are severe. Such an antenna has been successfully designed for Loran-C reception [4].

The input impedance of an electrically small monopole can be represented by a series circuit comprising a resistance R and a capacitive reactance $-1/\omega C$, such that $R \ll 1/\omega C$ [1]. The series resistance is the sum of the radiation resistance and other resistances attributed to ohmic (dissipative) losses. The monopole resistance R can be easily computed via standard formulas [5] and will not be further discussed here. The monopole capacitance C can be derived using electrostatic methods and depends on three principal quantities: its diameter d, length l, and height h measured from the bottom of the antenna to the ground plane. Such an arrangement is shown in Fig. 1(a), where the wall thickness t of the tube is assumed to be very thin compared to the diameter.

Aside from its role in characterizing the input reactance of an electrically small monopole antenna, the capacitance is of critical importance in the determination of the antenna's power handling ability (P_{max}) and bandwidth-radiation efficiency product ($BW \cdot \eta$) [5-6] given as follows:

$$P_{max} = \frac{640\pi^4 f^4 V_b^2 h_e^2 C^2}{c^2} \tag{1}$$

$$BW \cdot \eta = \frac{320\pi^3 f^4 h_e^2 C}{c^2} \tag{2}$$

where h_e = effective height, f = frequency, C = antenna capacitance, V_b = maximum allowable base voltage before breakdown, c = velocity of light. The above expressions were derived through use of the equivalent circuit model of the monopole as outlined above.

A precise determination of the input capacitance of an electrically small antenna may be obtained through the solution of the potential integral equation for the unknown charge distribution using the method of moments [7]. However, such a numerical method does not lend itself to rapid iterative design calculations.

Approximate analytical expressions for the input capacitance are available for two extreme cases, i.e., for a thin wire ($d/l \ll 1$)

and for a thick tube ($d/l \gg 1$, with vanishingly thin walls), each above a ground plane. The capacitance of a thin vertical wire above a ground plane was determined by Grover [8] while formulas for the input impedance were derived by King [9]. By the use of a method originally proposed by Howe [10], Grover obtained an analytical expression for the capacitance by assuming that the charge distribution along the antenna was constant. King's expressions were based on the approximate solution of Hallen's equation. The converse problem, that of the capacitance of a thick tubular monopole, was solved by Casey and Bansal [11]. Through modification of the per-unit length capacitance of a coplanar stripline given by Hanna [12], Casey and Bansal obtained an expression for the equivalent tubular monopole in terms of elliptic integrals.

Although the expressions cited above have been experimentally validated for some specific monopole dimensions, the extent of diameters, lengths and ground plane separations for which they are accurate has been unknown. When used for the rapid iteration of a design, capacitance values obtained with the known expressions will be of questionable value. A determination of the regions of validity of the existing tubular monopole capacitance formulas is therefore necessary for their successful implementation. It is the purpose of this paper to summarize the results of such an investigation and present new capacitance formulas for parameter ranges not covered by the existing expressions. The end result of this study is a collection of formulas that, taken together, extend the parameter range so that the computation of capacitance can be facilitated with reasonable accuracy for almost all design situations considered in practice.

2. APPROACH

The range of validity of Grover's formula for the capacitance of a thin wire or tubular monopole and the range of validity of the thick tubular monopole formula developed by Casey and Bansal will be examined by comparison with results obtained by a method of moments solution [13]. (It may be noted that the method of moments results have been experimentally verified [11,13].) The range of validity is defined here as that area where the formula agrees to within 10% of the method of moments results. A 10% error region is chosen since influences such as the antenna's proximity to other objects or irregularities in the ground plane may introduce variations of this magnitude in the observed capacitance.

With the regions of validity defined for the existing capacitance formulas, additional expressions will be presented that are suitable for parameter ranges not covered by the existing equations. An error analysis of these new capacitance formulas will follow.

Tubular monopoles can be fed in a variety of ways, two of which are shown in Fig. 2. In general, the monopole capacitance is approximately the sum of the individual capacitances of both the tube and the feed sections. The capacitance of a thin feed wire (Fig. 2(a)) is normally much smaller than the tube capacitance and can be neglected. In contrast, the capacitance of the conical feed as shown in Fig. 2(b) must usually be accounted for. Information on the computation of the illustrated feed capacitances can be found in [14-15]. In the case where there is a plate attached to both the feed wire and the lower end of the tube, (e.g., to approximate a solid cylinder) a first order estimate of the monopole capacitance is the sum of the individual capacitances. Information on the capacitance of a flat plate is given in [16]. The effects of top loading and base supports may be treated by techniques given by Belrose [3] and are not considered here.

3. EXISTING APPROXIMATIONS AND THEIR REGIONS OF VALIDITY

3.1 Thin Tubes

Consider the tubular monopole and associated coordinate system as described in Fig. 1(b). The electrostatic potential at any point along the tube surface due to an axisymmetric surface charge density $\sigma(z) = q(z)/\pi d$ induced on the tube is found by summing the contribution of the charge along the cylinder as [13]

$$V(z) = \frac{1}{4\pi\varepsilon_0} \cdot \int_h^{h+l} q(z')\left[K(z-z') - K(z+z')\right] dz' , \quad z \in (h, h+l) \quad (3)$$

where

$$K(\zeta) = \frac{1}{2\pi} \int_{-\pi}^{\pi} \frac{1}{\sqrt{\zeta^2 + d^2 \sin^2\frac{\varphi'}{2}}}\, d\varphi' \, . \quad (4)$$

In (3), q(z) is the charge per unit length while K(z - z′) and K(z + z′) are the kernels associated with the tube and its image, respectively. Note that a cylindrical coordinate system is used in (3) and (4), where φ denotes the azimuthal variable while the primed and unprimed coordinates refer to the source and observation points, respectively. Since the tube is highly conducting, it will be an equipotential surface with V(z) = V (= constant), where V is the potential of the tube with respect to ground.

For thin tubes or wires (d/*l* « 1), Grover derived a formula for the capacitance of a monopole using Howe's method of approximation. In Howe's approximation (contrary to the physical reality) the total charge Q is assumed to be uniformly distributed over the length of the tube, thereby reducing (3) to

$$V(z) \cong \frac{Q}{4\pi\varepsilon_0 l} \int_h^{h+l} \left[K(z-z') - K(z+z')\right] dz', \quad z \in (h, h+l) \quad (5)$$

Note that the potential becomes a function of position along the tube. The capacitance is estimated as C = Q/V_{av}, where V_{av} is the average of V(z) over (h,h+*l*). Upon application of the above procedure followed by further simplification under the condition d/*l* « 1, Grover derived the following [8]:

$$C = \frac{2\pi\varepsilon_0 l}{\ln\left(\frac{2}{D}\right) - \gamma} \quad (6)$$

where D = d/*l* and γ is defined as

$$\gamma = 1 + (1 + H)\ln(1 + H) - (1 + 2H)\ln(1 + 2H) + H\ln(4H) \quad (7)$$

where H = h/*l*. For simplicity, we will adopt the symbols D and H throughout the remainder of the paper. Note that as H → ∞, γ → 1 - ln 2 and Grover's formula yields the capacitance of a tube of length *l* in free space. However, as H → 0, γ → 1 and the capacitance does not diverge as expected, but instead approaches a constant.

An analysis of Grover's formula, based on a comparison with a method of moments solution, was performed in the parameter range of $-4 \le \log_{10}(H) \le 1$ and $-3 \le \log_{10}(D) \le 0$. Grover's formula produces data within 10% of the moment-method results for D ≤ 0.008 over the entire range of ground plane separations (see Fig. 3). Although Grover's formula does not produce the correct result in the limiting case as H → 0, it still yields sufficiently accurate data for small values of H with D ≤ 0.008. As H increases, Grover's formula generally improves until H = 0.04. Grover's formula, though not based on assumptions that accurately describe the charge and voltage distributions, provides a useful expression for the capacitance within the regions stated above.

The method of moments code that was used in this comparison is based on the solution of the potential integral equation (3) for the unknown charge density q(z). The numerical procedure employs pulse expansion functions and point matching. The kernel K(ζ) of the potential integral equation, defined in (4), is expressible in terms of the complete elliptic integral of the first kind, for which polynomial approximations exist [17]. For each data point computed, a sufficient number of basis functions was chosen to ensure convergence of the capacitance to at least three significant figures (see Appendix). The details of this program are provided in [13].

3.2 Thick Tubes

Casey and Bansal [11] developed an expression for the capacitance of a tubular monopole through comparison with a formula for the capacitance of a coplanar stripline. Figure 4 illustrates the approximate equivalence utilized in this development. The expression is based on a conformal mapping and is given by

$$C = 2\pi\varepsilon_0 d \frac{K(k')}{K(k)} , \tag{8}$$

where

$$k = \frac{H}{1+H} \tag{9}$$

and

$$k' = \sqrt{1-k^2} . \tag{10}$$

K(k) is the complete elliptic integral of the first kind. Note that accurate approximations exist for the ratio of the elliptic integrals in (8) [18-19]. For example, an expression developed by the authors [19] is

$$\frac{K(k')}{K(k)} \cong \frac{2}{\pi} \cosh^{-1}\left[\frac{1+k'}{k} + \frac{k\sqrt[4]{k'}}{4(1+k')}\right] . \tag{11}$$

Equation (8) will be referred to as the conformal mapping approximation (CMA) formula. The CMA formula has been shown to agree well with experimental data for tubes of various dimensions [11].

An error analysis of the CMA formula, based on a comparison with the method of moments solution in the parameter range of $-4 \le \log_{10}(H) \le 1$ and $-2 \le \log_{10}(D) \le 3$, revealed that (8) produced data within 10% of the method of moments results for thick monopoles within the region $D \gtrsim 2 / \ln[1 + (3 / H)]$ and $H \ge 10^{-4}$ (see Fig. 3). The former boundary region was obtained by fitting a curve to the calculated boundary points. It was also found that for sufficiently thick monopoles (i.e., D > 10), the relative error of the CMA is nearly independent of D. This independence occurs because the differences in the electric field lines associated with the monopole and the corresponding stripline change very little with increasing tube diameter.

For D > 10, the error in the CMA formula was also found to slowly oscillate with separation from the ground plane, and then monotonically increase for large H. The increasing error in the CMA formula for large H may occur because the electric field lines extending from the inside surface of the tube are no longer of the same shape as those extending from the outside surface. The required symmetry may thus be preserved for greater ground plane separations when the diameter of the tube is larger.

4. EXTENSION OF GROVER'S FORMULA

As discussed in the previous section, Grover's capacitance formula, based on Howe's method of approximation, is valid only for thin tubes while the CMA formula is valid for thick tubes. In an attempt to bridge the gap between the CMA and Grover formulas, the authors have extended the Grover formula to include fewer restrictions on D and H. The resulting expression is given by

$$C = \frac{Q}{V_{av}} = \frac{2\pi\varepsilon_0 l}{\Psi(D,H)} \tag{12}$$

where

$$\begin{aligned}\Psi(D,H) = {} & \sinh^{-1}\left(\frac{2}{D}\right) \\ & - (1+H)\sinh^{-1}\left(\frac{4(1+H)}{D}\right) \\ & + (1+2H)\sinh^{-1}\left(\frac{2(1+2H)}{D}\right) \\ & - H\sinh^{-1}\left(\frac{4H}{D}\right) + \frac{D}{2} - \sqrt{1+(D/2)^2} \\ & + \sqrt{H^2+(D/4)^2} + \sqrt{(1+H)^2+(D/4)^2} \\ & - \sqrt{(1+2H)^2+(D/4)^2} .\end{aligned} \tag{13}$$

The extended Grover formula (12) is considerably more involved than Grover's formula (6). For the case of very thin tubes ($D \ll 1$) it can be shown that (12) reduces to (6). The derivation of the extended Grover formula is given in [19].

A comparison of (11) with the method of moments indicates a small improvement over Grover's formula for $H \geq 0.1$. More specifically, for $H \geq 0.1$, one is able to model monopoles with the extended Grover formula for $D \leq 1.0$ in comparison to $D \leq 0.35$ with Grover's formula. Both formulas produce similar results for $H < 0.1$. Because the Howe approximation limits the ability of the extended Grover formula to yield an improvement over Grover's formula for small relative ground plane separations ($H < 0.1$), the added number of terms in the extended formula diminish its usefulness.

5. APPROXIMATE EXPRESSION FOR INTERMEDIATE PARAMETER RANGE

In the previous sections, the capacitance formulas presented were for cases in which the antenna is considered thin or thick. As a result, an expression was sought that produced a fit to the capacitance data obtained from a moment-method calculation for regions not accurately represented by either the CMA or Grover's formula. The area of interest is a rectangular region with boundaries defined by $-2.5 \leq \log_{10}(D) \leq 1$ and $-4 \leq \log_{10}(H) \leq 1$. This region was chosen since it was considered to cover most of the areas where the existing formulas fail and provides a sufficient amount of overlap. A suitable form for an expression that adequately describes the capacitance variation with variables D and H is arrived at by the observations that follow.

To be useful, the desired capacitance expression must possess the limiting behaviors described below.

5.1 Tube close to the ground plane

In this region, the capacitance can be represented by the the behavior of the CMA (8) for $H \rightarrow 0$. Here one can utilize the asymptotic representation for the ratio of elliptic integrals $K(k')/K(k)$ for small modulus k [20]:

$$\lim_{k \to 0}\left[\frac{K(k')}{K(k)}\right] = \frac{2}{\pi}\ln\left(\frac{4}{k}\right). \qquad (14)$$

The substitution of (9) into (14), followed by the application of (8) leads to the limiting behavior of the normalized capacitance, given as

$$\lim_{H \to 0}\left[\frac{C}{\varepsilon_0 l}\right] = 8D\ln(2) + 4D\ln\left(1 + \frac{1}{H}\right) \qquad (15)$$

Grover's expression (6) was not considered for vanishingly small H since it is only a function of D.

5.2 Tube far from the ground plane

In this region, the capacitance of the tube is independent of the height above the ground plane and

$$\lim_{H \to \infty}\left[\frac{C}{\varepsilon_0 l}\right] = \alpha(D) \qquad (16)$$

The function $\alpha(D)$ is determined from the method of moments data.

Expressions (15) and (16) can be combined to yield a function possessing the limiting behaviors described above, as

$$\frac{C}{\varepsilon_0 l} = \alpha(D) + 4D\ln\left(1 + \frac{\beta(D)}{H}\right). \qquad (17)$$

In (17), the function $\alpha(D)$ replaces $8D\ln(2)$ and $\beta(D)$ is introduced in order to allow the second term to remain valid for large values of D and H. The factor 4D in the second term has been retained since it is valid for small values of H.

The normalized tubular capacitance $C/(\varepsilon_0 l)$ was computed by the method of moments for the parameter range of $-2.5 \leq \log_{10}(D) \leq 1$ and $-4 \leq \log_{10}(H) \leq 1$. (The data is available from the authors upon request). From the data, the functions $\alpha(D)$

and β(D) was determined by nonlinear regression, with the following forms:

$$\alpha(D) \cong \frac{7}{\ln\left(1+\frac{2}{D}\right)} ,$$

$$\beta(D) \cong \frac{1+30D+124D^2}{70D(D+2)} . \quad (18)$$

The substitution of the expressions in (18) into (17) results in an expression for the normalized capacitance valid in the desired range, given by

$$\frac{C}{\varepsilon_o l} \cong \frac{7}{\ln\left(1+\frac{2}{D}\right)} + 4D\ln\left\{1+\left[\frac{1+30D+124D^2}{70HD(D+2)}\right]\right\} . \quad (19)$$

Equation (19) will be referred to as the approximate capacitance formula (ACF).

An error analysis of (19) indicates that the error in the ACF is within 10% of the method of moments results over virtually the entire region of $-2.5 \leq \log_{10}(D) \leq 1$ and $-4 \leq \log_{10}(H) \leq 1$. In particular, the error in the ACF is less than 3% for $H < 0.1$ and generally increases with H. The ACF is a simple formula that provides an accurate estimate of capacitance over the designated region of interest.

6. DISCUSSION OF RESULTS

Table I summarizes the ranges where the capacitance formulas discussed in this paper are within 10% of the method of moments results. The four formulas presented here are seen to be accurate for wide ranges in the parameters D and H. In the case of the CMA formula, the lower boundary defining the region in which the accuracy is better than 10% is given as an approximate function of H.

Although in practice monopoles are mounted close to the ground plane ($H \ll 1$), we observe that the capacitance formulas are accurate over a wide range of H. Undoubtedly, the use of a tubular monopole far removed from the ground is unlikely in most applications. In order to gauge the utility of these formulas for large separations from the ground, it would be instructive to do a simple comparison against known capacitance formulas for tubes of arbitrary diameters and lengths in free space.

For the investigation of tubular monopole capacitance formulas for large H, we define a ratio R as

$$R = \frac{C_{gp}}{C_{fs}} = 1 + \delta , \quad (20)$$

where C_{gp} and C_{fs} refer to the capacitances of a tube above a ground plane and in free space, respectively, and δ is the difference in the capacitances relative to the free space value. As H becomes large, $R \rightarrow 1$ (i.e., $\delta \rightarrow 0$). A "free space" boundary can be defined as the normalized height H that corresponds to a predetermined small value of δ ($\ll 1$). A mathematical fit describing the boundary for the height-to-length ratio H_{fsb} along which $\delta = 0.01$ is given by

$$H_{fsb} \cong \frac{35}{\ln\left(1+\frac{2}{D}\right)} , \quad (21)$$

applicable for $D \geq 10^{-3}$. Expression (21), obtained from an approximate fit to the method of moments data, essentially separates two regions; for $H < H_{fsb}$ the monopole formulas are appropriate, while for $H > H_{fsb}$ the free space expressions apply.

Expressions for the free space capacitance of thin and thick tubes have been derived by Howe [10] and Butler [21], respectively. The expressions are given as follows:

$$C_{Howe} = \frac{2\pi\varepsilon_o l}{\ln\left(\frac{4}{D}\right) - 1} , \quad D \ll 1 \quad (22)$$

$$C_{Butler} = \frac{2\pi^2 \varepsilon_0 d}{\ln(16D)} \ , \ D \gg 1 \qquad (23)$$

Butler [21] observed that the parameter range for each expression can be relaxed without serious error. He noted that at D ≅ 0.25 both expressions produce results within 4% of the precise value obtained by the method of moments, thereby allowing one.the means of computing the capacitance by using the appropriate expression above or below D ≅ 0.25.

Figure 3 shows the regions of acceptable accuracy of the tubular monopole capacitance formulas and free space tubular capacitance formulas (22), (23). Some of the fine detail has been removed for clarity. The extended Grover formula (12) is omitted in the figure since its useful region is close to that of Grover. Note that the Grover formula overlaps with that of Howe while the CMA result approaches the approximate free space boundary in an asymptotic fashion.

7. SUMMARY

Formulas have been presented for the computation of the input capacitance of electrically small tubular monopoles for a wide range of diameters and heights above ground. The regions of validity for the existing formulas were determined through comparison with precise results obtained from a standard method of moments code. Consequently, several regions lying between the thin and thick tube domains were identified where the existing formulas are not applicable. As a result, an approximate expression was constructed, effectively bridging the gap between the thin and thick tube domains. Taken as a whole, such an assembly of formulas allows for the determination of capacitance for a continuous range in terms of the normalized variables D and H for over six orders of magnitude, with errors usually much less than 10%. For large ground plane separations, it was shown that the monopole formulas approach the results obtained for a tube in free space.

8. APPENDIX

Convergence tests were performed to determine the required number of basis functions for different ranges of $\log_{10}$(D) and $\log_{10}$(H). Figure 5 shows the number of basis functions used in the method of moments algorithm for different ranges of tube thicknesses and separations above the ground plane. The basis functions listed in Fig. 5 provide convergence to at least three significant figures. Because of the variability in convergence with tube thickness, Fig. 5 is divided into three regions, i.e., thin, medium, and fat. Since the convergence of the tubular monopole capacitance slows considerably for $\log_{10}(H) < -3$, the number of basis functions N used in this report is given as a linear function of $\log_{10}$(H) for each tube-thickness region. In the thin-tube region ($-3 \le \log_{10}(D) \le -2$), we have

$$N = 1900 - 6200\left[\log_{10}(H) + 3.5\right], \quad -4 \le \log_{10}(H) \le -3.5 \,. \qquad (A1)$$

Similarly, in the medium-tube region ($-2 < \log_{10}(D) < 0$), the number of basis functions is given by

$$N = 1900 - 4100\left[\log_{10}(H) + 3\right], \quad -4 \le \log_{10}(H) \le -3 \,. \qquad (A2)$$

while in the fat-tube region ($0 \le \log_{10}(D) \le 3$), we have

$$N = 2500 - 5500\left[\log_{10}(H) + 3\right], \quad -4 \le \log_{10}(H) \le -3 \,. \qquad (A3)$$

Note that at the smallest ground-plane separation (i.e., $\log_{10}(H) = -4$), 5000 basis functions are required for a thin tube in contrast to 8000 basis functions for a fat tube.

As previously mentioned, the method of moments solution used here involves pulse basis functions and point matching. It is possible that a different formulation (e.g. a Galerkin method employing piecewise sinusoidal basis and testing functions) may converge more rapidly.

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Table I. Ranges of Validity of Tubular Monopole Capacitance Formulas (Error 10%)

Formula	**Range of H** **($H = h/l$)**	**Range of D** **($D = d/l$)**
Grover (6)	≤ 0.0004	≤ 0.008
	$0.0004 \le H \le 0.04$	$\le 0.27\,H^{0.45}$
	≥ 0.04	≤ 0.35
Extended Grover (12)	≤ 0.0005	≤ 0.007
	$0.0005 \le H \le 0.1$	$\le 0.33\sqrt{H}$
	≥ 0.1	≤ 1
Approximate Capacitance Formula (ACF) (19)	$10^{-4} \le H \le 10$	$0.003 \le D \le 10$
Conformal Mapping Approximation (CMA) (8)	$\ge 10^{-4}$	$\ge \frac{2}{\ln\left(1 + \frac{3}{H}\right)}$

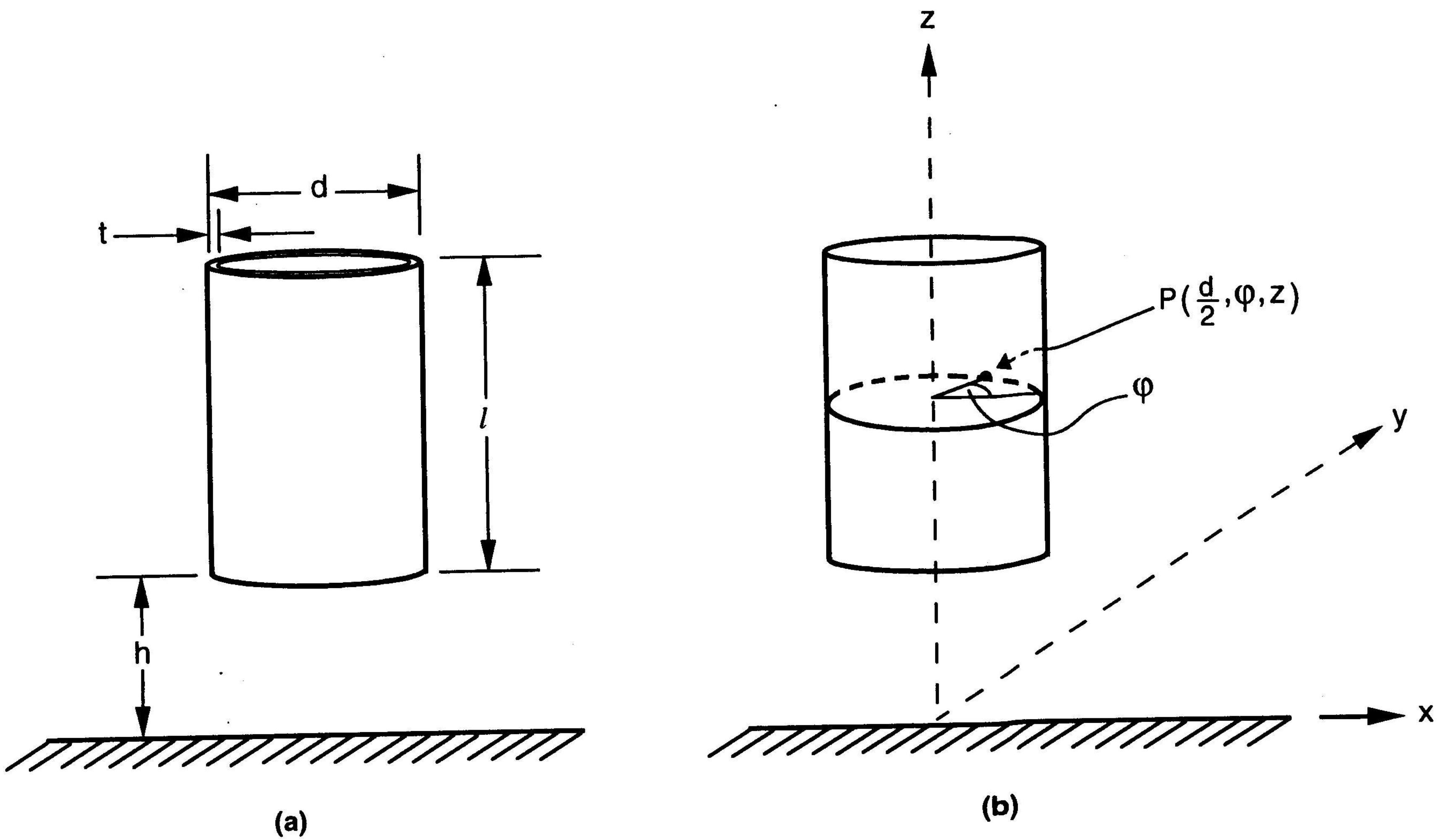

Figure 1 (a) Tubular monopole.
(b) Coordinate system used for tubular monopole analysis.
Note: $t \ll d, l$.

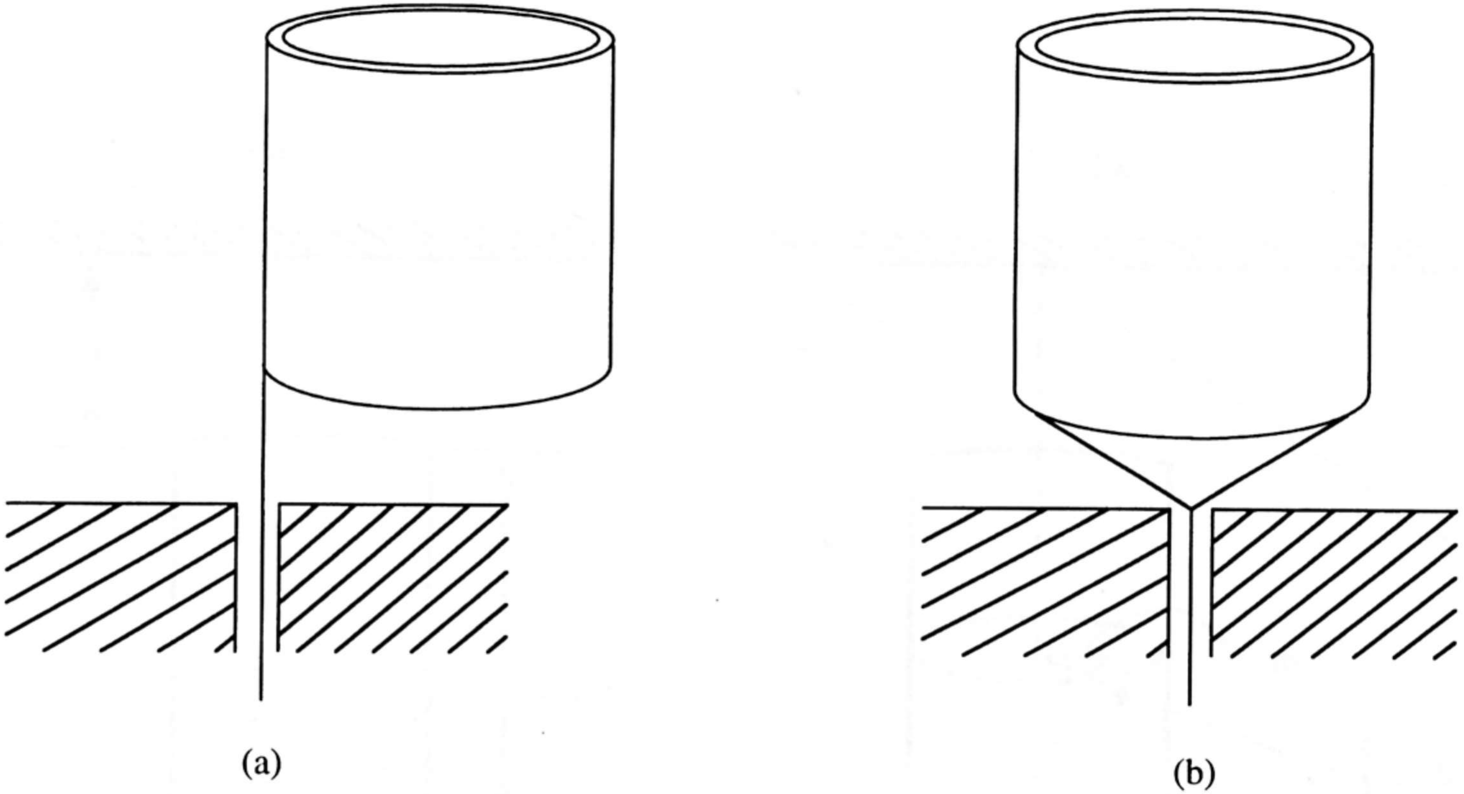

Figure 2 Typical methods for feeding tubular monopoles.
(a) Wire feed.
(b) Conical feed.

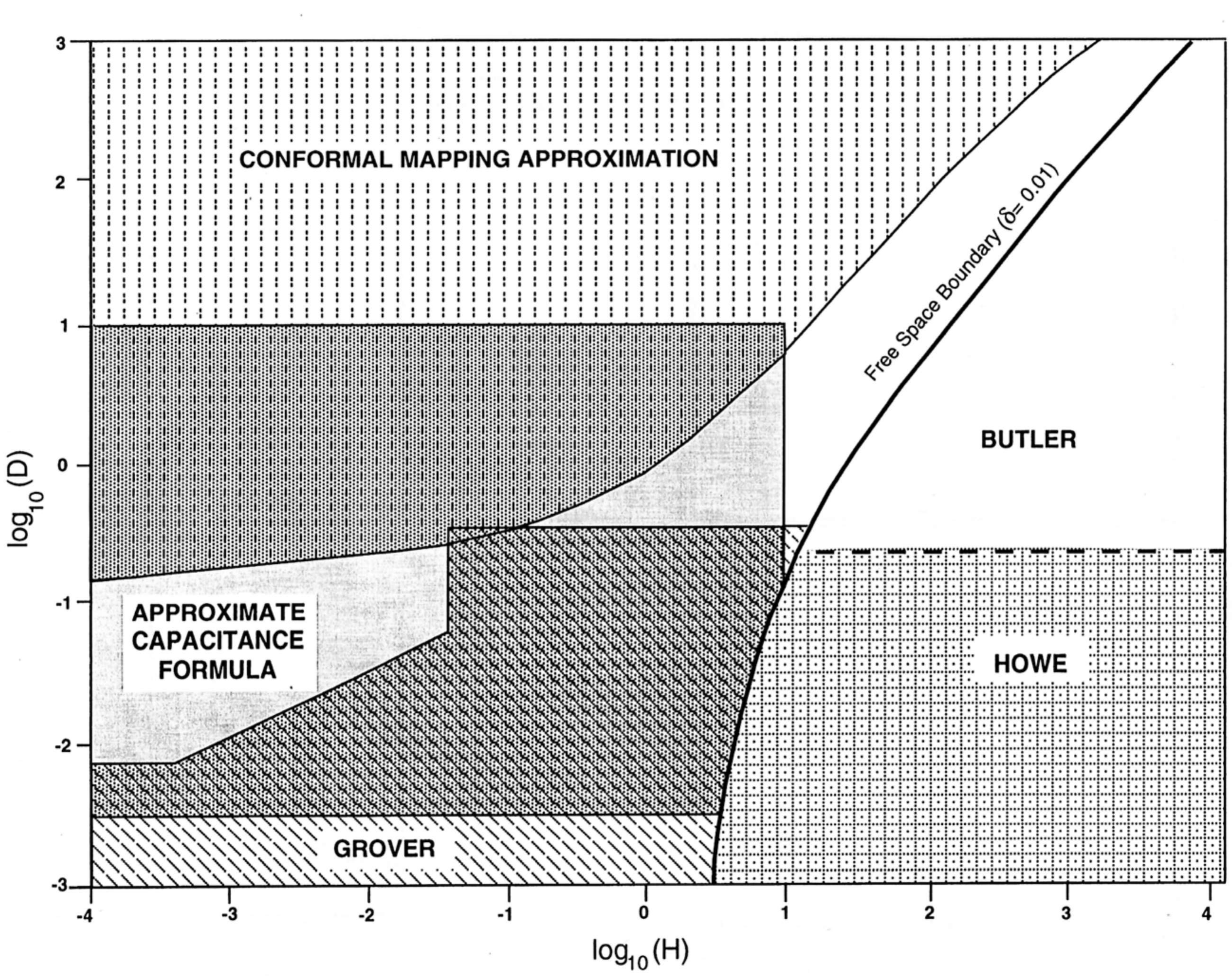

Figure 3 Regions of validity (error ≤ 10%) of tubular monopole capacitance formulas.
Note: $H = h/l$, $D = d/l$.

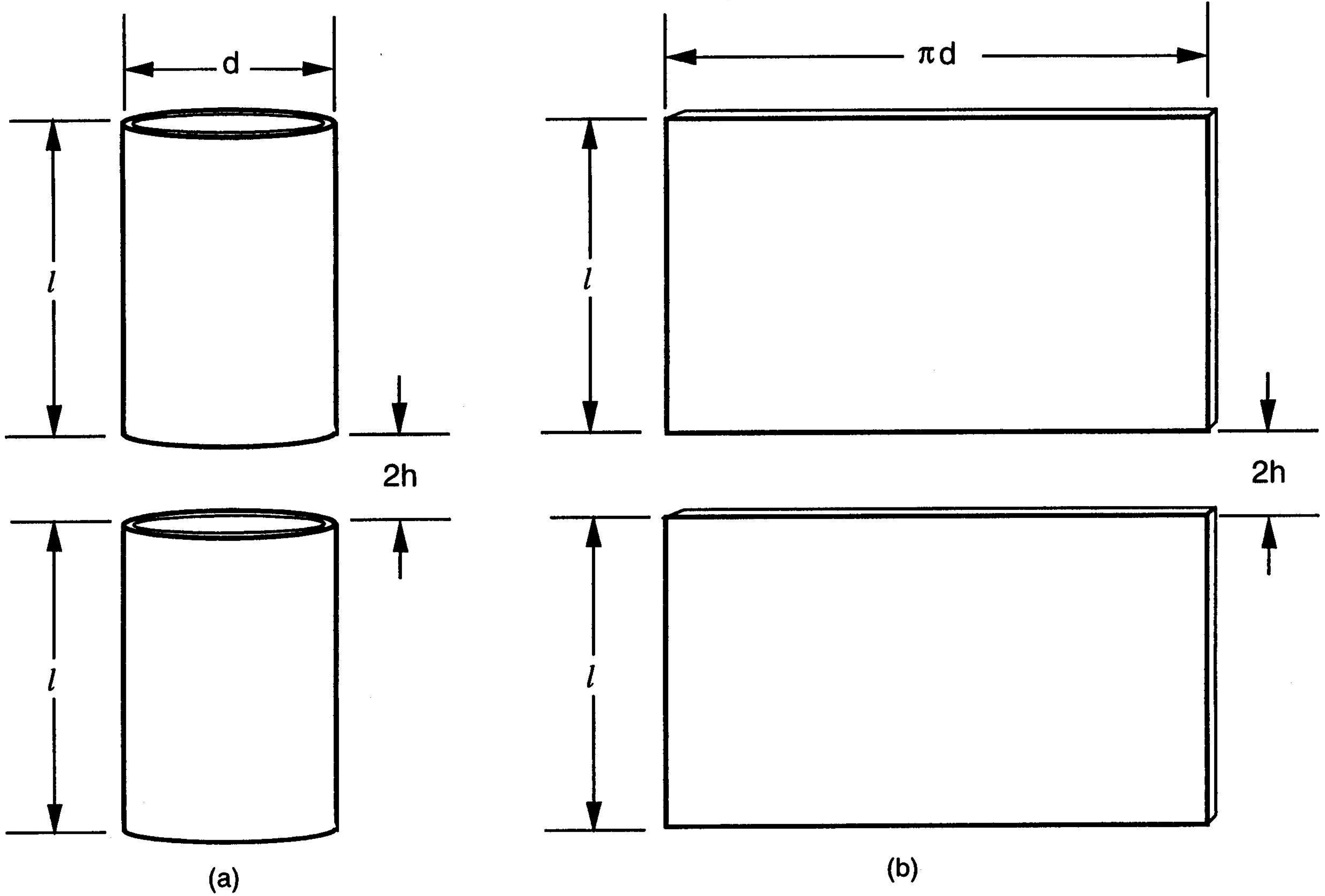

Figure 4 Model used in the derivation of the conformal mapping approximation (8).
(a) Tubular dipole.
(b) Equivalent coplanar stripline.
Note: tube thickness is assumed to be infinitesimal.

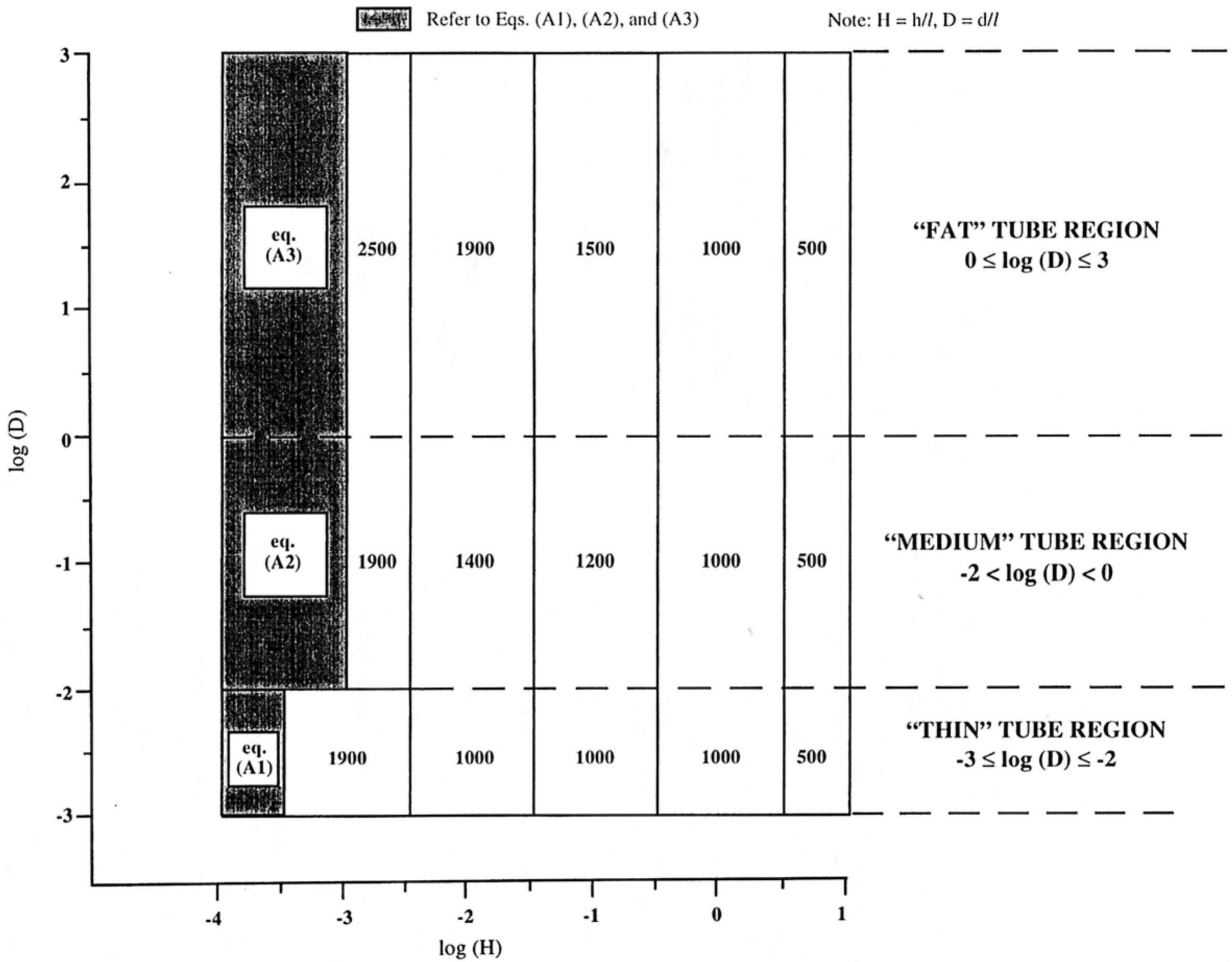

Figure 5. Number of basis functions required to insure a minimum of three significant figure accuracy in the method of moments algorithm used for computing tubular monopole capacitance.

The Practical CEMist

- practical topics in communications -

Perry Wheless, K4CWW

The paper which follows is a continuation of the topic started in the last issue of the *ACES Newsletter,* namely, the use of near earth and buried antennas for HF radio communications. The prior article, which appeared on pages 35-44 of volume 12, number 2 of the *Newsletter,* compiled most of the detailed equations needed for an analytic model of buried antennas of the so-called *snake* class. The present article adds some important equations relevant to the case of above ground, but near earth, deployment of these antennas. It also includes approximations for the frequency dependence of ground parameters. Its main purpose, however, is to report on development of a computer-based implementation of the analytic model, and to enter into the archival record results for some selected examples; this provides both a reference for other researchers and some useful information for radio engineers and HF radio communication system planners. These two papers, together, address the time harmonic response of *snake* antennas. The additions of transient response and signal angle-of-arrival features remain for the future.

Publication of the first paper produced numerous inquiries and statements of interest. Some readers perhaps may be disappointed to find the computer implementation in MATLAB, which is not universally available, but the authors are of the opinion that MATLAB is now a more sensible choice for tasks of this nature and scope than FORTRAN, the ubiquitous C++, and so forth. Readers who do not now have access to MATLAB, but are interested in exploring its capabilities, should note that a Student Edition is available at modest cost.

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On another subject, please allow me to emphasize for your attention that the paper submission rules for the ACES 1998 Symposium are new, and very different from past years. A full-length, camera ready paper is required, to be received by the Technical Program Chairman no later than November 25! See the *Call for Papers* which appears elsewhere in this *Newsletter*. If there is sufficient interest in an Amateur Radio Applications session, I will assist with organizing such a session. Please contact me at your earliest convenience if you wish to participate.

****

Finally, practical communicators everywhere are again encouraged to submit manuscripts for future installments of *The Practical CEMist*. We'll leave the post office box light on for you ...

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Computer Implementation of a *Snake* Antenna Analytical Model

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Abstract

A set of governing equations, comprising an analytical model for buried wire antennas referred to as the *snake* type, was presented in [1]. This antenna type has enjoyed increasingly popularity among HF radio communicators, especially below 7 MHz, in recent years. Additional equations pertinent to the above ground, but near earth, case are presented here. The frequency dependence of ground parameters is also addressed, and selected case runs of a computer implementation of the model are documented.

1 Introduction

The utility, geometry, and twelve variations of *snake* antennas for HF communications were discussed in [1], where most of the components for an analytical model are archived for convenient reference. Because there is interest in above ground, but near earth, variations of this antenna type, as well, additional equations governing that situation have been incorporated into this paper.

The permittivity of earth (ground) is frequency dependent, but often it is the case that the dielectric constant and conductivity are known at just one frequency. Formulas which allow a reasonable approximation of the frequency dependence are included here.

A preliminary computer implementation of the analytical model has been completed. Computer-based analysis results for several representative cases are documented in this paper. The intent is to complete an accurate and reliable computer code for this class of antennas, which will be made available freely to others for continuing academic pursuits into this area of research.

2 Some Remarks on Reference [1]

An error has been found in Eq. (4.4) of [1]. The correct equation is

$$\gamma = k_1\sqrt{\hat{\epsilon}_2}\left[\frac{H_0^{(2)}(k_2 b) + H_0^{(2)}(2k_2\left|-d\right|) + (k_2 b)\, ln\left(\frac{b}{a}\right) H_1^{(2)}(k_2 b)}{H_0^{(2)}(k_2 b) + \frac{\hat{\epsilon}_2}{\hat{\epsilon}_i}(k_2 b)\, ln\left(\frac{b}{a}\right) H_1^{(2)}(k_2 b)}\right]^{\frac{1}{2}}, \qquad (4.4\text{rev})$$

with γ defined as equal to $\beta - j\alpha$. Factor k_1 is the ordinary wavenumber in the air half-space, namely $k_1 = \omega\sqrt{\mu_0\epsilon_0}$, while k_2 is the complex wavenumber in the earth half-space. Note that $\hat{\epsilon}_2$ is *relative*, so the permittivity of free space must be included as an explicit factor in the calculation of k_2 according to $k_2 = \sqrt{\mu_0 \epsilon_0 \hat{\epsilon}_2}$.

3 Extensions to above ground, near earth

Corresponding to Eq. (4.4rev) above for the buried wire case, governing approximations for the above ground, but near earth, case are obtainable from King and Smith [2]:

$$\gamma = k_1 \left[\frac{\hat{\epsilon}_i \ln\left(\frac{z}{a}\right)}{\ln\left(\frac{b}{a}\right) + \hat{\epsilon}_i \ln\left(\frac{z}{b}\right)} \right]^{\frac{1}{2}} \left[1 - \frac{\ln(k_2 z) + j\left(\frac{\pi}{2}\right)}{\ln\left(\frac{2z}{a}\right)} \right]^{\frac{1}{2}}, |k_2 z| \leq 1.0 \tag{1}$$

$$\gamma = k_1 \left[\frac{\hat{\epsilon}_i \ln\left(\frac{z}{a}\right)}{\ln\left(\frac{b}{a}\right) + \hat{\epsilon}_i \ln\left(\frac{z}{b}\right)} \right]^{\frac{1}{2}} \left[1 - \frac{j}{k_2 z \ln\left(\frac{z}{a}\right)} \right]^{\frac{1}{2}}, |k_2 z| > 1.0 \tag{2}$$

where all quantities are defined in [1].

Then, corresponding to Eq. 4.3 in [1], the above ground result for the wire element characteristic impedance (again based on [2]) is

$$Z_{AC} = 60 \frac{\gamma}{k_1} \ln\left(\frac{2z}{a}\right). \tag{3}$$

4 Interface Loss Factor for Above Ground

The interface loss factor for buried wire elements is called F_2 and is given by the three equations Eq. (5.4) - Eq. (5.6) in [1]. There are three corresponding equations for the above ground, but near earth, case, based on [4]. First, for the skywave field, vertical polarization (E_Θ) :

$$F_2 = \left| 1 - \frac{\hat{\epsilon}_2 \sin\theta - \sqrt{\hat{\epsilon}_2 - cos^2\theta}}{\hat{\epsilon}_2 \sin\theta + \sqrt{\hat{\epsilon}_2 - cos^2\theta}} \left(e^{-j2k_1 z \sin\theta}\right) \right|^2. \tag{4}$$

The form applicable to skywave field, horizontal polarization $(E\phi)$ calculations is

$$F_2 = \left| 1 + \frac{sin\theta - \sqrt{\hat{\epsilon}_2 - cos^2\theta}}{sin\theta + \sqrt{\hat{\epsilon}_2 - cos^2\theta}} \left(e^{-j2k_1 z \sin\theta}\right) \right|^2, \tag{5}$$

and, for the groundwave vertical component $(E\theta)$ case, this factor becomes

$$F_2 = \left| \frac{\frac{k_1^2}{k_2^2}\left(1 - \frac{k_1^2}{k_2^2}\right)}{\frac{k_1^2}{k_2^2}\left(1 - \frac{k_1^2}{k_2^2}\right) + 1 - \frac{k_1^4 z^2}{k_2^2} + j2\frac{k_1^2 z}{k_2}} \right|. \tag{6}$$

Finally, the depth attenuation factor, F_5 in [1], is simply

$$F_5 = 1 \tag{7}$$

when the antenna element is above ground.

5 Ground Parameter Variation

Curve-fitted approximations describing ground parameter variation with frequency are in [3], and are repeated below for convenient reference:

$$\epsilon_{r2} = 3 + (\epsilon_{r2_{(ref)}} - 3)\left(\frac{f_{ref}}{f}\right)^{0.42} \tag{8}$$

and

$$\sigma_2 = \frac{1}{4}W^{1.5} + \left(\sigma_{2_{(ref)}} - \frac{1}{4}W^{1.5}\right)\left(\frac{f_{ref}}{f}\right)^{0.42} \tag{9}$$

with

$$W = \left[\frac{\left(\epsilon_{r2_{(ref)}} - 3\right)\left(f_{ref_{(MHz)}}\right)^{0.42}}{144}\right]^{1.85} . \tag{10}$$

The operating frequency is f, while f_{ref} is the frequency at which specified dielectric constant and conductivity values $\epsilon_{r2_{(ref)}}$ and $\sigma_{2_{(ref)}}$ are considered accurate.

6 Ancillary Equations

To be more realistic for applications, the computer implementation of the *snake* antenna analytic model takes into account mismatch losses, which may frequently amount to several decibels. The user inputs a transmission line impedance Z_0 Ohms, and several standard quantities are computed, starting with

$$\Gamma = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \tag{11}$$

where Z_{in} is the antenna feed-point impedance from the model. The standing wave formula is

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}, \tag{12}$$

return loss RL is given by

$$RL = 20 \log |\Gamma| , \tag{13}$$

and mismatch loss follows from

$$ML = 10 \log \left(1 - |\Gamma|^2\right) . \tag{14}$$

7 Results from Computer Implementation

Because MATLAB [5] has become the premier software package for interactive numeric computation, data analysis, and graphics at numerous academic institutions, and is also gaining widespread acceptance in industry, a computer implementation for the *snake* antenna model was carried out in MATLAB.

First, the impedance and mismatch results of two test cases are summarized in Table I below. These typical values both illustrate the impedance levels to be expected in applications, and provide numerical values that independent programmers can use for comparison. The *snake* of Example 1 is deployed above, but near ground, at a height of 1.0 m. For Example 2, the antenna element is buried at a depth of 0.5 m.

Table I. Summary of two impedance and mismatch examples.

Description	Example 1	Example 2
Input Parameters:		
Frequency (MHz)	10.0	10.0
Soil dielectric constant	10	4
Soil σ in mS/m	5	5
Wire insulation dielectric constant	5	2.25
Wire insulation σ in mS/m	0	0
Length of antenna element in m	20	13.4
Wire radius a in m	0.001	0.003175
Insulation radius b in m	0.005	0.0127
Transmission line impedance Ω	600	300
Feed (c=center, e=end)	c	c
Termination (o=open, m=matched)	o	o
Field (s=sky, g=ground)	s	s
Component (v=E_Θ, h=E_Φ)	v	v
Vary ground parameters/ref. MHz?	no	no
Wire height z (m); -z → buried	1.0	-0.5
Outputs:		
$\gamma = \beta - j\alpha$	0.2370-j0.0180	0.5252-j0.1867
Line char. impedance Z_{AC}	515.79-j39.27	159.11+j13.58
Ant. feedpoint impedance Z_{in}	359.03-j2.496	318.82+j22.90
Reflection coefficient magnitude $\|\Gamma\|$	0.2513	0.0479
VSWR	1.6712	1.1005
Return loss (dB)	-11.917	-26.400
Mismatch loss (dB)	-0.2832	-0.0100

Example 1 was subsequently re-run with the frequency entered as a vector running from 2 to 32 MHz in steps of 0.66 MHz. The program was instructed to vary the ground parameters with frequency, taking the values above as true at reference frequency 10.0 MHz. Figure 1 shows the graphical result, and clearly indicates the potential for broadband operation. The small glitch in the VSWR curve near 14 MHz is because $|k_2 z|$ becomes equal to one in that vicinity, and the two above-ground element propagation constant approximations do not meet seamlessly at the transition point.

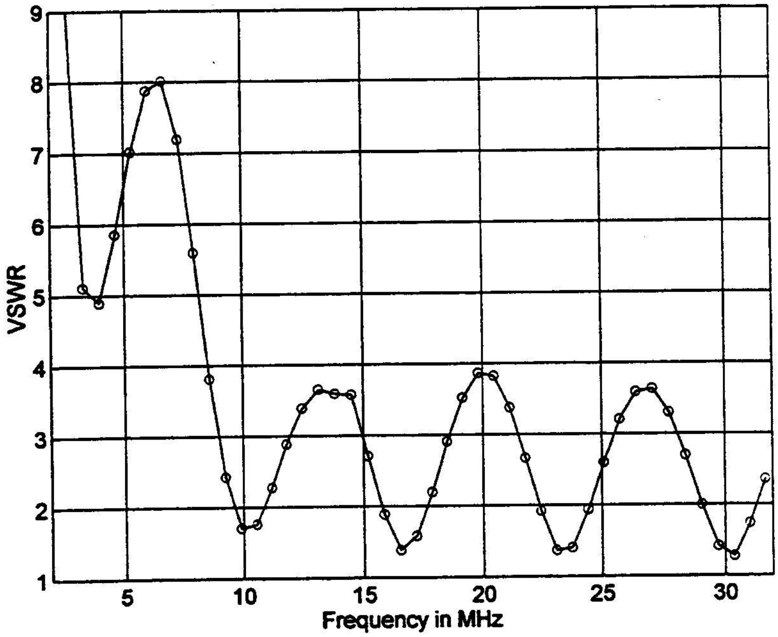


Figure 1. VSWR from 2 to 32 MHz for the antenna of Example 1.

In addition, radiation pattern plots for another four test cases are reported here. Table II summarizes the important details of these illustrative cases. Two computer runs were made for each case - first using the positive z (wire height) value indicated in Table II, and then with z = -0.5 m, also indicated on the same line of the table.

Table II. Summary of four radiation pattern examples.

Description	Example 3	Example 4	Example 5	Example 6
Frequency (MHz)	10	8.015	8.015	8.015
Soil dielectric constant	10	9.5	9.5	9.5
Soil σ in mS/m	5	6.7	6.7	6.7
Wire insulation dielectric constant	5	2.7	2.7	2.7
Wire insulation σ in mS/m	0	0	0	0
Length of antenna element in m	20	22.86	22.86	22.86
Wire radius a in m	0.001	0.0008	0.0008	0.0008
Insulation radius b in m	0.005	0.0012	0.0012	0.0012
Transmission line impedance Ω	450	450	450	450
Feed (c=center, e=end)	c	c	c	c
Termination (o=open, m=matched)	o	o	o	o
Field (s=sky, g=ground)	s	s	s	s
Component (v=E_Θ, h=E_Φ)	v	v	h	v
Vary ground parameters/ref. MHz?	no	no	no	no
Wire height z (m); -z → buried	1.0/-0.5	0.66/-0.5	0.66/-0.5	0.66/-0.5
Plot	v elev.	v elev.	h elev.	v az.
Θ/Φ conditions on plot	$\Phi = 0°$	$\Phi = 0°$	$\Phi = 90°$	$\Theta = 30°$

Solid line Z = 1.0 m **Vertical Polarization** **Maximum = 0 dBi**
Dashed line Z = -0.5 m **10 dB/division**

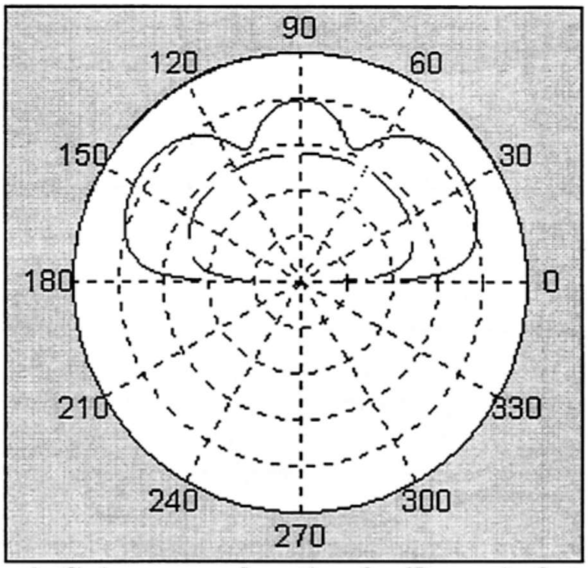


Figure 2. Gain versus elevation for Example 3, ϕ = 0°

Solid line Z= 0.66 m **Vertical Polarization** **Maximum = 0 dBi**
Dashed line Z = -0.5 m **10 dB/division**

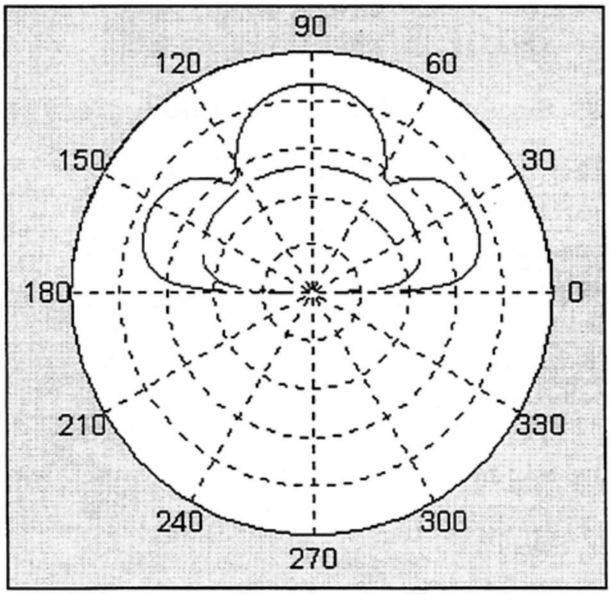
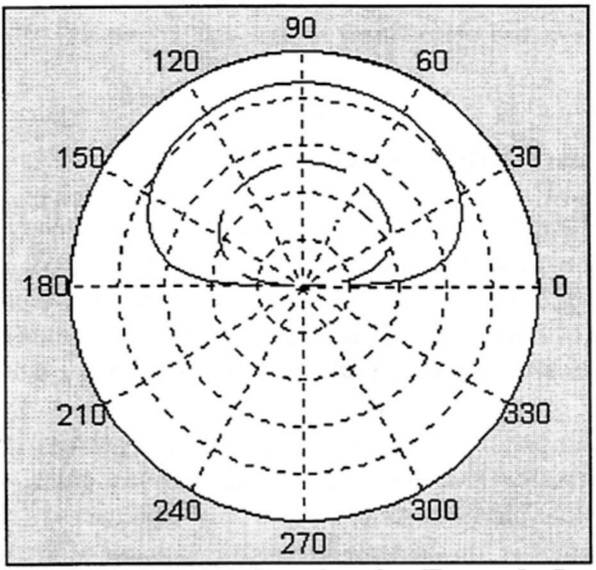
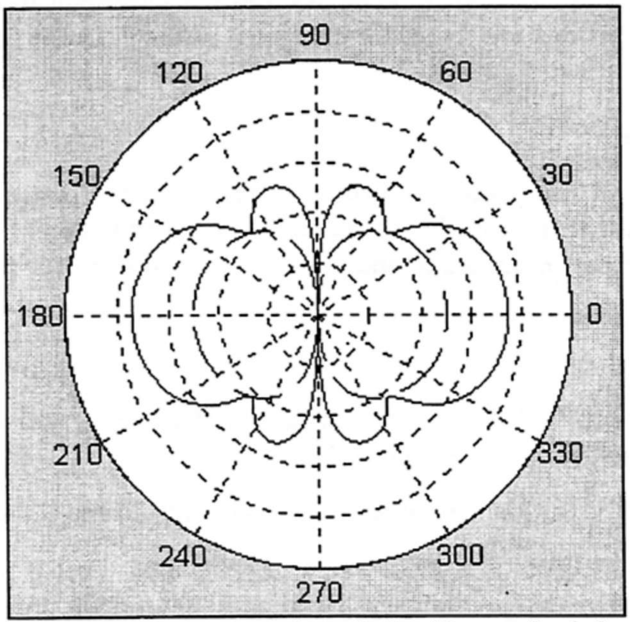


Figure 3. Gain versus elevation for Example 4, ϕ = 0°



Solid line Z = 0.66 m **Horizontal Polarization** **Maximum = 0 dBi**
Dashed line Z = -0.5 m **10 dB/division**

Figure 4. Gain versus elevation for Example 5, $\phi = 90°$



Solid line Z = 0.66 m **Vertical Polarization** **Maximum = 0 dBi**
Dashed line Z = -0.5 m **10 dB/division**

Figure 5. Gain versus azimuth for Example 6, $\theta = 30°$

The resultant radiation patterns are in Figures 2 through 5. The reader is reminded that the computer program includes mismatch loss into the computed gain patterns, unless a transmission line impedance of zero is specified, in which case mismatch loss is ignored. For brevity, a detailed commentary on the figures is omitted; clearly, however, near earth and buried antennas are often in the operational regime -15 dBi to -25 dBi even in their favored directions.

8 Conclusions and Future Research

A computer-based capability, using MATLAB, for the sinusoidal steady-state analysis of near earth and buried single (insulated) wire elements has been developed. It is intended that the code developed for this application will be freely distributed to support academic research into this important class of low-frequency antennas after a reasonable program of validation can be completed. It is presently anticipated that code will be available from the authors in the first quarter of 1998.

The ability to predict impedance conditions and radiation patternsfor *snake* antennas is of considerable interest to practical radio communicators. The low gains, compared to isotropic, are not necessarily objectionable for certain 'receive only' applications. However, the analytic model presented to this point is for the time harmonic response of the antenna. Many actual deployments, especially for 1.8 - 4.0 MHz communication systems, are motivated by the goal of discrimination against received (lightning-induced) static. Unfortunately, static bursts are transient signals of brief duration, and so it is necessary to include the transient response of *snakes* to arrive at a comprehensive electrical performance model. Computer-aided analysis of the transient response of this class of antennas and the intelligent incorporation of signal angle-of-arrival considerations are topics for continued research in the future.

9 Acknowledgment

The authors thank David Faust and his former colleagues at the now-defunct Eyring Communications Division for their significant contributions to this area of knowledge, and for their active encouragement of academic and individual research in the field of HF antennas.

References

[1] W.P. Wheless, Jr. and L.T. Wurtz, "Components of an analytical model for *snake* antennas," *ACES Newsletter*, vol. 12, no. 2, p. 35-44.

[2] R.W.P. King and G.S. Smith, *Antennas in Matter*, MIT Press, Cambridge, MA, 1982.

[3] M.B. King, R.B. Gilchrist, and D.L. Faust, *Eyring Low Profile and Buried Antenna Modeling Program*, Eyring (preliminary) Document 300-0085A, June 1991.

[4] G.A. Lavrov and A.S. Knyazev, *Near Earth and Buried Antennas*, Sovetskoye Radio, Moscow, 1965 (translated by the Joint Publications Research Service, U.S. Department of Commerce, Washington, D.C.).

[5] MATLAB is a registered trademark of The MathWorks, Inc., Natick, Massachusetts.

Patent Fundamentals for ACES Members

by Ray Perez

We are living in an era where scientific knowledge is increasingly being looked upon as a form of property. A general understanding of patents is becoming necessary for many engineers and scientists involved in applied or industrial research. By cutting away at the legal lingo this author presents some fundamentals of patents for our readers. In a future issue we'll try to address the subject of patenting software, so important to ACES members. The material presented herein is based largely on the experiences of this author in the process of filing his own/employer-sponsored patents in the US. Though the particulars in the patent process change from country to country, I believe that the general principles discussed are, for the most part, equivalent with those in other countries.

Most research engineers and scientists who work in an industrial setting are responsible for developing the technologies that their companies will later use to invent, produce, and market into product lines. In this era of enhanced competition among high technology companies, with increased pressures in time-to-market deliveries, there is a strong effort to safeguard industrial secrets and technological know-how. Most of this work is proprietary in nature (very little, if any, can be published) and becomes part of the company's "intellectual property". It is not unusual to say that for many enterprises the quality and quantity of intellectual property becomes a major part, not only of the company's success, but their employee's own success.

The history and driving forces in the patent process are very interesting. Patents in the US are promoted for the "progress of science and useful arts..." (US Congressional Patent Act of 1790). There is a mutually advantageous agreement between the inventor and the public at large, (represented by the government), in which the inventor makes a full disclosure of his/her invention to the public. He/she will be permitted a certain period of time to exercise full control and monopoly of the invention which allows the inventor to exclude other parties from making, marketing, selling, or using such invention in the US. This limited duration allows the inventors to make use of their patents. It encourages inventors to disclose their invention for the benefit of society, instead of keeping them secret, such that no one benefits in a direct manner. But keeping inventions secret is necessary where the intention is to keep technological innovations away from potential parties who would use it as a threat to mankind. (For example, the technological secrecy practiced by the military is highly justified within this reasoning).

The public disclosure takes the form of a patent issued by the US patent and trademark office (USPTO). Once the limited duration of the patent has expired, anyone is allowed to use the invention without any restrictions. However, even with this benefit, many companies decide not to file for patents with the rationale that the risks of letting their technological know-how be known outweighs, in the long run, any immediate benefits.

US patent laws specify three types of patents: a) utility patents, which protect mechanical, electrical, chemical, and or functional aspects of the invention, b) design patents which cover the visual and or ornamental appearance of an item, and c) plant patents, which cover new varieties of plants. Utility patents are the ones most commonly filed by technological companies; though often a combination of utility and design patents are filed because the device has not only aesthetic but technical innovations. Within utility patents there are four categories: 1) new and useful machines (e.g. personal dialysis machines in medicine), 2) processes (e.g. computer software), including chemical and mechanical processes, 3) articles of manufacture which include useful articles and products, typically without moving parts, and 4) compositions of matter (ICs). In general, a patentable invention must not be obvious in view of previous developments in the field. Thus, patents can not be given for trivial developments or for newly discovered laws of nature (e.g Maxwell's equations), naturally occurring components, scientific principles or mathematical relationships (e.g MOM, FDTD, FEM, GTD, etc). Most patents these days are given for direct improvement of existing products and processes. For example, in recent litigation cases that have made the news in national and international circles an enormous effort is spent by some in "reverse engineering" to "designing around" products which are already patented. This is a practice that is legal if it is done carefully but you must know what you are doing. A product or process that is based on a previous patent but which has been significantly "designed around" can also qualify as a patent.

An example of US patent efforts that can drive changes in an industry is found in the computer software field. Even though software can be considered a process invention and therefore patentable, software has been protected in the past by copyrights instead of by patents. However, new thinking and court cases have shown that copyrights do not include everything associated with software development. Such innovative developments in software can be better served with newly revised patent guidelines, which directly address software issues. In a future article we'll discuss, in more detail, patent considerations needed for software.

The process of obtaining US patent protection is described in Figure 1. Figure 1 is important since the patent seeker should use it to first assess if his invention is patentable. Figure 2 shows the steps followed during the patent process after a patent has been filed. The inventor should avail himself/herself of an experienced patent attorney (most companies already have these attorneys on their staff) to guide and advise the inventor during the processes described in Figures 1 and 2. Notice from Figure 1 that considerable research must first be done by the inventor to make sure his/her invention has not been described elsewhere in the world in some sort of printed publication for a period of more than one year before the patent publication is filed. Thus, one must be careful to note the publication date of any research that has the possibility of being patented.

Each patent is written in a specified format. It includes an abstract, a section describing the subject field of the invention and a review of past developments within the field.

These writings are followed by an accurate description of the invention which include a set of claims to bound the limitations of the invention. These claims are very important because they are one of the strongest assessments against possible later litigation. It is important that a patent application describes the best approach for producing the invention. It must describe all embodiments of the invention and must be as broad as

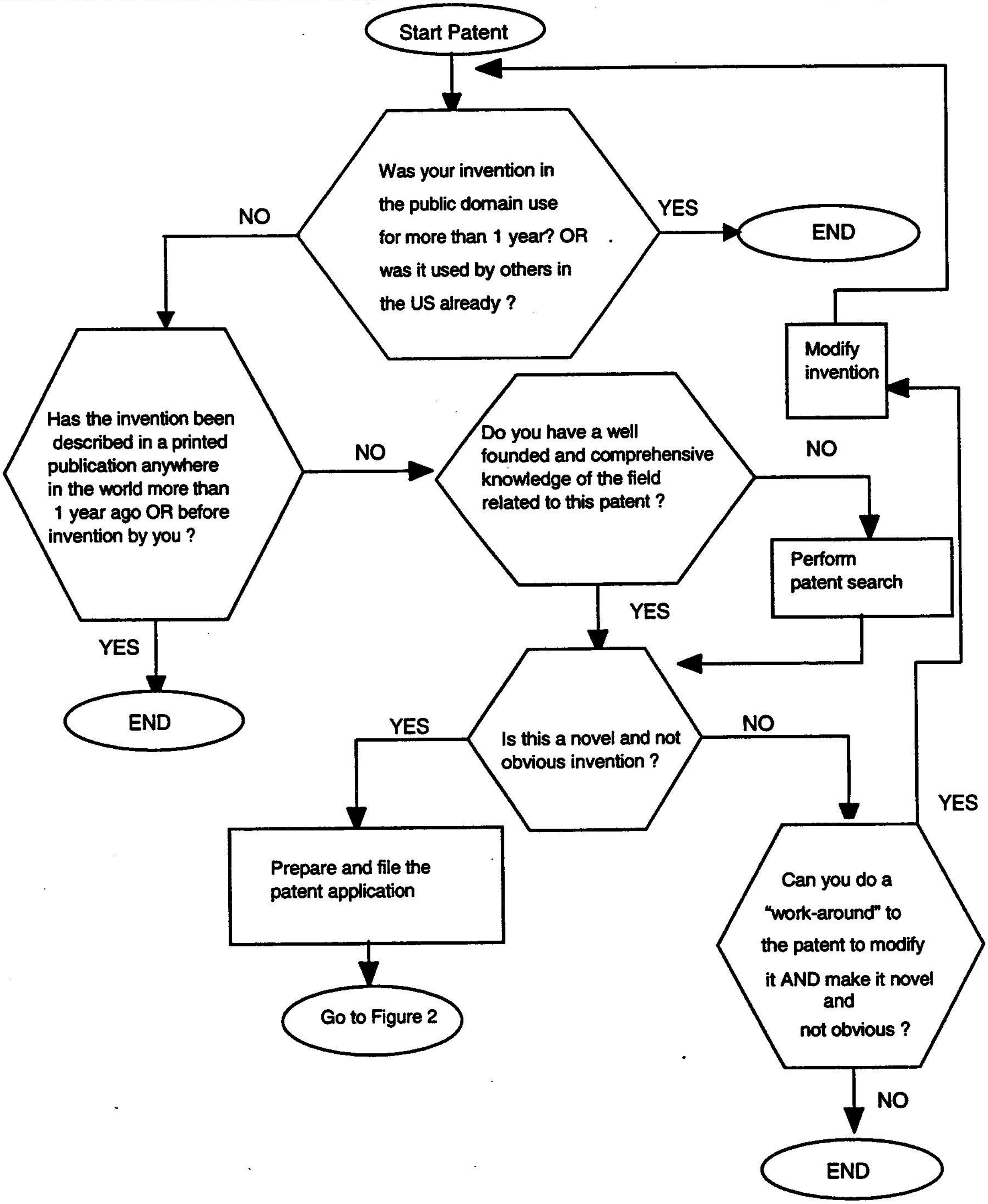


Figure 1. Check if your Invention is Patentable

possible. If the invention is described in narrow terms it leaves the door open for other parties to file "work around" patents and claim patent protection for other aspects of the same invention. It can't be unreasonably broad, otherwise it incurs the risk of being rejected by the patent office.

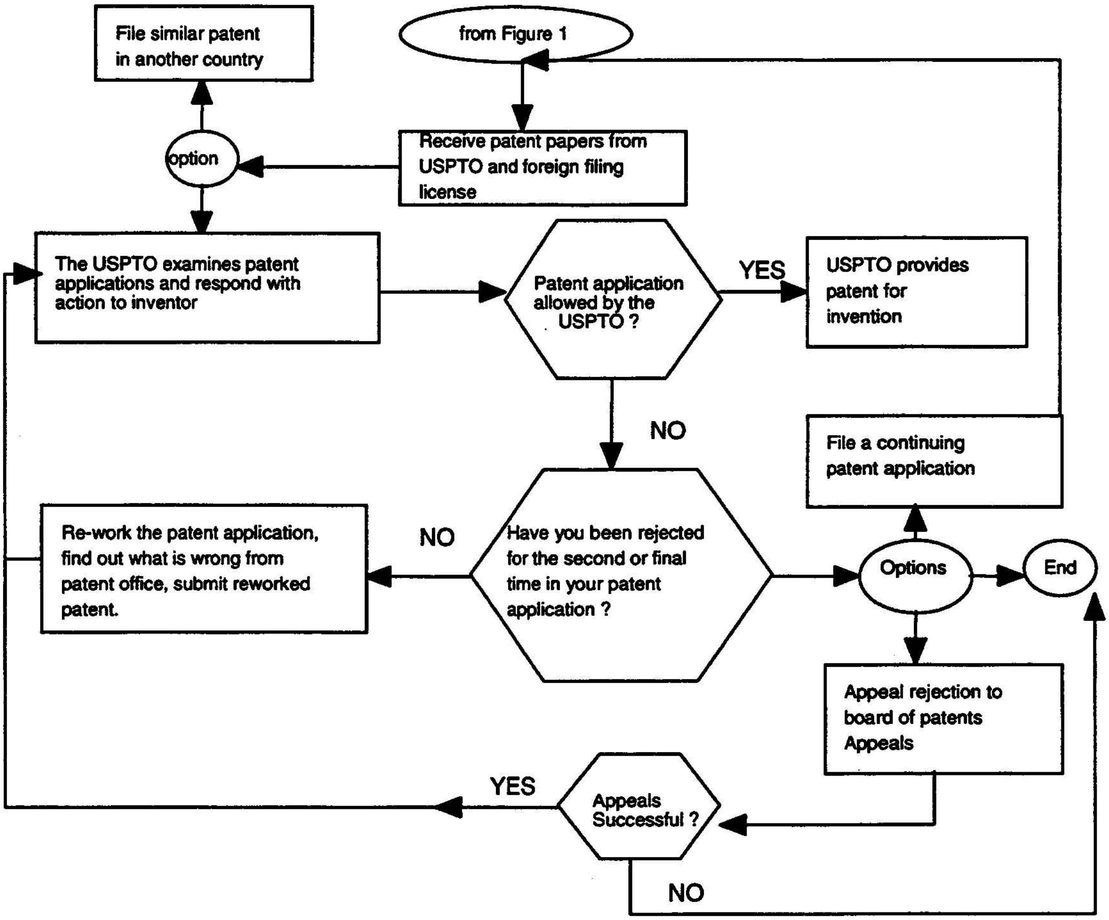


Figure 2. Patent Process.

The procedure followed in Figure 2 by the patent office is intended to include a phrase-by-phrase analysis of the patent application and a careful review of any drawings included with it. The objective is to assess if the invention has the utility, novelty and lack of obviousness required by federal law and whether the application is full, clear, concise and well written, and includes a good description of the subject matter. It is not unusual for a patent application to receive several rounds of reviews by the patent office and the inventor until it is finally approved or rejected. Once the patent has been accepted, patent protection is granted and ends 20 years after the filing date. After 20 years the invention becomes available for anyone to use without any restrictions. If a patent is rejected the inventor has three options: 1) quit the application process, 2) continuation of the filing process by filing a continuation-patent-application, or 3) appealing the decision to the courts or to the board of patent appeals and interference. A US patent is only good for the US, but the US and most other industrialized countries belong to international conventions governing patent protection. Therefore, an inventor who files in the US can retain the right to file in other countries within one year; probably the most difficult requirement is the translation of the patent application and some of the heavy taxes imposed to keep the patent in force. An important difference between a patent application issue in the US vs. other countries is that in the US priority is given to the first-that-invents, while in many other countries in the first-who-files. The difference is quite significant, since the first to invent is really the person who can show that he/she conceived the idea leading to the invention, later reduced to practice and later filing of the patent.

In the next issue concerning patent fundamentals we'll address the cost and benefits of patents, recent and future trends concerning patents and address the issue of software patents.

THE APPLIED COMPUTATIONAL ELECTROMAGNETIC SOCIETY

CALL FOR PAPERS

The 14th Annual Review of Progress in Applied Computational Electromagnetics

March 16-20, 1998

Naval Postgraduate School, Monterey, California

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

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

Early Registration Fees; (approximate*)		
	ACES MEMBERS	**$255**
	NON-MEMBER	**$295**
	STUDENT/RETIRED/UMEMPLOYED	**$115 (no proceedings)**
	STUDENT/RETIRED/UNEMPLOYED	**$150 (includes proceedings)**

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

1998 ACES Symposium

Sponsored by:	ACES, NPS, DOE/LLNL, U of KY, U of IL, BYU, DOD, SIAM, NCCOSC and AMTA
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Visit ACES on line at: www.emclab.umr.edu/aces

THE APPLIED COMPUTATIONAL ELECTROMAGNETIC SOCIETY

CALL FOR PAPERS

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

- Code validation
- Code performance analysis
- Computational studies of basic physics
- Examples of practical code application
- New codes, algorithms, code enhancements, and code fixes
- Computer Hardware Issues
- Partial list of applications:
    - antennas
    - radar imaging
    - shielding
    - EMP, EMI/EMC
    - dielectric & magnetic materials
    - microwave components
    - fiberoptics
    - communications systems
    - eddy currents
    - wave propagation
    - radar cross section
    - bioelectromagnetics
    - visualization
    - inverse scattering
    - MIMIC technology
    - remote sensing & geophysics
    - propagation through plasmas
    - non-destructive evaluation
- Partial list of techniques:
    - frequency-domain & time-domain techniques
    - integral equation & differential equation techniques
    - finite difference & finite element analysis
    - diffraction theories
    - modal expansions
    - hybrid methods
    - physical optics
    - perturbation methods
    - moment methods

+ + + NEW + + + INSTRUCTIONS FOR AUTHORS AND TIMETABLE + + + NEW + + +

November 25, 1997: Submission deadline. Submit four copies of a full-length, camera-ready paper to the Technical Program Chairman. Please supply the following data for the corresponding author: name, address, email address, FAX, and phone numbers.
See below for instructions for the format of paper.

December 20, 1997: Authors notified of acceptance.

PAPER FORMATTING REQUIREMENTS

The recommended paper length is 6 pages, with 8 pages as a maximum, including figures. The paper should be camera-ready (good resolution, clearly readable when reduced to the final print of 6 x 9 inch paper). The paper should be printed on 8-1/2 x 11 inch papers with 13/16 side margins, 1-1/16 inch top margin, and 1 inch on the bottom. On the first page, place title 1-1/2 inches from top with author and affiliation beneath the title. Single spaced type using 10 or 12 point front size, entire text should be justified (flush left and flush right). No typed page numbers, but number your pages lightly in pencil on the back of each page.

SHORT COURSES

Short courses will be offered in conjunction with the Symposium covering numerical techniques, computational methods, surveys of EM analysis and code usage instruction. It is anticipated that short courses will be conducted principally on Monday March 16 and Friday March 20. Fees for **Half-day course** will be: $90 per person if booked before 1 March 98; $100, if booked from 1 March to 15 March 98; and $110 if booked at Conference time. **Full-day Courses** will be: $140 if booked before 1 March 1998; $150 if booked from 1 March to 15 March; $160 if booked at Conference time. **Short Course Attendance is not covered by the Symposium Registration Fee!**

EXHIBITS

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

WANTED: for ACES '98

Papers on Amateur Radio CEM Applications

Perry Wheless is seeking authors for a proposed technical paper session on "CEM Applications in Amateur Radio" at the Applied Computational Electromagnetics Society's 1998 Symposium. ACES '98 is scheduled for the week of March 16-20, 1998, at the Naval Postgraduate School, Monterey, California.

A similar session was held in connection with the ACES '96 conference. The 1996 session was a well-attended and successful special evening event, which followed a "Hamz in ACES" dinner social. The session organization effort for ACES '97 was too little, too late, and so there was no session on this topic last year. A good slate of papers and high participation level for 1998 would help establish this session category as a regular feature of future conferences.

This is an opportunity for hams to combine their professional interests and hobby. ACES has a tradition of recognizing useful NEC applications, notably HF/VHF wire antannas, and the ACES annual conference is becoming an increasingly influential outlet for papers reporting the latest CEM developments in communications (EMI/EMC, propagation, etc).

There are new paper submission requirements in effect this year. Four copies of a full-length, camera-ready manuscript must be received by Dr. Jianming Jin no later than November 25, 1997. Please contact Perry directly if you would like to discuss a paper idea in advance of submission; he may be reached by telephone at 205-348-1757, or by email at wwheless@ua1vm.ua.edu. Prospective authors may also contact Dick Adler, K3CXZ, by email at rwa@ibm.net.

Thanksgiving will be here before you know it, so NOW is the time to select a topic and begin preparation of your paper.

Monterey is a unique setting, and the ACES annual Symposium is an important forum for the exchange of technical information among engineers and scientists working with Computational Electromagnetics. For an experience that is both pleasant and educational, you should plan now to be in Monterey the third week of March!

Perry, K4CWW

STUDENT BEST PAPER CONTEST

This will be for the "Best Paper",

submitted for publication in the 1998,

14th Annual Review of Progress.

(Student must be the presenter

on the paper chosen)

Submissions will be judged

by three (3) members of the BoD.

The prizes for the Student presenter

and his principal advisor will consist of:

(1) free Annual Review Attendance

for the following year;

(2) one free short course taken during the 1998 or

1999 Annual Review;

and

(3) $200 cash for the paper.

16-20 MARCH 1998

(NONE OF THIS MOTELS/HOTELS HAVE BEEN APPROACHED FOR ROOMS FOR OUR ACES 1998 SYMPOSIUM. WE HAVE RECOMMENDED THESE MOTELS, ETC IN THE PAST. THESE PRICES ARE ALL 1997 PRICES. THIS WILL BE UPDATED IN THE MARCH '98 NEWSLETTER).

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

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Rates: $80 Govt, $135 Conf

No Blocks of rooms are set aside at Monterey Bay Lodge, Embassy Suites or Super 8 Motel. Call and ask for conference rates!

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 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, and ask for either Government, or Conference rates.

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

Third Street Gate is the closest gate to the Conference Registration location. Gates open at 0600 (AM) and close at 1800 (6 PM) daily. After 1800 hours, the Main Gate (between Ninth and Tenth Streets), is the only gate open.

AIRLINE INFORMATION

The following airlines make connections from Los Angeles and San Francisco, CA. to Monterey, CA: American, United, Delta/Sky West, and US Air.

There is no connection directly from San Jose, CA to Monterey, CA. You can fly to San Jose, but then ground transportation must be used. Monterey-Salinas Airbus serves San Francisco International (SFO) and San Jose International (SJC). There are five departures daily from Monterey and Salinas, arriving at both SFO & SJC, appx. (2-4) hours later. There are also the same departures from SFO & SJC. For information and an updated schedule, phone (408) 442-2877 or (800) 291-2877.

THINGS TO DO AND SEE IN THE MONTEREY BAY AREA

There are many activities for children and adults not attending the Conference. The colorful blue Monterey Bay is a vision of historic Monterey, rich with natural beauty and many attractions from Fisherman's Wharf, (be sure to try the seafood cocktails), to Cannery Row, the Monterey Adobes and city parks, the Monterey Bay Aquarium, Maritime Museum of Monterey, and Pacific Grove Museum of Natural History. The "Artichoke Capital of the World" is only 15 miles from Monterey, in Castroville. Other things to do include: driving the17-Mile Drive in Pebble Beach; Whale watching, bicycle riding, roller blading, surfing, ocean kyaking, in Pacific Grove; taking a stroll on the white sandy beach in Carmel, a visit to Mission San Carlos Borromeo Del Rio Carmelo, in Carmel, etc. The Monterey Peninsula has 20 Golf Courses. Carmel has many Art Galleries. For more information, call the Monterey Peninsula Chamber of Commerce, Visitors and Convention Bureau at (408) 649-1770.

THE APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY
14TH ANNUAL REVIEW OF PROGRESS
IN APPLIED COMPUTATIONAL ELECTROMAGNETICS

March 16-20, 1998
Naval Postgraduate School
Monterey, CA

Pre-Registration Form

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BANQUET ☐ Meat ☐ Fish	☐ $ 30	☐ $ 30	☐ $ 30

Short Course information is not available at this time. (1) If you desire Short Course information, please contact Michael A. Jensen, ECE Dept. 459 CB, BYU, Provo, UT 84602, email:jensen@ee.byu.edu. (2) If you plan to attend this conference, and are NOT PRESENTING a paper, please return this form to Richard W. Adler, ECE Dept/Code EC/AB, Naval Postgraduate School, 833 Dyer Rd, Rm 437, Monterey, CA 93943-5121, email:rwa@ibm.net. (3) If you ARE AN AUTHOR ON a paper, send this form to: Jianming Jin, U of Illinois, ECE Dept. 1406 W. Green St. Urbana, IL 61801-2991. email:j-jin1@uiuc.edu. (See pg 44, Call for papers, for Short Course prices).

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November 1997

APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY
RICHARD W. ADLER, EXECUTIVE OFFICER
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