Applied Computational Electromagnetics Society

Newsletter
Volume 22 – No. 1
ISSN 1056-9170

March 2007

APPLIED COMPUTATIONAL ELECTROMAGNETICS SOCIETY (ACES)

NEWSLETTER

Vol. 22 No. 1 March 2007

TABLE OF CONTENTS

PERMANENT STANDING COMMITTEES OF ACES, INC.

COMMITTEE	CHAIRMAN	ADDRESS
NOMINATION and ELECTIONS	Rene Allard	Penn State University PO Box 30 State College, PA 16804-0030 rja5@psu.edu
FINANCE	Andrew Peterson	Georgia Institute of Technology School of ECE Atlanta, GA 30332-0250 peterson@ece.gatech.edu
PUBLICATIONS	Atef Elsherbeni	EE Department, Anderson Hall University of Mississippi University, MS 38677 atef@olemiss.edu
CONFERENCE	Osama Mohammed	Florida International University ECE Department Miami, FL 33174 mohammed@fiu.edu
AWARDS	Randy Haupt	Penn State University 1065 ARL Bldg. University Park, PA 16802 rlh45@psu.edu

MEMBERSHIP ACTIVITY COMMITTEES OF ACES, INC.

COMMITTEE	CHAIRMAN	ADDRESS
SOFTWARE VALIDATION	Bruce Archambeault	IBM 3039 Cornwallis Road, PO Box 12195 Dept. 18DA B306 Research Triangle Pk NC 27709 barch@us.ibm.com
HISTORICAL and CONSTITUTION / BYLAWS	Leo Kempel	2120 Engineering Building Michigan State University East Lansing, MI 48824 kempel@egr.msu.edu
MEMBERSHIP and COMMUNICATIONS	Vicente Rodriguez	ETS-LINDGREN L.P. 1301 Arrow Point Drive Cedar Park, TX 78613 rodriguez@ieee.org
INDUSTRIAL RELATIONS	Andy Drodz	ANDRO Consulting Services PO Box 543 Rome, NY 13442-0543 andro1@aol.com

ACES NEWSLETTER STAFF

EDITOR-IN-CHIEF, NEWSLETTER
Bruce Archambeault
IBM
3039 Cornwallis Road, PO Box 12195
Dept. 18DA B306
Research Triangle Park, NC 27709
Phone: 919-486-0120
email: barch@us.ibm.com

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

EDITOR-IN-CHIEF, PUBLICATIONS
Atef Elsherbeni
EE Department, Anderson Hall
University of Mississippi
University, MS 38677
Email: atef@olemiss.edu

MANAGING EDITOR
Richard W. Adler
Naval Postgraduate School/ECE Dept.
Code ECAB, 833 Dyer Road,
Monterey, CA 93943-5121
Fax: 831-649-0300
Phone: 831-646-1111
email: rwa@att.biz

EDITORS

CEM NEWS FROM EUROPE
Tony Brown
University of Manchester
PO Box 88 Sackville Street
Manchester M60 1QD United Kingdom
Phone: +44 (0) 161-200-4779
Fax: +44 (0) 161-200-8712
email: Anthony.brown@manchester.ac.uk

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

TECHNICAL FEATURE ARTICLE
Andy Drozd
ANDRO Consulting Services
PO Box 543
Rome, NY 13442-0543
Phone: 315-337-4396
Fax: 314-337-4396
email: androl@aol.com

PERSPECTIVES IN CEM
Alistair Duffy
School of Engineering and Technology
De Montfort University
The Gateway
Leiecester, UK LE1 9BH
+44(0)116 257 7056
apd@dmu.ac.uk

THE PRACTICAL CEMIST
W. Perry Wheless, Jr.
University of Alabama
PO Box 11134
Tuscaloosa, AL 35486-3008
Phone: 205-348-1757
Fax: 205-348-6959
email: wwheless@coe.eng.ua.edu

TUTORIAL
Giulio Antonini
UAq EMC Laboratory
Department of Electrical Engineering
University of L'Aquila
Poggio di Roio, 67040 Italy
Phone: +39-0862-43446
email: antonini@ing.univaq.it

ACES JOURNAL

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

ASSOCIATE Editor-in-Chief
Erden Topsokal
EE Department
Mississippi State University
Mississippi State, MS 39762
Phone 662-325-3669
email: topsakal@ece.msstate.edu

NEWSLETTER ARTICLES AND VOLUNTEERS WELCOME

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

AUTHORSHIP AND BERNE COPYRIGHT CONVENTION

PERSPECTIVES IN CEM

Anonymous Peer Review. Time to move on?

Alistair Duffy apd@dmu.ac.uk

In the last couple of *Perspectives* we have been discussing what is 'good enough' when it comes to modelling and simulations and how do we know that we have achieved this. This is a topic we will be revisiting in coming issues. This time I want to ask the question 'would open peer reviewing be better for the community than anonymous peer reviewing?' In fact do we need peer reviewing anyway?

This is a story I heard a few years ago. It might be a relevant metaphor.

A group of chimps were placed in an enclosure. There was a banana hanging from the ceiling and a table in the enclosure. Eventually, one of the chimps pulled the table over to where the banana was and pulled the banana down. As it was doing this, all the chimps were sprayed with a high pressure water jet. Whenever any of the chimps tried to remove the banana, the same thing happened. Eventually, none of the chimps took any notice of the banana. Then, half the chimps were replaced by a new batch. Some of the new ones went to get the banana but were stopped by those that anticipated the punishment. Eventually, all the chimps avoided the banana. Then the half that was in the enclosure from the start was replaced by new chimps. When they tried to get the banana, they were pulled back by the chimps that had never experienced the water spray but had been stopped by the original chimps. One of the new chimps asked why it shouldn't have the banana and was told by another "that's the way we always do things round here".

Why do we undertake anonymous peer reviewing, other than that's the way it has always been done? A cursory tour of the Web shows that this is a debate that is ongoing in many other forums. I don't want to rehearse any of those arguments in particular but offer some of my thoughts and invite your opinions for a future *Perspectives*. Here are some points that may help to seed the debate.

1. ***Anonymity allows referees to say what they really think about a paper. Promoting objectivity***.
    a. When I was a young academic, I would have felt very naked in being very critical about the papers of my 'elders and betters'. Perhaps, in the future, they would be in a position to referee my papers or grant applications, or perhaps they would be interviewing me for a job sometime in the future. I am sure this is a common sentiment for most young academics. Perhaps this supports keeping the system anonymous.
    b. Anonymity does leave the process open to bias and subjectivity. I am sure most of us have been at the receiving end of a "...the authors should consider the seminal work in this area of Professor Gartwobbler" type review. Perhaps it would be more objective if Professor Gartwobbler said "I think I have previously dealt with this problem, please look at this reference…". This could also help to avoid 'political' revisions and 'referee spotting' resulting in the natural response of "Ah! This must be Professor Gartwobbler, so (s)he will be happier if I reference their papers." Perhaps this supports an open system of reviewing.
2. ***If you are not prepared to put your name to a comment, should you really make it? Promoting ethical reviewing.***
    a. An open process may encourage critical debate: encouraging links that may not, otherwise, be made; raising questions that had not been previously considered, and probing a topic further. Perhaps this supports an open system of reviewing.
    b. An open process could encourage the developments of factions, tribalism and open warfare in research beyond what currently exists. Perhaps this supports keeping the process anonymous.

3. ***Misunderstandings are human and often resolved through dialogue. Promoting the communication of science.***
    a. Many of us have been in the position where we feel that a referee has missed the point. This could be because the descriptions in the paper are actually poor, there is real ambiguity in the paper, aspects of the paper are actually wrong, the reviewer wants to make a point which is not entirely consistent with the subject of the paper, the reviewer wants their opinion expressed through the paper being refereed or the reviewer is actually wrong. Being able to set up a direct dialogue could resolve some of these issues and be mutually beneficial. Perhaps this supports an open system of reviewing.
    b. The current editorial process actually allows these discussions to take place through the editor and these are mediated and recorded. The iterations of the revisions make take months but, with the editor, there is someone there to prevent discussions becoming full blown arguments. Perhaps this supports the anonymous system of reviewing.

If we were to move to an open system of reviewing, with referees effectively signing their comments, the role of the editor may change to something that is more like a moderator rather than a decision maker.

One big question is whether we could do away with reviewing entirely. After all, it is expensive financially and in the time of the editors and referees. Perhaps we could allow anything to be published and make peer commentary more acceptable. This is, very much, a blog-type approach. Personally, I don't think so. It would be too easy to publish ill thought out, wrong or possibly libellous material. Peer review, in whatever form encourages, at least, some basic quality control.

Anonymous peer review is ingrained in the way we publish research material. It is an accepted pillar of the research community. Is it time to change the architecture of this pillar to encourage open reviewing rather than anonymous reviewing?

If you have read through this article and nodded sagely saying "he's got a point" or shaken your head saying "what rubbish", send me your thoughts, opinions and favourite references on this subject and I will collate them for a future *Perspective.*

An Overview of Field-to-Transmission Line Interaction

C.A. Nucci[1], F. Rachidi[2], M. Rubinstein[3]
1 University of Bologna, Italy
2 Swiss Federal Institute of Technology, Lausanne, Switzerland
3 Western University of Applied Sciences, Yverdon, Switzerland

Abstract

In this paper, we discuss the Transmission Line (TL) theory and its application to the problem of external electromagnetic field coupling to transmission lines. After a short discussion on the underlying assumptions of the TL theory, we start with the derivation of field-to-transmission line coupling equations for the case of a single wire line above a perfectly conducting ground. We also describe three seemingly different but completely equivalent approaches that have been proposed to describe the coupling of electromagnetic field coupling to transmission lines. The derived equations are extended to deal with the presence of losses and multiple conductors. The time-domain representation of field-to-transmission line coupling equations which allows a straightforward treatment of non linear phenomena as well as the variation in the line topology is also described. Finally, solution methods in frequency domain and time domain are presented.

1 Transmission Line (TL) Approximation

The problem of an external electromagnetic field coupling to an overhead line can be solved using a number of approaches. One such approach makes use of antenna theory, a general methodology based on Maxwell's equations[1] [1]. When electrically long lines are involved, however, the antenna theory approach implies prohibitively long computational times and high computer resources. On the other hand, the less resource hungry quasi-static approximation [1], in which propagation is neglected and coupling is described by means of lumped elements, can be adopted only when the overall dimensions of the circuit are smaller than the minimum significant wavelength of the electromagnetic field. For many practical cases, however, this condition is not satisfied. As an example, let us consider the case of power lines illuminated by a lightning electromagnetic pulse (LEMP). Power networks extend, in general, over distances of several kilometres, much larger than the minimum wavelengths associated with LEMP. Indeed, significant portions of the frequency spectrum of LEMP extend to frequencies up to of a few MHz and beyond, which corresponds to minimum wavelengths of about 100 m or less (e.g. [2]).

A third approach is known as transmission line (TL) theory. The main assumptions for this approach are::

1) Propagation occurs along the line axis.

[1] Different methods based on this approach generally assume that the wire's cross section is smaller than the minimum significant wavelength (thin-wire approximation).

2) The sum of the line currents at any cross-section of the line is zero. In other words, the ground – the reference conductor – is the return path for the currents in the n overhead conductors.
3) The response of the line to the coupled electromagnetic fields is quasi transverse electromagnetic (quasi-TEM) or, in other words, the electromagnetic field produced by the electric charges and currents along the line is confined in the transverse plane and perpendicular to the line axis.

If the cross-sectional dimensions of the line are electrically small, propagation can indeed be assumed to occur essentially along the line axis only and the first assumption can be considered to be a good approximation.
The second condition is satisfied if the ground plane exhibits infinite conductivity since, in that case, the currents and voltages can be obtained making use of the method of images, which guarantees currents of equal amplitude and opposite direction in the ground.
The condition that the response of the line is quasi-TEM is satisfied only up to a threshold frequency above which higher-order modes begin to appear [1]. For some cases, such as infinite parallel plates or coaxial lines, it is possible to derive an exact expression for the cutoff frequency below which only the TEM mode exists [3]. For other line structures (i.e. multiple conductors above a ground plane), the TEM mode response is generally satisfied as long as the line cross section is electrically small [3].
Under these conditions, the line can be represented by a distributed-parameter structure along its axis.
For uniform transmission lines with electrically-small cross-sectional dimensions (not exceeding about one tenth of the minimum significant wavelength of the exciting electromagnetic field), a number of theoretical and experimental studies have shown a fairly good agreement between results obtained using the TL approximation and results obtained either by means of antenna theory or experiments (see for example [4]). A detailed discussion of the validity of the basic assumptions of the TL theory is beyond the scope of this paper. However, it is worth noting that, by assuming that the sum of all the currents is equal to zero, we are considering only 'transmission line mode' currents and neglecting the so-called 'antenna-mode' currents [1]. If we wish to compute the load responses of the line, this assumption is adequate, because the antenna mode current response is small near the ends of the line. Along the line, however, and even for electrically small line cross sections, the presence of antenna-mode currents implies that the sum of the currents at a cross section is not necessarily equal to zero [1, 3]. However, the quasi-symmetry due to the presence of the ground plane, if present, results in a very small contribution of antenna mode currents and, consequently, the predominant mode on the line will be transmission line [1].

2 Single-Wire Line Above a Perfectly-Conducting Ground

We will consider first the case of a lossless single-wire line above a perfectly conducting ground. This simple case will allow us to introduce various coupling models and to discuss a number of concepts essential to the understanding of the electromagnetic field coupling phenomenon. Later in this paper (Sections 4 and 5), we will cover the cases of lossy and multiconductor lines. The transmission line is defined by its geometrical parameters (wire radius *a* and height above ground *h*) and its terminations Z_A and Z_B, as illustrated in Fig. 1, where the line is illuminated by an external electromagnetic field. The problem of interest is the calculation of the induced voltages and currents along the line and at the terminations.

It is worth noting that the external exciting electric and magnetic fields $\vec{E}^e$ and $\vec{B}^e$ are defined as the sum of the incident fields, $\vec{E}^i$ and $\vec{B}^i$, and the ground-reflected fields, $\vec{E}^r$ and $\vec{B}^r$, determined in absence of the line conductor. The total fields $\vec{E}$ and $\vec{B}$ at a given point in space are given by the sum of the excitation fields and the scattered fields from the line, the latter being denoted as $\vec{E}^s$ and $\vec{B}^s$. The scattered fields are created by the currents and charges flowing in the line conductor and by the corresponding currents and charges induced in the ground.

Three seemingly different but completely equivalent approaches have been proposed to describe the coupling of electromagnetic fields to transmission lines. In what follows, we will present each one of them in turn. We will first derive the field-to-transmission line coupling equations[2] following the development of Taylor et al. [5].

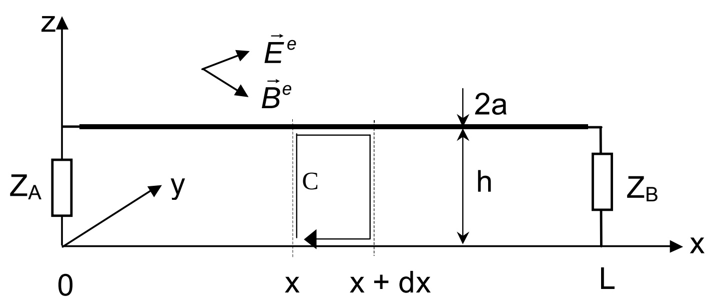


Figure 1: Geometry of the problem.

2.1 Taylor, Satterwhite and Harrison Model

2.1.1 Derivation of the First Field-to-Transmission Line Coupling (Generalized Telegrapher's) Equation

Consider the single conductor transmission line of height h in Figure 1. Applying Stokes' theorem to Maxwell's equation $\nabla\vec{E} = -j\omega\vec{B}$ for the area enclosed by the closed contour C yields

$$\oint_C \vec{E} \cdot dl = -j\omega\iint_S \vec{B} \cdot \vec{e}_y dS \tag{1}$$

[2] The field-to-transmission line coupling equations are sometimes referred to as generalized telegrapher's equations.

Since the contour has a differential width Δx, Equation (1) can be written as[3]

$$\int_0^h [E_z(x+\Delta x, z) - E_z(x,z)]dz + \int_x^{x+\Delta x} [E_x(x,h) - E_x(x,0)]dx \\ = -j\omega \int_0^h \int_x^{x+\Delta x} B_y(x,z)dxdz \tag{2}$$

Dividing by Δx and taking the limit as Δx approaches zero yields

$$\frac{\partial}{\partial x}\int_0^h E_z(x,z)dz + E_x(x,h) - E_x(x,0) = -j\omega \int_0^h B_y(x,z)dz \tag{3}$$

Since the wire and the ground are assumed to be perfect conductors, the total tangential electric fields, $E_x(x,h)$ and $E_x(x,0)$, are zero. Defining also the total transverse voltage $V(x)$ in the quasistatic sense (since $h \ll \lambda$) as

$$V(x) = -\int_0^h E_z(x,z)dz \tag{4}$$

equation (3) becomes

$$\frac{dV(x)}{dx} = -j\omega \int_0^h B_y(x,z)dz = -j\omega \int_0^h B_y^e(x,z)dz - j\omega \int_0^h B_y^s(x,z)dz \tag{5}$$

where we have decomposed the B-field into the excitation and scattered components.

The last integral in (5) represents the magnetic flux between the conductor and the ground produced by the current $I(x)$ flowing in the conductor.

Now, Ampère-Maxwell's equation in integral form is given by

$$\oint_{C'} \vec{B}^S \cdot d\vec{l} = I + j\omega \iint \vec{D} \cdot d\vec{s} \tag{6}$$

If we use a path C' in the transverse plane, defined by a constant x in such a manner that the conductor goes through it, Equation (6) can be rewritten as

$$\oint_{C'} \vec{B}_T^S(x,y,z) \cdot d\vec{l} = I(x) + j\omega \iint \vec{D}_X(x,y,z) \cdot \vec{a}_X ds \tag{7}$$

where the subindex T is used to indicate that the field is in the transverse direction, $\vec{a}_x$ is the unit vector in the x direction, and where we have explicitly included the dependence of the fields on the three Cartesian coordinates.

If the response of the wire is TEM, the electric flux density D in the x direction is zero and Equation (7) can be written as

$$\oint_{C'} \vec{B}_T^S(x,y,z) \cdot d\vec{l} = I(x) \tag{8}$$

[3] The coordinate y will be implicitly assumed to be 0 and for the sake of clarity, we will omit the y-dependency unless the explicit inclusion is important for the discussion.

Clearly, *I(x)* is the only source of $\vec{B}_T^S(x,y,z)$. Further, it is apparent from Equation (8) that $\vec{B}_T^S(x,y,z)$ is directly proportional to *I(x)*. Indeed, if *I(x)* is multiplied by a constant multiplicative factor which, in general, can be complex, $\vec{B}_T^S(x)$ too will be multiplied by that factor. Further, the proportionality factor for a uniform cross-section line must be independent of *x*.

Let us now concentrate on the *y* component of $\vec{B}_T^S(x,y,z)$ for points in the plane *y=0*. Using the facts we just established that *I(x)* and $\vec{B}_T^S(x)$ are proportional and that the proportionality factor is independent of x, we can now write

$$B_y^S(x,y=0,z)=k(y=0,z)I(x) \tag{9}$$

where *k(y,z)* is the proportionality constant.

With this result, we now go back to the last integral in Equation (5),

$$\int_0^h B_y^S(x,z)dz$$

Note that, although the value of y is not explicitly given, *y=0*. The integral represents the per unit length magnetic flux under the line. Substituting (9) into it, we obtain

$$\int_0^h B_y^S(x,z)dz=\int_0^h k(y=0,z)I(x)dz \tag{10}$$

We ca rewrite (10) as follows

$$\int_0^h B_y^S(x,z)dz=I(x)\int_0^h k(y=0,z)dz \tag{11}$$

Equation (11) implies that the per-unit-length scattered magnetic flux under the line at any point along it is proportional to the current at that point. The proportionality constant, given by $\int_0^h k(y=0,z)dz$, is the per-unit-length inductance of the line.

This results in the well-known linear relationship between the magnetic flux and the line current, the proportionality constant being the line per-unit-length inductance:

$$\int_0^h B_y^S(x,z)dz=L'I(x) \tag{12}$$

Assuming that the transverse dimension of the line is much greater than the height of the line, (*a*<<*h*), the magnetic flux density can be calculated using Ampere's Law and the integral can be evaluated analytically [1]. For *h*>>*a*, $L'\cong\frac{\mu_o}{2\pi}\ln\left(\frac{2h}{a}\right)$.

Inserting (12) into (5), we obtain the first generalized telegrapher's equation

$$\frac{dV(x)}{dx} + j\omega L' I(x) = -j\omega \int_0^h B_y^e(x,z)dz \qquad (13)$$

Note that, unlike the classical telegrapher's equations in which no external excitation is considered, the presence of an external field results in a forcing function expressed in terms of the exciting magnetic flux. This forcing function can be viewed as a distributed voltage source along the line.

Attention must paid to the fact that the voltage *V(x)* in (13) depends on the integration path since it is obtained by integration of an electric field whose curl is not necessarily zero (Equation (4)).

2.1.2 Derivation of the Second Field-to-Transmission Line Coupling Equation

To derive the second telegrapher's equation, we will assume that the medium surrounding the line is air ($\varepsilon = \varepsilon_o$) and we will start from the second Maxwell's equation $\nabla \times \vec{H} = \vec{J} + j\omega\varepsilon_o \vec{E}$. Rearranging the terms and writing it in Cartesian coordinates for the *z*-component:

$$j\omega E_z(x,z) = \frac{1}{\varepsilon_o \mu_o}\left[\frac{\partial B_y(x,z)}{\partial x} - \frac{\partial B_x(x,z)}{\partial y}\right] - \frac{J_z}{\varepsilon_o} \qquad (14)$$

The current density can be related to the E-field using Ohm's law, $\vec{J} = \sigma_{air}\vec{E}$, where σ_{air} is the air conductivity. Since the air conductivity is generally low, we will assume here that $\sigma_{air}=0$ and will therefore neglect this term[4].

Integrating (14) along the *z* axis from 0 to *h*, and making use of (4), we obtain

$$\begin{aligned} -j\omega V(x) &= \frac{1}{\varepsilon_o \mu_o}\int_0^h \left[\frac{\partial B_y^e(x,z)}{\partial x} - \frac{\partial B_x^e(x,z)}{\partial y}\right]dz \\ &+ \frac{1}{\varepsilon_o \mu_o}\int_0^h \left[\frac{\partial B_y^s(x,z)}{\partial x} - \frac{\partial B_x^s(x,z)}{\partial y}\right]dz \end{aligned} \qquad (15)$$

in which we have decomposed the magnetic flux density field into the excitation and scattered components.

Since the excitation fields are the fields that would exist if the line were not present, they must satisfy Maxwell's equations. Applying Maxwell's equation (14) to the components of the excitation electromagnetic field and integrating along *z* from 0 to *h* along a straight line directly under the line yields

$$\frac{1}{\varepsilon_o \mu_o}\int_0^h \left[\frac{\partial B_y^e}{\partial x} - \frac{\partial B_x^e}{\partial y}\right]dz = j\omega \int_0^h E_z^e dz \qquad (16)$$

Using (12), (16) and given that $B_x^s = 0$ by virtue of the assumed TEM nature of the line response, Equation (15) becomes

---

[4] This term will eventually result in an equivalent parallel conductance in the coupling equation (see Section 5).

$$\frac{dI(x)}{dx} + j\omega C'V(x) = -j\omega C' \int_0^h E_z^e(x,z)dz \tag{17}$$

where C' is the per-unit-length line capacitance related to the per-unit-length inductance through $\varepsilon_o \mu_o = L'C'$. Equation (17) is the second field-to-transmission line coupling equation.

For a line of finite length, such as the one represented in Fig. 1, the boundary conditions for the load currents and voltages must be enforced. They are simply given by

$$V(0) = -Z_A I(0) \tag{18}$$

$$V(L) = Z_B I(L) \tag{19}$$

2.1.3 Equivalent Circuit

Equations (13) and (17) are referred to as the *Taylor* et al. model. They can be represented using an equivalent circuit, as shown in Fig. 2. The forcing functions (source terms) in (13) and (17) are included as a set of distributed series voltage and parallel current sources along the line.

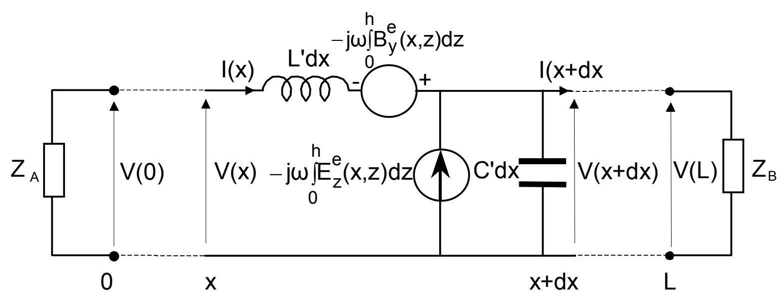


Figure 2: Equivalent circuit of a lossless single-wire overhead line excited by an electromagnetic field. *Taylor* et al. model.

2.2 Agrawal, Price and Gurbaxani Model

An equivalent formulation of field-to-transmission line coupling equations was proposed in 1980 by *Agrawal*, *Price* and *Gurbaxani* [6]. This model is commonly referred to as the Agrawal model. We will call it the *model of Agrawal et al.* or *the Agrawal et al. model* hereafter.

The basis for the derivation of the *Agrawal* et al. model can be described as follows: The excitation fields produce a line response that is TEM. This response is expressed in terms of a scattered voltage $V^s(x)$, which is defined in terms of the line integral of the scattered electric field from the ground to the line, and a scattered current $I^s(x)$ which flows in the line. The total voltage $V(x)$ and the total current $I(x)$ (the quantities that are actually measurable) are computed as the sum of the excitation and the scattered voltages and currents.

The coupling equations in the model of *Agrawal et al.* are used to obtain the scattered voltage and the scattered current only. Specific components of the incident fields appear either as a source term in the coupling equations or are used to compute the total voltage $V(x)$, which corresponds to that used in the *model of Taylor et al.* In the *model of Agrawal et al.*, the total current $I(x)$ is identical to the scattered current and it is obtained directly from the coupling equations. As we will see in the next section when we present the Rachidi's model [7], it is possible to define a distinct excitation current $I_e(x)$.

In the *model of Agrawal et al.*, the rational behind the writing of the telegrapher's equations in terms of the scattered quantities only is that, whereas the incident fields are arbitrary (they are of course constrained to satisfy Maxwell's equations and the ground boundary conditions), the scattered response is TEM, which allows for them to be calculated using TL theory.

The total voltage can be obtained from the scattered voltage through

$$V(x) = V^s(x) + V^e(x) = V^s(x) - \int_0^h E_z^e(x,z)dz \tag{20}$$

The field-to-transmission line coupling equations as derived by *Agrawal et al.* [6] are given by

$$\frac{dV^s(x)}{dx} + j\omega L' I(x) = E_x^e(x,h) \tag{21}$$

$$\frac{dI(x)}{dx} + j\omega C' V^s(x) = 0 \tag{22}$$

Note that in this model, only one source term is present (in the first equation) and is simply expressed in terms of the exciting electric field tangential to the line conductor $E_x^e(x,h)$.

The boundary conditions in terms of the scattered voltage and the total current as used in (21) and (22), are given by

$$V^s(0) = -Z_A I(0) + \int_0^h E_z^e(0,z)dz \tag{23}$$

$$V^s(L) = Z_B I(L) + \int_0^h E_z^e(L,z)dz \tag{24}$$

The equivalent circuit representation of this model (equations (21)-(24)) is shown in Fig. 3. For this model, the forcing function (the exciting electric field tangential to the line conductor) is represented by distributed voltage sources along the line. In accordance with boundary conditions (23) and (24), two lumped voltage sources (equal to the line integral of the exciting vertical electric field) are inserted at the line terminations.

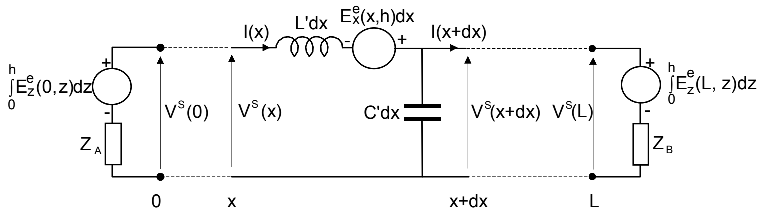


Figure 3: Equivalent circuit of a lossless single-wire overhead line excited by an electromagnetic field. *Agrawal et al. model*.

It is also interesting to note that this model involves only electric field components of the exciting field and the exciting magnetic field does not appear explicitly as a source term in the coupling equations.

2.3 Rachidi Model

Another form of coupling equations, equivalent to the *Agrawal et al.* and to the *Taylor et al.* models, has been derived by *Rachidi* [7]. In this model, only the exciting magnetic field components appear explicitly as forcing functions in the equations:

$$\frac{dV(x)}{dx} + j\omega L' I^s(x) = 0 \tag{25}$$

$$\frac{dI^s(x)}{dx} + j\omega C' V(x) = \frac{1}{L'} \int_0^h \frac{\partial B_x^e(x,z)}{\partial y} dz \tag{26}$$

in which $I^s(x)$ is the so-called scattered current related to the total current by

$$I(x) = I^s(x) + I^e(x) \tag{27}$$

where the excitation current $I^e(x)$ is defined as

$$I^e(x) = -\frac{1}{L'} \int_0^h B_y^e(x,z) dz \tag{28}$$

The boundary conditions corresponding to this formulation are

$$I^s(0) = -\frac{V(0)}{Z_A} + \frac{1}{L'} \int_0^h B_y^e(0,z) dz \tag{29}$$

$$I^s(L) = \frac{V(L)}{Z_B} + \frac{1}{L'} \int_0^h B_y^e(L,z) dz \tag{30}$$

The equivalent circuit corresponding to the above equivalent set of coupling equations is shown in Fig. 4. Note that the equivalent circuit associated with the *Rachidi model* could be seen as the dual circuit - in the sense of electrical network theory - of the one corresponding to the *Agrawal et al. model* (Fig. 3).

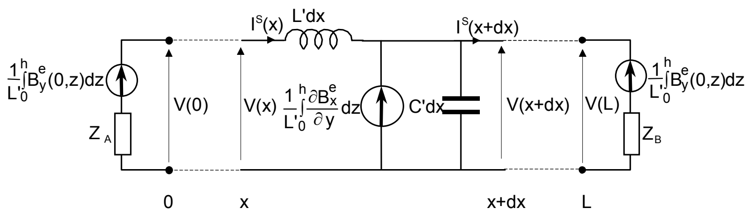


Figure 4: Equivalent circuit of a lossless single-wire overhead line excited by an electromagnetic field. *Rachidi model*.

3 Contribution of the Different Electromagnetic Field Components

Nucci and *Rachidi* [8] have shown, on the basis of a specific numerical example that, as predicted theoretically, the total induced voltage waveforms obtained using the three coupling models presented in Sections 2.1, 2.2 and 2.3 are identical. However, the contribution of a given component of the exciting electromagnetic field to the total induced voltage and current varies depending on the adopted coupling model. Indeed, the three coupling models are different but fully equivalent approaches that predict identical results in terms of total voltages and total currents, in spite of the fact that they take into account the electromagnetic coupling in different ways. In other words, the three models are different expressions of the same equations, cast in terms of different combinations of the various electromagnetic field components, which are related through Maxwell's equations.

4 Inclusion of Losses

In the calculation of lightning-induced voltages, losses are, in principle, to be taken into account both in the wire and in the ground. Losses due to the finite ground conductivity are the most important ones, and they affect both the electromagnetic field and the surge propagation along the line [9].

Let us make reference to the same geometry of Fig. 1, and let us now take into account losses both in the wire and in the ground plane. The wire conductivity and relative permittivity will be denoted σ_w and $\varepsilon_{rw,}$ respectively, and the ground, assumed to be homogeneous, is characterized by its conductivity σ_g and its relative permittivity ε_{rg}. The *Agrawal* et al. coupling equations extended to the present case of a wire above an imperfectly conducting ground can be written as (for a step by step derivation see [1])

$$\frac{dV^s(x)}{dx} + Z'I(x) = E_x^e(x,h) \tag{31}$$

$$\frac{dI(x)}{dx} + Y'V^s(x) = 0 \tag{32}$$

where Z' and Y' are the longitudinal and transverse per-unit-length impedance and admittance, respectively, given by [1, 9][5]

$$Z' = j\omega L' + Z'_w + Z'_g \tag{33}$$

$$Y' = \frac{(G' + j\omega C')Y'_g}{G' + j\omega C' + Y'_g} \tag{34}$$

in which

- L', C' and G' are the per-unit-length longitudinal inductance, transverse capacitance and transverse conductance, respectively, calculated for a lossless wire above a perfectly conducting ground:

$$L' = \frac{\mu_o}{2\pi}\cosh^{-1}\left(\frac{h}{a}\right) \cong \frac{\mu_o}{2\pi}\ln\left(\frac{2h}{a}\right) \qquad \text{for } h >> a \tag{35}$$

$$C' = \frac{2\pi\varepsilon_o}{\cosh^{-1}(h/a)} \cong \frac{2\pi\varepsilon_o}{\ln(2h/a)} \qquad \text{for } h >> a \tag{36}$$

$$G' = \frac{\sigma_{\mathrm{air}}}{\varepsilon_o}C' \tag{37}$$

- Z'_w is the per-unit-length internal impedance of the wire; assuming a round wire and an axial symmetry for the current, the following expression can be derived for the wire internal impedance (e.g. [10]):

$$Z'_w = \frac{\gamma_w \, \mathrm{I}_o(\gamma_w a)}{2\pi a \sigma_w \, \mathrm{I}_1(\gamma_w a)} \tag{38}$$

where $\gamma_w = \sqrt{j\omega\mu_o(\sigma_w + j\omega\varepsilon_o\varepsilon_{rw})}$ is the propagation constant in the wire and I_o and I_1 are the modified Bessel functions of zero and first order, respectively;

- Z'_g is the per-unit-length ground impedance, which is defined as [11, 12]

$$Z'_g = \frac{j\omega \int_{-\infty}^{h} B_y^s(x,z)dx}{I} - j\omega L' \tag{39}$$

where B_y^s is the y-component of the scattered magnetic induction field.

Several expressions for the ground impedance have been proposed in the literature (e.g. [13]). *Sunde* [14] derived a general expression for the ground impedance, which is given by

$$Z'_g = \frac{j\omega\mu_o}{\pi}\int_0^{\infty}\frac{\mathrm{e}^{-2hx}}{\sqrt{x^2+\gamma_g^2}+x}dx \tag{40}$$

---

[5] In [1] the per unit length transverse conductance has been disregarded.

where $\gamma_g = \sqrt{j\omega\mu_o(\sigma_g + j\omega\varepsilon_o\varepsilon_{rg})}$ is the propagation constant in the ground.

As noted in [13], *Sunde*'s expression (40) is directly connected to the general expressions obtained from scattering theory. Indeed, it is shown in [1] that the general expression for the ground impedance derived using scattering theory reduces to the *Sunde* approximation when considering the transmission line approximation. Also, the results obtained using (40) are shown to be accurate within the limits of the transmission line approximation [1].

The general expression (40) is not suitable for a numerical evaluation since it involves an integral over an infinitely long interval. Several approximations for the ground impedance of a single-wire line have been proposed in the literature (see [11] for a survey). One of the simplest and most accurate was proposed by *Sunde* himself and is given by the following logarithmic function

$$Z'_g \cong \frac{j\omega\mu_o}{2\pi}\ln\left(\frac{1+\gamma_g h}{\gamma_g h}\right) \tag{41}$$

It has been shown [11] that the above logarithmic expression represents an excellent approximation to the general expression (40) over the frequency range of interest.

Finally, Y'_g is the so-called ground admittance, given by [1]

$$Y'_g \cong \frac{\gamma_g^2}{Z'_g} \tag{42}$$

5 Case of Multiconductor Lines

Making reference to the geometry of Fig. 5, the field-to-transmission line coupling equations for the case of a multi-wire system along the *x*-axis above an imperfectly conducting ground and in presence of an external electromagnetic excitation are given by [1, 4, 15]

$$\frac{d}{dx}[V_i^s(x)] + j\omega[L'_{ij}][I_i(x)] + [Z'_{g_{ij}}][I_i(x)] = [E_x^e(x,h_i)] \tag{43}$$

$$\frac{d}{dx}[I_i(x)] + [G'_{ij}][V_i^s(x)] + j\omega[C'_{ij}][V_i^s(x)] = [0] \tag{44}$$

in which

- $[V_i^s(x)]$ and $[I_i(x)]$ are frequency-domain vectors of the scattered voltage and the current along the line;

- $[E_x^e(x,h_i)]$ is the vector of the exciting electric field tangential to the line conductors;

- [0] is the zero-matrix (all elements are equal to zero);

- $[L'_{ij}]$ is the per-unit-length line inductance matrix. Assuming that the distances between conductors are much larger than their radii, the general expression for the mutual inductance between two conductors *i* and *j* is given by [1]

$$L'_{ij} = \frac{\mu_o}{2\pi} \ln\left(\frac{r_{ij}^2 + (h_i + h_j)^2}{r_{ij}^2 + (h_i - h_j)^2} \right) \tag{45}$$

The self inductance for conductor *i* is given by

$$L'_{ii} = \frac{\mu_o}{2\pi} \ln\left(\frac{2h_i}{r_{ii}} \right) \tag{46}$$

- $[C'_{ij}]$ is the per-unit-length line capacitance matrix, which can be evaluated directly from the inductance matrix using the following expression [1]

$$\left[C'_{ij}\right] = \varepsilon_o \mu_o \left[L'_{ij}\right]^{-1} \tag{47}$$

- $[G'_{ij}]$ is the per-unit-length transverse conductance matrix. The transverse conductance matrix elements can be evaluated starting either from the capacitance matrix or the inductance matrix using the following relations

$$\left[G'_{ij}\right] = \frac{\sigma_{air}}{\varepsilon_o} \left[C'_{ij}\right] = \sigma_{air} \mu_o \left[L'_{ij}\right]^{-1} \tag{48}$$

In most practical cases, the transverse conductance matrix elements G'_{ij} are much smaller than $j\omega C'_{ij}$ [3] and can therefore be neglected in the computation.

- Finally, $[Z'_{g_{ij}}]$ is the ground impedance matrix. The general expression for the mutual ground impedance between two conductors *i* and *j* derived by Sunde is given by [14]

$$Z'_{g_{ij}} = \frac{j\omega\mu_o}{\pi} \int_0^\infty \frac{e^{-(h_i + h_j)x}}{\sqrt{x^2 + \gamma_g^2} + x} \cos(r_{ij} x) dx \tag{49}$$

In a similar way as for the case of a single-wire line, an accurate logarithmic approximation is proposed by *Rachidi* et al. [15] which is given by

$$Z'_{g_{ij}} \cong \frac{j\omega\mu_o}{4\pi} \ln\left[\frac{\left(1 + \gamma_g \left(\frac{h_i + h_j}{2}\right)\right)^2 + \left(\gamma_g \frac{r_{ij}}{2}\right)^2}{\left(\gamma_g \frac{h_i + h_j}{2}\right)^2 + \left(\gamma_g \frac{r_{ij}}{2}\right)^2} \right] \tag{50}$$

Note that in (43) and (44), the terms corresponding to the wire impedance and the so-called ground admittance have been neglected. This approximation is valid for typical overhead power lines [9].

The boundary conditions for the two line terminations are given by

$$[V_i^s(0)] = -[Z_A][I_i(0)] + [\int_0^{h_i} E_z^e(0,z)dz] \qquad (51)$$

$$[V_i^s(L)] = [Z_B][I_i(L)] + [\int_0^{h_i} E_z^e(L,z)dz] \qquad (52)$$

in which $[Z_A]$ and $[Z_B]$ are the impedance matrices at the two line terminations.

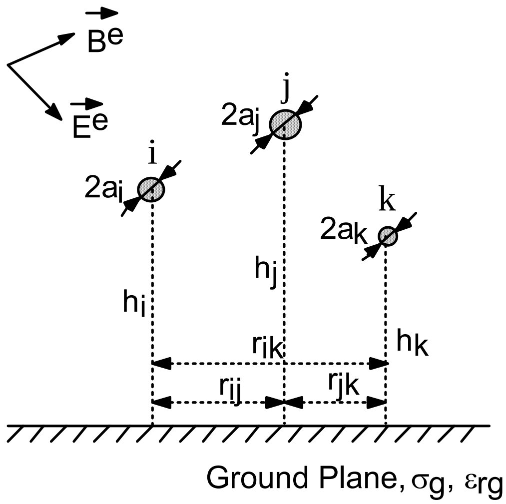


Figure 5: Cross-sectional geometry of a multiconductor line in presence of an external electromagnetic field.

6 Time-Domain Representation of the Coupling Equations

A time domain representation of the field-to-transmission line coupling equations is sometimes preferable because it allows the straightforward treatment of non linear phenomena as well as the variation in the line topology [4]. On the other hand, frequency-dependent parameters, such as the ground impedance, need to be represented using convolution integrals.

The field-to-transmission line coupling equations (43) and (44) can be converted into the time domain to obtain the following expressions

$$\frac{\partial}{\partial x}\left[v_i^s(x,t)\right] + \left[L'_{ij}\right]\frac{\partial}{\partial t}\left[i_i(x,t)\right] + \left[\xi'_{g_{ij}}\right] \otimes \frac{\partial}{\partial t}\left[i_i(x,t)\right] = \left[E_x^e(x,h_i,t)\right] \qquad (53)$$

$$\frac{\partial}{\partial x}\left[i_i(x,t)\right] + \left[G'_{ij}\right]\left[v_i^s(x,t)\right] + \left[C'_{ij}\right]\frac{\partial}{\partial t}\left[v_i^s(x,t)\right] = 0 \qquad (54)$$

in which $\otimes$ denotes convolution product and the matrix $\left[\xi'_{g_{ij}}\right]$ is called the transient ground resistance matrix; its elements are defined as

$$\left[\xi'_{g_{ij}}\right] = \mathrm{F}^{-1}\left\{\frac{\left[Z'_{g_{ij}}\right]}{j\omega}\right\} \tag{55}$$

The inverse Fourier transforms of the boundary conditions written, for simplicity, for resistive terminal loads read

$$\left[v_i(0,t)\right] = -\left[R_A\right]\left[i_i(0,t)\right] + \left[\int_0^{h_i} E_z^e(0,z,t)dz\right] \tag{56}$$

$$\left[v_i(L)\right] = \left[R_B\right]\left[i_i(0)\right] + \left[\int_0^{h_i} E_z^e(L,z,t)dz\right] \tag{57}$$

where $\left[R_A\right]$ and $\left[R_B\right]$ are the matrices of the resistive loads at the two line terminals.

The general expression for the ground impedance matrix terms in the frequency domain (49) does not have an analytical inverse Fourier transform. Thus, the elements of the transient ground resistance matrix in the time domain are to be, in general, determined using a numerical inverse Fourier transform algorithm. However, analytical expressions have been derived which are shown to be reasonable approximations to the numerical values obtained using an inverse FFT [13].

7 Frequency-Domain Solutions

Different approaches can be employed to find solutions to the presented coupling equations. This section and Section 8 present some solution methods in the frequency domain and in the time domain, respectively.

To solve the coupling equations in the frequency domain, it is convenient to use Green's functions that relate, as a function of frequency, the individual coupling sources to the scattered or the total voltages and currents at any point along the line. Green's functions solutions require integration over the length of the line, where the distributed sources are located. This approach is the subject of section 7.1.

Under special conditions, it is possible to obtain more compact solutions or even analytical expressions. In particular, if the solutions are required at the load terminations only, it is possible to write the load voltages and currents in a compact manner, where the complexity is essentially hidden in the source terms. This formulation, termed the BLT equations, will be presented in Section 7.2.

7.1 Green's Functions

The field-to-transmission line coupling equations, together with the boundary conditions, can be solved using Green's functions, which represent the solutions for line current and voltage due to a point voltage and/or current source [1]. In this section, we will present the solutions, using the *Agrawal at al. model* for the case of a single-conductor line. Similar solutions can be found for the case of a multiconductor line (see, for instance, [1], [3]).

Considering a voltage source of unit amplitude at a location x_s along the line[6], the Green's functions for the current and the voltage along the line read, respectively [1],

$$G_I(x;x_S)=\frac{e^{-\gamma L}}{2Z_c\left(1-\rho_1\rho_2e^{-2\gamma L}\right)}\left(e^{-\gamma(x_>-L)}-\rho_2e^{\gamma(x_>-L)}\right)\left(e^{\gamma x_<}-\rho_1e^{-\gamma x_<}\right) \tag{58}$$

and

$$G_V(x;x_S)=\frac{\delta e^{-\gamma L}}{2\left(1-\rho_1\rho_2e^{-2\gamma L}\right)}\left(e^{-\gamma(x_>-L)}+\delta\rho_2e^{\gamma(x_>-L)}\right)\left(e^{\gamma x_<}-\delta\rho_1e^{-\gamma x_<}\right) \tag{59}$$

where

- $x_<$ represents the smaller of x or x_S, and $x_>$ represents the larger of x or x_S.

– δ=1 for $x > x_S$ and δ= -1 for $x < x_S$.

- $\gamma=\sqrt{Z'Y'}$ is the complex propagation constant along the transmission line,

- $Z_c=\sqrt{Z'/Y'}$ is the line's characteristic impedance.

- ρ_1 and ρ_2 are the voltage reflection coefficients at the loads of the transmission line given by

$$\rho_1=\frac{Z_A-Z_c}{Z_A+Z_c}\qquad \rho_2=\frac{Z_B-Z_c}{Z_B+Z_c} \tag{60}$$

The solutions in terms of the total line current and *scattered* voltage can be written as the following integrals of the Green's functions [1]

$$\begin{aligned}I(x)=&\int_0^L G_I(x;x_S)V_S'dx_S+\\&G_I(x;0)\int_0^h E_z^e(0,z)dz-G_I(x;L)\int_0^h E_z^e(L,z)dz\end{aligned} \tag{61}$$

$$\begin{aligned}V^S(x)=&\int_0^L G_V(x;x_S)V_S'dx_S+\\&G_V(x;0)\int_0^h E_z^e(0,z)dz-G_V(x;L)\int_0^h E_z^e(0,z)dz\end{aligned} \tag{62}$$

Note that the second and the third terms on the right hand side of (61) and (62) are due to the contribution of equivalent lumped sources at the line ends (see Fig. 3).

The total voltage can be determined from the scattered voltage by adding the contribution from the exciting field as

[6] Since only distributed series voltage sources are present in the model of *Agrawal et al.*, it is not necessary to consider a parallel unitary current source.

$$V(x) = V^s(x) - \int_0^d E_z^e(x,z)dz \tag{63}$$

7.2 BLT Equations

If we are interested in the transmission line response at its terminal loads, the solutions can be expressed in a compact way by using the so-called BLT (Baum, Liu, Tesche) equations [1],

$$\begin{bmatrix} I(0) \\ I(L) \end{bmatrix} = 1/Z_c \begin{bmatrix} 1-\rho_1 & 0 \\ 0 & 1-\rho_2 \end{bmatrix} \begin{bmatrix} -\rho_1 & e^{\gamma L} \\ e^{\gamma L} & -\rho_2 \end{bmatrix}^{-1} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix} \tag{64}$$

$$\begin{bmatrix} V(0) \\ V(L) \end{bmatrix} = \begin{bmatrix} 1+\rho_1 & 0 \\ 0 & 1+\rho_2 \end{bmatrix} \begin{bmatrix} -\rho_1 & e^{\gamma L} \\ e^{\gamma L} & -\rho_2 \end{bmatrix}^{-1} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix} \tag{65}$$

where the source vector is given by

$$\begin{pmatrix} S_1 \\ S_2 \end{pmatrix} = \begin{pmatrix} \frac{1}{2}\int_0^L e^{\gamma x_s} E_x^e(x_s,h)dx_s + \frac{1}{2}\int_0^h E_z^e(0,z)dz - \frac{e^{\gamma L}}{2}\int_0^h E_z^e(L,z)dz \\ \frac{-1}{2}\int_0^L e^{\gamma(L-x_s)} E_x^e(x_s,h)dx_s - \frac{e^{\gamma L}}{2}\int_0^h E_z^e(0,z)dz + \frac{1}{2}\int_0^h E_z^e(L,z)dz \end{pmatrix} \tag{66}$$

Note that, in the BLT equations, the solutions are directly given for the total voltage and not for the scattered voltage.

For an arbitrary excitation field, the integrals in Equation (66) cannot be performed analytically. However, for the special case of a plane wave excitation field, the integrations can be performed analytically and closed-form expressions can be obtained for the load responses. General solutions for vertical and horizontal field polarizations are given in [1].

8 Time-Domain Solutions

Several approaches can be used to solve the coupling equations in the time domain ([1, 3]). We will present here simple analytical expressions that can be obtained for the case of a lossless line involving infinite summations.

Under the assumption of a lossless line, it is possible to obtain analytical solutions for the transient response of a transmission line to an external field excitation [1]. In this case, the propagation constant becomes purely imaginary $\gamma = j\omega / c$ and the characteristic impedance is purely real $Z_c = \sqrt{L'/C'}$. If we assume further that the termination impedances are purely resistive, the reflection coefficients ρ_1 and

ρ_2, too, become real. For $\left|\rho_1\rho_2 e^{-2\gamma L}\right| < 1$, the denominator in Green's functions (58) and (59) can be expanded to[7]

$$\frac{1}{\left(1-\rho_1\rho_2 e^{-2\gamma L}\right)} = \sum_{n=0}^{\infty}\left(\rho_1\rho_2 e^{-j\omega 2L/c}\right)^n \tag{67}$$

With the above transformation, it is easy to show that all the frequency dependences in (64) and (65) will be in the form $e^{-j\omega\tau}$, τ being a constant. Therefore, it is possible to convert the frequency domain solutions analytically and to obtain the following transient responses for the load voltages (for details, see [1])

$$v(0,t) = (1+\rho_1)\sum_{n=0}^{\infty}\left(\rho_1\rho_2\right)^n \frac{1}{2}\left(\rho_2 v_s(t-\frac{2(n+1)L-x_s}{c}) - v_s(t-\frac{2nL+x_s}{c})\right) \tag{68}$$

$$v(L,t) = (1+\rho_2)\sum_{n=0}^{\infty}\left(\rho_1\rho_2\right)^n \frac{1}{2}\left(v_s(t-\frac{2(n+1)L-x_s}{c}) - \rho_1 v_s(t-\frac{2(L+1)+x_s}{c})\right) \tag{69}$$

where

$$v_s(t) = \int_0^L E_x^e(x_s,h,t)dx_s + \int_0^h E_z^e(0,z,t)dz - \int_0^h E_z^e(L,z,t)dz \tag{70}$$

Note that $E_x^e(x_s,h,t)$, $E_z^e(0,z,t)$ and $E_z^e(L,z,t)$ are time-domain components of the exciting field.

9 Conclusions

We discussed the Transmission Line (TL) theory and its application to the problem of external electromagnetic field coupling to transmission lines. After a short discussion on the underlying assumptions of the TL theory, the field-to-transmission line coupling equations were derived for the case of a single wire line above a perfectly conducting ground. Three different but completely equivalent approaches that have been proposed to describe the coupling of electromagnetic field coupling to transmission lines were also presented and discussed. The derived equations were extended to deal with the presence of losses and multiple conductors. The time-domain representation of field-to-transmission line coupling equations which allows a straightforward treatment of non linear phenomena as well as the variation in the line topology was also described. Finally, solution methods in frequency domain and time domain were presented.

[7] For a lossless line with reflection coefficients of magnitude 1, the condition $\rho_1\rho_2 e^{-2\gamma L} = 1$ will be met at a number of resonance frequencies causing the solutions to be unbounded.

10 References

[1] F. M. Tesche, M. Ianoz, and T. Karlsson, *EMC Ananlysis methods and computational models*. New York: Wiley Interscience, 1997.

[2] V. Cooray, *The Lightning Flash*: IEE, 2003.

[3] C. R. Paul, *Analysis of multiconductor transmission lines*. New York: John Wiley and Sons, 1994.

[4] C. A. Nucci and F. Rachidi, "Interaction of electromagnetic fields generated by lightning with overhead electrical networks," in *The Lightning Flash*: IEE, 2003, pp. 425-478.

[5] C. D. Taylor, R. S. Satterwhite, and C. W. Harrison, "The response of a treminated two-wire transmission line excited by a nonuniform electromagnetic field," *IEEE Transactions on Antennas and Propagation*, vol. AP-13, pp. 987-989, 1965.

[6] A. K. Agrawal, H. J. Price, and S. H. Gurbaxani, "Transient response of multiconductor transmission lines excited by a nonuniform electromagnetic field," *IEEE Transactions on Electromagnetic Compatibility*, vol. EMC22, pp. 119-29, 1980.

[7] F. Rachidi, "Formulation of the field-to-transmission line coupling equations in terms of magnetic excitation fields," *IEEE Transactions on Electromagnetic Compatibility*, vol. 35, pp. 404-407, 1993.

[8] C. A. Nucci and F. Rachidi, "On the contribution of the electromagnetic field components in field-to-transmission lines interaction," *IEEE Transactions on Electromagnetic Compatibility*, vol. 37, pp. 505-508, 1995.

[9] F. Rachidi, C. A. Nucci, I. M., and C. Mazzetti, "Influence of a lossy ground on lightning-induced voltages on overhead lines," *EEE Trans. on EMC*, vol. 38, pp. 250-263, 1996.

[10] S. Ramo, J. R. Whinnery, and T. van Duzer, *Fields and waves in communication electronics*, 3 ed. New York: Wiley, 1994.

[11] F. Rachidi, C. A. Nucci, M. Ianoz, and C. Mazzetti, "Importance of losses in the determination of lightning-induced voltages on overhead lines," *EMC '96 ROMA. International Symposium on Electromagnetic Compatibility. Univ. Rome `La Sapienza', Rome, Italy*, vol. 2, 1996.

[12] F. M. Tesche, "Comparison of the transmission line and scattering models for computing the HEMP response of overhead cables," *IEEE Transactions on Electromagnetic Compatibility*, vol. 34, 1992.

[13] C. Nucci and F. Rachidi, "Interaction of electromagnetic fields generated by lightning with ovrehead electrical networks," in *The Lightning Flash*, V. Cooray, Ed. London: IEE, 2003, pp. 425-478.

[14] E. D. Sunde, *Earth conduction effects in transmission systems*. New York: Dover Publication, 1968.

[15] F. Rachidi, C. A. Nucci, and M. Ianoz, "Transient analysis of multiconductor lines above a lossy ground," *IEEE Trans. on PWDR*, vol. 14, pp. 294-302, 1999.

Implementing Efficient Array Traversing for FDTD simulation

Luis R. de Jussilainen Costa and Keijo Nikoskinen

Abstract

Two data types and two nested-looping techniques for efficient implementation of the FDTD algorithm in C are discussed. The different constructs were run on six computer platforms indicating significant performance improvement on some platforms with proper implementation. The extent of the improvement depends on the data type and compiler used.

Index Terms

FDTD implementation, nested loops, optimal loops, array types.

I. Introduction

The finite-difference time-domain (FDTD) method for solving Maxwell's equations discretises the six field components in space and time and uses difference equations to simulate the electric and magnetic fields in the time domain [11]. The field and material parameter values are stored in arrays whose position in the array represents the location in space at a given time. These values are updated using values from the previous time point. Hence, the FDTD algorithm entails accessing and updating floating point numbers in several three-dimensional (3D) arrays. Modified flavors of this algorithm, like the Alternate-Direction Implicit FDTD (ADI-FDTD) method [5] to mention one, all traverse and update values stored in 3D arrays.

The simplicity and elegance of the algorithm has made the FDTD method a popular and invaluable tool for electromagnetic (EM) field simulation in the time domain, from which frequency-domain information can be extracted, if desired [9]. Also, lumped elements (LE) can be embedded into the FDTD grid either by devising a suitable updating equation to

L.R. de J. Costa is with the Circuit theory laboratory, HelsinkiUniversity of Technology, P.O. Box 3000, FIN-02015 TKK, Finland.luis@ct.tkk.fi

K. Nikoskinen is with the Electromagnetics laboratory, HUT, P.O. Box3000, FIN-02015 TKK, Finland

model the LE(s), or by using a circuit simulator like Aplac[1] to compute the LE current that is introduced into a dielectric region in the FDTD grid via the conduction current density [8]. The latter approach enables an on-the-fly cosimulation of nonlinear LE circuits with the FDTD field simulator and has been implemented into the EM tool of the Aplac simulator and design tool [1].

Since modelling real-life design problems often requires large grids, simulation times can be prohibitively large even with the computing power available today. Thus, implementing the FDTD algorithm as efficiently as possible is of paramount importance; the feasablity of a simulation or cosimulation may depend on this.

In the following, the implementation of two array types, a 3D array and a one-dimensional array, referred to here as a vector, and their traversal in two different ways are discussed. The test program, written in C [4], emulates the standard FDTD algorithm. The times taken to traverse the array types in the two ways by the optimally compiled program are compared. Traversing is performed in a manner natural to the programming language and in another, more efficient, way. It turns out that the execution speed of the program is compiler-dependent, and judicious programming [3] can improve execution speed significantly.

II. Implementing the Data Types and Array Traversing

In this discussion, double precision numbers are updated by the FDTD algorithm but the conclusions hold for single precision as well. The 3D array and vector can be allocated statically, as possibly in a do-it-yourself application-specific FDTD program, whence the number of grid points in the x, y, and z directions must be known at compile time, or dynamically with the `malloc()` function, as for a general-purpose FDTD simulator, where this data is required only at run time [7, pp. 945–946]. A vector can be used instead of the 3D array in Figure 3 by arranging the data, for example, as illustrated in Figure 1.

$0,0,0$	$1,0,0$	$\cdots$	$X,0,0$	$0,1,0$	$1,1,0$	$\cdots$	$X,Y,0$	$0,0,1$	$\cdots$	i,j,k	$\cdots$	X,Y,Z

Fig. 1. A vectorised 3D array.

As in the 3D array, the coordinate (i, j, k) specifies a position in the vector of length XYZ

[1] See www.aplac.com.

```
for (k=ks; k<=ke; k++) {
 for (j=js; j<=je; j++) {
  for (i=is; i<=ie; i++) {
   *(*(*(ar3d+k)+j)+i) = 1.0;}}}
```

```
for (k=ks; k<=ke; k++) {
 for (j=js; j<=je; j++) {
  for (i=is; i<=ie; i++) {
   *(ar1d+X*(Y*k+j)+i) = 1.0;}}}
```

Fig. 2. Standard code fragments to traverse a 3D array (left) and a vector (right).

as well, but now the position is explicitly calculated as

$$\text{location} = XY \cdot k + X \cdot j + i = X(Y \cdot k + j) + i. \tag{1}$$

The statement `*(*(*(ar3d+k)+j)+i)` accesses an element in the 3D array `ar3d` with three additions and dereferences, while for the vector, from (1), two additions and multiplications suffice. So, from the number-of-access-calculations point of view, the vector seems more efficient.

The ultimate criterion for choosing an array type for programming the FDTD algorithm depends on how quickly the array is traversed. Another desirable feature is code readability. This discussion is limited to traversing the entire 3D computational space. The efficiency of the two nested-loop implementations discussed below for the two data types are compared in Section III.

The standard C code to traverse a 3D array and a vector from starting point $(i_\mathrm{s}, j_\mathrm{s}, k_\mathrm{s})$ to end point $(i_\mathrm{e}, j_\mathrm{e}, k_\mathrm{e})$ is given in Figure 2. Assigning three auxilliary pointers, `dep = ar3d`, `row = *dep` and `col = *row`, as shown in Figure 3, speeds up traversing. This scheme maximises memory access in unit strides resulting in better performance since the next array (memory) location is simply obtained by incrementing the current position value by one.

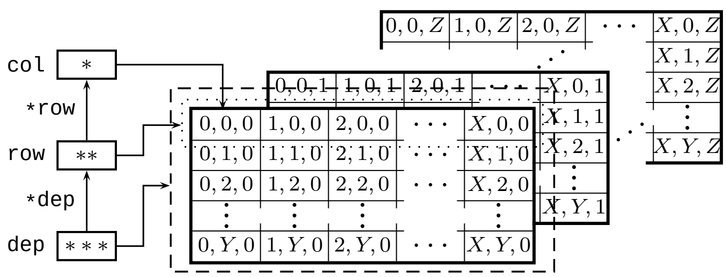


Fig. 3. Pointers to the first column and row in the first matrix of a 3D array. The numbers in the boxes are the position coordinates in the array.

Moving computations from the inner to the outer loops or altogether outside (a technique called frequency reduction [10, sec. 12-5.2] standardly used by compiler optimisers to generate efficient executable code) results in further speed up. For the vector, rearranging (1) to

```c
double ***dep, **row, *col;
 ...
dep = ar3d + ks;
for (k=ks; k<=ke; k++) {
 row = *dep + js;
 col = *row + is;
 dep++;
 for (j=0; j<=je; j++) {
  for (i=0; i<=ie; i++) {
   *col++ = 1.0;}
  row++;
  col = *row + is;}}
```

```c
int adi, adj, adk; double *ptr;
...
adi = X - ie - 1 + is;
adj = (Y - je - 1 + js)*X;
adk = (Y*ks + js)*X + is;
ptr = ar1d + adk - adj;
for (k=ks; k<=ke; k++) {
 ptr += adj;
 for (j=js; j<=je; j++) {
  for (i=is; i<=ie; i++) {
   *ptr++ = 1.0;}
  ptr += adi;}}
```

Fig. 4. Refined code for traversing a 3D array (left) and a vector (right).

allow for frequency reduction and replacing the operators =, * and + with the computationally faster binary operator += results in an efficient method for traversing the array. The modified code fragments for the two array types are given in Figure 4.

The code structure for looping in the two data types is similar. So, macros implementing either one form or the other can be defined, as shown in Figure 5. Writing the program in this macro language allows the development of easily maintainable FDTD software that is portable on several platforms and always having the optimum data type for efficient nested loop traversing.

```c
#define DeclVars double ***dep,**row,*ptr
#define UseArray(a) double ***(a)
#define SetPtrTo(a) dep=(a)+ks
#define IncrKPtr row=*dep+js;ptr=*row+is;\
        dep++
#define IncrJPtr row++;ptr=*row+is
```

```c
#define DeclVars int adi,adj,adk;double *ptr
#define UseArray(a) double *(a)
#define SetPtrTo(a) adi=X-ie-1+is;\
      adj=(Y-je-1+js)*X;adk=(y*ks+js)*X+is;\
      ptr=(a)+adk-adj
#define IncrKPtr ptr+=adi
#define IncrJPtr ptr+=adj
```

```c
DeclVars; UseArray(arr);
...
SetPtrTo(arr);
for (k=ks; k<=ke; k++) {
  IncrKPtr;
  for (j=js; j<=je; j++) {
    for (i=is; i<=ie; i++) {
      *ptr++ = 1.0;}
    IncrJPtr;}}
```

Fig. 5. Macros to implement looping for the 3D array (top-left) and vector (top-right), and the resulting macro code for nested looping (bottom-centre).

III. Comparison of the Two Data Types

The test code consisted of the standard and refined loops in Figures 2 and 4, with arrays allocated alone and as members of a structure, both, statically and dynamically. The traversing speeds for the four array set-ups for the 3D array and vector in the standard and refined loops were measured by recording the starting time t_0 and the time t_1 after 10^5 runs using C's standard library function `clock()` and calculating the traversing time as $(t_1 - t_0)/$`CLOCKS_PER_SEC`. This test code was compiled on the six platforms with the compilers and compilation options in Table I. Additionally, 32 and 64 bit executables for the AMD and Itanium machines were compiled. The optimisation options for the compiler were chosen so as to generate a correctly computing executable with as much optimisation as possible (e.g., the O3 option for the Itanium compiler produced an executable that did not work). The average of 20 measured traversing times are given in Tables II and III. In a similar comparison [1], [2], the test code was compiled with the compilation options used for Aplac, that used less optimisation.

TABLE I

The platforms, compilers and optimisation options used.

Processor	Operating System
Digital AlphaPC 164LX 533 MHz	Digital UNIX OSF1 V4.0D (Rev. 878)
HP D270/2 (PA RISC 2.0)	HP-UX B.10.20 A 9000/871
Itanium 2 1.3 GHz	HP-UX B.11.22
AMD Athlon 64 3000+ 1.8 GHz	Linux 2.6.8.24-19
Pentium 4 3 GHz	SELinux
Sun Ultra 2 UPA/SBus (UltraSPARC 200 MHz)	SunOS 5.8

Compiler	Compilation command and options	Platform
DEC C V5.6-071	`cc -std -O5 -Olimit 3000`	Alpha
HP C Compiler A.10.33	`cc -Aa -Onolimits`	HPUX 10
HP aC++/ANSI C A.05.52	`-Ae +O2 +Onolimits +Ofast +DD32`	HPUX 11
Gnu CC gcc 3.3.4	`gcc -ansi -m32 -O3`	Linux
Gnu CC gcc 4.0.0	`gcc -ansi -O3`	SELinux
WorkShop Compilers C 4.2	`cc -fast -O4 -xtarget=ultra2/2200`	Sun

Time differences in the performance of the two data types are not big enough to be definitive, but it is clear the refined loops are faster on the Itanium and Alpha computers.

TABLE II

TIME TAKEN TO TRAVERSE ONE ARRAY WITH DIMENSIONS $50 \times 20 \times 10$ 10^5 TIMES. 'STD.' REFERS TO THE STANDARD AND 'REF.' TO THE REFINED NESTED LOOPS.

Array	Static		Dynamic		Static		Dynamic	
	Std	Ref	Std	Ref	Std	Ref	Std	Ref
	Alpha				HP D270			
`***ar3d`	3.18	-	9.20	3.75	6.30	-	16.40	6.72
`*ar1d`	2.83	2.30	2.80	2.27	6.29	6.57	6.32	6.56
`s->ar3d`	2.84	-	9.53	4.02	6.29	-	21.25	6.47
`s->ar1d`	4.16	3.65	3.14	2.27	6.30	6.57	12.04	6.56
	Itanium 32-bit				Itanium 64-bit			
`***ar3d`	1.58	-	2.48	0.67	3.29	-	2.47	0.62
`*ar1d`	1.58	0.62	0.67	0.63	3.29	0.62	0.62	0.62
`s->ar3d`	0.64	-	4.01	0.63	0.67	-	4.01	0.62
`s->ar1d`	0.67	0.63	1.83	0.62	0.67	0.63	1.82	0.62
	AMD 32-bit				AMD 64-bit			
`***ar3d`	1.34	-	1.37	1.34	1.33	-	1.37	1.38
`*ar1d`	1.35	1.31	1.36	1.31	1.36	1.32	1.68	1.30
`s->ar3d`	1.34	-	1.37	1.35	1.34	-	1.36	1.75
`s->ar1d`	1.79	1.79	1.34	1.31	1.33	1.31	1.69	1.30
	Pentium 4				Sun			
`***ar3d`	1.31	-	1.26	1.32	7.88	-	26.05	8.65
`*ar1d`	1.32	1.29	1.31	1.29	7.48	7.29	6.87	8.73
`s->ar3d`	1.28	-	1.26	1.33	7.94	-	36.46	7.87
`s->ar1d`	1.37	1.30	1.37	1.29	7.29	7.58	21.37	7.70

The Gnu compilations seem to produce executables that, roughly, run equally well for all the arrays and loop configurations. Also, when the innermost loop is smaller than the outermost, the code executes faster in the Itanium machine, contrary to expectations. The code was also compiled on the Sun workstation with the Gnu compiler gcc 3.3.2 which resulted in an executable that was significantly slower – even upto ten times slower in some cases. These timing results are not included here.

A second test was run, now traversing seven arrays as members of a structure in the standard and refined loops, performing the following calculation emulating an FDTD update equation:

```
*p=0.9*(*p)+0.8*(*(q++)*(*(r++)-*(s++))-*(t++)*(*(u++)-*(v++)));
```

`p`, `q`, `r`, `s`, `t`, `u` `v` are pointers to an element in seven different arrays, either 3D or a vector. This test result given in Table IV shows the average of 20 runs, which indicates that the vector is the obvious choice for the Alpha computer but, unexpectedly, not for the HP D270.

TABLE III

TIME TAKEN TO TRAVERSE ONE ARRAY WITH DIMENSIONS $10 \times 20 \times 50$ 10^5 TIMES. 'STD.' REFERS TO THE STANDARD AND 'REF.' TO THE REFINED NESTED LOOPS.

Array	Static		Dynamic		Static		Dynamic	
	Std	Ref	Std	Ref	Std	Ref	Std	Ref
	Alpha				HP D270			
`***ar3d`	5.61	-	11.50	6.62	6.44	-	15.64	6.50
`*ar1d`	5.79	4.82	5.78	4.63	6.51	7.01	6.45	7.01
`s->ar3d`	4.85	-	11.38	6.17	6.45	-	21.10	6.49
`s->ar1d`	7.26	6.30	4.85	4.63	6.43	7.03	12.14	7.02
	Itanium 32-bit				Itanium 64-bit			
`***ar3d`	0.01	-	1.53	0.53	0.02	-	1.52	0.52
`*ar1d`	0.01	0.47	0.47	0.47	0.02	0.47	0.48	0.47
`s->ar3d`	0.47	-	2.91	0.54	0.47	-	2.90	0.52
`s->ar1d`	0.48	0.48	1.19	0.47	0.47	0.48	1.19	0.47
	AMD 32-bit				AMD 64-bit			
`***ar3d`	2.16	-	2.30	2.30	2.18	-	2.46	2.47
`*ar1d`	2.09	2.07	2.26	2.05	2.21	2.06	2.55	2.07
`s->ar3d`	2.17	-	2.34	2.29	2.21	-	2.46	2.86
`s->ar1d`	2.58	2.40	2.19	2.05	2.18	2.04	2.54	2.08
	Pentium				Sun			
`***ar3d`	1.22	-	1.24	1.38	12.58	-	31.39	12.93
`*ar1d`	1.29	1.23	1.30	1.23	12.42	12.06	12.60	13.20
`s->ar3d`	1.22	-	1.24	1.44	12.55	-	41.54	13.85
`s->ar1d`	1.29	1.23	1.29	1.24	15.59	14.37	26.92	13.88

Using the refined loop is clearly advantageous in the HP D270 and Itanium machines, but in the other machines the advantage is slight. The gcc-compiled executables, regardless of the machine, executed at roughly the same speed for all the array and loop configurations, the configuration of the vector in the refined loop only just emerging on the top.

From these results, it may be concluded that the traversing times for the two array types is compiler-dependent. It appears that all compiler optimisers are not yet able to produce efficient when looping code is in its standard form, a little help from the programmer may do wonders to execution speed. The gcc compiler runs at roughly the same speed for all the array configurations discussed. Some of the results reported in [1] [2] used the gcc 2.96 compiler with O2 as the optimisation option, with the result that the difference in traversing speed between the 3D array and vector in the refined loop was slightly bigger than that reported here. The use of newer gcc compilers and the O3 optimisation option does not change the general result.

TABLE IV

TIME TAKEN TO TRAVERSE SEVEN ARRAYS AS PART OF A DATA STRUCTURE, I.E., `s->a`, 10^5 TIMES USING THE STANDARD AND REFINED NESTED LOOPS.

Array size	1D Std	1D Ref	3D Std	3D Ref	1D Std	1D Ref	3D Std	3D Ref
	Alpha				HP D270			
$50 \times 20 \times 10$	74.03	73.76	107.12	108.35	1938.05	53.23	576.08	426.87
$50 \times 10 \times 20$	74.11	73.79	107.63	108.49	2771.63	371.21	577.30	64.27
$20 \times 50 \times 10$	72.23	71.01	113.89	114.70	2176.26	832.03	1119.32	70.19
$20 \times 10 \times 50$	72.44	71.07	114.02	114.90	1973.21	227.32	1440.19	641.56
$10 \times 50 \times 20$	75.95	74.64	127.99	128.83	1936.91	220.61	651.07	1065.09
$10 \times 20 \times 50$	76.28	74.51	127.83	128.90	2502.48	203.95	589.48	239.02
	AMD 32-bit				AMD 64-bit			
$50 \times 20 \times 10$	114.48	111.63	115.51	113.51	188.63	183.60	186.38	185.30
$50 \times 10 \times 20$	114.27	111.72	116.23	113.36	188.63	183.58	186.20	186.68
$20 \times 50 \times 10$	114.63	112.02	118.94	117.42	188.79	183.87	191.20	191.70
$20 \times 10 \times 50$	114.86	112.11	118.99	117.38	188.81	184.05	191.73	191.72
$10 \times 50 \times 20$	115.32	112.52	126.47	125.22	189.29	184.35	203.73	201.24
$10 \times 20 \times 50$	115.35	112.41	126.32	124.91	188.96	184.08	202.15	203.37
	Itanium 32-bit				Itanium 64-bit			
$50 \times 20 \times 10$	9.63	8.45	24.64	8.59	9.71	8.62	24.71	8.79
$50 \times 10 \times 20$	9.64	8.46	24.66	8.62	9.70	8.60	24.61	8.81
$20 \times 50 \times 10$	11.33	9.30	25.26	9.51	11.05	9.14	25.47	9.31
$20 \times 10 \times 50$	11.38	9.33	25.39	9.69	11.11	9.17	25.64	9.58
$10 \times 50 \times 20$	13.92	13.17	24.19	19.07	13.92	13.16	24.49	23.24
$10 \times 20 \times 50$	13.93	13.17	24.18	20.73	13.93	13.17	24.50	22.49
	Pentium 4				Sun			
$50 \times 20 \times 10$	218.94	216.62	222.07	219.14	169.83	172.76	187.02	178.35
$50 \times 10 \times 20$	217.18	215.06	220.44	217.99	170.22	172.49	189.29	181.09
$20 \times 50 \times 10$	218.09	215.90	220.76	219.36	170.87	172.14	186.24	183.70
$20 \times 10 \times 50$	218.22	216.33	220.85	219.81	172.73	173.07	191.01	184.90
$10 \times 50 \times 20$	217.06	214.64	220.86	219.92	173.21	175.64	199.89	191.38
$10 \times 20 \times 50$	216.82	214.73	220.10	220.46	173.98	175.51	201.57	192.09

IV. DISCUSSION

The optimiser in a C compiler is able to rearrange `for` loops, among other things, to obtain machine code that runs faster than the unoptimised code. The looping refinement discussed in this paper is one of the strategies used by compiler optimisers to produce efficient executables. Similarly, machine codes for accessing 3D arrays and vectors are arranged efficiently; a good compiler would automatically vectorise 3D arrays to produce a fast executable. Different compilers optimise code with a varying degree of success, which accounts for the differences in execution speed of the different array and looping configurations. So, writing `for` loops in the manner discussed provides the means to obtain code to efficiently traverse arrays independent of the optimiser power available today.

The reason why the `for` loop refining results in a more efficient executable program stems from the C language philosophy that the programmer is always right [6]. Pointer addressing is C's forte, but for the compiler's optimiser this is a problem. The optimiser cannot always be sure that the memory pointed to by the pointer is legal, or that there has been intentional or unintentional overlapping of memory allocations (called memory aliasing). So, when optimising a `for` loop code fragment, the C optimiser will never change the order in which data is loaded to or stored from the registers it uses, which often results in slower executable code. Changing the order of execution in the code by hand clarifies the situation, so allowing better optimisation. The current C standard ISO/IEC9899:TC2 approved in 2004, which contains corrections to the ISO/IES9899:1999 standard, already addresses this situation by allowing the programmer to give the optimiser greater freedom, where desired. It appears that the Gnu compilers used in this study use are able to cope with this situation, which explains why the two arrays in the two loops executed at similar speeds. Until other compiler vendors implement more powerful optimisers, refining the loops, as discussed above, and using other methods, such as those discussed in [3], is a way to squeeze out better performance from computationally intense programs.

V. Conclusions

A 3D array and a vector, implemented in C, were traversed in two differently realised nested loops with the FDTD algorithm in mind. Traversing times for the two array types, indicating program efficiency, show that the choice in array type and looping code is compiler dependent. Although the compiler optimises the program for speed, manipulating the loops using compiler programming techniques generally results in more efficient code. However, for the Gnu C compiler versions 3.3 and above the choice of array type and the `for` looping code is not very significant. A macro language may be used to program the algorithm allowing development of easily maintainable code having the optimum data and program structure on several platforms.

References

[1] L. de Jussilainen Costa, *Incorporating Lumped Elements into an Efficiently Implemented FDTD-Based Electromagnetic Simulator*, Licentiate's thesis, Helsinki University of Technology, Department of Electrical and Telecommunications Engineering, September 2005.

[2] L. R. de Jussilainen Costa, “Implementing Efficient Array Traversing for FDTD-Lumped Element Cosimulation,” in *Progress in Industrial Mathematics at ECMI 2004*, Proceedings of the 13th European Conference on Mathematics for Intustry, European Consortium for Mathematics for Industry, Springer, June 21-25 2004.

[3] K. Dowd and C. Severance, *High Performance Computing,* Second Edition, O’Reilly & Associates, Inc., Cambridge, 1998.

[4] B. W. Kernighan and D. M. Ritchie, *The C Programming Language,* Second edition, Prentice Hall PTR, New Jersey, 1988.

[5] T. Namiki, “A New FDTD Algorithm Based on Alternating-Direction Implicit Method,” *IEEE Transactions on Microwave Theory and Techniques*, vol. MTT-47, no. 10, pp. 2003–2007, October 1999.

[6] A. Polyakov, *HPC (High Performance Computing) in C*, February 2006, `http://fy.chalmers.se/˜appro/hpc_in_c.html`.

[7] W. H. Press, S. A. Teukolsky, W. T. Vettering, and B. P. Flannery, *Numerical Recipes in C: The Art of Scientific Computing,* Second Edition, Cambridge University Press, New York, 1992.

[8] W. Sui, *Time-Domain Computer Analysis of Nonlinear Hybrid Systems*, CRC Press, Chelmsford, Massachusetts, 2002.

[9] A. Taflove and S. C. Hagness, *Computational Electrodynamics: the Finite-Difference Time Domain Method,* Second edition, Artech House, Boston, 2000.

[10] J.-P. Tremblay and P. G. Sorenson, *The Theory and Practice of Compiler Writing,* McGraw-Hill Book Company, Singapore, 1985.

[11] K. S. Yee, “Numerical Solution of Initial Boundary Value Problems Involving Maxwell’s Equations in Isotropic Media,” *IEEE Transactions on Antennas and Propagation*, vol. AP-14, no. 3, pp. 302–307, May 1966.

The 23rd Annual Review of Progress in Applied Computational Electromagnetics

March 19-23, 2007
Verona, Italy

Symposium General Chair: **Sami Barmada**

Symposium Technical Chair: **Atef Elsherbeni**

Vice Chair: **Antonino Musolino**

Short Course Chair: **Rocco Rizzo**

Administrative Assistants: **Mohamed Al Sharkawy**

and

Matthew Inman

February 22, 2007

Conference Sponsors

Gold Level

Schmid & Partner Engineering AG

Silver Level

FEKO
WIPL-D

Conference Exhibitors

FEKO
TICRA

ACES 2007 Short Courses

Title and Presenter	Room

Monday, March 19, 2007 – Full Day
Conservative Finite Difference Method: A Recipe for Combining the Simplicity of FDM with the Flexibility of FEM
Alireza Baghai-Wadji

Monday, March 19, 2007 – Half Day (AM Session)
The Iterative Multi-Region Technique for Large Scale EM Problems
Atef Elsherbeni

Monday, March 19, 2007 – Half Day (PM Session)
Efficient Modeling of Electrically Large Structures
Branko Kolundzija

Monday, March 19, 2007 – Half Day (PM Session)
Surface Impedance Boundary Conditions
Luca Di Rienzo and Nathan Ida

Monday, March 19, 2007 – Half Day (PM Session)
Modelling Techniques for Small Antennas and Metamaterials
Yang Hao and Raj Mittra

ACES 2007 Invited Plenary Talks

Title and Presenter	Room
Tuesday, March 20, 2007	
"Integral Equations in Computational Electromagnetics" **Piergiorgio L. E. Uslenghi**	**Aida**
"Overcoming the Multi-Scale Problems in EMI/EMC Analysis" **Sergey Yuferev**	**Aida**
Wednesday, March 21, 2007	
"The Life of James Clerk Maxwell" **James Rautio**	**Aida**
"Multi-Level Modeling for Complex Microwave and High-Speed Design" **Wolfgang J. R. Hoefer**	**Aida**
Thursday, March 22, 2007	
"Computational Electromagnetics in Biomedical Problems: Challenges and Some Solutions" **Maria A. Stuchly**	**Aida**
"Computational Electromagnetics Applied to Portable Antenna Research" **Antonio Faraone**	**Aida**

ACES 2007 Sessions Overview

Session Title	Room
Tuesday, March 20, 2007 (Sessions 1-11)	
1- Plenary Session - A	Aida
2- Advanced Computational Techniques in Electromagnetics - 1	Aida
3- EM Applications in Medicine	Rigoletto 1&2 Atto
4- Metamaterial Structures with Application to Guided-Wave Electromagnetics and Antennas	Nabucco 2 Atto
5- Modeling and Applications of Microwave Metamaterial	Nabucco 1 Atto
6- Six Port Technology in Software Radio Wireless Communication Systems	Turandot
7- Numerical Challenges in Modeling Metamaterials	Turandot
8- FEKO Modeling and Analysis	Rigoletto 1&2 Atto
9- Student Paper Competition	Nabucco 1 Atto
10- Electromagnetic Modeling, Inversion and Applications	Nabucco 2 Atto
11- Modeling EM in Maritime Enviroment	Aida
Wednesday, March 21, 2007 (Sessions 12-22)	
12- Plenary Session - B	Aida
13- Advanced Computational Techniques in Electromagnetics - 2	Rigoletto 1&2 Atto
14- Advances in Electromagnetic Modeling by WIPL-D Software	Aida
15- New Techniques for Computational Electromagnetic Validation	Nabucco 2 Atto
16- Computational RF and Thermal Dosimetry	Turandot
17- Efficient Numerical Solutions of Large Multi-dimensional Inverse Scattering Problems	Nabucco 1 Atto
18- Computational Methods for Nondestructive Evaluation and Materials Characterization	Nabucco 2 Atto
19- CST Modeling and Analysis	Aida
20- Modeling of Biomedical Problems - 1	Rigoletto 1&2 Atto
21- Computer Simulation of Electromagnetic-System Testing	Turandot
22- MEFiSTo Modeling and Analysis	Nabucco 1 Atto

ACES 2007 Sessions Overview

Session Title	Room
Thursday, March 22, 2007 (Sessions 23-34)	
23- Plenary Session - C	Aida
24- Nature-Based Stochastic Optimization Methods	Turandot
25- Modeling of Biomedical Problems - 2	Nabucco 1 Atto
26- MoM and Applications	Rigoletto 1&2 Atto
27- Poster Sessions 1	Poster Hall
28- Poster Sessions 2	Poster Hall
29- Detection and Imaging: Theoretical, Algorithmic, Technology and System Advances	Nabucco 2 Atto
30- SEMCAD X: Recent Modeling Advances for Virtual Prototyping	Aida
31- High Power Microwave	Turandot
32- Macromodeling for EMC and SI Complex Systems	Rigoletto 1&2 Atto
33- Advanced EMC Modeling	Nabucco 1 Atto
34- Advanced Modeling Techniques and The Application of Microwave Devices	Turandot
Friday, March 23, 2007 (Sessions 35-43)	
35- Ill-Posed Electromagnetic Inverse Problems: Theory and Applications	Rigoletto 1&2 Atto
36- Wideband and Multiband Antennas	Turandot
37- Innovation in the Macromodeling of High Speed Interconnects	Nabucco 2 Atto
38- Advances in Conformal Time-Domain Methods: Finite-Volume and Discontinuous Galerkin	Nabucco 1 Atto
39- Analysis and Design of Antennas for Wireless Communications	Aida
40- Applications Based on FDTD	Turandot
41- Computational Electromagnetics for Photonics	Rigoletto 1&2 Atto
42- Imaging, Computation and Inverse Methods in Biomedicine	Nabucco 2 Atto
43- Microwave and Optical Devices, Propagation	Nabucco 1 Atto

ACES Conference 2007

Day	Time	Aida	Turandot	Nabucco 1 Atto	Nabucco 2 Atto	Rigoletto 1&2 Atto	Poster Hall
Monday, March 19	8:00 - 5:00	FD Method - Alireza - SC					
	8:00 - 12:00		IMR - Elsherbeni - SC				
	1:00 - 5:00			Large S. - Branko - SC	IBC - Luca & Nathan - SC	Small Ante. - Mittra & Hao - SC	
Tuesday, March 20	8:00 - 8:15	**ACES Business Meeting**					
		Prof. O. Mohamed					
	8:15 - 8:30	**Welcome, Prof. S. Barmada**					
	8:30 - 9:30	**Prof. Piergiorgio Uslenghi**					
	9:30 - 10:30	**Prof. Sergey Yuferev**					
	10:30 - 11:00	**Break**					
	11:00 - 1:00	Adavanced Computational - 1	Six port Technology	Modeling and Appl. of Microwave	Metamatrial Structures - GW	EM Applications in Medicine	
	1:00 - 2:30	Lunch					
	2:30 - 4:30	Adavanced Computational - 1	Numerical Challenges in Mod.	Student Paper Competition	Metamatrial Structures - GW	FEKO Modeling and Anal.	
	4:30 - 4:50	Break					
	4:50 - 6:30	Modeling EM in Maritime	Numerical Challenges in Mod.	Student Paper Competition	Electromagnetic Modeling, Inv.	FEKO Modeling and Anal.	
Wednesday, March 21	8:30 - 9:30	**Prof. James Rautio**					
	9:30 - 10:30	**Prof. Wolfgang Hoefer**					
	10:30 - 11:00	**Break**					
	11:00 -1:00	Modeling by WIPL-D	Computational RF and Thermal	Multi-dimensional Inverse Scattering	Compu. Electromagnetic Valida.	Adavanced Computational - 2	
	1:00 - 2:30	Lunch					
	2:30 - 4:30	CST Modeling and Analysis	Computational RF and Thermal	Multi-dimensional Inverse Scattering	Nondestructive Evaluation	Modeling of Biomedical - 1	
	4:30 - 4:50	Break					
	4:50 - 6:30	CST Modeling and Analysis	Computer simulation - Testing	MEFiSTo Modeling and Analysis	Nondestructive Evaluation	Modeling of Biomedical - 1	
Thursday, March 22	8:30 - 9:30	**Prof. Maria Stuchly**					
	9:30 - 10:30	**Prof. Antonio Faraone**					
	10:30 - 11:00	**Break**					
	11:00 -1:00	SEMCAD X	Nature-Based Stochastic	Modeling of Biomedical - 2	Detection and Imaging	MoM and Applications	Poster Sessions - 1
	1:00 - 2:30	Lunch					
	2:30 - 4:30	SEMCAD X	High Power Microwave	Advanced EMC Modeling	Detection and Imaging	Macromodeling for EMC - SI	Poster Sessions - 2
	4:30 - 4:50	Break					
	4:50 - 6:30		Advanced Modeling Techniqu	Advanced EMC Modeling	Detection and Imaging	Macromodeling for EMC - SI	
Friday, March 23	8:30 - 10:30	Wireless Communications	Wideband and Multiband Ant	Advanced in Conformal Time-Domain	Innovation in the Macromodel	ILL-Posed Electomagnetic Inverse	
	10:30 - 11:00	Break					
	11:00 -1:00	Wireless Communications	Applications Based on FDTD	Advanced in Conformal Time-Domain	Innovation in the Macromodel	Comp. Electromagnetics - Photonics	
	1:00 - 2:30	Lunch					
	2:30 - 4:30	Wireless Communications	Applications Based on FDTD	Microwave, Optical Devices	Imaging, Computation and Inv.	Comp. Electromagnetics - Photonics	

ACES 2007 Technical Program

The 23rd Annual Review of Progress in Applied Computational Electromagnetics
Verona, Italy
March 19-23, 2007

Monday, March 19

8:00-11:00 **Short Course Registration**

8:30-5:00 **Short Courses**

12:00-5:00 **Conference Registration**

5:00-7:00 **ACES Board of Directors Meeting**

7:00 PM **Reception**

Tuesday, March 20

8:00-5:00 **Conference Registration**

8:00-5:00 **Exhibitors**

Room: **Aida**
8:00-8:15 **ACES Business Meeting**
Osama Mohamed

8:15-8:30 **Welcome**
Sami Barmada

8:30-10:30 **Plenary Session - A** **Session 1**

8:30-9:30 "Integral Equations in Computational Electromagnetics"
Piergiorgio L. E. Uslenghi

9:30-10:30 "Overcoming the Multi-Scale Problems in EMI/EMC Analysis"
Sergey Yuferev

10:30-11:00 Break

Room: **Aida** **Session 2**
11:00-4:30 **Advanced Computational Techniques in Electromagnetics - 1**
Session Organizer: Alireza Baghai-Wadji
Session Chairs: Alireza Baghai-Wadji and Joe LoVetri

11:00-11:20 "A Dielectric-Scalable FDTD Algorithm for Adaptively Modeling Inhomogeneous Media"
Mohammed F. Hadi

11:20-11:40 "One Hybrid Method Application on Anisotropic Strip Lines Determination"
Nebojša B. Raičević and Saša S. Ilić

11:40-12:00	"A Hybrid Implicit/Explicit Finite-Difference Scheme for the Numerical Solution of the Vector Parabolic Equation Governing Electromagnetic Field Propagation in Straight and Curved Rectangular Tunnels" Paolo Bernardi, Diego Caratelli, Renato Cicchetti, and Orlandino Testa
12:00-12:20	"Improving the Parallel Efficiency of the SPAI Preconditioner in FEKO" Johannes J. van Tonder_ and Ulrich Jakobus
12:20-12:40	"Genetic Optimization for Optimum 3G Network Planning: an Agent-Based Parallel Implementation" Beatrice Di Chiara, Alessandra Esposito, Stefano Luceri, and Luciano Tarricone
12:40-1:00	"Application of the Energy-Based Stability Condition on the Spatial Wavelet-Transformed FDTD Scheme" Winfried Bilgic, Ingo Wolff , and Daniel Erni
1:00-2:30	Lunch
2:30-2:50	"Modeling MC Effects between Antenna Array-Elements in a Microcellular Environments Using FMM" S. Cookey Ekpo, Armstrong Sunday and Edidiong-Obong Ekpo
2:50-3:10	"2D Canonical and Perturbed Quantum Potential-Well Problem: A Universal Function Approach" Istiaque Ahmed and Alireza Baghai-Wadji
3:10-3:30	"Perspective of the Uniaxial Wavelet-Transformed FDTD Scheme" Winfried Bilgic, Ingo Wolff, and Daniel Erni
3:30-3:50	"A Novel Formulation of the Volume Integral Equation for Electromagnetic Scattering" W. C. Chew and L. E. Sun
3:50-4:10	"FMM Based MOR Applied to 2-D Electromagnetic Scattering Problems" Ozgur Tuncer, Dzianis Lukashevich and Peter Russer
4:10-4:30	"On the Calculation of Linearly-Perturbed Harmonic Oscillator" P. Peidaee and A. R. Baghai-Wadji

Room: **Rigoletto 1&2 Atto** **Session 3**

11:00-1:00 **EM Applications in Medicine**

Session Organizers: Erdem Topsakal and Ahmed Kishk

Session Chairs: Erdem Topsakal and Magda El-Shenawee

11:00-11:20	"Hyperthermia a Treatment for Cancer: Maturation of its Clinical Application" Gerard C van Rhoon and J. van der Zee
11:20-11:40	"Heating of Deep Seated Tumours using Microwaves Radiation" Hana Trefn´a and Mikael Persson
11:40-12:00	"Small Biocompatible Antennas for In-Body Wireless Data Telemetry" Erdem Topsakal, Tutku Karacolak, and Jose Pvillalta
12:00-12:20	"Interpreting Artificial Neural Network Output for the Microwave Detection of Breast Cancer" Douglas A. Woten, Magda El-Shenawee, and John Lusth
12:20-12:40	"Measurement of the Entrainment of Bioelectric Sources in the Epileptic Brain from Scalp EEG" U. Aguglia, F. La Foresta, N. Mammone, F.C. Morabito and M. Versaci
1:00-2:30	Lunch

Room: **Nabucco 2 Atto** **Session 4**

11:00-4:30 **Metamaterial Structures with Application to Guided-Wave Electromagnetics and Antennas**

Session Organizers: Alexander Yakovlev and Giampiero Lovat

Session Chairs: Alexander Yakovlev and Giampiero Lovat

11:00-11:20 "Physics of Wave Propagation in Miniaturized Metamaterial-based Waveguides: Analytical, Numerical and Experimental Investigation"
Silvio Hrabar, Ivan Paskovic, and Bruno Margitic

11:20-11:40 "Cylindrical Metamaterial Sub-Wavelength Antennas Supporting Higher-Order Leaky Modes for Cellular and Satellite Applications"
Andrea Alù1, Filiberto Bilotti, Nader Engheta, and Lucio Vegni

11:40-12:00 "Split Ring Resonator Slab Modeling for a Metamaterials Loaded Loop Antenna"
Chris Fazi, Shouyuan Shi, Iftekhar Mirza, and Dennis Prather

12:00-12:20 "Using Eelectromagnetic Band Gap (EBG) Superstrate Layer to Enhance the Bandwidth and Gain of a Dual Band Microstrip Patch Antenna"
Farshad Keshmiri, and Majid Tayarani

12:20-12:40 "Understanding the Electromagnetic Characteristics of Real Metamaterials via Rigorous Field Simulation"
Raj Mittra

1:00-2:30 Lunch

2:30-2:50 "Rigorous Analysis of Metasurfaces Composed of Wire Arrays with Linear and Non-Linear Inclusions"
Oleksandr Malyuskin, Alexander G. Schuchinsky, and Vincent F. Fusco

2:50-3:10 "Loaded Transmission-Line Meshes as Artificial Materials for some Antenna Applications"
P. Ikonen, P. Alitalo, and S. Tretyakov

3:10-3:30 "Numerical Modeling of Leaky-Wave Propagation in Grounded Wire-Medium Slabs"
P. Burghignoli, G. Lovat, F. Capolino, D. R. Jackson, and D. R. Wilton

Room: **Nabucco 1 Atto** **Session 5**

11:00-1:00 **Modeling and Applications of Microwave Metamaterial**

Session Organizers: Yang Hao and Raj Mittra

Session Chairs: Raj Mittra and Yang Hao

11:00-11:20 "Experimental Verification of a 5-Order Bandpass E-Plane Filter with EBG Resonators"
George Goussetis and Constantin Constantinides

11:20-11:40 "On Effective Material Parameters of Metamaterials"
C.R. Simovski and S.A. Tretyakov

11:40-12:00 "Stability and Numerical Dispersion Analysis for A Spatially Dispersive Finite-Difference Time-Domain Method"
Yan Zhao, Pavel Belov, and Yang Hao

12:00-12:20 "Finite Element Modeling of Dual-core Photonic Crystal Fiber"
Kaisar R. Khan and Thomas X. Wu

12:20-12:40 "Numerical Implementation of the Array Scanning Method (ASM) for 2DPeriodic Materials"
Filippo Capolino, David R. Jackson, and Donald R. Wilton

12:40-1:00 "Fast Method to Compute an Efficient Basis to Simulate Metamaterials with Macro Basis Functions"
Xavier Radu and Christophe Craeye

1:00-2:30 Lunch

Room: **Turandot** **Session 6**

11:00-1:00 **Six Port Technology in Software Radio Wireless Communication Systems**
Session Organizers: R. G. Bosisio, M. Bozzi, and M. R. Soleymani
Session Chairs: R. G. Bosisio and M. Bozzi

11:00-11:20 "Six-Port Direct QPSK Modulator at VHF band"
Xiao Hu, Serioja O. Tatu, and Renato G. Bosisio

11:20-11:40 "Calibration of Six-Port Receivers by Applying Linear Equalization"
Thomas Eireiner, Matthias Wetz, Qingxia Lu, Christian Pietsch, Ivan Periša, and Thomas Müller

11:40-12:00 "Numerical Model of Six-port and its Applications"
Yanyang Zhao, Jean-François Frigon, Ke Wu, and Renato G. Bosisio

12:00-12:20 "A Compact Multi-Layer Analog Front-End of a Six-Port Receiver"
Alexander Koelpin, Sebastian Winter, Robert Weigel

12:20-12:40 "Review of Six-Port Interferometer Technology"
Yansheng Xu, Luca Gerardi, Yanyang Zhao, Maurizio Bozzi, Luca Perregrini, Ke Wu, and Renato G. Bosisio

12:40-1:00 "A Direct and Broadband "n-port" Demodulator for Wireless Communication Systems"
Sara Abou Chakra and Beatriz Amante García

1:00-2:30 Lunch

Room: **Turandot** **Session 7**

2:30-6:30 **Numerical Challenges in Modeling Metamaterials**
Session Organizers: F. Bilotti, F. Capolino, C. Craeye, S. Tretyakov, and L. Vegni
Session Chair: C. Craeye

2:30-2:50 "New Homogenization Approach for the Numerical characterization of Periodic Microstructured Metamaterials"
Mário Silveirinha

2:50-3:10 "Efficient MoM Analysis of Metamaterials Involving Dielectric Structures"
Xavier Dardenne, Nicolas Guerin, and Christophe Craeye

3:10-3:30 "Numerical Investigation of Beaming from Simple Sources in Grounded Wire-Medium Slabs"
P. Burghignoli, G. Lovat, F. Capolino, D. R. Jackson, and D. R. Wilton

3:30-3:50 "On the Effects of Numerical Material Parameters and Switching Time in FDTD Modelling of Left-Handed Metamaterials"
Yan Zhao, Pavel Belov, and Yang Hao

3:50-4:10 "Artificial Magnetic Conductors for Wideband Antenna Applications"
Gopinath Gampala and Alexander B. Yakovlev

4:10-4:30 "Investigation of Transmission Properties of Multilayer Metamaterial Structures with MLFMA"
Levent GÄurel, ÄOzgÄur ErgÄul, and Alper ÄUna

4:30-4:50 Break

4:50-5:10 "Numerical Modeling of Metamaterials in Electromagnetics Using the Finite Element Method"
Kezhong Zhao, Seung-Cheol Lee, Vineet Rawat, and Jin-Fa Lee

5:10-5:30 "Effective Description and Power Balance of Metamaterials"
Chryssoula A. Kyriazidou, Harry F. Contopanagos, and Nicolaos G. Alexopoulos

5:30-5:50 "Some Considerations on the Reliability of Finite Element Simulators for Problems Involving Metamaterials"
Gaia Cevini, Giacomo Oliveri and Mirco Raffetto

5:50-6:10 "Exact Modelling of a Finite Sample of Metamaterial"
Ignace Bogaert and Femke Olyslager

Room: **Rigoletto 1&2 Atto** **Session 8**

2:30-6:30 **FEKO Modeling and Analysis**
Session Organizer: C. J. Reddy
Session Chairs: Randy L. Haupt and Ulrich Jakobus

2:30-2:50 "The Use of FEKO for the Modeling of Test Set-ups for Radiated Susceptibility"
Flavia Grassi, Giordano Spadacini, Filippo Marliani, and Sergio A. Pignari

2:50-3:10 "Estimation of Radiated Power Density from a Large-scale Phased Array Antenna using FEKO"
Masahiro Tanabe and Yasuharu Masuda

3:10-3:30 "FEKO Simulation of a Wedge Mounted Four Element Array Antenna"
Steven Weiss, Ozlem Kilic, Robert Dahlstrom and Chad Patterson

3:30-3:50 "ICNIRP Compliance Investigation for TETRA Radio System"
Ernst H. Burger, Valpré Kellerman, Marnus J. van Wyk and Frans J. C. Meyer

3:50-4:10 "FEKO Simulations and Measurements of Electrical Field Distributions around a Car"
Yoshihide Yamada, Kouichi Tanoshita, Kouji Nakatani and Satoru Horiuchi

4:30-4:50 Break

4:50-5:10 "Art as Antenna: A Characterization of the Miami Hyatt-Regency Lobby Sculpture Using EMSS-FEKO™"
B. David Moore and P.E.

5:10-5:30 "A Holographic Dipole from a Monopole Mounted in a Dual Parabolic Reflector"
Keith Snyder

5:30-5:50 "Recent Extensions in FEKO: FEM Excitations, Cable Coupling, and Ideal Receiving Antennas"
Ulrich Jakobus, Marianne Bingle, Johann J. van Tonder, and Frank Illenseer

5:50-6:10 "Aircraft Antenna Modeling and Analysis"
David W. Estlick and Christopher Beaupre

6:10-6:30 "Interfacing FEKO and MATLAB for Microstrip Antenna Design"
Randy L. Haupt

Room: **Nabucco 1 Atto** **Session 9**

2:30-6:30 **Student Paper Competition**

Session Chairs: Amir Zaghloul and Allen Glisson

2:30-2:50 "Design and Modeling of an RFID Reader Antenna Using Full-Wave Time-Domain Numerical Techniques"
Anya Traille, Terence Wu, and Manos M. Tentzeris

2:50-3:10 "Design and Simulation of a Broadband LNA for a C Band Pulse Altimeter"
Robab Kazemi, Ramezan A. Sadeghzadeh, and Reza Fatemi

3:10-3:30 "Space Use Radial Line Slot Antenna with Honeycomb Structure"
Hideki Ueda, Jiro Hirokawa, Makoto Ando, Yukio Kamata, and Osamu Amano

3:30-3:50 "Synthesized Antenna Arrays for Future Mobile Networks"
J. Pontes, A. Lambrecht, and W. Wiesbeck

3:50-4:10 "A Delta Method Based Technique to Determine Mean Value and Variance of the Response of an Electromagnetic Device with Uncertain Parameters"
Mauro Tucci, Antonino Musolino, and Giancarlo Becherini

4:10-4:30 "Practical Implementation of a CPML Absorbing Boundary for GPU Accelerated FDTD Technique"
Matthew J. Inman, Atef Z. Elsherbeni, James G. Maloney, and Bradford N. Baker

4:30-4:50 Break

4:50-5:10 "Aligning Curves for More Accurate Curve Comparisons"
Robert S. Edwards, Martin P. Robinson, John F. Dawson, Andy C. Marvin, and Stuart J. Porter

5:10-5:30 "Efficient Time-domain Sensitivity Analysis Using Coarse Grids"
Yunpeng Song, Natalia K. Nikolova, and Mohamed H. Bakr

5:30-5:50 "Application of the NCP Parameter-Choice Method to the General-Form Tikhonov Regularization of 2-D/TM Inverse Scattering Problems"
Puyan Mojabi and Joe LoVetri

5:50-6:10 "Parallel High-Order EM-FVTD on an Unstructured Mesh"
Ian Jeffrey, Dmitry K. Firsov, Colin Gilmore, Vladimir Okhmatovski, and Joe LoVetri

Room: **Nabucco 2 Atto** **Session 10**

4:50-6:30 **Electromagnetic Modeling, Inversion and Applications**

Session Organizers: Ganquan Xie, Michael Oristaglio, and Jianhua Li

Session Chairs: Shirook Ali and L. Botha

4:50-5:10 "Estimating Distributed Objects Inside Buildings by Moving Sensors"
Marija M. Nikolic, Arye Nehorai, and Antonije R. Djordjevic

5:10-5:30 "Short-pulse Electromagnetic Scattering from Buried Perfectly-conducting Cylinders"
Fabrizio Frezza, Pasquale Martinelli, Lara Pajewski, and Giuseppe Schettini

5:30-5:50 "Verification of the CADRCS RCS Tool for NCTR Work"
L. Botha

5:50-6:10 "A Two-Step Procedure for Obstacle Characterization under a Rough Surface"
O. Cmielewski, H. Tortel, A. Litman and M. Saillard

Room: **Aida** **Session 11**

4:50-6:30 **Modeling EM in Maritime Enviroment**
Session Organizers: Ozlem Kilic and Jerry Smith
Session Chairs: Ozlem Kilic and Jerry Smith

4:50-5:10 "Role of Multiple Scattering in the Radar Observations of Sea Surface at Small Grazing Angles"
Valerian I. Tatarskii and Viatcheslav V. Tatarskii

5:10-5:30 "Modeling Electromagnetic Wave Interactions with Sea Spray"
Ozlem Kilic

5:30-5:50 "Effect of Shadowing on Propagation over Rough Water"
Jerry R. Smith and Mark S. Mirotznik

5:50-6:10 "Novel Hardware Platforms for Shipboard Modeling of Electromagnetic Phenomena"
Dennis W. Prather, James P. Durbano, Eric J. Kelmelis

6:10-6:30 "Investigation of Statistical Properties of Range-Resolved, Low-Grazing Sea Clutter using 2-D Direct Numerical Scattering Simulations"
Jakov V. Toporkov and Mark A. Sletten

Wednesday, March 21

8:00-5:00 **Conference Registration**

8:00-5:00 **Exhibitors**

Room: **Aida**

8:30-10:30 **Plenary Session - B** **Session 12**

8:30-9:30 "The Life of James Clerk Maxwell"
James Rautio

9:30-10:30 "Multi-Level Modeling for Complex Microwave and High-Speed Design"
Wolfgang J. R. Hoefer

10:30-11:00 Break

Room: **Rigoletto 1&2 Atto** **Session 13**

11:00-1:00 **Advanced Computational Techniques in Electromagnetics - 2**
Session Organizer: Alireza Baghai-Wadji
Session Chairs: Alireza Baghai-Wadji and Mohammed Hadi

11:00-11:20 "Phase-Matching the Hybrid M24/S_{22} FDTD Algorithm"
Mohammed F. Hadi and Rabih K. Dib

11:20-11:40 "Convergence Acceleration Method for the Radiation of Vertical Electric Dipole on Large Sphere"
Ting Fei, Le-Wei Li, and Tat Soon Yeo

11:40-12:00 "Computation Method for Cutoff Frequency and Modal Field of Waveguides of Arbitrary Cross Section"
Nguyen Hoang Hai, Yoshinori Namihira, Kaijage Shubi, S. M. Abdur Razzak, and Feroza Begum

12:00-12:20 "A Super-Phase Coherent 3D High-Order FDTD Algorithm"
Mohammed F. Hadi

12:20-12:40 "On the Determination of the Eigenpairs of 1D Positive Differential Operators with Periodic Boundary Conditions"
A. Rezaee and A. R. Baghai-wadji

12:40-1:00 "Diakoptic Surface Integral Equation Formulation Applied to 3-D Electrostatic Problems"
Dragan I. Olćan, Ivica M. Stevanović, Juan R. Mosig, and Antonije R. Djordjević

1:00-2:30 Lunch

Room: **Aida** **Session 14**

11:00-1:00 **Advances in Electromagnetic Modeling by WIPL-D Software**

Session Organizer: Branko Kolundzija

Session Chairs: Branko Kolundzija and Saad Tabet

11:00-11:20 "Interfacing WIPL-D with Mechanical CAD Software"
Nataliya Bliznyuk and Bojan Janic

11:20-11:40 "Conformal Antenna Solutions for DMB terminal at S Band"
Saša Dragaš and Alberto Pellon

11:40-12:00 "Slotted Coaxial Line and Associated Measurement System for Determination of Dielectric Properties of Gas Plasma"
Ralf Klukas and IRK-Dresden

12:00-12:20 "Analysis of a Physically and Electrically Large UHF Antenna Array using WIPL-D"
Saad N. Tabet, Oliver E. Allen and John S. Asvestas

12:20-12:40 "Two Element Phased Array Dipole Antenna on Finite EBG Ground Plane"
Mitsuo Taguchi, Shinya Tanaka, and Kazumasa Tanaka

12:40-1:00 "Time-Domain Response of 3-D Structures Calculated Using WIPL-D"
Dragan I. Olćan, Marija M. Nikolić, Branko M. Kolundžija, and Antonije R. Djordjević

1:00-2:30 Lunch

Room: **Nabucco 2 Atto** **Session 15**

11:00-1:00 **New Techniques for Computational Electromagnetic Validation**

Session Organizer: Antonio Orlandi

Session Chairs: Antonio Orlandi and Alistar Duffy

11:00-11:20 "Modeling Nonlinear Interactions between RF and Optical Fields In Traveling Wave Modulators using a Hybrid Approach"
A. Vukovic, E.V. Bekker, P. Sewell, T. M. Benson, J. Paul, N. K. Sakhnenko and A. G. Nerukh

11:20-11:40 "Using FSV to Compare Noisy Datasets"
J. Knockaert, J. Peuteman, J. Catrysse, R. Belmans

11:40-12:00 "The Importance of Proper Model Validation for EMI/EMC and Other CEM Applications"
Bruce Archambeault

12:00-12:20 "Quantifying EMC Measurement Accuracy Using Feature Selective Validation"
Alan Denton, Anthony Martin, and Alistair Duffy

12:20-12:40 "A Statistical Toolkit for Validation"
Alistair Duffy and Antonio Orlandi

12:40-1:00 "Development of a Benchmarking System for Hardware and Software-Based Computational Electromagnetic Solvers"
James P. Durbano, Fernando E. Ortiz, Ahmed S. Sharkawy, and Michael R. Bodnar

1:00-2:30 Lunch

Room: **Turandot** **Session 16**

11:00-4:30 **Computational RF and Thermal Dosimetry**
Session Organizers: Jafar Keshvari and Antonio Faraone
Session Chairs: Jafar Keshvari and Antonio Faraone

11:00-11:20 "Thermal Elevation in Human Eye due to Walkie-Talkie Source"
C. Buccella, V. De Santis, and Mauro Feliziani

11:20-11:40 "Standardization of the Computational Methodology for Assessing Human Exposure to RF Emitters Inside and Nearby Automotive Vehicles"
Antonio Faraone, Giorgi Bit-Babik, and Jagadish Nadakuduti

11:40-12:00 "RF-Induced Temperature Elevations in the Inner Ear and Deep Brain Tissue Caused by Handheld Devices in the 400 MHz to 1850 MHz Range"
G. Schmid, R. Überbacher, T. Samaras

12:00-12:20 "Effect of the Hand in SAR Compliance Tests of Body Worn Devices"
Andrea Schiavoni and Mauro Francavilla

12:20-12:40 "Hyperthermia Treatment Modeling: is Prescriptive, Quantitative SAR Dosimetry to be Preferred over Thermal Dosimetry?"
M. de Bruijne, T. Samaras and G. C. Van Rhoon

12:40-1:00 "Temperature Rise in Human Tissue from SAR"
Christopher W. Penney and Raymond J. Luebbers

1:00-2:30 Lunch

2:30-2:50 "Computational Evaluation of SAR and Temperature Changes in the Head Models Carrying Metallic Implants following Exposure to 900, 1800 and 2450 MHz Dipole Near Field"
Hanna Matikka, Reijo Lappalainen and Jafar Keshvari

2:50-3:10 "Temperature Distribution in the Eye: Comparing Infrared Exposure to Radiofrequency Exposure"
V.M.M. Flyckt, B.W. Raaymakers, H. Kroeze and J.J.W. Lagendijk

3:10-3:30 "Numerical Analysis of a Printed E-Field Probe Array Used for Rapid SAR Assessment"
Benoît Derat, Andrea Cozza, Olivier Merckel, and Jean-Charles Bolomey

3:30-3:50 "The “Virtual Family” Project – Development of Anatomical Whole-Body Models of Two Adults and Two Children"
Andreas Christ, Wolfgang Kainz, Eckhart Hahn, Katharina Honegger, Jianxiang Shen, Wolfgang Rascher, Rolf Janka, Werner Bautz, Berthold Kiefer, Peter Schmitt, Hans-Peter Hollenbach, Ji Chen, Anthony Kam, Esra Neufeld, Michael Oberle, and Niels Kuster

Room:	**Nabucco 1 Atto** **Session 17**
11:00-4:30	**Efficient Numerical Solutions of Large Multi-dimensional Inverse Scattering Problems** **Session Organizers: Dominique Lesselier and Ann Franchois** **Session Chairs: Dominique Lesselier and Ann Franchois**
11:00-11:20	"New Solution Strategies for Solving Large Scale 3D EM Inverse Problems" Gregory A Newman and Michael Commer
11:20-11:40	"On Combining Model Reduction and Gauss-Newton Algorithms for Inverse Frequency Domain Maxwell Equation" Vladimir Druskin and Mikhail Zaslavsky
11:40-12:00	"Imaging Damaged Parts of Buried Objects from Electromagnetic Cauchy Data" Fioralba Cakoni and Houssem Haddar
12:00-12:20	"Overview of Inverse Scattering, Imaging, and Parallel Computing" W. C. Chew, G. L. Wang, and A. J. Hesford
12:20-12:40	"Near Well-Bore Imaging of the Triaxial Induction Logging Data using the Multiplicative Regularized Contrast Source Inversion Method" Aria Abubakar and Tarek M. Habashy
12:40-1:00	"Low-Frequency Modeling of 3-D Coupled Obstacles and Inversion by Differential Evolution" A. Br´eard, G. Perrusson, and D. Lesselier
1:00-2:30	Lunch
2:30-2:50	"Full-Wave Three-Dimensional Microwave Imaging with a Regularized Gauss-Newton Method" J. De Zaeytijd and A. Franchois
2:50-3:10	"Eddy Current Imaging of Surface Breaking Defects by using Monotonicity Based Methods" G. Rubinacci, A. Tamburrino, and S. Ventre
3:10-3:30	"Nanoscopy with Grating-Assisted Optical Diffraction Tomography" P. C. Chaumet, K. Belkebir, F. Drsek, H. Giovannini, and A. Sentenac
3:30-3:50	"A PSO-Based Three-Dimensional Multi-Resolution Approach for the Numerical Solution of Large Inverse Scattering Problems" M. Donelli, G. Franceschini, D. Franceschini, and A. Massa
3:50-4:10	"Shape Reconstruction in 3D Electromagnetic Induction Tomography using a Level Set Technique" O. Dorn and U. Ascher
4:10-4:30	"3D MT Inversion with a Limited-Memory QN Method: Confirmation of Robustness" Anna Avdeeva and Dmitry Avdeev

Room:	**Nabucco 2 Atto** **Session 18**
2:30-6:30	**Computational Methods for Nondestructive Evaluation and Materials Characterization** **Session Organizer: Jeremy Knopp** **Session Chairs: Jeremy Knopp and Michael Havrilla**
2:30-2:50	"Electromagnetic Interactions with an Electrically Uniaxial Composite Layering" S. Ossand´on, M. Lambert, and D. Lesselier

2:50-3:10 "Clutter Removal and Inversion of Eddy-Current Impedance Data"
R. Kim Murphy, Harold A. Sabbagh, Elias H. Sabbagh, John C. Aldrin, Jeremy S. Knopp, and Eric Lindgren

3:10-3:30 "Modeling Pitting and Corrosion Phenomena by Eddy-Current Volume-Integral Equations"
R. Kim Murphy, Harold A. Sabbagh, Elias H. Sabbagh, John C. Aldrin, Eric Lindgren, and Jeremy S. Knopp

3:30-3:50 "Application of a Volume-Integral Code to Gap + Insert Problems in Aerospace Nondestructive Evaluation"
R. Kim Murphy, Harold A. Sabbagh, Elias H. Sabbagh, John C. Aldrin, and Jeremy S. Knopp

3:50-4:10 "A Novel Method for Simultaneously Extracting Electric and Magnetic Properties of Shielding Materials Using Two Coupled Collinear Open-Ended Waveguides"
James W. Stewart and Michael J. Havrilla

4:10-4:30 "Reliability Demonstration for an Eddy Current NDE Technique Using a Computational Electromagnetic Model-Assisted Approach"
John C. Aldrin, Jeremy Knopp, Eric Lindgren, Charles Annis, Harold A. Sabbagh, Elias H. Sabbagh, and R. Kim Murphy

4:30-4:50 Break

4:50-5:10 "Multi-Resolution Analysis of Mortar Diffusion Back-Scattered Signal in Civil Buildings"
Matteo Cacciola, Fabio La Foresta, Francesco Carlo Morabito, and Mario Versaci

5:10-5:30 "Using Circuit Simulation Optimization to Determine the Electrical Properties of Polymeric Composite Materials"
Lorenzo Bennett, W. Elliott Hutchcraft, Richard K. Gordon, Ellen Lackey, James G.Vaughan, and Reid Averill

5:30-5:50 "Application of Volume-Integral Equations to Modeling Anisotropic Grain Noise in Eddy-Current NDE"
Elias H. Sabbagh, Harold A. Sabbagh, R. Kim Murphy, Aparna Sheila-Vadde, and Mark P. Blodgett

5:50-6:10 "Reduced Magnetic Vector Potential and Electric Scalar Potential Formulation for Eddy Current Modeling"
Zhiwei Zeng, Xin Liu, Yiming Deng, Lalita Udpa, Jeremy S. Knopp, and Gary Steffes

Room: **Aida** **Session 19**
2:30-6:30 **CST Modeling and Analysis**
Session Organizer: Thomas Weiland
Session Chair: Thomas Weiland

2:30-2:50 "Co-simulation with CST Microwave Studio and TICRA GRASP"
Michael J. Schneider and Richard W. Roberts

2:50-3:10 "FIT Modeling of Injection Probes for Bulk Current Injection"
Luca Di Rienzo, Flavia Grassi, and Sergio A. Pignari

3:10-3:30 "Applying EM Analysis Techniques during the Design Process of a High Speed Multi Pin Connector"
Thomas Gneiting

3:30-3:50 "Application of CST Microwave Studio for the Development of Mobile Communication Infrastructure RF Filters"
Roland Rathgeber

3:50-4:10 "Propagation of Ultrawideband Pulses and Specific Absorption rate within the Human Head"
Elena Filonenko, Jeff Hand, Tony Vilches, and Chris Toumazou

4:10-4:30 "3D EM-Simulation and Design of a Triple Mode Dielectric Cavity Filter with UMTS Characteristics"
Mark B. Child

4:30-4:50 Break

4:50-5:10 "Numerical Predictions by MWS of Conducted and Radiated Disturbances on Circuits and Cables Produced by an ESD Event"
S. Caniggia and F. Maradei

5:10-5:30 "Bandwidth Improvement of Monoconical Antenna Using Edge Bending Technique"
A. Mehdipour, H. Aliakbarian and M. Kamarei

5:30-5:50 "EMC, Power Integrity and SAR applications by using CST STUDIO SUITE 2006"
G.Antonini, A.di Pasquale, A.Orlandi, and R.M. Rizzi

5:50-6:10 "Electromagnetic Analysis use Cases with CST Microwave Studio"
Antti Renko

6:10-6:30 "Use of MW Studio in the Implementation of Metamaterial Configurations in Planar Circuit Technology"
Francisco Falcone, Eduardo Jarauta, Jesús Illescas, Israel Arnedo, Miguel Beruete, Txema Lopetegi, M. Angel Gómez-Laso, José Antonio Marcotegui, and M Sorolla

Room: **Rigoletto 1&2 Atto** **Session 20**

2:30-6:30 **Modeling of Biomedical Problems - 1**
Session Organizer: Maria Stuchly
Session Chairs: Carey Rappaport and Michael Okoniewski

2:30-2:50 "RF Power Requirements in Human MRI: Does Higher Field Strength Necessitate Higher RF power?"
Tamer S. Ibrahim and Lin Tang

2:50-3:10 "Two-Element T-Array for Cross-Polarized Breast Tumor Detection"
Houssam Kanj and Milica Popovic

3:10-3:30 "Numerical and Experimental Study of Electrode-Tissue Contact Surface in Electrochemotherapy of Cutaneous Tumor"
Selma Corovic, Bassim Al Sakere, Damijan Miklavcic, and Lluis M. Mir

3:30-3:50 "Recent Advances in Biomedical Modeling: Hyperthermia Treatment Planning"
Nicolas Chavannes1, Esra Neufeld and Niels Kuster

3:50-4:10 "Numerical Models of Radio Frequency Ablation in Myocardium"
John A. Pearce

4:10-4:30 "Modeling Functional Imaging of Breast by Microwave Radiometry"
Fernando Bardati and Santina Iudicello

4:30-4:50 Break

4:50-5:10 "Clutter Reduction in Tissue Sensing Adaptive Radar (TSAR) Measurements used for Early Stage Breast Cancer Detection"
D. J. Kurrant, E. C. Fear, and D. T. Westwick

5:10-5:30 "Optimization Algorithms for Modeling of Electromagnetic Sources"
Markus Johansson, Andreas Fhager and Mikael Persson

5:30-5:50 "Two-Pole Debye Model for Normal Breast Tissue in the Microwave Frequency Range"
Mariya Lazebnik, Susan C. Hagness, John H. Booske, and Michal Okoniewski

5:50-6:10 "Modeling and Inversion of Weakly Scattering Structure in Electrically Large Cells"
Ersel Karbeyaz and Carey Rappaport

6:10-6:30 "Investigating the Effects of External Fields' Polarization on the Coupling of Pure Magnetic Waves to the Human Body in Very Low Frequencies"
L. Golestani-Rad, B. Elahi, and J. Rashed.Mohasse

Room: **Turandot** **Session 21**
4:50-6:30 **Computer Simulation of Electromagnetic-System Testing**
Session Organizer: Ross Speciale
Session Chair: Ross Speciale

4:50-5:10 "Application of Nonlinear Time Series Analysis to the Ionospheric Data"
Victor A. Eremenko and Natalia I. Manaenkova

5:10-5:30 "Computer-Simulation of Near-Field Phased-Array Radiation-Pattern Scanning"
Ross A. Speciale

5:30-5:50 "Wave Propagation on Two Dimensional Doubly-Periodic Guiding Structures"
Ross A. Speciale

Room: **Nabucco 1 Atto** **Session 22**
4:50-6:30 **MEFiSTo Modeling and Analysis**
Session Organizer: Poman So
Session Chair: Poman So

4:50-5:10 "Using YATPAC for Modeling of a Marchand Balun"
Hristomir Yordanov and Peter Russer

5:10-5:30 "MEFiSTo Modeling and Analysis for EM Education"
Poman So

5:30-5:50 "Advanced Multi-Level Electromagnetic Modeling and Design with MEFiSTo"
Wolfgang J. R. Hoefer

Thursday, March 22

8:00-5:00 **Conference Registration**

8:00-5:00 **Exhibitors**

Room: **Aida**
8:30-10:30 **Plenary Session - C** **Session 23**

8:30-9:30 "Computational Electromagnetics in Biomedical Problems: Challenges and Some Solutions"
Maria A. Stuchly

9:30-10:30 "Computational Electromagnetics Applied to Portable Antenna Research"
Antonio Faraone

10:30-11:00 Break

Room: **Turandot** **Session 24**

11:00-1:00 **Nature-Based Stochastic Optimization Methods**
Session Organizers: Douglas Werner and Ping Werner
Session Chairs: Douglas Werner and Ping Werner

11:00-11:20 "Optimizing Optical Negative Index Materials: Feedback from Fabrication"
Alexander V. Kildishev*, Uday K. Chettiar, Hsiao-Kuan Yuan, Wenshan Cai, and Vladimir M. Shalaev

11:20-11:40 "Array Thinning Using Ant Colony Optimization"
Stefano Mosca and Matteo Ciattaglia

11:40-12:00 "Benchmark Problems for Antenna Optimization"
Mario Fernández Pantoja, Amelia Rubio Bretones, Salvador González García, and Rafael Gómez Martín

12:00-12:20 "Design and Application of Autopolyploidy Based Polyfractal Expansions for Large Scale Genetic Algorithm Optimization of Antenna Arrays"
Joshua S. Petko and Douglas H. Werner

12:20-12:40 "Parallel Particle Swarm Optimization with Sub-Boundary Partitioning for Frequency Selective Surfaces Design"
Simone Genovesi, Agostino Monorchio, Raj Mittra, and Giuliano Manara

Room: **Nabucco 1 Atto** **Session 25**

11:00-1:00 **Modeling of Biomedical Problems - 2**
Session Organizer: Maria Stuchly
Session Chairs: Maria Stuchly and Paul Meaney

11:00-11:20 "FDTD Calculations of Specific Energy Absorption Rate in Seated and Standing Human Voxel Models from 10 MHz to 300 MHz"
Richard Findlay and Peter Dimbylow

11:20-11:40 "The Effect of Body Posture and Size on the Calculation of Induced Current Densities from Applied Electric and Magnetic Fields at 50 Hz"
Peter Dimbylow and Richard Findlay

11:40-12:00 "Interaction between Pacemakers Implanted in Realistic Human Models and the Radio Frequency Field Produced by Magnetic Resonance Imaging Apparatus"
S. Pisa , G. Calcagnini, M. Cavagnaro, E. Piuzzi, E. Mattei, P. Bernardi

12:00-12:20 "Optimal Coupling Bath Selection for Microwave Imaging in the Neoadjuvant Breast Chemotherapy Monitoring Mode"
Paul M. Meaney, Christine A Kogel, Peter A. Kaufman, Stephen P. Poplack, Margaret W. Fanning, Keith D. Paulsen

12:20-12:40 "2-D Computational Study of the Microwave-Induced Thermoacoustic Effect on Human Breast with Tumor"
Guangran Zhu and Milica Popovic

12:40-1:00 "SAR and Diversity Performance of Wireless Handheld Devices with Dual Antennas"
R. Eliassi, Y. Rahmat-Samii, P. Hui, and A. Toropainen

1:00-2:30 Lunch

Room: **Rigoletto 1&2 Atto** **Session 26**

11:00-1:00 **MoM and Applications**

Session Chairs: Andrew Drozd and Raed Shubair

11:00-11:20 "New Basis functions for the Electromagnetic Solution of Arbitrarily-shaped, Three Dimensional Conducting bodies using Method of Moments"
Anne I. Mackenzie, Michael E. Baginski, and Sadasiva M. Rao

11:20-11:40 "Analysis of Radiofrequency Coils for Magnetic Resonance Imaging using the Numerical Electromagnetic Code (NEC)"
Ricardo Marcal Matias

11:40-12:00 "Wavelet Packet Transform of the Method of Moments Matrix for Large-Scale Problems"
S. H. Zainud-Deen, H. A. Malhat, K. H. Awadalla, and H. A. Sharshar

12:00-12:20 "Wavelet Packet Transform with Iterative Technique based on Method of Moments"
S. H. Zainud-Deen, H. A. Malhat, K. H. Awadalla, and H. A. Sharshar

12:20-12:40 "A Partial Analytical Solution for the Logarithmic Singularity Associated with MoM Applied to Dielectrics and its Evaluation with Polynomial Quadratures"
Thierry Gilles, Marc Piette, and Christophe Craeye

12:40-1:00 "Comparisons of CEM Predictions to IR Images of EM Fields for Complex Systems"
John Norgard, Randall Musselman, Andrew L. Drozd, and Irina P. Kasperovich

1:00-2:30 Lunch

Room: **Poster Hall** **Session 27**

11:00-1:00 **Poster Sessions 1**

Session Chairs: Richard K. Gordon

"On The Capacity of Indoor MIMO Channels"
Shirook Ali, Geyi Wen, and Farzaneh Kohandani

"Approximately Low Frequency Electromagnetic Study of a Converter-Fed Squirrel Cage Induction Motor"
C. Grabner

"A Potential Method for EM Scattering Calculations"
Magnus Herberthson

"EM Scattering from Bodies of Revolution using the Locally Corrected Nystrom Method"
Aihua W. Wood

"Micro Hall-type Electric Propulsion System: Simultaneous Solution of Plasma Magneto-hydrodynamic Instability and Thruster Core Overheating"
Takeshi Furukawa

"Stochastic Optimizationof a Patch Antenna"
S. Alfonzetti, G. Borzì, E. Dilettoso, and N. Salerno

"Variable Phase-Shifter/Down Converter for Active Microstrip Phased Array Antenna Applications"
L. F. Herrán, S. Ver Hoeye, M. Fernández, and F. Las Heras

"Indoor Field Strength Prediction Based on Neural Network Model and Particle Swarm Optimization"
Ivan Vilovic, Niksa Burum, and Zvonimir Sipus

"CEST : a Complex Environment Simulation Tool"
Emidio Di Giampaolo

"Validity of Approximate Boundary Conditions in Analysis of Strip-Loaded Planar and Curved Surfaces"
Zvonimir Sipus and Per-Simon Kildal

"Solutions of Large Integral-Equation Problems with Parallel Preconditioned MLFMA"
Levent GÄurel, ÄOzgÄur ErgÄul, and Tahir Malas

"Design and Fabrication of a Microstrip TRL Calibration Kit for Measurement of RF Components"
Dalia Elsherbeni, Elliott Hutchcraft, Darko Kajfez, and Richard K. Gordon

"Apertures-Coupled Multi-Layer Cylindrical Dielectric Resonator Antennas and Modal Analysis"
Wei Huang and Ahmed A. Kishk

1:00-2:30 Lunch

Room: **Poster Hall** **Session 28**

2:30-4:30 **Poster Sessions 2**

Session Chairs: Elliott Hutchcraft and A. A. Arkadan

"A Parallel Code for Time Dependent Acoustic Scattering Involving Passive or Smart Obstacles"
Francesco Zirilli

"Increased Performance in Computational Electromagnetics through the use of Graphics Processing Units"
Maxwell Woolsey, W. Elliott Hutchcraft, and Richard K. Gordon

"Theoretical and Experimental Analysis of Rectangular Waveguides with Isotropic Chiral Media"
Álvaro Gómez, Ismael Barba, Ana C. L. Cabeceira, José Represa, Gregorio Molina-Cuberos, Mª José Núñez, José Margineda, Ángel Vegas, and Miguel A. Solano

"To the Glory of G.Galileo and J.K.Maxwell: Electromagnetic Modeling of the Origin of Saturn's Rings from Superconducting Particles of the Protoplnetary Cloud"
Vladimir V. Tchernyi

"Application of Web-Splines for Coaxial Waveguides"
Gökhan Apaydin, Niyazi Ari, and Selim Seker

"Reduced-Order Root-MUSIC Source Localization Using Displaced Sensor Arrays"
R. M. Shubair

"Analysis of Slotted Rectangular Microstrip Antenna Using De-segmentation and PDCM Method"
Byoung Woo Park and Dong Kug Seo

"Analytical Study on Reduction Uneven Heating of Food Inside Industrial Microwave Oven by using of Water Film"
Ryosuke SUGA, Taichi IJUIN, Osamu HASHIMOTO, Tetsuya TAKATOMI, and Shinya WATANABE

"Mixed 3D Finite Element and Circuit Based Modelling of Unshielded Twisted Pairs"
Sriram Dorai and Anthony J Peyton

"MONURBS: A Parallelized Fast Multipole Multilevel Code for Analyzing Complex Bodies Modeled by Nurbs Surfaces"
I. González, E. García, F. Sáez de Adana, M. F. Cátedra

"On the Numerical Determination of Electromagnetic Fields Near Material Interfaces Using Radial Basis Functions in a Meshless Method"
Richard K. Gordon, W. Elliott Hutchcraft, Brandon Smith, and John Ashmore

"Optimization of Circuit Equivalent Model for MESFETs"
Lisa Jordan, Elliott Hutchcraft, Richard K. Gordon and Darko Kajfez

"Dispersion Engineering with MATLAB"
Giuseppina Monti, Luciano Tarricone

Room: **Nabucco 2 Atto** **Session 29**

11:00-6:30 **Detection and Imaging: Theoretical, Algorithmic, Technology and System Advances**
Session Organizers: Andrea Massa and Christian Pichot
Session Chairs: Andrea Massa and Christian Pichot

11:00-11:20 "Two Approaches for Inverse Profiling from Phaseless Data"
Kamal Belkebiry, Lorenzo Croccoz, Michele D'Urso, Tommaso Isernia, and Amélie Litman

11:20-11:40 "A New Method for Shape Reconstruction of Perfectly Conducting Targets"
Lorenzo Crocco, Ibrahim Akduman, Mehmet Cayören, and Ali Yapar

11:40-12:00 "2.5D Forward Solver to Model Scattering of Long Dielectric Cylinders in an Active Millimeter Wave Imaging System"
S. Van den Bulcke and A. Franchois

12:00-12:20 "Microstrip Antenna with Shorting Pins as a Sensor for Landmines Detection"
S.H. Zainud-Deen, M. E. Badr, K.H. Awadalla, and H.A. Sharshar

12:20-12:40 "Two-and-half Dimension Integral Equation Method for Geophysical Electromagnetic Problems"
Aria Abubakar, Peter M. van den Berg, and Tarek M. Habashy

12:40-1:00 "On the MUSIC-Type Electromagnetic Imaging of a Small Collection of 3-D Dielectric Spheres from its Multi-Static Response using Exact and Asymptotic Numerical Data"
E. Iakovleva and D. Lesselier

1:00-2:30 Lunch

2:30-2:50 "Electrical Impedance Tomography with Resistor Network Approximation on Optimal Grids"
Liliana Borcea, Vladimir Druskin, Fernando Guevara Vasquez, and Leonid Knizhnerman

2:50-3:10 "Quadratic Time-Frequency Distribution as Applied to Detection of Objects Buried under a Rough Surface"
Nicolas Morelle, Marc Saillard, and Nadege Thirion-Moreau

3:10-3:30 "Multi-Frequency/Multi-Scaling Techniques for the Electromagnetic Inversion of Lossless Profiles - A Numerical Comparison"
D. Franceschini, M. Donelli, G. Franceschini, and A. Massa

3:30-3:50 "Microwave Tomographic Techniques for Explosive and Flammable Liquid Detection"
Paul M. Meaney, Edward M. Godshalk, Timothy Raynolds, Gregory C. Burke, and Keith D. Paulsen

3:50-4:10 "Model-Based Inversion Algorithm for Structural and Conductivity Reconstruction of Marine Controlled-Source Electromagnetic Data"
Yan Zhang, Aria Abubakar, and Tarek Habashy

4:10-4:30 "Inverse Scattering and Edge Detection: The Threshold Problem for the Linear Sampling Method"
M. Piana, M. Brignone, R. Aramini, and J. Coyle

4:30-4:50 Break

4:50-5:10 "Crack Detection using a Level-Set Technique and Thin Shapes"
D. ´Alvarez, O. Dorn, and M. Moscoso

5:10-5:30 "Reconstruction of 3-D Irregular Shape of Breast Cancer Tumor Using the Adjoint-Field Scheme in the Microwave Imaging Algorithm"
Magda El-Shenawee, Oliver Dorn, and Miguel Moscoso

5:30-5:50 "Pade Via Lanczos Inversion Using Multiple Measurements"
Rob F. Remis

5:50-6:10 "Conducting Scatterer Reconstruction Using Differential Evolution and Particle Swarm Optimization"
Ioannis T. Rekanos

Room: **Aida** **Session 30**
11:00-6:30 **SEMCAD X: Recent Modeling Advances for Virtual Prototyping**
Session Organizer: Nicolas Chavannes
Session Chairs: Nicolas Chavannes and Erdem Ofli

11:00-11:20 "Reliable Prediction of Mobile Telecommunications Equipment Performance for Different In-Use Conditions by TCAD"
P. Futter, N. Chavannes, R. Tay, K. Pokovic, and N. Kuster

11:20-11:40 "Technical Equipment for Research of Biological Effects of EM Field"
Jan Vrba, Luca Vannucci, Peter Peschke, Frantisek Vožeh, Max Vojtíšek, PaoloTogni, Jan Vrba(jr), Tomáš Drížďal, and Radim Zajicek

11:40-12:00 "Dosimetric Evaluation and Comparison of Different Exposure Setups Used in Provocation Studies"
Clementine Boutry, Albert Romann, Sven Kuehn, Neviana Nikoloski, Jafar Keshvari, and Niels Kuster

12:00-12:20 "Evaluation of Emerging Hardware Platforms for Faster Electromagnetic Simulations"
Ryan Schneider, Dan Cyca, Chris Mason, and Michal Okoniewski

12:20-12:40 "Advantage of Modeling Broadband Antennas with SEMCAD-X FDTD Conformal Solver"
Houssam Kanj, Yi Zhang and Milica Popović

12:40-1:00 "A Patch Antenna Design for a Head and Neck Hyperthermia Applicator"
Margarethus M. Paulides, Jurriaan F. Bakker, and Gerard C. Van Rhoon

1:00-2:30 Lunch

2:30-2:50 "A Combined Numerical and Experimental Procedure for the MR-Safety Testing of Stents"
Eugenia Cabot, Andreas Christ, Michael Oberle, and Niels Kuster

2:50-3:10 "Computational Study on the Effect of Pierced Metallic Objects at 900 MHz"
José Fayos-Fernández, Antonio M. Martínez-González, and David Sánchez-Hernández

3:10-3:30 "Failure Modes and Effects Analysis (FMEA) on the RF Performance of Mobile Phones Using TCAD"
R. Tay, P. Futter, N. Chavannes, G.H. Ng, and N. Kuster

3:30-3:50 "An Ontology-Based Decision Maker for Electromagnetic Problem Solving"
Alessandra Esposito, Luciano Tarricone, and Laura Vallone

3:50-4:10 "Research of Medical and Industrial Applications of Microwaves Supported by SEMCAD"
Jan VRBA

Room: **Turandot** **Session 31**
2:30-4:30 **High Power Microwave**
Session Organizer: Ross Speciale
Session Chair: Ross Speciale

2:30-2:50 "Unusual Features of the Pseudo Non-Diffracting Microwave Vortex"
Ross A. Speciale

2:50-3:10 "Fundamental Physical Requirements for Microwave-Vortex Radiation-Systems"
Ross A. Speciale

3:10-3:30 "A Pseudo Non-Diffracting Microwave Vortex"
Ross A. Speciale

3:30-3:50 "Split-Torus Configuration of the Toroidal/Helical Electron-Orbits for High-Power Microwave Amplifiers"
Ross A. Speciale

3:50-4:10 "High-Efficiency Energy-Storage for Pulsed HPM Sources"
Ross A. Speciale

4:10-4:30 "Exact Expressions of the Orbit-Curvature and Curvature-Radius of the Toroidal/Helical Orbits"
Ross A. Speciale

Room: **Rigoletto 1&2 Atto** **Session 32**

2:30-6:30 **Macromodeling for EMC and SI Complex Systems**
Session Organizer: Giulio Antonini
Session Chairs: Giulio Antonini and Marc Piette

2:30-2:50 "Full-Spectrum Convolution Macromodeling for the Full-Wave PEEC Method"
Sergey V. Kochetov, Guenter Wollenberg, and Marco Leone

2:50-3:10 "Parallelized Integral Equation Methods for Signal Integrity"
Vikram Jandhyala, James Pingenot, Indranil Chowdhury, Arun Sathanur, and Devan Williams

3:10-3:30 "Combined Loss Mechanism and Stability Model for the Partial Element Equivalent Circuit Technique"
Albert Ruehli and Giulio Antonini

3:30-3:50 "Electromagnetic Modeling of Automotive Platforms based on the PEEC Method"
Jonas Ekman, Giulio Antonini, Giuseppe Miscione, and Peter Anttu

3:50-4:10 "Rational Approximation of Noisy Frequency Responses"
D. Deschrijver, M. Schoeman, T. Dhaene, and P. Meyer

4:10-4:30 "An Improved Time-Domain Near-Field to Far-Field Transformation in Two Dimensions"
J. Alan Roden, Steven L. Johns, and Joseph Sacchini

4:30-4:50 Break

4:50-5:10 "Macro-Modeling of the Defected Ground Structure by the Rational Function Fitting"
Sungtek Kahng

5:10-5:30 "Virtual Source Modeling of the High-Frequency Scattering of the Infinite Conducting Strip under Cylindrical Wave Excitation"
Marc Piette

Room: **Nabucco 1 Atto** **Session 33**

2:30-6:30 **Advanced EMC Modeling**
Session Organizers: Lionel Pichon and Philip Sewell
Session Chairs: Lionel Pichon, Ana Vukovic, and Antonio Maffucci

2:30-2:50 "Conducted Electromagnetic Interference Prediction in Integrated Motor Drive"
O. A. Mohammed, S. Ganu, Z. Liu, N. Abed, S. Liu

2:50-3:10	"Rigorous Investigation of Induced Fields on Different Parts of a Typical PCB Exposed to External Radiation" L. Golestani-Rad, S. Hamidifar, and J. Rashed-Mohassel
3:10-3:30	"A General Framework for Mixed Structured/Unstructured PEEC Modelling" Fabio Freschi, and Maurizio Repetto
3:30-3:50	"High-Frequency Full-Wave Analysis of Interconnects with Inhomogeneous Dielectrics through an Enhanced Transmission Line Model" A. G. Chiariello, A. Maffucci, G.Miano, F.Villone, and W. Zamboni
3:50-4:10	"Performance Capability Modeling and Optimization of RF and Millimeter Wave Systems Using Hybrid Statistical/Electromagnetic Techniques" Daniela Staiculescu, Lara Martin, Jong-Hoon Lee, and Manos Tentzeris
4:10-4:30	"Electromagnetic Analysis of the Numerical Dispersion and Lossy Media Using the One-Step method" D. Lautru, J. Silly-Carette, M. F. Wong, J. Wiart, and V. Fouad Hanna
4:30-4:50	Break
4:50-5:10	"Interconnect Macro-Modeling using 3D Computational Techniques" Brahim Essakhi, Jérémie Bénel, Gilles Akoun, and Lionel Pichon
5:10-5:30	"Transmission Line Matrix Method coupled to Integral Equations for simulation of Electromagnetic Interferences" Fabien Ndagijimana, Amir Reza Attari, J. Dansou, and K. Barkeshli
5:30-5:50	"Transient Response of a Thin Wire above a Real Ground using a Simplified Reflection Coefficient Approach" D.Poljak, N.Kovač
5:50-6:10	"Development of Time-Domain Surface Macromodels from Material Measurements" Ian D. Flintoft, John F. Dawson, Andrew C. Marvin and Stuart J. Porter
6:10-6:30	"Capabilities of Empirical TLM Air-vent Model" Nebojsa Doncov, Bratislav Milovanovic

Room: **Turandot** **Session 34**

4:50-6:30 **Advanced Modeling Techniques and The Application of Microwave Devices**

Session Organizer: Michiko Kuroda

Session Chairs: Michiko Kuroda and Manos Tentzeris

4:50-5:10	"Improved Version of the Second-Order Mur Absorbing Boundary Condition Based on a Nonstandard Finite Difference Model" James B. Cole and Saswatee Banerjee
5:10-5:30	"A New Approach for Deembedding Active Devices from Active Grids" C. Rieckmann, Y. Hao, and C. G. Parini
5:30-5:50	"Analysis of Parylene-C as a Novel Structural Material for Electrostatic Capacitive MEMS RF Switches" Jian-Ming Chen, Guang-Min Wu, Jian-Jun Zhao, Ze-Bin Fan, and Li Zhu
5:50-6:10	"Transient Effect of 3D RF-MEMS Structures with Moving Plate" Hiroshi Iwamatsu and Michiko Kuroda

Friday, March 23

8:00-12:00 **Conference Registration**

Room: **Rigoletto 1&2 Atto** **Session 35**
8:30-10:30 **Ill-Posed Electromagnetic Inverse Problems: Theory and Applications**
Session Organizer: Michael Zhdanoy
Session Chairs: Michael Zhdanoy and Michael Zhdanov

8:30-8:50 "Real-Time Inversion of Electromagnetic Logging Data in Vertical and Deviated Wells"
Michael A. Frenkel

8:50-9:10 "On the Structure Electromagnetic Inverse Problem"
Peter S. Martyshko and Alexey L. Roublev

9:10-9:30 "Imaging of a Subsurface Conductivity Distribution using a Time-Domain ElectroMagnetic Borehole Conveyed Logging Tool"
Erik J. Banning, Terry Hagiwara, and Richard M. Ostermeier

9:30-9:50 "Regularized Three-Dimensional Inversion of Array Tensor Induction Logging Data"
Michael S. Zhdanov and Alexander Gribenko

9:50-10:10 "A Hybrid Finite Difference Frequency Domain and Particle Swarm Optimization Techniques for Forward and Inverse Electromagnetic Scattering Problems"
S. H. Zainud-Deen, Mourad S. Ibrahim, and Emad El-Deen

10:10-10:30 "Rigorous Three-Dimensional Magnetotelluric Inversion and Resolution Analysis"
Michael S. Zhdanov

10:30-11:00 Break

Room: **Turandot** **Session 36**
8:30-10:30 **Wideband and Multiband Antennas**
Session Organizer: Marc Piette
Session Chairs: Marc Piette and Ross Speciale

8:30-8:50 "A Novel Miniaturized Dual-Band Inverted-F Antennas with Spiraling Tail"
Yu-Shin Wang and Shyh-Jong Chung

8:50-9:10 "Finite Array Analysis through Combination of Macro Basis Functions and Array Scanning Methods"
Christophe Craeye and R´emi Sarkis

9:10-9:30 "Design of More Affordable and Reliable Electronically-Steered Phased Arrays"
Ross A. Speciale

9:30-9:50 "Network Digital Ionospheric Station "PARUS": Development and Perspective"
Alexander L. Karpenko and Natalia I. Manaenkova

9:50-10: 10 "Investigation of a Microstrip Antenna Array Conformal to a Paraboloidal Surface"
Sharath Kumar, Maryam Parsa, and Amir I. Zaghloul

10:30-11:00 Break

Room:	**Nabucco 2 Atto**	**Session 37**

8:30-1:00 **Innovation in the Macromodeling of High Speed Interconnects**
Session Organizer: Flavio Canavero
Session Chairs: Flavio Canavero and Antonio Maffucci

8:30-8:50 "Macromodeling of High-Speed Interconnects with Complex Disontinuities"
Rodolfo Araneo, Salvatore Celozzi, and Francescaromana Maradei

8:50-9:10 "Study of Sensitivity and Response Bounds Definition of Microwave Circuits by the Use of the Adjoint Network in the Wavelet Domain"
Sami Barmada, Antonino Musolino, and Rocco Rizzo

9:10-9:30 "Broad-band Characterization of Wire Interconnects Using a Surface Integral Formulation with a Surface Effective Impedance"
A. Maffucci, G. Rubinacci, S. Ventre, F. Villone, and W. Zamboni

9:30-9:50 "A Simplified Statistical Model for Crosstalk in Balanced Twisted Pairs"
Sergio A. Pignari and Giordano Spadacini

9:50-10:10 "Design Optimization of EM Launchers"
A. A. Arkadan and N. Al Awar

10:30-11:00 Break

11:00-11:20 "Fast Low-Frequency Impedance Extraction using a Volumetric Three-Dimensional Integral Formulation"
A. Maffucci, G. Rubinacci, A. Tamburrino, S. Ventre, and F. Villone

11:20-11:40 "Optimization of a High-Speed Interconnect Link under Signal Integrity Constraints"
S. Grivet-Talocia, M. Bandinu, I. S. Stievano, and F. Canavero

11:40-12:00 "Full Wave Analysis of Propagation in Arbitrary Section Dielectric and Conducting Transmission Lines"
Mario Lucido, Gaetano Panariello, and Fulvio Schettino

12:00-12:20 "Low-Frequency Analysis of Electromagnetic Interference from SMPS"
Ugo Reggiani, Leonardo Sandrolini, and Gian Lorenzo Giuliattini Burbui

1:00-2:30 Lunch

Room:	**Nabucco 1 Atto**	**Session 38**

8:30-1:00 **Advances in Conformal Time-Domain Methods: Finite-Volume and Discontinuous Galerkin Methods**
Session Organizers: Pierre Bonnet and Christophe Fumeaux
Session Chairs: Pierre Bonnet and Christophe Fumeaux

8:30-8:50 "A Discontinuous Galerkin Method to Solve Maxwell Equation in Time Domain"
E. Montseny, S. Pernet, X. Ferrieres, M. Zweers, and G. Cohen

8:50-9:10 "Evaluation of FVTD Dissipation and Time-Domain Hybridization for MSRC Studies"
S. Lallechere, P. Bonnet, S. Girard, F. Diouf, and F. Paladian

9:10-9:30 "Local Time Stepping Discontinuous Galerkin Time Domain Method for Solving Maxwell Equations"
Man-Faï Wong and Joe Wiart

9:30-9:50 "DG-FEM for CEM with Uncertainty"
C. Chauvi`ere, J. S. Hesthaven, L. Lurati, and L. C. Wilcox

10:30-11:00 Break

11:00-11:20 "CFS – PML for Absorbing Boundary Condition in Discontinuous Galerkin Method in the Time Domain"
Christophe Guiffaut, Stephanie Petit Halajda, and Alain Reineix

11:20-11:40 "Necessary Stability Criterion for Unstructured Mesh Upwinding FVTD Schemes for Maxwell's Equations"
Dmitry K. Firsov and Joe LoVetri

11:40-12:00 "Different Perfectly Matched Absorbers for Conformal Time-Domain Method: A Finite-Volume Time-Domain Perspective"
Krishnaswamy Sankaran, Thomas Kaufmann, Christophe Fumeaux, and R¨udiger Vahldieck

1:00-2:30 Lunch

Room: **Aida** **Session 39**

8:30-4:30 **Analysis and Design of Antennas for Wireless Communications**
Session Organizer: Paolo Nepa
Session Chairs: Paolo Nepa and Giovanni Riccio

8:30-8:50 "Singly-Fed Circularly Polarized Electromagnetically Coupled Patch Antenna"
Amir Hajiaboli and Milica Popović

8:50-9:10 "Harmonic Tunning for Ku-Band Dielectric Resonator Antennas"
A. Guraliuc, G. Manara, G. Nenna, P. Nepa, G. Pelosi, and S. Selleri

9:10-9:30 "Microstrip Antenna Array with Beamforming Network for WLAN Applications"
Traii Mbarek, Ghayoula Ridha, and Gharsallah Ali

9:30-9:50 "Design of Mobile Phone Antenna with Multi-band for SAR reduction"
Nam Kim, Seungwoo Lee, Sang-myeong Park, and Ho-min Lee

9:50-10:10 "Beam Scanning using Integrated Microstrip Ferrite Phase Shifter"
Sheikh Sharif Iqbal and Mir Riyaz Ali

10:10-10:30 "A Finite Element Domain Decomposition Method for the Analysis of Finite Antenna Arrays"
Vineet Rawat, Kezhong Zhao, Seung-Cheol Lee, and Jin-Fa Lee

10:30-11:00 Break

11:00-11:20 "Accurate 3D Characterization and Synthesis of Real Antenna Arrays via Support Vector Regression"
Rafael G. Ayestaran and Fernando Las-Heras

11:20-11:40 "Wireless Communication Antennas: Special Requirements and New Designs of Dielectric Resonator Antenna"
Yahia M. M. Antar and Debatosh Guha

11:40-12:00 "EFIE-MoM Techniques with Wires and Plates for Modeling Antenna Near Field"
Jaime Laviada, Fernando Las-Heras, and Marcos R. Pino

12:00-12:20 "Design, Analysis and Experimental Evaluation of a New Broadband Antenna for Naval Systems"
L. Mattioni and G. Marrocco

12:20-12:40 "Interaction between Mobile Antennas and Human Proximities"
S. H. Zainud-Deen, Emad El-Deen, H. A. Sharshar, and M. A. Binyamin

1:00-2:30 Lunch

2:30-2:50	"Radiation Pattern of a Networks Antenna Supplied with Butler Matrix, Comparison with a Multi-Layer Structure" Traii Mbarek, Ghayoula Ridha, and Gharsallah Ali
2:50-3:10	"Investigation of Dielectric Resonator Antennas for Base Station Application" Andreas Lambrecht, Juan Pontes, and Werner Wiesbeck
3:10-3:30	"Integrated Disk-loaded Monopole Array Antenna and the Small PIFA Antennas" M. R. Kamarudin, P. S. Hall, F. Colombel, and M. Himdi
3:30-3:50	"A Nonredundant Sampling Based Method for the Directivity Computation" F. D'Agostino, F. Ferrara, C. Gennarelli, R. Guerriero, and G. Riccio
3:50-4:10	"Partitioned Square Loop Antenna" Veysel Demir, Roger Hasse, Darko Kajfez, and Atef Elsherbeni

Room: **Turandot** **Session 40**

11:00-4:30 **Applications Based on FDTD**

Session Chairs: Malgorzata Celuch and Nader Farahat

11:00-11:20	"Evaluation of FDTD Regimes for Scattering from Periodic Structures" Bartlomiej W. Salski and Wojciech K. Gwarek
11:20-11:40	"A New Design of Broadband Microstrip Leaky - Wave Antenna" Onofrio Losito
11:40-12:00	"Modeling of Active Circuits Using FDTD Approach" Iman Farghadan, Tohid Zargar Ershadi, and Ahmad Fayaz
12:00-12:20	"Analysis of Optical Fiber Waveguides using the Body of Revolution Version of the Finite Difference Time Domain Method" Nader Farahat, Raj Mittra, and Jose Carrion
12:20-12:40	"1D Multipoint Auxiliary Propagator (1D-MAP) for Perfectly Matching Plane Wave Huygen's Sources in FDTD" Tengmeng Tan and Michael E. Potter
12:40-1:00	"Open Stripline Resonator Sensor for Gauging in Industrial Applications" Nathan Ida and Nader Farahat
1:00-2:30	Lunch
2:30-2:50	"Parallel FDTD Processing on Shared Memory Computers" Tomasz Ciamulski, Maciej Sypniewski, Andrzej Wieckowski, Mats Hjelm, and Hans-Erik Nilsson
2:50-3:10	"Modeling and Characterization of Spiral Inductors Based on a Standard Silicon Technology" V. Palazzari, P. Placidi, F. Placentino, A. Scarponi, F. Alimenti, L. Roselli, and A. Scorzoni
3:10-3:30	"Electromagnetic Scattering by Conducting/Dielectric Objects" S. H. Zainud-Deen, Emad El-Deen, and Mourad S. Ibrahem

Room: Rigoletto 1&2 Atto **Session 41**

11:00-4:30 **Computational Electromagnetics for Photonics**

Session Organizer: Gerard Berginc

Session Chairs: Gerard Berginc and Alex Maradudin

11:00-11:20 "Simulation and Optimization of Photonic Crystal Structures"
Christian Hafner, Jasmin Smajic, Cui Xudong, and Ruediger Vahldieck

11:20-11:40 "Analysis of the Scattering from Rough Surfaces with the Curvilinear Coordinate Method and the Short-Coupling Approximation"
Karim Aït Braham and Richard Dusséaux

11:40-12:00 "Near-Field Imaging of a Silver Nanowire Using a Thin Silver Film"
Zhengtong Liu, Alexander V. Kildishev, Vladimir P. Drachev, and Vladimir M. Shalaev

12:00-12:20 "On the Design of Optical Antenna"
Christian Hafner, Cui Xudong, Andre Bertolace, and Ruediger Vahldieck

12:20-12:40 "Theoretical Model for Diffuse Optical Wave Scattering from a Three-Dimensional Slab Bounded by Randomly Rough Surfaces"
Gerard Berginc and Claude Bourrely

12:40-1:00 "Control of the Coherence of Light Scattered from a One-Dimensional Randomly Rough Surface that Acts as a Schell-Model Source"
Tamara A. Leskova, Alexei A. Maradudin, and Eugenio R. M´endez

1:00-2:30 Lunch

2:30-2:50 "Modeling Localized Surface Plasmons in Light Tunneling and New Optical Sensing Approach"
Yuyang Feng, Morten Willatzen, and Niels Lervad Andersen

2:50-3:10 "Replacement of Ensemble Averaging by the use of a Broadband Source in Scattering from Randomly Rough Surfaces"
Alexei A. Maradudin, Tamara A. Leskova, and Eugenio R. M´endez

3:10-3:30 "Modeling of Micro-Structured Surfaces for Antireflecting Properties in the Infrared Domain"
R. Bouffaron, L. Escoubas, J.J. Simon, Ph. Torchio, G. Berginc, and Ph. Masclet

Room: Nabucco 2 Atto **Session 42**

2:30-4:30 **Imaging, Computation and Inverse Methods in Biomedicine**

Session Organizers: Michele Piana and Serguei Semenov

Session Chairs: Michele Piana and Serguei Semenov

2:30-2:50 "The Linear Sampling Method, a New Regularized Solution and Real Data"
R. Aramini, M. Brignone, and J. Coyle

2:50-3:10 "An Inverse Scattering Problem for a Partially Coated Buried Obstacle"
Michele Di Cristo and Jiguang Sun

3:10-3:30 "On Recent Machine Learning Algorithms for Brain Activity Interpretation"
Marco Prato, Luca Zanni, and Gaetano Zanghirati

3:30-3:50 "Applications of a No-Sampling Approach to the Linear Sampling Method"
R. Aramini, M. Brignone, and M. Piana

3:50-4:10 "Microwave Imaging for Early Breast Cancer Detection using a Shape-Based Strategy"
Natalia Irishina, Miguel Moscoso, and Oliver Dorn

4:10-4:30 "Microwave Tomographic Approach for Extremities Imaging. Formulation of the Problem and Initial Imaging"
Serguei Y. Semenov, James F. Kellam, Peter Althausen, Thomas C. Williams, Aria Abubakar, Alexander Bulyshev, and Yuri Sizov

Room: **Nabucco 1 Atto** **Session 43**

2:30-4:30 **Microwave, Optical Devices, and Propagation**

Session Organizer: Rodica Ramer

Session Chair: Rodica Ramer

2:30-2:50 "V Transmission Lines Frequency Operation Band"
Payam Nayeri, Ahmed Cheldavi, and Farshad Keshmiri

2:50-3:10 "Subwavelength Metallic Grating Simulation using FDTD"
Saswatee Banerjee, Tetsuya Hoshino, and James B. Cole

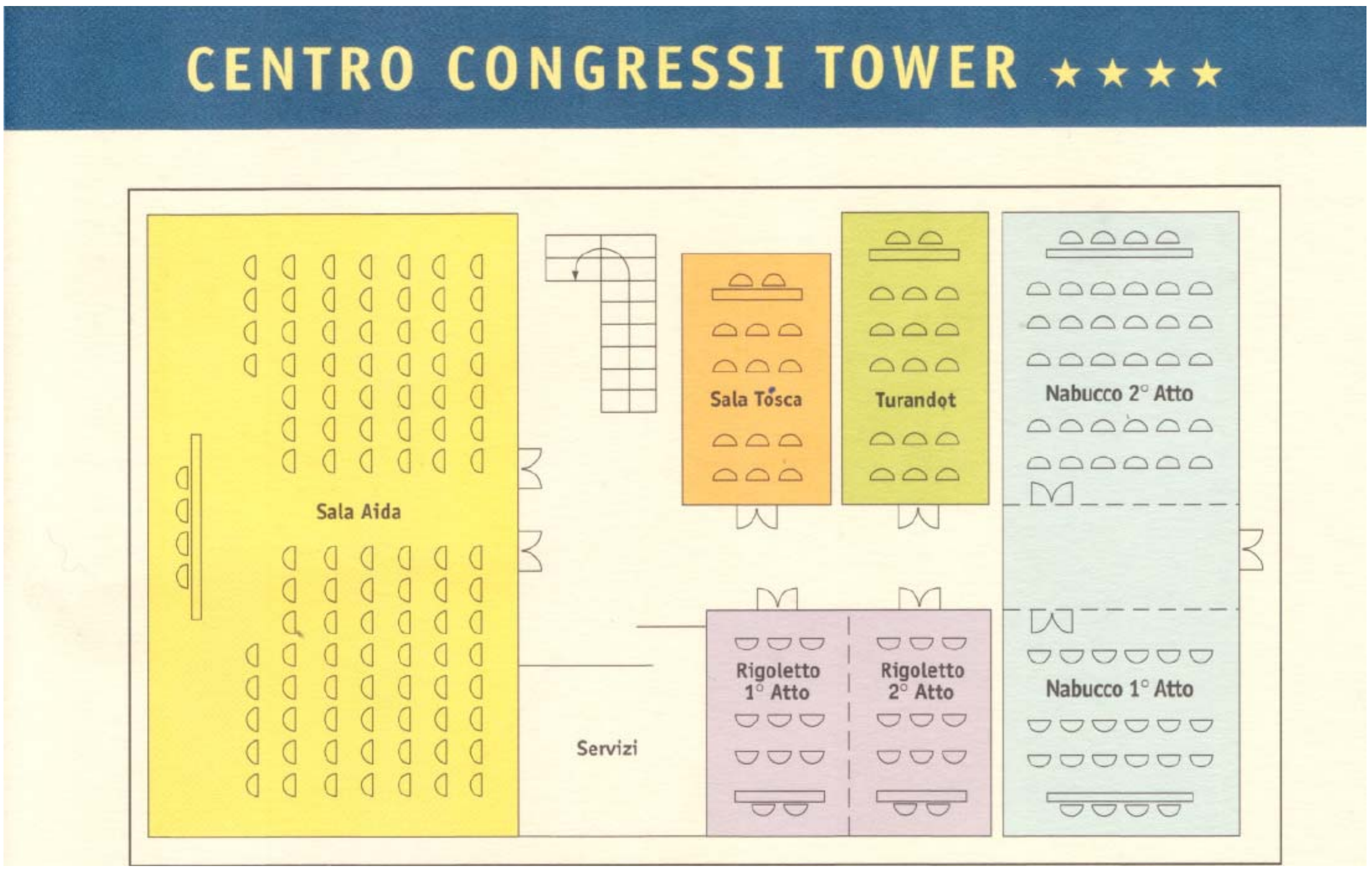
3:10-3:30 "Geometrical and Statistical Properties of the Scattering Area in Multipath Propagation Modeling"
Mohammed T. Simsim, Noor M. Khan, and Rodica Ramer

3:30-3:50 "Interval-based robust design of a microwave power transistor"
P. Lamberti and V. Tucci

Conference Venu

Montresor Tower Hotel
via Mantegna 30/a - 37012 Bussolengo
Verona ITALY

www.montresor.it
tel +39 045 6761111
fax +39 045 6762222



ADVERTISING RATES		
	FEE	**PRINTED SIZE**
Full page	$200	7.5” × 10.0”
1/2 page	$100	7.5” × 4.7” or 3.5” × 10.0”
1/4 page	$50	3.5” × 4.7”

All ads must be camera ready copy.

Ad deadlines are same as Newsletter copy deadlines.

Place ads with Bruce Archambeault, barch@us.ibm.com. The editor reserves the right to reject ads.

DEADLINE FOR THE SUBMISSION OF ARTICLES

Issue	Copy Deadline
March	February 1
July	June 1
November	October 1

For the ***ACES NEWSLETTER***, send copy to Bruce Archambeault (barch@us.ibm.com) in the following formats:

1. A PDF copy.
2. A MS Word (ver. 97 or higher) copy. If any software other than WORD has been used, contact the Managing Editor, Richard W. Adler **before** submitting a diskette, CD-R or electronic file.

Last Word

Albert Einstein, when asked to describe radio, replied: "You see, wire telegraph is a kind of a very, very long cat. You pull his tail in New York and his head is meowing in Los Angeles. Do you understand this? And radio operates exactly the same way: you send signals here, they receive them there. The only difference is that there is no cat."