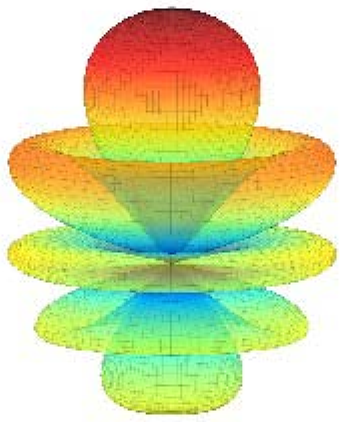

ACES

The Applied Computational Electromagnetics Society

NEWSLETTER

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In this issue:

Editor's note:

I hope you enjoyed the previous edition of the ACES Newsletter. As always, if you have any comments or suggestions, please get in touch with me.

We are still working on getting this into a better format for emailing, I hope the mechanics of this will be cracked soon and the ACES Newsletter will be even easier to browse.

So, what awaits you below? I am pleased to be able to present

some information on the remaining Fellow. I always enjoy reading this sort of material because I find out so much about people I know professionally, in some cases personally, that I never knew. Todd Hubing is no exception.

Those of you who read the Newsletter of about a year ago will have read about the EMC Laboratory at the University of L'Aquila. No doubt you also heard how much damage was done by a recent earthquake. Giulio Antonini has provided an update. I am not sure you will enjoy reading this but I am sure that it will be a reminder of the awe inspiring power of nature.

The second part of Fred Tesche's article on Sphere Shielding is also included. If you haven't read Part 1, why not go to the ACES website?

No doubt your diary is already marked to be in Tampere, Finland, 26 – 29 April 2010. The Newsletter also includes a brief outline of some of the CEM work that is currently underway there.

Finally, I think it would be helpful to the general readership to know about updates and advances in software. In this issue, you can read about FEKO's latest innovation.

If you have any articles, stories or information you wish to submit to the Newsletter, please send your file (preferably word or pdf) to me at least a month before the scheduled month of publication in order to give me time to look at it and get back to you with any possible changes.

If you wish to place an advert in the Newsletter, please contact me directly for more information.

I am aiming to have a publication schedule of January, March, May, July, September, November. I hope I will get on track soon!

Wishing you all well

Alistair Duffy

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2009 Class of ACES Fellows

In introducing Ed Miller, Randy Haupt and Leo Kempel, last month, I said "*I hope you enjoy reading about the Fellows as much as I have enjoyed finding out about them. We are fortunate in the ACES Community to have such accomplished and inspiring colleagues who all have the time and interest to help nurture younger ACESians."* This applies as much to Todd Hubing as it does to Ed, Randy and Leo. Again, congratulations to them all.

Todd Hubing

Where were you born and brought up, and where do you live now and what circumstances brought you there?

I was born in Wisconsin (north central U.S.) and grew up there. I went to college (MIT) on the east coast where I met my wife, who grew up in Texas (south central U.S.). I could never get her to move as far north as Wisconsin and she couldn't get me to move as far south as Texas, so we spent the next 25 years living in the "middle" latitudes (Indiana, North Carolina and Missouri). My first engineering interest was acoustics. I chose to go to Purdue University for graduate school specifically because of their acoustics research laboratory. However, I graduated during an economic recession and couldn't find a job in acoustics, so I accepted a position at IBM working in an area I had never heard of before called "electromagnetic compatibility" (EMC). My timing was fortunate, because at the time IBM had just introduced their first personal computer and the FCC had just begun to regulate the unintentional electromagnetic emissions from "computing devices". EMC analysis was very similar to acoustics analysis and I found it to be just as interesting and, in many ways, more challenging. IBM subsidized my education at North Carolina State University as I pursued a Ph.D. degree. At that time, I became interested in the rapidly growing field of computational electromagnetic modelling, particularly as it applied to solving problems in electromagnetic compatibility. I was fortunate to have access to IBM's excellent computer resources and even received a fellowship from IBM that allowed me to take a year away from the office to complete my Ph.D. research.

When my wife completed her Ph.D. in 1989, she "suggested" that we apply for faculty positions at a university. By this time we had two small children and we wanted to raise them in a small town. We also wanted to be in the middle of the country so that we were not too far from her relatives in Texas or mine in Wisconsin. So we got a list of the top 50 electrical engineering graduate programs in the U.S. and we crossed out every school that was not in the middle of the country or was in a large city. There were only 4 schools remaining on the list when we were finished, so we wrote letters applying for a pair of faculty positions to each school. Amazingly, we actually got interviews at two of the four schools. The University of Kansas was interested in my resume and was willing to interview my wife. The University of Missouri-Rolla (UMR) was interested in my wife's resume and was willing to interview me.

It was while I was interviewing at the University of Kansas that I first learned about a new organization called the Applied Computational Electromagnetics Society. A senior faculty member there encouraged me to submit a paper to the ACES conference based on my Ph.D. dissertation work; so I did. (It was in Monterey and I had never been to California before.)

We received offers from both universities and wound up accepting the offer from UMR. At UMR, I started an electromagnetic compatibility laboratory with one graduate student, a portable spectrum analyzer, and a sign on the door of the undergraduate electromagnetics lab. I met two people during my first year at UMR that were instrumental in the success of my new lab. Don Weiss, from Intel, came up to me after my talk at the ACES conference to introduce himself. Don and Intel provided the first external funding for my research (and Intel continues to fund research at the lab even today).

The other person who was instrumental in both my success and the success of the lab, was Tom Van Doren. I had been at UMR for several months before I met Tom. Back then, Tom taught at UMR one semester per year and he taught short courses all over the country the rest of the time. Tom's area of expertise was EMC and I had occasionally received flyers for his short courses when I was at IBM. His presence at UMR was one of the reasons I decided to accept the faculty position there. However, the department chairman had warned me not to get “involved” with Tom. He was worried that I might get caught up in the lucrative short course business at the expense of my research and prospects of getting tenure. However, Tom turned out to be one of the most research-oriented EMC people I had ever met. He loved investigating new ideas and discussing EMC concepts. Tom has had a greater influence on my research and my life than any other colleague before or since that time.

A couple years later, we were joined by a new faculty member who had just graduated from the University of Illinois named Jim Drewniak. Jim’s technical and management skills contributed significantly to the development of our lab. Over the next 15 years, we continued to grow and prosper. We formed an industry consortium, which provided a steady source of research funding and we were joined by three more faculty members. With a total of 6 faculty, each of us were able to focus on various EMC research topics while sharing administrative and lab management responsibilities.

In 2006, I was offered an endowed chair position with the newly formed Clemson University International Center for Automotive Research (CU-ICAR). In the 1990s, EMC was transforming from a problem-solving skill to an integral part of product design and development. Today, automotive electronics is undergoing a similar transformation providing excellent opportunities for university research labs. I was attracted to Clemson by the opportunity to start a new laboratory in a growth area, much like the opportunity I had at UMR 20 years ago.

What did you read at university, which university(ies) and why this (these) subjects?	I became interested in acoustics while working at a summer job with a company that made mufflers and silencers for internal combustion engines. My interest became a passion when I took an undergraduate course in acoustics taught by Prof. Amar G. Bose at MIT. Prof. Bose was already a multimillionaire at the time and CEO of a successful company (Bose Corporation). He didn't have to teach, but he taught the acoustics class because he loved teaching. He was a major influence in my decision to pursue graduate studies and ultimately in my decision to become a university professor.
What is your current job and what does it entail? What are you most proud of achieving?	My official title is Michelin Professor of Vehicular Electronic Systems Integration at Clemson University. I teach courses and conduct research related to EMC and vehicle electronics. I'm proud of the EMC laboratory and research program we built at UMR. I hope to build a similar program in automotive electronics at Clemson.
If you weren't doing this job, what would your ideal occupation be? What are your abiding passions?	This is my ideal occupation. My abiding passion is solving engineering problems that make a real difference to society.
If you were abandoned in an underground laboratory with no immediate chance of release and with the opportunity of only using one numerical technique, which technique would you want to use and why?	Oddly, if I had to choose only one technique, it would be FDTD (a nice general purpose technique). However, most of the complex system modeling we do relies on FEM and MOM codes. It is fortunate that the world doesn't have to rely on a single numerical EM modeling technique. The 'big problem' that needs to be addressed is making codes that recognize geometries they are not able to analyze and that refuse to run unless there is a reasonable expectation that the results will be correct.

What 'big problem' would you want to spend your time trying to solve with your modelling?	One day, we will have EM modeling software that reviews the geometry to be modelled, selects the modeling technique to use, generates its own mesh and validates its own results.
If you had a 'one shot' time machine to bring someone from any period of history to keep you company in the underground laboratory, who would you choose and why?	That person would certainly be my wife, Nancy. However, if you are looking for a famous scientist, it would be interesting to have a conversation with Richard Feynman.
Any interesting stories or anecdotes?	Sure, lots of them … my first introduction to EM circuits, my ill-fated job interview with Bose, my fortuitous introduction to EMC at IBM, etc. However, I've gone on too long already. I'd be happy to swap stories with other ACESians at the next conference.

ACES Conference – Student Paper Competition

The Student Paper Competition at the 2009 ACES Conference in Monterey, CA displayed some of the best cutting edge research papers in many areas of electromagnetics from time-domain and frequency-domain computational advances to practical applications and designs of antennas for RFID and GPS. There were a total of 25 paper submissions from universities and research institutes around the world. This total was narrowed to ten finalists, and each of these

The author - Gerald DeJean

Gerald R. DeJean received the B.S. degree in Electrical and Computer Engineering from Michigan State University in December of 2000, and the M.S. and Ph.D. degrees in Electrical and Computer Engineering from the Georgia Institute of Technology in May of 2005 and January of 2007, respectively. He has authored and co-authored over 40 papers in refereed Journals and Conference Proceedings. He currently works at Microsoft Research as a researcher in the field of RF and antenna design. In November 2008, he was appointed to the position of adjunct assistant professor at the Georgia Institute of Technology. His research interests include antenna design, RF/microwave design and characterization, and 3D system-on-package (SOP) integration of embedded functions that focuses largely on modern commercial RF systems.

participants prepared an oral presentation for judging. Approximately, 20-30 conference attendees stopped by the competition and enjoyed the intense battle between students whose experience ranges from 1st year graduate students to 4th and 5th year students. The 1st place winner was a paper entitled “A Symmetric Hybrid Time-Domain Finite Element Method for Transient Field-Circuit Simulation” by Rui Wang and Jian-Ming Jin from the University of Illinois at Urbana-Champaign. The winner of the 2nd place prize was a paper entitled “Integral Equation Methods for Near-Field Far-Field Transformation” by Carsten H. Schmidt and Thomas F. Eibert from the University of California – Los Angeles. Last, but not least, a paper entitled “The Generation of a Plane Wave in the Near Field of a Line Source Using an Array of Conducting Cylinders” by Bassem Henin, Atef Elsherbeni, Mohamed H. Al Sharkawy, and Fan Yang from the University of Mississippi captured the 3rd place prize. This year, a panel of three judges reviewed the oral presentations. In future competitions, some suggestions have been made to open the final competition judging to the audience or revert back to a poster presentation. These and many other suggestions will be taken into account for the preparation of the 2010 ACES conference in Tampere, Finland. Overall, the competition was very successful.

If you have any thoughts or suggestions about improving the student paper competition, please get in touch at dejean@microsoft.com.

Electromagnetic Field Shielding of a Spherical Shell – Revisited

Part 2: A Shell with an Aperture

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Abstract

This paper continues with an investigation of the EM shielding of a spherical enclosure. Part 1 of this paper has investigated the frequency dependent shielding of an integral imperfectly conducting spherical shell. This study continues here to consider the shielding of a perfectly conducting hollow sphere having an aperture.

As noted in Part 1, previous studies of the EM shielding provided by these objects have concentrated on evaluating the E- and H-fields at the center of the shield, where only one term of the spherical wave function expansion is needed. While the internal H-field in the shielded volume of the conducting shell is very close to being constant, the same is not true for the E-field, where there can be a significant variation in the E-field intensity from point to point within the interior.

In the present Part 2, the treatment of the hollow sphere with an aperture is obtained using a quasi-static model, which also permits the determination of the E-fields anywhere in and around the sphere. Using this model, the statistical behavior of the internal E-field is described.

This paper also appears as *Interaction Note 607*, June 5, 2008, Dr. Carl Baum, editor, at www.ece.unm.edu/summa/notes

1. Introduction

The work reported in this paper is a re-visitation of two classical canonical shielding problems: a thin spherical shell made of imperfectly conducting material, which is presented in Part 1, and a perfectly conducting hollow sphere with an aperture, which is discussed in Part 2.

In this Part 2, a quasi-static model useful for computing the internal E-field in a sphere with a hole is reviewed. Because the dual H-field problem can be solved from the E-field solution in this case, only the E-field shielding is discussed here. A Monte Carlo simulation is also performed for this shield, and the corresponding CPDs for the E-field are presented.

2. Quasi-Static Shielding by a Spherical Shell with an Aperture

As mentioned earlier in Part 1, a completely closed spherical shield is not the best geometry to use for trying to represent the shielding of a realistic enclosure. This is because most enclosures have apertures and conducting penetrations. To better understand the effect of an aperture on the shielding of a spherical enclosure, the quasi-static models of Casey [1] can be used. These models are useful for electrically small enclosures, where $k_2 b < 1$. For higher frequencies, the dynamic model of ref. [2] can be used, but this is not discussed further here.

Figure 1 shows the geometry of a thin, perfectly conducting spherical shell of radius *b* with an aperture, which is immersed in a quasi-static E-field. Two different orientations of the E-field are considered: Case 1 is with the E-field oriented in the $\hat{z}$ direction, and Case 2 is with the E-field in the $\hat{x}$ direction. The aperture is located symmetrically at the bottom of the sphere and is defined by the opening half-angle θ_o, or by the angle $\alpha = \pi - \theta_o$.

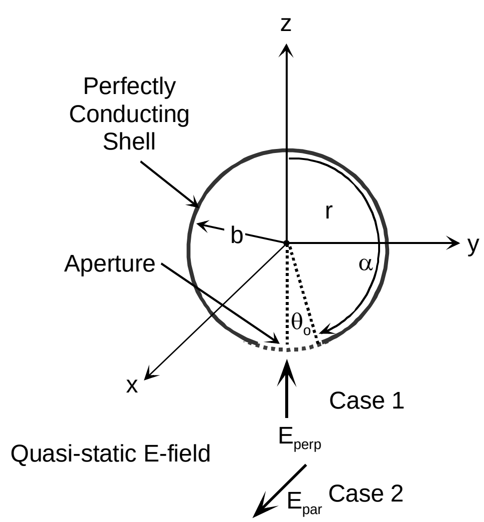


Figure 1. Geometry of a thin, perfectly conducting sphere having a circular aperture and illuminated by a quasi-static E-field.

For this sphere with aperture, we are interested in computing the internal E- and H-fields and describing their statistical distributions throughout the shielded volume. In [**Error! Bookmark not defined.**], both the E-field excitations and the dual H-field excitations of the sphere have been formulated. However, in the numerical studies reported there, only the E-fields at the center of the sphere have been considered. Also, as shown in [**Error! Bookmark not defined.**], the E- and H-field solutions are related, with Case 1 for the E-field having the same solution as Case 2 for the H-field, and vice versa. Thus, in the development in this part of the paper, we will consider only the E-field case[1].

In using this quasi-static shielding model it is important to keep in mind that it is inherently different from the penetrable spherical shield model discussed in Part 1 of this paper, where at low frequencies the H-field is able to diffuse easily into the shield. In the present model with an assumed perfectly conducting shield, this diffusion mechanism is not present and the shield does offer protection against the H-field.

2.1 Case 1 -- Axially Symmetric Excitation of the Uncharged Sphere with Aperture

For the case of the z-directed excitation E-field, the solution is independent of the ϕ coordinate. From quasi-static considerations, the electric potential function for this "incident" E-field is

$$V^i(r,\theta) = -E_o r\cos\theta \quad (1)$$

and the potential function arising from induced charges on the sphere with hole can be expressed as a sum of static functions as

$$\begin{aligned} V^s(r,\theta) &= E_o b\sum_{n=0}^{\infty} a_n^{(1)}\left(\frac{r}{b}\right)^n P_n\left(\cos\theta\right) \quad (r \le b) \\ &= E_o b\sum_{n=0}^{\infty} a_n^{(1)}\left(\frac{r}{b}\right)^{-(n+1)} P_n\left(\cos\theta\right) \quad (r \ge b) \end{aligned} \quad (2)$$

where $P_n\left(\cos\theta\right)$ is the Legendre polynomial of order *n*, and $a_n^{(1)}$ are unknown expansion coefficients. The total potential is the sum of the two:

$$V(r,\theta) = V^i(r,\theta) + V^s(r,\theta)\,. \quad (3)$$

By using boundary conditions on the sphere that $V(b,\theta) = V_o$ a constant (but unknown) for $0 \le \theta < \alpha$ and that $\partial V(r,\theta)/\partial r$ is continuous over the opening ($r = b$, $\alpha < \theta \le \pi$), Casey shows that by using Eqs.(1) and (2) the boundary conditions can be put into a dual series equation of the form

$$\begin{aligned} &\sum_{n=0}^{\infty} a_n^{(1)} P_n\left(\cos\theta\right) = \frac{V_o}{E_o b} + \cos\theta \qquad (0 \le \theta < \alpha) \\ &\sum_{n=0}^{\infty} (2n+1) a_n^{(1)} P_n\left(\cos\theta\right) = 0 \qquad (\alpha < \theta \le \pi) \end{aligned} \quad (4)$$

Using the assumption that the sphere is uncharged, Casey further observes that the *n* = 0 term in the series must vanish and he then develops an analytical solution for the coefficients $a_n^{(1)}$. (See

[1] This is not to underemphasize the need for knowing the internal H-field, however. As noted in ref.[i] of Part 1, the excitation of an internal wire in the sphere with an aperture requires knowledge of both the E- and H-fields.

[**Error! Bookmark not defined.**] for more details). The resulting solution is

$$a_n^{(1)} = \frac{1}{\pi}\left(\frac{\sin(n-1)\alpha}{n-1} + \frac{\sin(n+2)\alpha}{n+2}\right) - \frac{1}{\pi}\left(\frac{\sin\alpha + \frac{1}{2}\sin 2\alpha}{\alpha + \sin\alpha}\right)\left(\frac{\sin n\alpha}{n} + \frac{\sin(n+1)\alpha}{n+1}\right). \quad (5)$$

From the total potential the E-field is computed as

$$\begin{aligned} E(r,\theta,\phi) &= -\nabla V(r,\theta,\phi) \\ &= \frac{\partial V}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{\theta} + \frac{1}{r\sin\theta}\frac{\partial V}{\partial \phi}\hat{\phi}, \end{aligned} \quad (6)$$

or in component form,

$$\begin{aligned} E_r(r,\theta) &= E_o \cos\theta - E_o \sum_{n=1}^{\infty} a_n^{(1)} n \left(\frac{r}{b}\right)^{n-1} P_n(\cos\theta) \qquad (\text{for } r<b) \\ &= E_o \cos\theta + E_o \sum_{n=1}^{\infty} a_n^{(1)} (n+1) \left(\frac{r}{b}\right)^{-(n+2)} P_n(\cos\theta) \quad (\text{for } r>b) \end{aligned} \quad (7a)$$

$$\begin{aligned} E_\theta(r,\theta) &= -E_o \sin\theta - E_o \sum_{n=1}^{\infty} a_n^{(1)} \left(\frac{r}{b}\right)^{n-1} P_n^1(\cos\theta) \qquad (\text{for } r<b) \\ &= -E_o \sin\theta - E_o \sum_{n=1}^{\infty} a_n^{(1)} \left(\frac{r}{b}\right)^{-(n+2)} P_n^1(\cos\theta) \quad (\text{for } r>b) \end{aligned} \quad (7b)$$

$$E_\phi(r,\theta) = 0. \quad (7c)$$

In Eq.(7b) the relationship

$$\frac{dP_n(\cos\theta)}{d\theta} = P_n^1(\cos\theta) \qquad (8)$$

is used.

Casey computes the shielding only at the center of the sphere, where only the *n* = 1 term contributes to the sum. In this case, he gets an E-field transfer function in closed form as

$$TE^{(1)} \equiv \frac{\left|E^{in}(0)\right|}{E_o} = \frac{1}{\pi}\left[\theta_o - \frac{1}{3}\sin 3\theta_o + \frac{\left(\sin\theta_o - \frac{1}{2}\sin 2\theta_o\right)}{\pi - \theta_o + \sin\theta_o}\right] \qquad (9)$$

where $\theta_o = \pi - \alpha$ is the opening angle of the aperture in the sphere, as shown in Figure 1.

2.2 Case 2 – X-directed E-field Excitation of the Uncharged Sphere with Aperture

The potential function for excitation field in x- direction is given as

$$V^i(r,\theta) = -E_o r \sin\theta \cos\phi \qquad (10)$$

and the corresponding potential arising from interaction with the sphere with hole is

$$\begin{aligned} V^s(r,\theta,\phi) &= E_o b\cos\phi \sum_{n=0}^{\infty} a_n^{(2)} \left(\frac{r}{b}\right)^n P_n^1(\cos\theta) \qquad (r \le b) \\ &= E_o b\cos\phi \sum_{n=0}^{\infty} a_n^{(2)} \left(\frac{r}{b}\right)^{-(n+1)} P_n^1(\cos\theta) \quad (r \ge b) \end{aligned} \quad . \qquad (11)$$

In this expression, the associated Legendre polynomials $P_n^1(\cos\theta)$ are used, and the expansion coefficients $a_n^{(2)}$ are different from those found for Case 1. Noting that symmetry in this case requires that the total potential on the sphere be zero and applying the previously mentioned boundary conditions, Casey develops another dual series equation for the unknown coefficients for this case:

$$\begin{aligned} &\sum_{n=0}^{\infty} a_n^{(2)} P_n^1(\cos\theta) = \sin\theta \qquad (0 \le \theta < \alpha) \\ &\sum_{n=0}^{\infty} (2n+1) a_n^{(2)} P_n^1(\cos\theta) = 0 \qquad (\alpha < \theta \le \pi) \end{aligned} \quad . \qquad (12)$$

The solution for $a_n^{(2)}$ is shown to be

$$a_n^{(2)} = \frac{-1}{\pi n(n+1)}\left(\frac{n+1}{n-1}\sin(n-1)\alpha + \sin n\alpha - \sin(n+1)\alpha - \frac{n}{n+2}\sin(n+2)\alpha\right) \quad (13)$$

and the resulting E-field components inside and outside the sphere are calculated from Eq.(6) as

$$E_r(r,\theta,\phi) = E_o \sin\theta\cos\phi - E_o\cos\phi\sum_{n=1}^{\infty} a_n^{(2)} n\left(\frac{r}{b}\right)^{n-1} P_n^1(\cos\theta) \qquad (\text{for } r<b)$$

$$= E_o \text{ in}\,\theta\cos\phi + E_o\cos\phi\sum_{n=1}^{\infty} a_n^{(2)}(n+1)\left(\frac{r}{b}\right)^{-(n+2)} P_n^1(\cos\theta) \quad (\text{for } r>b)$$

(14a)

$$E_\theta(r,\theta,\phi) = E_o \cos\theta\cos\phi - E_o\cos\phi\sum_{n=1}^{\infty} a_n^{(2)}\left(\frac{r}{b}\right)^{n-1} \frac{\partial}{\partial\theta} P_n^1(\cos\theta) \qquad (\text{for } r<b)$$

$$= E_o \cos\theta\cos\phi - E_o\cos\phi\sum_{n=1}^{\infty} a_n^{(2)}\left(\frac{r}{b}\right)^{-(n+2)} \frac{\partial}{\partial\theta} P_n^1(\cos\theta) \quad (\text{for } r>b)$$

(14b)

$$E_\phi(r,\theta,\phi) = -E_o \sin\phi + E_o\frac{\sin\phi}{\sin\theta}\sum_{n=1}^{\infty} a_n^{(2)}\left(\frac{r}{b}\right)^{n-1} P_n^1(\cos\theta) \qquad (\text{for } r<b)$$

$$= -E_o \sin\phi + E_o\frac{\sin\phi}{\sin\theta}\sum_{n=1}^{\infty} a_n^{(2)}\left(\frac{r}{b}\right)^{-(n+2)} P_n^1(\cos\theta) \quad (\text{for } r>b) \, .$$

(14c)

In Eq.(14b) the derivative of the associated Legendre function $\frac{\partial}{\partial\theta}P_n^1(\cos\theta)$ can be calculated from the relationship

$$\frac{\partial}{\partial\theta}P_n^m(\cos\theta) = \frac{-1}{\sin\theta}\left[(n+1)\cos\theta\, P_n^m(\cos) - (n-m+1)P_{n+1}^m(\cos\theta)\right] \quad (15)$$

For this case, the E-field transfer function at the center of the sphere given by Casey is

$$TE^{(2)} = \frac{1}{\pi}\left[\theta_o - \frac{1}{2}\sin\theta_o - \frac{1}{2}\sin 2\theta_o + \frac{1}{6}\sin 3\theta_o\right]. \qquad (16)$$

2.3 Numerical Results

The $\hat{r}$, $\hat{\theta}$ and $\hat{\phi}$ components E-fields in the vicinity of the sphere given by Eqs.(7) and (14) have been calculated numerically, and a total E-field transfer function TE developed. It was found, as in ref. [**Error! Bookmark not defined.**], that a large number of terms in the summations were required to achieve convergence throughout the sphere. Typically, 150 terms were used for these calculations.

Figure 2 presents a comparison of the calculated TE functions at the center of the sphere for Case 1 and Case 2 with those reported by ref. [**Error! Bookmark not defined.**] (in his Figure 2). This plot depicts the variation of the shielding as the aperture half-angle θ_o varies from zero (no aperture) to 180° (no sphere). The present analysis overlays exactly on Casey's results, and partially validates the numerical implementation of the solution. Figure 3 presents the same shielding data as in Figure 2, but with TE expressed in dB.

Since Eqs.(7) and (14) are valid inside and outside the sphere, it is possible to develop contour plots of the total E-field transfer functions that show the E-field leaking through the aperture.

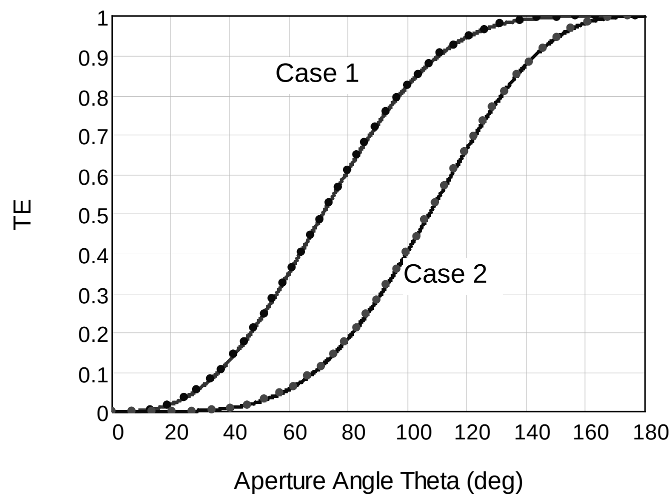


Figure 2. Plot of the E-field transfer function at the center of the spherical enclosure as a function of the aperture half-angle θ_o, for Case 1 (*E* in *z*-direction) and Case 2 (*E* in *x*-direction). Dots represent Casey's results, solid lines are for the present analysis

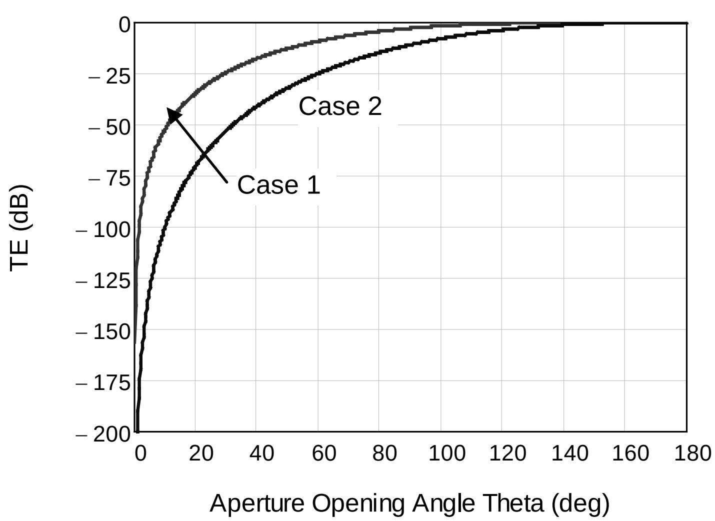
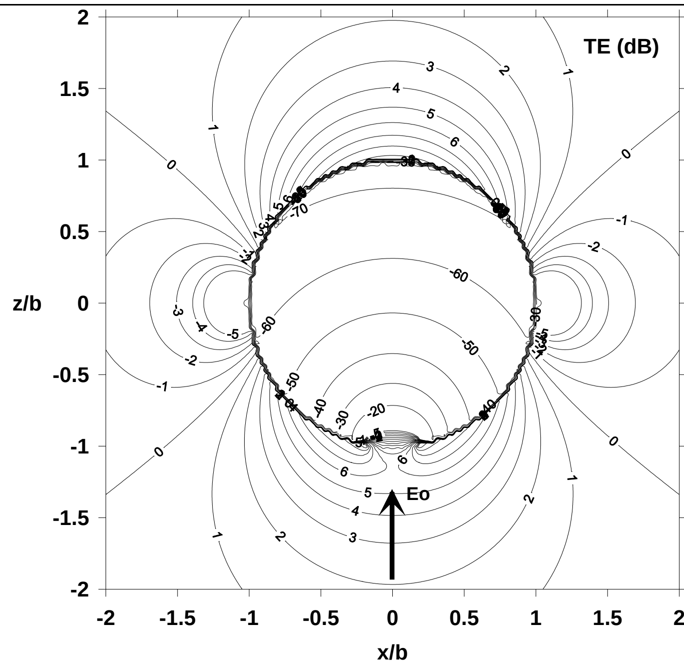
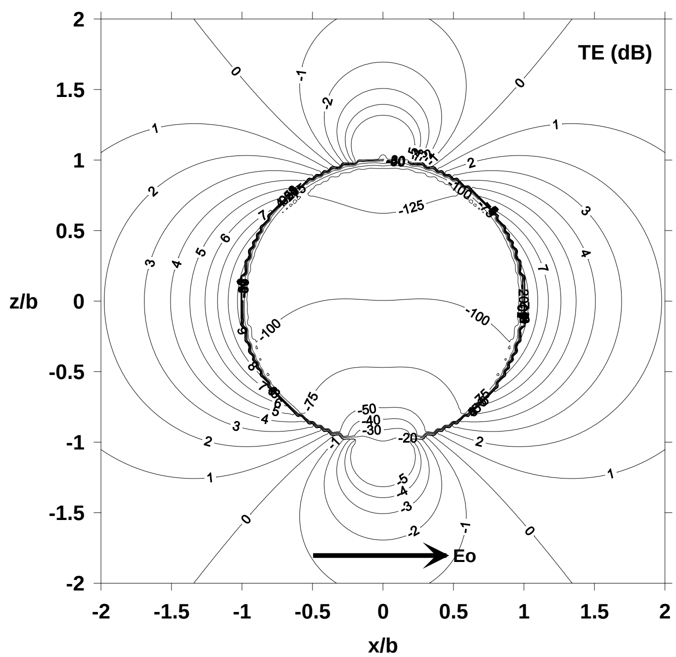


Figure 3. Plots of the E-field transfer function (expressed in dB) at the center of the sphere, as a function of the aperture angle θ_o.



a. Case #1 (*E* in z-direction)

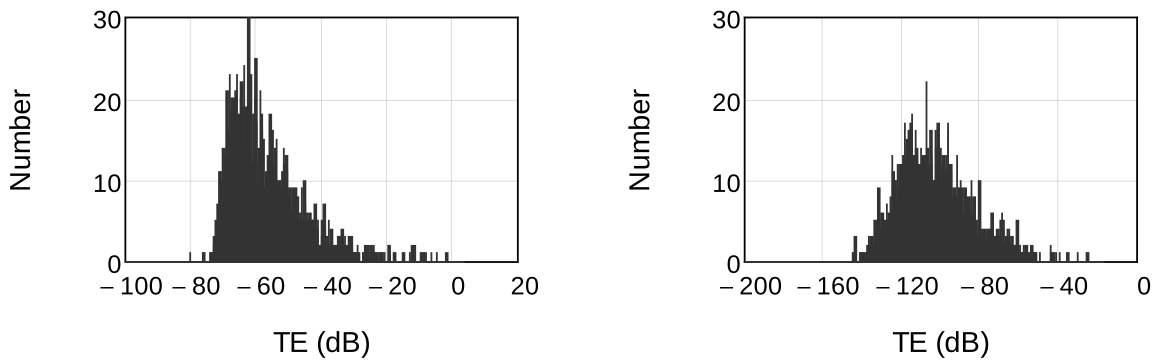


b. Case #2 (*E* in x-direction)

Figure 4. Contour plots of TE (in dB) in the vertical *z-x* plane for Case 1 (*a*) and Case 2 (*b*) excitations. (Aperture half-angle θ_o = 10º).

2.4 Statistical Description of the Internal Fields

A Monte Carlo simulation with 3000 random internal points was conducted and the results for the total E-fields for Cases 1 and 2 binned. For the aperture half-angle of θ_o = 10º, Figure 5 shows the resulting histograms, which are typical of those for the other angles.

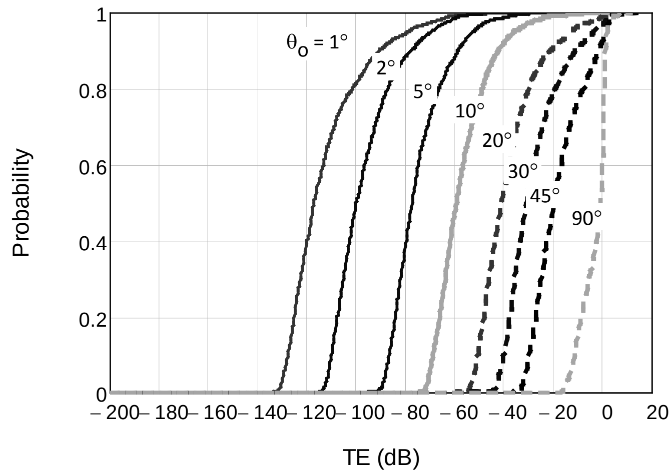


a. Case #1 (*E* in *z*-direction) b. Case #2 (*E* in *x*-direction)

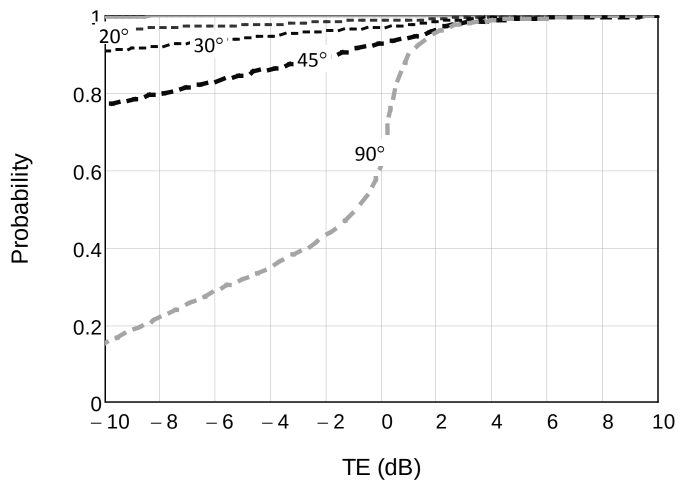
Figure 5. Example of the histogram functions for the internal E-field transfer functions for an aperture half-angle of θ_o = 10º.

Calculations were performed for aperture half-angles of 1, 2, 5, 10, 20, 30, 45 and 90 degrees and the CPDs of the E-field transfer functions computed. Figure 6 presents the results for Case 1 and the Case 2 results are in Figure 7. Also shown in these figures is a close-up plot of the responses near 0 dB, which show that there are some points within the r = b sphere that have E-fields larger than the excitation field. This occurs at points near the rim of the aperture, where the E-field is large due to the sharp edge.

Table 1 summarizes these distributions by the mean values of the E-field transfer function and the standard deviations. Also shown is the TE value at the center of the sphere. While this value is not exactly equal to the mean value of TE, it is usually within about 5 dB of the mean. Thus, the value at the center does provide a useful measure of the average shielding provided by this structure.

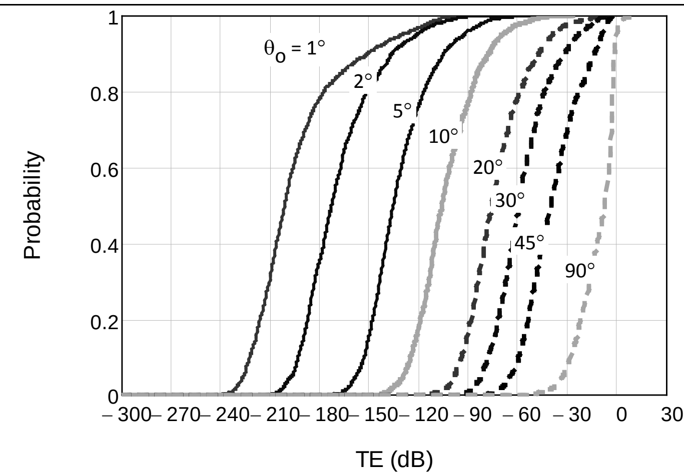


a. All responses

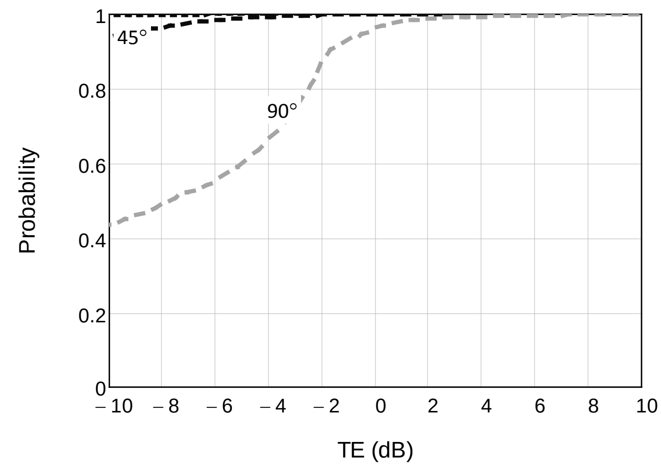


b. Expanded scale near 0 dB

Figure 6. Cumulative probability distributions for the E-field within the sphere with aperture for Case 1, shown for various values of the aperture half-angle θ_o.



a. All responses



b. Expanded scale near 0 dB

Figure 7. Cumulative probability distributions for the E-field within the sphere with aperture for Case 2, shown for various values of the aperture half-angle θ_o.

Table 1. Summary of the mean values and standard deviations of the distributions computed for the internal E-fields in the sphere with aperture.

	Case 1			Case 2		
Aperture Angle (deg)	Avg. TE (dB)	TE Std. Dev. (dB)	TE (dB) from [**Error! Bookmark not defined.**]	Avg. TE (dB)	TE Std. Dev. (dB)	TE (dB) from [**Error! Bookmark not defined.**]
1	-112.6	15.6	-111.9	-194.3	28.1	-199.7
2	-96.7	12.9	-93.9	-168.4	22.8	-169.6
5	-74.8	11.3	-70.0	-131.9	19.5	-129.9
10	-57.0	11.1	-52.0	-103.4	18.5	-99.8
20	-38.2	12.1	-34.3	-73.1	18.2	-69.9
30	-28.0	11.4	-24.3	-57.1	17.4	-52.7
45	-17.8	10.2	-14.9	-38.7	16.9	-36.0
90	-3.2	5.1	-2.7	-11.6	11.0	-10.8

3. Summary and Comments

This paper has examined two canonical shielding problems with the goal of trying to gain a better understanding of the EM shielding provided by real shielding enclosures. The shield considered in Part 1 of the paper was a spherical shell – one being made of finitely conducting material (aluminum) and having a finite wall thickness, and the shield treated in this second part of the paper was a perfectly conducting hollow sphere with an aperture. The wall thickness was zero in this latter case. In this study, the analysis for the first case in Part 1 was frequency-dependent, while the analysis for the second was quasi-static.

The reason for choosing these simple shapes was that the calculation of the internal fields could be done mathematically through the use of spherical harmonics. This provides the possibility of evaluating the E- and H-fields anywhere inside or outside the sphere. In developing this analysis, closed form expressions for the expansion coefficients were found, and these do not appear to be generally available in the literature. Moreover, a unique scaling technique was introduced that permits the accurate evaluation of the spherical Hankel function terms of the wave functions. This scaling is not an approximation to the Hankel functions, but is exact.

The benefit of this type of solution is that a Monte Carlo simulation can be used to develop probability distributions for the internal fields that show the variability of the field magnitudes. The difficulty, however, is that the solution is in the form of an infinite series of factors, which, at times, is difficult to sum. Moreover, there are numerical challenges in calculating the required Hankel functions of complex argument inside the lossy material due to numerical overflow and underflow.

From the formulation and application of the model described in this paper, the following observations regarding the shielding of the sphere deserve mention:

1. Most previous shielding studies of spherical shapes have concentrated on the behavior of the E- and H-fields at the center of the sphere. For a uniform sphere made of finitely conducting material, the use of the center as an observation point is appropriate for the H-field, as this field is seen to be nearly constant. However, it is not correct for the E-field, since there can be large variations of this field inside the sphere, and the E-field at the center is relatively low. This provides a gross overestimate of the amount of E-field shielding provided by the sphere.

2. A better way to describe the internal fields within the sphere (and any other enclosure, for that matter) is through a cumulative probability distribution that represents that variation of the internal fields

3. For the perfectly conducting spherical shell with an aperture, there are also large variations of the E- and H-fields within the interior. However, it is noted that for this type of shield, the value of the field at the center of the sphere is close to the average value of the field inside – at least for apertures with opening half-angles from 0 to 90 degrees. Nevertheless, there can be significant variations of the internal fields, with a standard deviation of 5 to 30 dB being found the cases considered here.

4. Finally, while not considered here, but very important nevertheless, the presence of conducting penetrations into the interior of the sphere will radically change the statistical behavior of the internal fields. Since this type of penetration is very common, the shielding of most practical enclosures will be ultimately determined by this type of penetration and not by diffusion and aperture penetrations that have been considered in this paper. Clearly this area requires more investigation and quantification.

4. References

1. Casey, K. F., "Quasi-Static Electric- and Magnetic-Field Penetration of a Spherical Shield Through a Circular Aperture", *IEEE Trans EMC*, Vol. EMC-27, No. 1, February 1985.

2. Senior, T. B. A., and G. Desjardins, "Electromagnetic Field Penetration into a Spherical Cavity", *IEEE Trans EMC*, Vol. EMC-16, No. 4, November 1974.

3. Yang, F. C. and C. E. Baum, "Use of Matrix Norms of Interaction Supermatrix Blocks for Specifying Electromagnetic Performance of Subshields", *Interaction Notes*, Note 427, April 1983.

Members Labs update – University of L'Aquila EMC laboratory

You may recall that Giulio Antonini wrote a piece for the newsletter a little while ago about the EMC Lab at the University of L'Aquila. You may also recall the recent earthquake in L'Aquila. Here, Giulio talks about the earthquake and its aftermath.

Main entrance to the engineering building

A strong earthquake struck the university town of L'Aquila (capital city of the Abruzzo region) on early Monday April 6th 2009. The earthquake, 5.8 in the Richter scale, struck at 3:32 a.m. local time in a quake-prone Abruzzo region that has had at least nine smaller jolts since the beginning of April and left death and destruction in its wake. In 22 seconds, the length of the major tremor, the life of thousands people suddenly changed. Upwards of 40,000 residents were left homeless, 298 people were killed and at least 1,600 were injured, 200 seriously. For several days, rescue workers tried to rescue people from collapsed homes, including a student dormitory where a dozen students remained trapped inside. The majority of the damage occurred in the old town of the medieval city of L'Aquila and the surrounding villages.

The University of L'Aquila, which has about 27000 students, has been seriously affected with fifty-five students killed and only two buildings, on the university's two out-of-town campuses, remaining structurally sound. The school of engineering, which is placed at the top of a hill in the L'Aquila, where I

Main corridor before…

… and after

work as Associate Professor of Electrical Engineering, was also seriously damaged, as shown by these pictures. If the earthquake had struck later in the day, the number of victims among the students and Faculty would have been much higher. Teaching activities have been re-located and re-scheduled. Thanks to the huge effort of everyone in the University, all the lectures started again in the month following the earthquake: firstly in tents and now in other towns in the region. We are confident that almost all the courses will be completed as normal. The Electromagnetic Compatibility Laboratory of which I'm member, is now hosted by an industrial company, Technolabs, in L'Aquila, which has generously offered their safe structures to allow our students to keep working on their projects.

Although the earthquake hit most of us in our personal and professional lives, we are strongly determined to rise up and make our University a better place where our students can learn, grow and prepare for their professional futures. We owe this to all the students who lost their lives that damned night.

Some CEM research in Tampere, Finland – host of the 2010 ACES Conference.

The next host city of ACES Conference – Tampere, Finland – has a lot of activities going on in terms of Radio Frequency Identification (RFID). Tampere is the home city of some leading RFID companies, such as UPM Raflatac and Confidex, and the

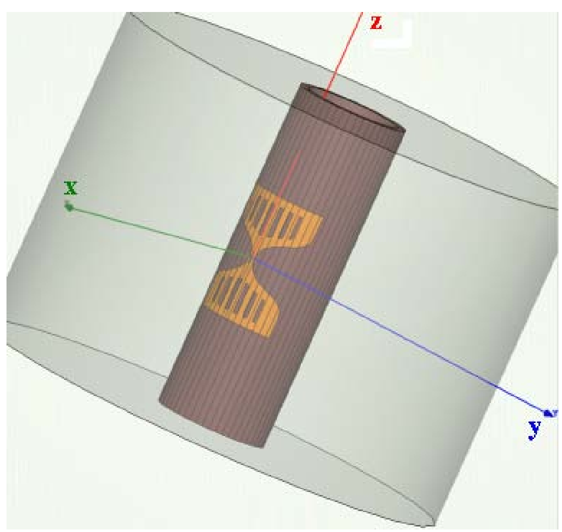
About the authors

Lauri Sydänheimo *received the M.Sc. and Ph.D. degrees in electrical engineering from Tampere University of Technology (TUT). He is currently a Professor with the Department of Electronics, TUT, and works as the Research Director of Tampere University of Technology's Rauma Research Unit. He has authored over 120 publications in the field of RFID tag and reader antenna design and RFID system performance improvement. His research interests are focused on wireless data communication and radio frequency identification (RFID).*

Department of Electronics at Tampere University of Technology has a very active and innovative RFID research group.

One of the main industries in Finland is the paper industry. Paper industry applications are also among the most challenging applications of RFID systems. The RFID research group in Tampere University of Technology has developed the first passive UHF RFID tag design for identifying industrial paper reels. This tag can be read omnidirectionally around an industrial paper reel through the thick paper layer.

Computational electromagnetic modeling has played an important role also in developing this tag antenna design. By electromagnetic modeling the tag antenna design can be very accurately optimized before moving on to the laboratory and field testing of the antenna.



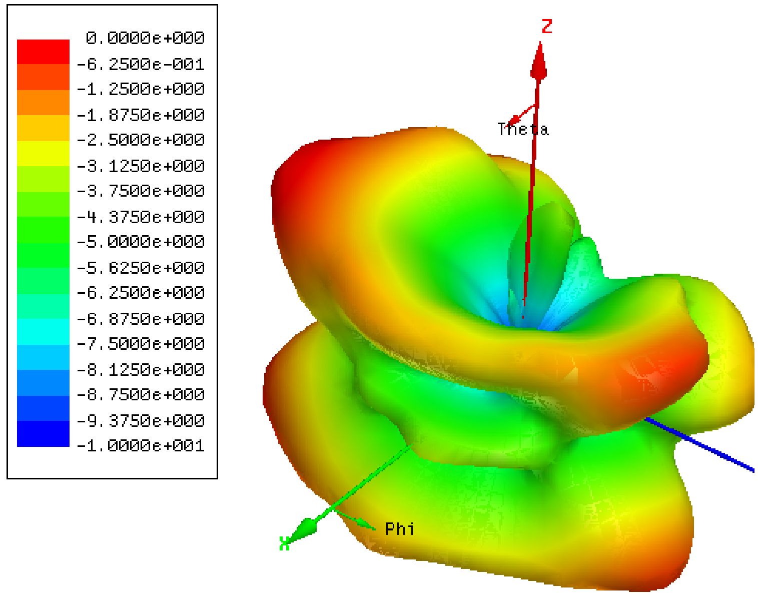
Model of the paper reel and the tag antenna.

Leena

Ukkonen *received the M.Sc. and Ph.D. degrees in electrical engineering from Tampere University of Technology (TUT) in 2003 and 2006, respectively.*

She is currently working at the TUT, Department of Electronics as Senior Research

Scientist leading the RFID research group. She has authored over 60 publications in the field of RFID antenna design and industrial RFID applications. Her research interests are focused on passive UHF radio frequency identification (RFID) antenna development for tags and readers.



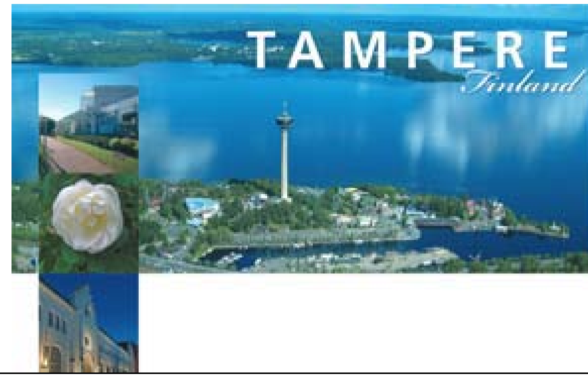
Three-dimensional radiation pattern of the paper reel tag antenna.

As general chairs of the ACES 2010 Conference we wish you a warm welcomed to Tampere!

Prof. Lauri Sydänheimo and Dr. Leena Ukkonen

Tampere University of Technology

Conference 2010 call for papers.



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The 26th International Review of Progress in Applied Computational Electromagnetics

In conjunction with RFIDay 2010

April 26 to 29, 2010, Tampere, FINLAND

General Chairs ***Lauri Sydänheimo and Leena Ukkonen***, Tampere University of Technology
Technical Program Chair ***Atef Elsherbeni***, The University of Mississippi

The international ACES symposium serves as a forum for developers, analysts, and users of computational techniques applied to electromagnetic field problems at all frequency ranges. The symposium includes technical presentations, software demonstrations, vendor booths, short courses, and hands-on workshops.

Papers may address general issues in applied computational electromagnetic or focus on specific applications, techniques, codes, or computational issues of potential interest to the Applied Computational Electromagnetics Society membership. The following is a list of suggested topics, although contributions in other areas of computational electromagnetics will be considered.

Suggested Topics:
Integral Equation Methods Differential Equation Methods Fast and Efficient Methods Hybrid and Multi-Physics Modeling EM Modeling of Complex Mediums Modeling Electrically Large Structures Inverse Scattering and Imaging Techniques Optimization Techniques for EM-based Design Asymptotic and High Frequency Techniques Low Frequency Electromagnetics Computational Bio-Electromagnetics Printed and Conformal Antennas Modeling and Performance of RFID Systems Wideband and Multiband Antennas
Dielectric Resonator Antennas Phased Array Antennas Smart Antenna and Arrays EBG and Artificial Materials Nanotechnology Applications Frequency Selective Surfaces MEMS-NEMS and MMIC EMC/EMI Applications Propagation Analysis Remote Sensing Applications RFID Systems and Applications Modeling and Analysis of TeraHertz Antennas High Performance Computing Parallel and GPU Computations Modeling and Applications of Metamaterial
Modeling and Analysis of Small Antennas

All authors of accepted papers will have the option to submit an extended version of their paper or papers for review and publication in the ACES Journal.

SYMPOSIUM STRUCTURE

The international annual ACES Symposium traditionally includes: (1) oral sessions, regular and invited, (2) poster sessions, (3) a student paper competition, (4) short courses, (5) software demonstration, (6) an awards banquet, (7) vendor exhibits, and (8) social events. The ACES Symposium also includes plenary and panel sessions, where invited speakers deliver original essay-like reviews of hot topics of interest to the computational electromagnetics community.

PAPER FORMATTING REQUIREMENTS

The recommended paper length, including text, figures, tables and references, is four (4) pages, with six (6) pages as a maximum. Submitted papers should be formatted for printing on 8.5x11-inch U.S. standard paper, with 1inch top, bottom, and side margins. On the first page, the title should be 1-1/2 inches from top with authors, affiliations, and e-mail addresses beneath the title. Use single line spacing, with 11 or 12-point font size. The entire text should be fully justified (flush left and flush right). No typed page numbers. A sample paper can be found in the conference section on ACES web site at: ***http://aces.ee.olemiss.edu*.** Each paper should be submitted in camera-ready format with good resolution and clearly readable.

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No email, fax or hard-copy paper submission will be accepted. Photo-ready finished papers are required, in Adobe Acrobat format (*.PDF) and must be submitted through ACES web site using the "Upload" button in the left menu, followed by the selection of the "Conference" option, and then following the on-line submission instructions. Successful submission will be acknowledged by email after completing all uploading procedure as specified on ACES web site.

SUBMISSION DEADLINE AND REGISTRATION REQUIREMENT

Submission deadline is **November 16, 2009.** A signed ACES copyright-transfer form must be mailed to the conference technical chair immediately following the submission as instructed in the acknowledgment of submission email message. Papers without an executed copyright form will not be considered for review and possible presentation at the conference. Upon the completion of the review process by the technical program committee, the acceptance notification along with the pre-registration information will be emailed to the corresponding author on or about **January 15, 2010.** Each presenting author is required to complete the paid pre-registration and the execution of any required paper corrections by the firm deadline of **January 31, 2010** for final acceptance for presentation and inclusion of accepted paper in the symposium proceedings.

BEST STUDENT PAPERS CONTEST

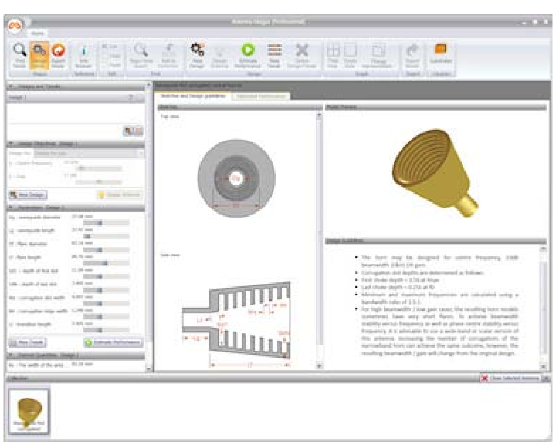
The best three (3) student papers presented at the 26th Annual Review will be announced at the symposium banquet. Members of the ACES Board of Directors will judge student papers submitted for this competition. The first, second, and third winners will be awarded cash prizes of **$300, $200**, and **$100**, respectively.

For questions please contact the conference chair ***Leena Ukkonen*** +358-44-5341507, ***aces2010@tut.fi*** or visit ACES on-line at: ***http://aces.ee.olemiss.edu***

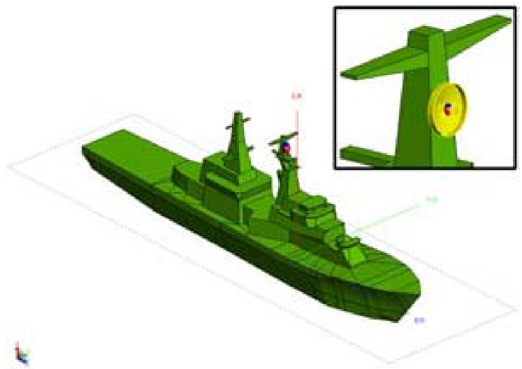
Software innovations

There is a lot going on in the commercial software sector. I would like to bring some of those innovations to the general readership. Thanks to FEKO for providing the first update.

At the beginning of May 2009, a new software solution was introduced to the market, to aid engineers engaged in antenna design and antenna placement analysis. Antenna Magus is the first design tool of its kind. It offers a huge searchable collection of antennas, which can be explored to find, synthesize and export antenna models. Antenna Magus does not aim to replace electromagnetic analysis tools like FEKO, but rather to compliment such tools. Antenna Magus can export synthesized antennas as FEKO models. These models may then be further refined, customised, analysed and optimised in FEKO, which is ideally suited to the accurate and efficient analysis of antennas. FEKO is widely used in industry.



Should one look beyond the antenna itself, to the placement of antennas within their operating environment, then the combination of Antenna Magus and FEKO is especially beneficial. This is due to the state-of-the-art methods available within FEKO to analyse electrically large structures, such as the MLFMM and hybrid asymptotic methods (MoM-PO, MoM-GO and MoM-UTD). This frees placement analysts from the detailed modeling of individual antennas, allowing them to focus more on the placement study and to save valuable development time in the process. The distributors of FEKO are very excited about bringing the value-adding functionality of Antenna Magus to existing and new customers. See www.feko.info/antennamagus for further information.



This Antenna Magus screenshot shows a waveguide-fed, corrugated, conical horn antenna being designed. This figure shows an Antenna Magus model of a dual director, short backfire antenna, imported into FEKO and mounted onto a naval platform, for full EM analysis.

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The last word

"We can't solve problems by using the same kind of thinking we used when we created them." – Albert Einstein