# TriComp WaveSim Benchmark Electromagnetic Scattering Calculations

Numerical software for electromagnetic calculations has become an active commercial field. A result is that the purchaser is presented with an array of impressive sounding options that may be of questionable utility. The calculations described in this report give some perspective on what you actually need to solve field problems. They are direct comparisons of WaveSim results to numerical solutions described at the recent **Review of Applied Computational Electromagnetics** in Monterrey, California. The results have been published in E.C. Michielssen (ed.), **Proc. Rev. Appl. Comp. Electromagnetics** (Naval Postgraduate School, Monterrey, 1997). The Field Precision paper, *Trak_RF - Simulation of Electromagnetic Fields and Particle Trajectories in High-power RF Devices*, appears on page 1102.

## Example 1. Scattering solutions with close absorbing boundaries

The paper *A Modified Mei Method for Solving Scattering Problems with the Finite-element Method* by Y.Li and Z.J. Cendes of Ansoft Corporation (page 566) describes a extended effort to implement nearby absorbing boundaries to simulate wave scattering from objects in free space. The calculation uses second-order elements and a method to set boundary currents to represent perfect absorbers. The authors also present results using the method of moments and the hybrid moment-finite-element method.

In contrast, the **TriComp** solution uses standard linear elements with our newly developed termination layer and distributed source techniques to represent free space boundaries (a paper is in preparation for the **J. Comp. Physics**). The **WaveSim** solution uses the same dimensions as the Ansoft results and took a total of one hour to complete. This time includes setting up the boundaries, running the solution, and graphing the results. The run time on a Pentium was less than one minute.

**Figure 1** compares the results. The plot shows induced surface current density on a perfectly conducting square rod as a function of position for an incident 30 MHz plane wave with $E_z$ polarization. The position starts from the middle of the front side and moves around to the back. The solid line is the **WaveSim** result, the dashed line is the Ansoft result with Mei boundaries, and the dotted line is the hybrid result which the authors considered as a reliable baseline. There is almost perfect agreement between **WaveSim** and the hybrid model. Note also that **WaveSim** does a better job of resolving discontinuities on the edges of the object.

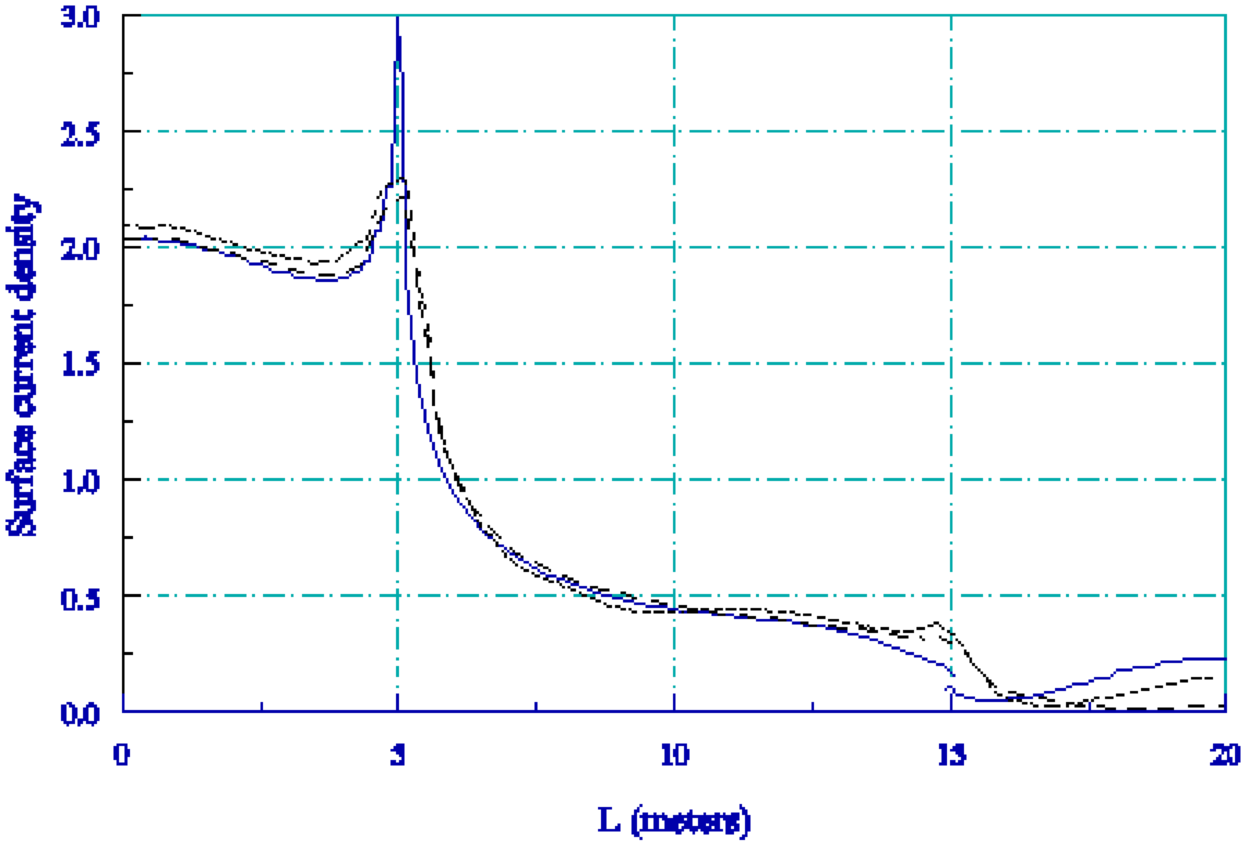


**Figure 1**

**Figure 2** shows a more difficult problem, scattering from a reentrant object on which the Mei method failed. The figure shows the **WaveSim** results with waves traveling from right to left and a symmetry boundary at the bottom. The length of solution region is 12.7 m.

**Figure 3** shows a comparison of current density moving along the object surface from the front to the back. The **WaveSim** result is the solid line and the Mei boundary calculation is the dashed line. The dotted line is a boundary-element calculation which the authors found necessary to treat the concave object. **WaveSim** agrees well with the BEM calculation and does a better job of resolving the current discontinuity at the outer edge and the enhancement at the downstream tip. While the BEM is useful for conducting objects, the finite-element formulation of **WaveSim** has a strong advantage for complex objects with mixed dielectric.

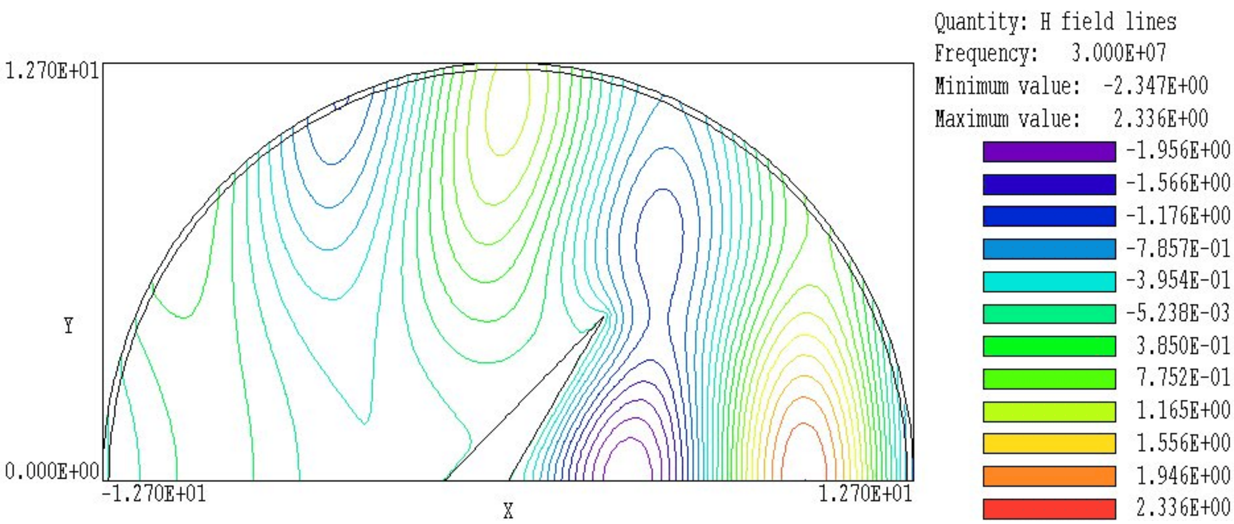


**Figure 2**

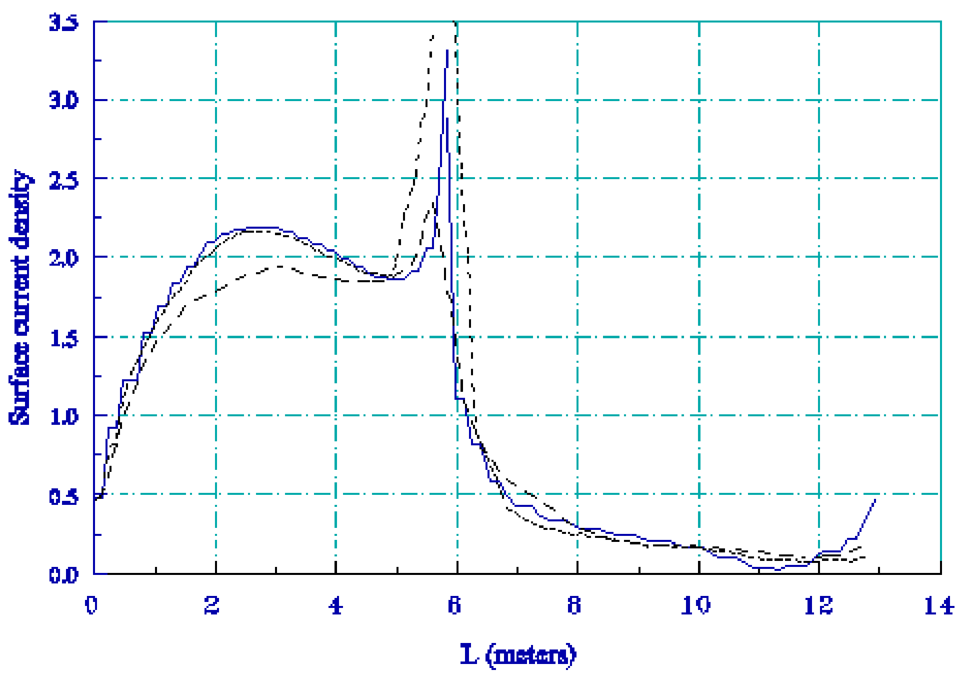


**Figure 3**

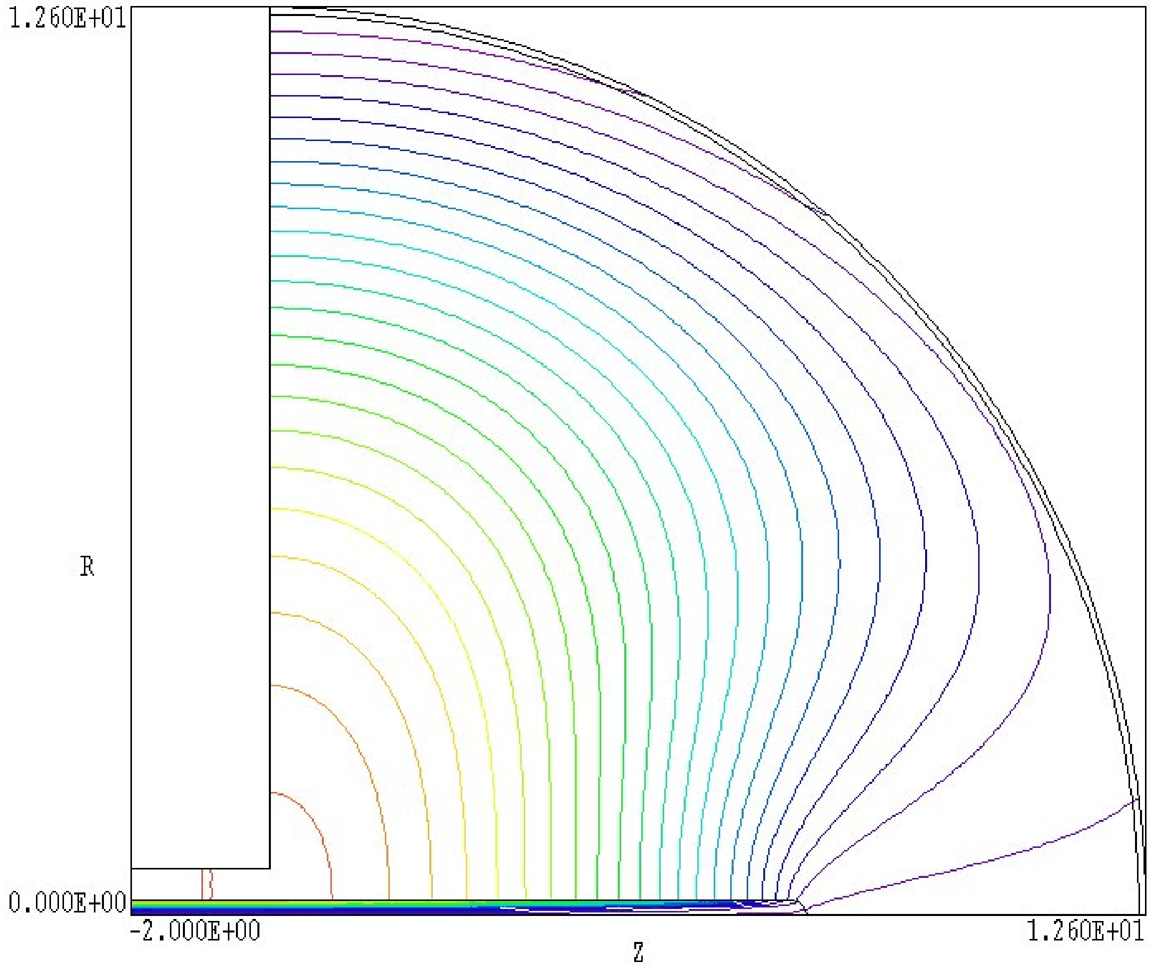


**Figure 4**

# Example 2. Absorbing boundaries in antenna applications

The paper *Investigation of the Limitations of Perfectly-matched Absorber Boundaries in Antenna Applications* by J.F. DeFord of Ansoft Corporation (page 592) describes another method to implement free-space boundaries in finite-element calculations. The technique involves defining a boundary layer with orthotropic dielectric properties at least three elements thick with a programed graduation of element thickness. The paper includes a benchmark calculation for a well-characterized monopole antenna. In contrast, the termination layer technique in **WaveSim** achieves similar attenuation with an isotropic layer only one element thick. **Figure 4** shows electric field lines in the **WaveSim** solution for the benchmark calculation, a monopole antenna above a ground plane. The solution region length is 12.8 cm with the cylindrical axis of symmetry at the bottom. The thin hemispherical absorbing layer is visible at the outer boundary.

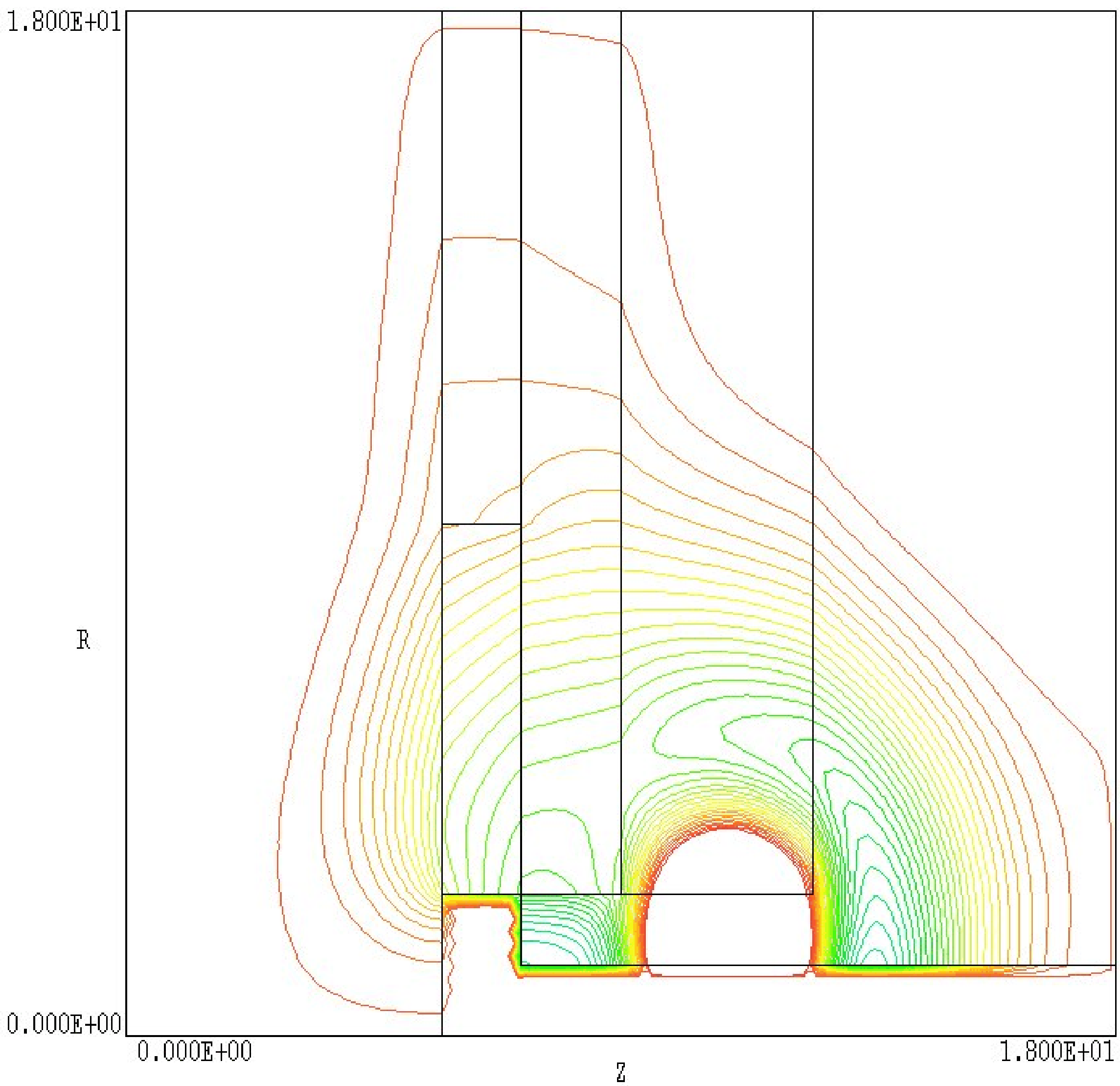


**Figure 5**

The antenna is feed by the 67 ohm coaxial transmission line at the left. The antenna admittance is calculated from values of the real and imaginary parts of $rH_\theta$ in the line. At 900 MHz **WaveSim** predicts a real admittance of 0.033 (S) independent of the solution volume size compared to values in the Ansoft calculation that range from 0.020 to 0.035 (S), depending on the boundary location.

# Example 3. Geophysical application

The paper *The Spectral Lanczos Decomposition Method for Solving Axisymmetric Low-frequency Electromagnetic Diffusion by the Finite-element Method* by M. Zunoubi, et.al. (Univ. of Illinois) and D. Kennedy (Mobil R&D Corporation) (page 598) describes an interesting method to extract information on system response at multiple frequencies from a single finite-element solution. I was interested in the benchmark calculation of the paper, a simulation of electric fields near a vertical borehole penetrating layered horizontal beds. The example addresses a practical application from oil well logging and involves a complex geometry of multiple materials in the low frequency regime. **Figure 5** shows a replication of the result with **WaveSim** for a solution region of length 18 m (cylindrical axis on the left). The plot shows electric field lines for a drill step excited by toroidal magnetic coil at 100 kHz. There are seven surrounding regions with conductivity ranging from 0.02 to 1.0 mhos/m. Results quite similar to those reported in the paper. Differences arise because the **WaveSim** calculation is fully electromagnetic.