Broadband Radiation and Scattering

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Electromagnetic phenomena are a central thread through much of modern engineering. There are two fundamental classes of applications: open region problems (where the energy propagates in unbounded space) and closed region problems (where the energy is guided by a waveguide structure or cavity).

This effort strives to enhance our computational electromagnetics (CEM) capability in broadband radiation and scattering in open regions. Broadband fields consist of energy with a robust spectrum, and include applications such as electromagnetic interference and electromagnetic compatibility noise analysis, broadband radar, and accelerator wakefield calculations.

LLNL analysis codes are limited by the accuracy of radiation boundary conditions (RBCs), which truncate space. We have developed improved RBCs by extending the perfectly matched layer (PML) approach to non-Cartesian meshes, and by developing discrete-time-domain, boundary-integral techniques that are compatible with high-accuracy, finite element methods and capable of arbitrary accuracy. These approaches have been compared to the traditional first-order absorbing boundary condition for a variety of radiation and scattering problems.

Project Goals

The ultimate deliverable is an enhanced CEM capability that can provide accurate and efficient computational solutions to broadband radiation and scattering problems. The algorithms for improved RBCs will be incorporated into LLNL's existing EMSolve code.

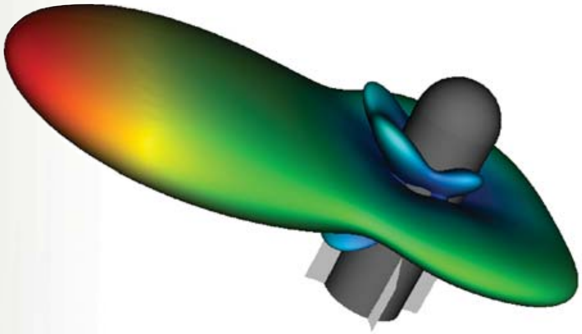

Figure 1. Scattered far-field generated by a broadside pulse hitting a rocket. The hybrid RBC was used to avoid the necessity of a huge air mesh.

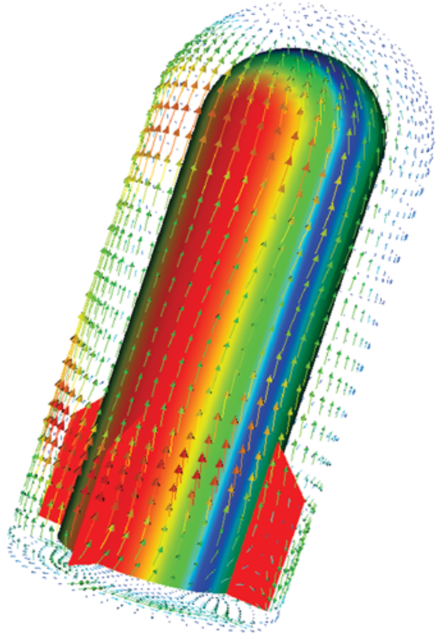

Figure 2. The electric field magnitude on the rocket surface and the equivalent vector currents produced by the hybrid RBC.

The result will be a 10- to 1000-fold improvement in the accuracy of simulations. Improved algorithms and our existing high-performance computer hardware will place LLNL's CEM activity among the top capabilities in the world. This research and the resulting capability will be documented in appropriate peer-reviewed publications.

Relevance to LLNL Mission

Electromagnetics is a truly ubiquitous discipline that touches virtually every major LLNL program. Our work supports the national security mission by reducing the time and money spent in building and testing existing programs. It will enable computer simulations for new devices and systems, performance analysis of systems critical to nonproliferation efforts, and the design of micropower impulse radar and other microwave systems.

FY2006 Accomplishments and Results

Figures 1 to 5 are samples of our FY2006 CEM work. We have completed the development of the parallel hybrid finite element boundary element code.

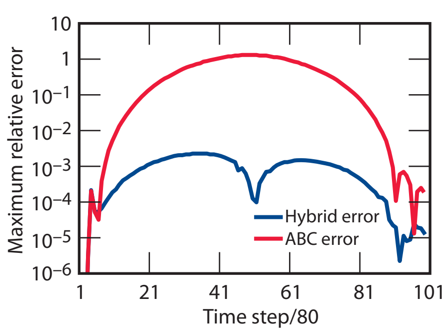

Figure 3. Pulsed Dipole Problem: the maximum relative error for the hybrid solution and the conventional ABC boundary condition solution as a function of time.

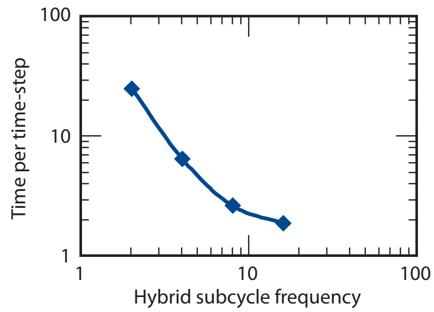

Figure 4. Pulsed Dipole Problem: computational cost per time-step for the hybrid method as the sub-cycling frequency changes.

Several different formulations for RBCs are now available, including boundary conditions based on the electric field, magnetic field, or both at the boundary. A formulation using both the electric and magnetic fields was found to eliminate late-time stability issues due to interior resonances. We have collaborated with a professor at the University of Washington who is an expert on time-domain integral equations. It was found that the boundary element time-step could be different than the finite element time-step. By sub-cycling the boundary element computations at some multiple of the finite element time-step, large improvements in speed were observed, especially for very large meshes. This sub-cycling allows for a trade-off between speed and accuracy.

For a z-oriented pulsed dipole problem (with a known solution), we have achieved almost a 1000-fold increase in accuracy using our hybrid code (Fig. 3). The conventional Absorbing Boundary Condition (ABC) method fails to converge when applied on a spherical grid with a maximum radius of 1. In contrast, the hybrid solution shows good accuracy. Figures 4 and 5 show the behavior of our computation costs and error when sub-cycling of the hybrid boundary element calculation is applied.

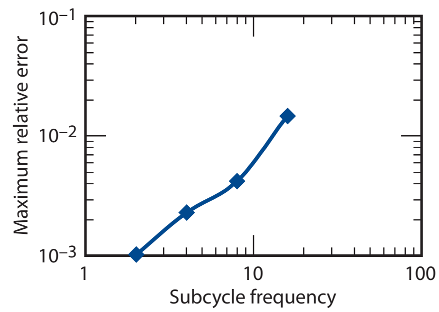

Figure 5. Pulsed Dipole Problem: maximum relative error behavior for the hybrid method as the sub-cycling frequency changes.

Related Reference

Fasenfest, B., D. White, M. Stowell, R. Sharpe, N. Madsen, J. Rockway, N. J. Champagne, V. Jandhyala, and J. Pingenot, "A Hybrid FEM-BEM Unified Boundary Condition with Sub-Cycling for Electromagnetic Radiation," *IEEE Antennas and Propagation Society International Symposium*, Albuquerque, New Mexico, July 9-14, 2006.