PSTD Simulation of Two-Dimensional Scattering by a Random Cluster of Electrically Large Dielectric Cylinders

Snow H. Tseng*, Jed Greene, and Allen Taflove
ECE Department
Northwestern University,
Evanston, IL 60208

Joseph T. Walsh, Jr.
Biomedical Engineering Department
Northwestern University,
Evanston, IL 60208

Duncan Maitland
Lawrence Livermore National Laboratory
Livermore, CA 94550

The goal of this research is to investigate the two-dimensional (2-D) electromagnetic wave scattering properties of a random cluster of electrically large dielectric cylinders. This problem arises in the study of the passage of a laser beam through biological tissues containing tubules, fibrils, and collagen fibers. We seek to determine the relative impact upon the scattering cross-section of the cluster's global geometry versus the distribution, composition, and geometry of the cylinders comprising the cluster.

In principle, finite-difference time-domain (FDTD) methods can be used to model this problem. However, the spatial resolution requirements of FDTD limit are applicability to clusters having a relatively small number of electrically large cylinders. A more promising approach is the pseudo-spectral time-domain (PSTD) technique, which permits the use of much lower-resolution grids than FDTD. This allows 2-D clusters having hundreds or even thousands of electrically large cylinders to be modeled using available computers.

In this paper, we report the application to this problem of PSTD with the UPML absorbing boundary condition. Using a parallel-processing computer at Lawrence-Livermore National Laboratory, simulation results have been obtained for the optical scattering properties of random clusters of thousands of ~10-μm diameter dielectric cylinders. Each cluster modeled has macroscopic overall dimensions in the order of 1 mm $\times$ 1 mm.

Our research provides perhaps the first results for the electromagnetic scattering properties of a large-scale random system of particles obtained by rigorously solving Maxwell's equations with subwavelength resolution. In addition to this potential theoretical advance, this work may provide practical means to apply optical technology to diagnose pathological conditions such as cancer and to track tissue changes during therapeutic interventions.