SCATTERING at LOW GRAZING ANGLES from LARGE SCALE TWO DIMENSIONAL RANDOM ROUGH SURFACES USING the STEEPEST DESCENT FAST MULTIPOLE METHOD (SDFMM)

W. C. Chew, M. El-Shenawee, V. Jandhyala, and E. Michielssen
Center for Computational Electromagnetics
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign
1406 W. Green St., Urbana IL 61801
Tel: 217-333-7309, Fax: 217-333-5962, e.mail: w-chew@uiuc.edu

Introduction and Background

The analysis of low grazing angle (LGA) electromagnetic scattering from two dimensional random rough surfaces is a challenging research problem. In spite of several analytical and numerical techniques that have been developed during the last few years, the problem of LGA scattering from practical random rough surfaces remains unsolved. The memory and CPU requirements of classical computational techniques prohibit the analysis of the LGA scattering phenomena, and the accuracy provided by many of these techniques simply is not adequate to solve this problem.

The objective of this work is to analyze LGA electromagnetic scattering for practical random rough surfaces using an enhanced SDFMM. This technique is a hybridization of the Multilevel Fast Multipole Algorithm (MLFMA) and the Steepest Descent Path (SDP) method. It has been successfully used to analyze electromagnetic scattering from two dimensional quasi planar surfaces. Recently, the SDFMM has been enhanced by parameter selection ruler that provides *a priori* error estimates [1]. The SDFMM dramatically accelerates the iterative solution of the method of moments equations for a large class of structures. When using an iterative solver, both the memory and the computational cost for the SDFMM are of $O(N)$ while they are of $O(N^2)$ for the conventional MOM technique.

For the LGA scattering problem, accuracy is an important factor in any numerical technique because of the shadowing effects that occur at these angles. In the SDFMM, there are tradeoffs between accuracy and both the CPU time and the required memory that can be fully controlled by the proper choice of SDFMM parameters. This makes the SDFMM a prime candidate for solving the LGA scattering problem.

Results and Discussion

A random rough surface is modeled as a finite object chosen large enough such that a practical LGA antenna beam does not excite the surface edges. An example considered in this paper is a surface of $115\lambda \times 28\lambda$ which results in a number of MOM current unknowns equal to 617,096 (using eight unknowns per wavelength). A Gaussian beam (with half beam width equal to 4λ) excites the surface at an angle of 80° from the normal direction. The surface is assumed to be perfect conductor with Gaussian statistics. The roughness parameters are 0.5λ for the rms height and 1.0λ for the correlation length. Preliminary results show that the SDFMM is efficient for analyzing LGA scattering problem.

Reference

[1] M. El-Shenawee, V. Jandhyala, E. Michielssen, and W. C. Chew, Proceedings of the IEEE APS-URSI '98, pp. 182, Atlanta, GA, June 1998.

A Cost-Effective Parallel Implementation of the Sparse-Matrix Canonical Grid Method for Two-Dimensional Random Rough Surfaces (3D Scattering Problems)

C. H. Chan and S. Q. Li
Department of Electronic Engineering
City University of Hong Kong, 83 Tat Chee Ave
Kowloon, Hong Kong

L. Tsang and Q. Li
Department of Electrical Engineering
University of Washington, Box 352500
Seattle, WA 98195-2500, USA

Tel: (852) 2788-9360 Fax: (852) 2788-7791 Email: eechic@cityu.edu.hk

Monte Carlo simulation of random rough surfaces continues to be an important problem due to its broad applications. With the advent of modern computers and development of efficient algorithms, electromagnetic scattering from two-dimensional lossy dielectric random rough surfaces, once an intractable 3D scattering problem, can now be computed. Over the years, we have systematically developed the sparse-matrix canonical grid method (SMCG) for analyzing 2D random rough surfaces. More recently, a physic-based two-grid method (PBTG) is developed in conjunction with the SMCG to study scattering by lossy dielectric rough surfaces with high permittivity. Depending on the roughness of the surface, CPU time on a DEC Alpha 4100 with 128MBytes of RAM for a 16x16 λ^2 is between 15 hours to 1 day. The total number of unknowns involved is slightly less than 400 thousands. For a large surface, more computer resources are required. We then turn our attention to implementing the combined PBTG-SMCG on a cost-effective parallel-computing platform, namely, the Beowulf system.

Our Beowulf system consists of 17 computing nodes which are connected to two 3Com Superstack LinkSwitch 3000 Fast Ethernet switch with twelve 100BaseTX ports. Each computing node has an Intel 233 MHz Pentium MMX processor, 128 MByte SDRAM and a 3Com 3C905 Network Interface for connecting to the communication switch. Note that faster processors were not available to us when the system was built. The system software requires Redhat Linux and the Message Passing Interface (MPI). The whole set up is about 60% the cost of the DEC Alpha 4100.

The combined PBTG-SMCG algorithm requires the decomposition of the matrix equation into a strong part and a weak part. In each step of the iterative solution, contributions from the strong part of the matrix require a sparse-matrix-vector multiplication. This computation can be equally divided among all the processors. On the other hand, the contributions from the weak part of the matrix are computed efficiently by fast Fourier transform algorithm (FFT). We adopted the MPI version of the FFTW developed by the Laboratory for Computer Science at MIT. This FFT package was written in C so we wrote a wrapper for its integration to our Fortran code. For the same problem of 400 thousand unknowns, the parallel code required 20 hours of CPU. We emphasize that this code has not been optimized and yet it has a minimum speed up factor of 12.5 when comparing the CPU times between 16 processors and 1 processor. With this cost-effect computing platform, we hope to analyze 32x32 λ^2 rough surface with 1.5 million unknowns.