32nd URSI GASS, Montreal, 19-26 August 2017

ON THE FULL-WAVE SOLUTION FOR ELECTROMAGNETIC SCATTERING FROM SNOWPACKS

Mostafa Zaky*, and Kamal Sarabandi
University of Michigan –Ann Arbor, 48109, USA

1. Extended Abstract

In this paper, an efficient full-wave electromagnetic solver for scattering from snowpacks is discussed. The electromagnetic scattering from snow layer is completely solved in two steps; 1) reconstruction of computer samples that follow the statistical behavior of the random medium, and 2) numerical solution for the electromagnetic scattering response of such medium. Since the snow is a two-phase medium which is a mixture of ice and air particles, the generation of 3D computer samples of snow is done by incorporating the Lineal-path correlation function (as a second order statistics) on top of the 3D exponential autocorrelation function to guarantee a macroscopic connectivity of the ice particles inside the mixture [1]. The implementation of this reconstruction method can be viewed simply by the role of the Lineal-path correlation function as a spatial filter acting on the 3D exponential correlation function to filter out the high fluctuating components representing the sharp discontinuities between the ice particles. After the medium sample is generated, the electromagnetic scattering response is characterized through numerical solution.

The Statistical S-matrix WAve Propagation in Spectral Domain (SSWaP-SD) [2] was developed recently for estimating the long-distance attenuation from 2D sparse random medium based on the statistics of the solution of a small slab. This method employs an implicit assumption as the medium is considered to be statistically homogeneous. The SSWaP-SD method is implemented by dividing the medium into similar slabs, representing each slab as an S-matrix whose elements relates the scattered power to the incident power for a specific direction and polarization, and later on, these S-matrices are combined in a cascading algorithm that accounts for the multiple scattering interactions between different slabs. Therefore, the electromagnetic scattering response of a large domain can be deduced from the statistics of a smaller portion of the medium. The most challenging part of using SSWaP-SD technique is to accurately represent a thin slab into an equivalent scattering matrix.

In this work, both Finite Element Method (FEM)-based commercial solver (HFSS) and Method of Moments based on Discrete Dipole Approximation (MoM-DDA) [3] code are used to determine the scattered field from a thin layer of snow. The FEM software depends on solving Maxwell's differential equation in the finite-extent of an element (tetrahedron) by a certain interpolation function of the field values on either the nodes or the edges of the tetrahedron element. These field values are used to form a sparse matrix equation that is used later to get the solution. On the other hand, MoM-DDA method is an integral-equation based numerical solver which represents each small cube by a dipole. Then, these dipoles are coupled to each other using the 3D dyadic Green's function and the final form is casted into a dense matrix equation that needs to be solved iteratively. One major difference between both methods is the domain discretization technique. HFSS uses a tetrahedron-based adaptive meshing algorithm to describe the snow samples, while a cubic-based mesh is generated through our implementation of the MoM-DDA method. Both techniques show good agreement in the results of the coherent scattered power. The simulation time of the MoM-DDA is way less than HFSS due to the reduced number of unknowns in the cubic-based mesh compared to the tetrahedron-based one. After the comparison between both results, many larger samples of the snowpack are generated and simulated by MoM-DDA method to form the statistical S-matrix of the basic slab through Mote-Carlo simulations. Then, the basic S-matrix is used to generate pseudo-random versions of it representing the other slabs. These S-matrices are cascaded at the end to calculate the total forward and backward scattered fields from a large domain of snowpack in an efficient way that accounts for both coherent and incoherent interactions inside the medium.

2. References

1. M. Zaky and K. Sarabandi, "Electromagnetic scattering from a 3D random volume using SSWaP-SD method for radar remote sensing of snow," *2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Beijing, 2016, pp. 1892-1894, doi: 10.1109/IGARSS.2016.7729486.
2. A.A. Ibrahim, and K. Sarabandi, "Simulation of Long Distance Wave Propagation in 2-D Sparse Random Media: A Statistical S-Matrix Approach in Spectral Domain," in *Antennas and Propagation, IEEE Transactions*, vol.62, no.5, pp.2708-2720, May 2014, doi: 10.1109/TAP.2014.2307580.
3. B. Draine and P. Flatau, "Discrete-Dipole Approximation For Scattering Calculations," *Journal of Optical Society of America*, A 11, 1491-1499 (1994), doi: 10.1364/JOSAA.11.001491.