3-D Numerical Solutions of Maxwell's Equations with Near Field Precondition on Random Rough Soil Surfaces from L-band to Ku-band

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Radar remote sensing of land surfaces satellites are moving forward with rapid pace. This includes Soil Moisture Active Passive (SMAP) for L-band, Radarsat-2 for C-band, TerraSAR-X for X-band, and Global Precipitation Measurement (GPM) for Ku-band. For bare soils, rough surface creates backscattering that contains information of the soil moisture. For the study of backscattering from bare surface, there are empirical (Dubois), analytical (SPM & AIEM), and numerical models. 3D Numerical Method of Maxwell equation (NMM3D) is 3D full-wave solutions of Maxwell's equations for rough surface using Monte-Carlo simulations. NMM3D has been developed with hybrid UV/PBTG/SMCG fast method for parallel computing. Results of NMM3D were shown in good agreement with POLARSCAT ground-based measurement for L-band soil surface application for both co-polarization and cross-polarization and adopted in active algorithm in SMAP mission.

In previous study of NMM3D, hybrid UV/PBTG/SMCG method was applied to accelerate the parallel computation. In this study, the calculation is extended for rms height up to 0.453λ for surface of 32 by 32 λ^2. The extension allows us to study the scattering of rough surface with practical rms height in high frequency. The key advancement here is the implementation of precondition. Near-field precondition is implemented to further improve computation efficiency for both surface size of 16 by 16 λ^2 and 32 by 32 λ^2. The physically-based near-field precondition matrix is applied to the impedance matrix without losing accuracy. Faster simulation is achieved consistently. Computation efficiency of cross-comparison is also presented for original and preconditioned NMM3D.

Polarization ratio, HH/VV, is studied to address the dependence on frequency for same fields (or same physical parameters for model). HH/VV is useful by providing additional information to study land surface. Results from NMM3D are also validated with POLARSCAT measurement data for L, C, X, and Ku bands. NMM3D shows good agreement with data and better performance over other models while considering co-polarization, cross-polarization, and polarization ratio (HH/VV).