Brightness Temperature of Layered Media with Rough Surface via FDTD Method

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Various theories were proposed to study the Earth soil with profiles of dielectric properties and physical temperature, for example, the dense media radiative transfer-multilayer (DMRT-ML) model, the microwave emission model of layered snowpack (MEMLS), the DMRT theory under quasi-crystalline approximation (QCA), the bicontinuous model under discrete dipole approximation (DDA). When the particles were densely packed and adhered together to form aggregates, the T matrices in the Mie scattering theory were used to form the QCA-Mie-DMRT model.

Rough interfaces between adjacent layers affect the brightness temperature of the layered medium. Different methods were proposed to solve the scattering problems involving rough interfaces, for example, the extended boundary condition method (EBCM), the stabilized extended boundary condition method (SEBCM), method of moments (MoM) and the radiative transfer (RT) theory. However, they still face some challenges. For example, the EBCM and SEBCM can only be applied to homogeneous media, and the EBCM may become unstable as the rms height of a rough surface is too large. The 3D EBCM and SEBCM are usually implemented with periodic boundary conditions. The MoM takes enormous computational time in solving volume integral equations. The RT theory does not give detailed information of fields and rough surfaces.

In this work, a finite difference time domain (FDTD) method is proposed to compute the bistatic scattering coefficients from a rough surface and the bistatic transmission coefficients (BTCs) through the rough surface. The radiative transfer theory is integrated to predict the brightness temperature measured from the layered medium embedding the rough surface.

The brightness temperature measured at a specific direction from a snow-covered soil is contributed by the reflection of downwelling brightness temperature from the atmosphere incident upon the snow surface and the transmission of upwelling brightness temperature from the soil through the snow-air interface. The bistatic reflection coefficients and transmission coefficients by the rough surface can be computed by using the FDTD method. The reciprocity theorem is used to reduce the computational time. The upwelling brightness temperature from the soil below the rough surface is computed by using the radiative transfer theory, assuming that all interfaces below are flat surfaces. Gaussian and exponential rough surfaces, characterized by rms surface height and correlation distance, are chosen in the simulations and the brightness temperature thus obtained are compared with the literatures for further analysis.