MICROWAVE SCATTERING PROPERTIES OF DRY SNOW USING THE BI-CONTINOUS RANDOM MEDIA

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Abstract

In this paper, we introduce bi-continuous random media morphology to describe the snow structure. Both analytical method and numerical method are used to study the scattering properties of bi-continuous media with discrete permittivities in the frequency of 18.7GHz. The bi-continuous medium is based on a continuous representation of interfaces between inhomogeneities within the medium [1]. The computer-generated bi-continuous random structures are illustrated and exact correlation function of the three dimensional structure is also derived. The microwave scattering properties is calculated by analytic Born approximation based on the derived correlation functions. Numerical method is based on discrete dipole approximation (DDA) accelerated by FFT. In small contrast of the two permittivities, the analytical method and numerical method agree to each other. In the case of snow, due to the irregular microcosmic structure and large contract of the permittivities, the cross polarization should be non-zero. The numerical method gives fairly large cross polarization which is underestimated by Born approximation.

The modeling of wave propagation and scattering in random media with discrete permittivity have widely applications in microwaves remote sensing on snow [2] [3]. Discrete permittivities can be described as discrete values for different part of sample structure. It can be consist of two or more kinds of media. Snow is such kind of media, which consists of mixtures of ice particles and air for dry snow and ice, air and water for wet snow. In this paper, we focus on the scattering properties on the dry snow whose permittivities vary discretely assuming the values of 3.2 for ice and 1 for air. In situation when the grain sizes or the scales of the inhomogeneities are not too small compared with the wavelength of the electromagnetic waves which is the case in microwave remote sensing on snow, the incoherent fields which have random phases will contribute significantly. That will result in stochastic fluctuations of the electromagnetic waves. In the following section, we carefully study bistatic scattering phase matrices which can be used in a dense media radiative transfer theory. In the past, we have modeled the bistatic scattering by considering the dense media of spherical ice grains and clusters. Both of the analytic methods (QCA) and numerical method (NMM3D) have been developed.

In this paper, we consider a different approach to solve the scattering problem of media with discrete permittivities. Instead of using particles, the mathematical formalism developed by Cahn [4] is applied in this study to simulate the morphologies of random porous structures. We describe mathematically the bi-continuous random media. The model is based on a continuous representation of interfaces between inhomogeneities within the medium, which are constructed from a large number of stochastic, continuous, sinusoidal waves with random phases and in random directions. The random structure is then defined by setting a level on this Gaussian random process according to the required volume fractions of inhomogeneities. We also derived the exact correlation function of the three dimensional bi-continuous structures by assuming gamma distribution of the wavelength and normal distribution of the phase rigorously. To describe the intrinsic structure of the snow pack, we calculate the specific surface area (SSA) rather than grain size. This parameter is to be shown strongly dependent on snow history and snow type and can also be compared with snow measurements [5].

The scattering of electromagnetic waves by the simulated random media is calculated by using analytical and numerical approaches. The analytic Born approximation is based on the derived correlation functions. We also used DDA-FFT [6] to solve the Maxwell equations numerically. In the numerical simulations, convergence tests are performed with respect to discretization, realization size and number of realizations. Results between the numerical and analytic approaches are compared.

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