Snow sensing based on two-frequency radiative transfer theory

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Snow depth and snow-water content are crucial parameters in the hydrological information for water runoff and land use applications. Therefore, remote sensing of these parameters is a very important task. Most current parameter retrieval algorithms are based on the radar cross section (RCS) and are subject to poor accuracy and uncertainty in some cases, such as, very wet snow cases where the RCS is very small. Here, we investigate the frequency correlation function as a potential additional variable. It is shown that the phase of frequency correlation function can be used for snow parameter retrieval.

In this problem, we apply a three-layered medium model consisting of air, snow, and either ground or ice. The interfaces between layers are assumed to be rough surfaces with known statistics in terms of rms height and correlation length. The snow layer is assumed to be dry snow which has a homogeneous air background and ice particles as scatterers. This can be applied to several scenarios, such as, snow on the ground or snow on sea ice by only changing the properties of the third medium and some parameters. The frequency correlation functions are calculated based on the two-frequency vector radiative transfer theory. The radiative transfer theory accounts for the multiple volume scattering and the interaction between volume scattering and the surface scattering. Both are expected to be the main contributions in the scattering process.

The two-frequency radiative transfer theory is derived based on the quantity called the *two-frequency modified Stokes vector* which has a similar definition as the well-known modified Stokes vector, except that the correlation of the waves are from two different frequencies. As a result, the extinction and scattering matrices have to be modified accordingly. However, the general form of the two-frequency radiative transfer equation remains the same as the conventional radiative transfer equation. Therefore, the methods that can be used to solve for the solution in the conventional radiative transfer equation are still applicable to the two-frequency radiative transfer equation.

Because the fractional volume of ice particles is more than 0.1, the dense media radiative transfer theory is used. We calculate the effective propagation constant and the albedo based on the quasi-crystalline approximation with coherent potential (QCA-CP). We investigate the characteristics of the frequency correlation function for several snow types using frequency in the C-band (~5 GHz), Ku-band (~13 GHz), and Ka-band (~37 GHz).