Microwave Band Radiative Transfer in the Rain Medium Implications for Radar Sounding and Radiometry

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Abstract— Natural media consisting of preferably oriented non-spherical particles demonstrate electromagnetic anisotropy and optical dichroism. Typical example is rain in the millimeter wave band. In addition, rain fields are spatially inhomogeneous. Thus, theoretical investigation of active and passive millimeter wave probing of rain ultimately demand numerical solution of polarized radiative transfer equation in three dimensional dichroic scattering medium.

Authors present results of extensive numerical simulations of active and passive millimeter wave sounding of raining atmosphere. Absorption and scattering in the rain medium have been calculated rigorously from the first principles for different wavelengths and temperatures with public available T-matrix codes. Radiative fields of thermal emissions of the rain in uniform dichroic slab medium of rain and three-dimensional rain cell have been simulated with the discrete ordinate (DO) codes for the vectorial radiative transfer equation (VRTE) for the polarized radiation. The three dimensional cubic rain cell model ($3 \times 3 \times 3\,\mathrm{km}$), uniformly filled with falling raindrops, is investigated and compared to the flat layered slab model of the raining atmosphere. Non-spherical falling raindrops with a reasonable degree of approximation can be regarded to be oblate spheroids with vertically oriented rotational axis of symmetry. Ratio of axes of the spheroid depends on the raindrop size, while the raindrop sizes are distributed statistically according to Marshall-Palmer distribution. Physical (thermodynamic) temperature in the atmosphere is non-uniform and decreases with height $T_2 = (300 - 7z)\,\mathrm{K}$, where z is a height in km.

Underlying surface in the flat layer model is black (lambertian reflection coefficient $R = 0$) of gray with partial lambertian reflection ($R = 0.25$) surface. In the cubic rain cell model, underlying surface within the square bottom of the cell is also black or gray as well as in the uniform slab model. Thermal radiative emission of the heated underlying surface is slightly vertically polarized. Outside the bottom surface, it is totally black ($R = 0$). Role of three-dimensional inhomogeneous structure of the medium in formation of outgoing radiation field has been revealed and investigated. Diffuse reflections of the radar pulses from rain cells and slabs have also been simulated with the VRTE DO codes, and in addition with the Monte-Carlo algorithms for the scalar radiative transfer equation (RTE) without polarization.

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