Temperature and Texture Dependent Spectroscopic Dielectric Model for Frozen Mineral Soils at 0.1–15 GHz

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Abstract— Dielectric models of topsoil are a crucial element of remote sensing retrieval algorithms that are used to obtain geophysical characteristics of the land surface, such as soil moisture, temperature, and freeze/thaw state. Contemporary radiometers and radars acting from space are functioning in the frequency range from 1.2 GHz to 89 GHz. In addition, the GPR and TDR instruments, which are used for subsurface sensing, operate in the megahertz band. Therefore, there exist a need to work out the spectroscopic dielectric models of moist soils covering both the GHz and MHz frequency ranges. A method of developing such a model is outlined in [1] and [2] in the cases of one type organic rich soil and one type mineral soil, respectively. Currently, a problem of developing such a model for an aggregate of natural soils, having varying textures should be still solved. In this paper, this problem is considered for a set of mineral arctic soils collected on Yamal peninsular.

The dielectric model being developed is based on the measured dielectric data attained for 5 types of mineral soils, with clay fraction varying from 10 to 50%, soil water contents changing in the range from zero to the value of field moisture capacity, temperature ranging from -1 to -30°C, frequency bound from 0.05 to 15 GHz. The measured dielectric data were processed in accordance with the methodology given in [1] and [2]. Namely, the refractive mixing dielectric model was applied with the Debye multi-relaxation equations to fit the measurements of the soil's complex dielectric constant as a function of soil moisture and wave frequency. The spectroscopic parameters of the dielectric relaxations for the bound, transient bound, and unbound soil water components were derived as a function of temperature. Further, these temperature dependences were expressed using the respective thermodynamic parameters, providing a complete set of parameters for the temperature-dependent multi-relaxation spectroscopic dielectric model for each type of measured mineral soils. Thus, obtained spectroscopic and thermodynamic parameters were expressed as a set of empirical functions of percentages of clay contents contained in the respective soil types. Finally, the temperature and texture dependent spectroscopic dielectric model for frozen mineral soils at 0.05–15 GHz appeared to be presented as an ensemble of analytical expressions, and it provides for the values of complex dielectric constants of frozen soil using the dry soil density, clay percentage, gravimetric moisture, temperature, and wave frequency as input variables.

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