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Laboratory experiment simulating Martian surface observation with submillimeter-wave polarimetric radiometry

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Energy and materials exchange between the ground and atmosphere on Mars is deeply related to Martian water cycle. It is worthwhile to observe the spatial and temporal variability of physical temperatures and material compositions in the Martian subsurface from orbiter. Millimeter/submillimeter radiometer is expected to achieve continuously monitoring the Martian subsurface. However, such measurement has never been conducted in planetary explorations. We assess the effectiveness of this observation method by laboratory experiment.

By observing millimeter/submillimeter emission from the Martian subsurface in several incident angles and two polarizations, we can derive physical temperatures and permittivity of the subsurface. In order to estimate those properties from observed emissions, we need to know relationship between emissivity or/and reflectivity and the properties of surface in millimeter/submillimeter wave region. To discuss feasibility of this observation, it is necessary to experimentally demonstrate such estimation from the millimeter/submillimeter observation. It is also important to study the effective skin depth of the material surface in the observation.

We developed an experiment system to examine millimeter/submillimeter wave scattering and emission characteristics of the simulated Martian surface in a chamber. The chamber is designed to measure both emission from simulated surface using a receiver and reflection of the surface using a transmitter and a receiver. We can measure arbitrary-polarized emissions with arbitrary incident angles by moving mirrors in the experiment system. The experiment system is designed to set up the incident angles to an accuracy of 1 degree and measure the brightness temperatures to an accuracy of 2K.

Reflectivity measurements were made first, because emission characteristic is basically predictable from the precise reflection measurements. In experiment, we measured the reflectivity of 2 specimens at 230 GHz frequency range, 13 incident angles (from 20 to 80 per degrees in units of 5 degrees) and 2 polarizations (V and H polarized waves). We examined if we can distinguish two different samples from the reflectivity. Samples we measured are glass and PET plates. An electric property of glass is similar to the main component of Martian rocks and a PET has a permittivity similar to water ice in 230 GHz frequency range. The result of this experiment shows that it is distinguishable the glass plate from the PET plate with reflectivity at 20-70 degree angles in V polarized wave. Then, we measured reflectivity of samples of two layers consisting of the PET and the glass plates at the same conditions (frequency, incident angle and polarization) as the previous experiment. We determined the upper limit of the thickness of the glass plate that we can detect the signal of the PET plate which is placed under the glass plate from the reflectivity measurement at incident angles 65 and 70 degrees in V polarization. The glass thickness of the result was 3.0 mm. The effective skin depth of the glass plate was found to be about twice of the measurement wavelength. From these experiment results, it is estimated that water ice or temperature subsurface is detectable in the depth up to twice wavelength of millimeter/submillimeter by observing radiation from the Martian subsurface. We plan to examine whether able to distinguish between a glass and a PET by emission measurement. Furthermore, it is necessary to confirm the relationship between an effective skin depth and a permittivity of surface in future research.

Keywords: Mars, surface observation, submillimeter-wave