Permittivity of subsurface on Mars and its importance for electromagnetic wave reflection method such as radar sounder and ground penetrating radar

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Recent planetary explorations have successfully acquired a large amount of high- resolution remote-sensing data of extraterrestrial bodies, especially the moon and Mars. However, the surfaces of solid bodies not having the condense atmosphere are generally covered by regolith, which is an essential problem for previous remote-sensing techniques such as cameras and spectroscopies to obtain critical information to understand the evolution of solid bodies. Hence, subsurface explorations schemes, such as using seismic waves and electromagnetic waves, have been applied or being discussed. Especially, the ‘electromagnetic wave reflection method’ such as radar sounder (MARSIS and SHARAD) and ground penetrating radar (RIFMAX and WISDOM) is capable of obtaining information of subsurface within a short time and visualizing the subsurface structures without contacting the surface, and then the method would be widely used in the future landing/rover missions.

The electromagnetic wave reflection method uses the electrical property of EM waves that reflects from the boundary of the materials having the different permittivity and has the potential to visualize the subsurface structures based on the travel time of the reflected wave. The estimation of subsurface structures needs the velocity of EM waves in a medium, and the velocity is decided by the relative permittivity of medium such as rocks. However, the value of permittivity is controlled by many parameters such as frequency, temperature, water content, bulk density, chemical composition, and so on, and it is required to use the permittivity under the condition according to its state. Especially, on the Martian surface, the temperature is lower than the terrestrial condition and the water content in the soils or rocks is basically zero. So, it is required to measure the permittivity under low temperature and dry condition. We developed the measurement system which is capable of measuring the real part of permittivity of regolith simulant with 5 % measurement error under the low temperature and dry condition using the coaxial probe method. We found that the permittivity values become about 7-20 % lower at -60 ˚C, which is the average temperature on the Martian surface, compared with the room temperature. Using the measured permittivity, we calculated the permittivity structure on the subsurface on Mars. As a result, the calculated permittivity is higher about 60 % than assumed before at 1.5 km depth, which is the estimated depth to exist a water-filled lake on the Martian south polar by Orosei et al. (2018). Our results suggest that it is important to measure the permittivity of rocks under the proper condition and use it for the interpretations of the electromagnetic wave reflection method such as radar sounder and ground penetrating radar on Mars.

Keywords: Relative permittivity, Electromagnetic wave reflection method, Radar sounder, Ground penetrating radar (GPR)

