Estimations of subsurface structures and dielectric properties of lunar mare regions from Lunar Radar Sounder (LRS) observations

Yuu Tominaga[1]; Takayuki Ono[2]; Atsushi Kumamoto[3]; Hiromu Nakagawa[4]

[1] Dept. of Earth and Planetary Science, Tokyo Univ.; [2] Department of Astronomy and Geophysics, Tohoku Univ.; [3] Planet. Plasma Atmos. Res. Cent., Tohoku Univ.; [4] Dept. of Geophysics, Tohoku Univ.

Surface stratigraphic and tectonic features revealing the formation and evolution of the planetary body can be scanned by a ground-penetrating radar or radar sounder onboard a spacecraft.

The Lunar Radar Sounder (LRS) onboard the Kaguya spacecraft has been exploring the lunar subsurface since 20 Nov. 2007. The LRS uses the HF band (5MHz) enabling subsurface data to be obtained to a depth of several kilometers (Ono et al., accepted). In this study, the LRS data reveal the subsurface structures and dielectric properties of lunar mare regions.

Pulses transmitted by the sounder will reflect at lunar surfaces and at boundary faces between these layers at which the dielectric constants display sharp discontinuities. Time delays of the reflected echoes indicate the apparent depths of layers. Note that the apparent depth means the range of vertical propagation in vacuum. Using numerical models, we estimated dielectric properties of these layers from the intensities of the reflected echoes.

There are clutter echoes reflected by the roughness of lunar surfaces and from the objects on the ground such as craters. It is basically difficult to find the surface and subsurface boundary faces when there are a lot of clutter echoes. In order to solve this problem, we used the data stacking method (Kobayashi et al., 2002). It enables us to reduce clutter echoes.

The regions we chose for our analyses are those called Mare Serenitatis and Mare Crisium. We found prominent reflectors from subsurface lying at apparent depth of 300 m in Mare Serenitatis, and 450 m in Mare Crisium. Previously, the Apollo Lunar Sounder Experiment (ALSE) onboard the Apollo 17 Command Service Module also revealed subhorizontal layering in these regions (e.g., Peeples et al., 1976). They also found the boundary faces between surface and subsurface layers. They concluded that the dielectric constants of surface layers are 8.7, and two reflectors were inferred at depths of 900 m in Mare Serenitatis, and 1400 m in Mare Crisium. Instead, no such reflectors were detected at depths of 900 m in the LRS radargrams for Serenitatis. More detailed analyses are necessary to conclusively show whether the ALSE reflectors exist or not.

Based on Ono et al., (2000), we made a numerical model of subsurface structures in these regions from our estimations, and using these models and echo powers we estimated dielectric constants of these layers. In order to statistically determine the dielectric constants, we performed histogram analysis with all pulse data.

Firstly, we assumed a model which simply consisted of two basaltic layers. The prominent reflectors were from boundary faces between two basaltic layers. Owing to the previous research (Olhoeft et al., 1975), the loss tangent of the surface layer was assumed to be 0.003. We concluded that the dielectric constant of surface basaltic layer was 2.7 and that of subsurface layer was 9.2.

However, it is known that the lunar subsurface of mare regions consists of some layers, basaltic layers generated by lava flows and ejecta layers generated by accumulations of fragmental debris due to crater impacts (e.g., Campbell et al., 2006). To be accurate, further development about the dielectric difference between ejecta layers and basaltic layers should be considered in this model.

We performed further attempt to consider these ejecta layers. We assumed a model consisted of four layers. There were two basaltic layers that had same dielectric constants. On the surface layer and between surface and subsurface layers there were ejecta layers. We found that the dielectric constant of basaltic layers was 7.5 when we assumed that the dielectric constant and the depth of the ejecta layer were 3.8 and 7 m, respectively. Our estimations are in close agreement with the dielectric constant inferred by Strangway et al. (1974).