かぐやLRSを用いた月表層の誘電率と電気伝導度の推定

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Estimation of the permittivity and the electrical conductivity of lunar surface from LRS data

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Lunar Radar Sounder (LRS) onboard the SELENE (KAGUYA) spacecraft is a frequency modulated continuous wave (FMCW) radar with carrier frequencies from 4 to 6 MHz and its purpose is exploring lunar subsurface structures. LRS succeeded in global sounder observations and detection of subsurface reflectors in some maria.

In order to understand the evolution of the moon, it is important to investigate lunar subsurface structures. The phase velocity of the electromagnetic wave in each medium is necessary to convert delay time of the echo into actual distance. If the subsurface permeability is equal to that in the vacuum, the phase velocity is determined by the permittivity. In the past, the permittivity was estimated from lunar sample rocks of Apollo or ALSE (Apollo Lunar Sounder Experiment) data.

On the othernhand, the electrical conductivity is useful to know the composition of the Moon. It is important for the future exploration of the satellite to establish the method of calculating the permittivity and the electrical conductivity from sounder observation data.

Loss tangent is a ratio of the conduction current to the displacement current. If loss tangent is small enough, the permittivity and the electrical conductivity inside the Moon can be estimated by comparing amplitudes and phases of the source pulses and the received echoes. However, observed data is mixed with local signal to compress the source pulse. Therefore, it is necessary to restore the original waveforms from the recorded echoes.

In order to calculate expected echoes, we assume horizontally stratified Moon and simulate the wave propagation beneath the Moon's surface. The subsurface model has the permittivity and the conductivity as parameters, and the number of subsurface layers is determined by considering existing radargrams of the LRS data. Both permittivity and conductivity are determined by comparing the calculated echoes and the restored waveforms from the observed data.

The lunar surface topography influences the simulation as well. The received echoes are originated not only from the nadir direction but also from off-nadir direction. The surface topography can cause complicated wave scattering. Therefore, lateral reflections have to be considered as the surface becomes rougher.