Geophysical Research Abstracts
Vol. 17, EGU2015-4748, 2015
EGU General Assembly 2015

KAGUYA Lunar Radar Sounder (LRS) observation of lunar surface echo and its calibration

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Lunar Radar Sounder (LRS) is an HF radar of which the center frequency of transmitted pulse is 5 MHz. LRS was installed to KAGUYA which flew to the Moon in 2007. During the operation period of 19 months, LRS performed radar sounding observation from the orbit at the nominal altitude of 100 km to cover whole surface of the Moon with its foot print. The total number of LRS observations (pulse transmissions) exceeded 108. We extracted the nadir surface echo out of each observation which made a surface echo map of the Moon, i.e. a mosaic image of the Moon of an HF frequency (5 MHz).

The observed surface echoes carry information regarding lunar surface and that of shallow subsurface (near-surface) whose depth scale is smaller than the range resolution of the LRS ($\sim$ 150 m in vacuum). An inversion algorithm is applied to extract such information. However, inversion algorithms often assume a simple model of Fresnel reflection. One should remove the effect of surface roughness from the LRS data before practicing inversion. For this purpose, we carried out simulation of LRS observation to evaluate the surface roughness effect on the LRS data quantitatively.

The simulation is based on Kirchhoff approximation theory. Digital Elevation Model (DEM) of KAGUYA Terrain Camera (TC) mission was used in the simulation to simulate the actual lunar terrain. LRS observation simulation was performed in the range from -90 to 70 degrees in longitude and in the range from -30 to 70 degrees in latitude at every 0.1 degree interval in both directions. The simulation revealed

1) LRS surface echo observation is sensible to the surface terrain: even wrinkle ridges and small craters are well recognized in the mosaic image of simulation surface echo map.

2) Little difference was found in the mosaic image of an old mare surface and a young mare surface.

3) However, apparent difference was found in the shape of the distribution functions of echo intensity of an old mare surface and a young mare surface.

We used the simulation result to remove the surface roughness effect on the LRS data to obtain the plane surface echo intensity. The resultant data revealed

1) Highland surface presents weak echo intensity than mare surface.

2) Young mare surface presents more intense echo than old mare surface.

3) Some areas in maria presents significantly weak echo than surrounding mare surface.

These findings are attributed to the property of near-surface subsurface.

Our inversion found that the young mare surface material has larger permittivity than the old mare surface material.