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LRS data analysis methods for the detection of lunar subsurface echoes

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Lunar Radar Sounder (LRS) is one of onboard science missions of KAGUYA. The primary objective of sounder system of LRS is to investigate lunar subsurface structure. LRS is a ground-penetrating FM-CW radar system of HF-band. The range resolution of transmission pulses is 75 m in vacuum. LRS detects lunar subsurface echoes reflected from subsurface interface where discontinuous change of dielectric constant of the material occurs in the direction of depth. LRS will perform global sounder observations, and we aim to deduce a lunar global subsurface structure model. Several series of echoes implying subsurface interfaces are found several 100s of m under mare regions such as Mare Serenitatis. On the other hand, reliable subsurface echoes are not recognized yet because numerous clatter echoes from extremely-deformed ground surface are recorded in LRS data of highland regions. Subsurface echo detection in highland regions accounting for 80% of lunar surface is highly significant issue for our goal. Here we introduce data processing for B-scan data products which are available in PDS format. Then we explain method under consideration for analyzing LRS data of both mare and highland regions.

'A-scope' is a plot of signal power spectrum as a function of range. The time series data of A-scope are called 'B-scan'. Because LRS instruments change timing of data recording (measurement delay time) according to the predicted distance between KAGUYA spacecraft and lunar surface, observation range with respect to the spacecraft varies from pulse to pulse. In addition, flight altitude of KAGUYA differs in the range of several 10s of km. Therefore a trace of surface echoes in unprocessed B-scan images does not correspond to actual lunar topography. In order to reconstruct lunar surface topography in B-scan images, we have to correct the effects of variations of the measurement delay time and flight altitude of KAGUYA. We plan to produce the corrected B-scan data as a PDS product (BScan-high ver.2). We also plan to produce a PDS product with low resolution in the direction of flight track from BScan-high ver.2 (BScan-low).

We attempt to apply some data processing methods, (1) data stacking in the direction of flight track, (2) contrast enhancement, and (3) migration processing, to the corrected data for the purpose of detection of expected subsurface echoes. The most intense signal detected in A-scope data is surface nadir echo. The A-scope data also include various noises in addition to surface off-nadir backscattering echoes. Therefore expected subsurface echoes seem to be buried in these noises and echoes. We first consider the data processing procedure for the data of mare regions. The ground surface of mare regions is relatively smooth and therefore surface off-nadir backscattering echoes occur less frequently. In order to cancel random noises in B-scan images, we stack A-scope data in the direction of the flight track. Then we enhance contrast of the B-scan images. As a result, possible subsurface echoes are detected in some mare regions.

In contrast to mare regions, numerous surface clutters occur in highland regions because of impact craters on the surface. The surface clutters appear in B-scan images as obvious hyperbolic patterns. It seems to be difficult to detect echoes from expected subsurface interfaces among such intense surface clutter echoes in the same approach as mare regions. We attempt to apply migration processing to stacked waveform data of highland regions. Migration is an analysis method used for the data of refraction seismic survey. We obtain the location or depth of reflection point by specifying propagation velocity of transmitter pulse. We use migration programs built in Seismic Unix package. As a result, each hyperbolic pattern in B-scan images is focused on a surface crater image. Migration processing seems to be an effective method to detect subsurface echoes in LRS B-scan images of highland regions.