Current status of acquisition and processing of tracking data from SELENE (KAGUYA) satellites for lunar gravity field estimation

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Introduction: Two small spin-stabilized sub-satellites, Rstar (OKINA) and Vstar (OUNA), have successfully been separated from Main satellite of SELENE (KAGUYA) and inserted into planned elliptical orbits on October 9 and 12, 2007, respectively. These spacecraft are dedicated to improving our knowledge of the global lunar gravity field with the mission instruments on-board, i.e., RSAT (a satellite-to-satellite Doppler tracking sub-system) and VRAD (artificial radio sources for VLBI). We have started collecting new types of tracking data for the lunar-orbiting satellites, i.e., 4-way Doppler tracking between the Main satellite and Rstar (i.e., a direct far-side gravity observation), and multi-frequency differential VLBI tracking between Rstar and Vstar. A global lunar gravity field with unprecedented accuracy is expected to be estimated through precision orbit determination by using these tracking data.

Data acquisition scheduling: JAXA UDSC (Usuda Deep Space Center) 64m antenna is used for 2-way range and Doppler tracking of R/Vstar as well as the Main satellite 4-way Doppler measurements (some Main satellite 2-way measurements were also carried out during initial check out phase). The GN (Ground Network) stations, at different locations on the Earth, acquire almost continuous 2-way Doppler data of the Main satellite. Since the three SELENE satellites have different orbital periods, the visibility conditions are different day by day, which makes the tracking scheduling somewhat complicated. The basic idea is to transfer scientific data down to UDSC while the Main satellite is visible from the station, and switch the antenna to Rstar or Vstar during the occultation of Main satellite (i.e., on the far-side). When the satellites geometry and antenna beam pattern allow the 4-way link, the 4-way Doppler observation is carried out. The differential VLBI data are collected by four Japanese domestic stations of VERA. Antenna time of about 24 hours/week is assigned to SELENE. Four stations outside Japan, Hobart, Shanghai, Urumqi, and Wettzell, also take part in international SELENE VLBI observation campaign which takes place in January and May, 2008.

Preliminary results of tracking data residual: As a test case, we investigated the Doppler residuals for the arc of December 2-3, 2007. The 4-way Doppler data were collected while the Main satellite is over the deep far-side. The RMS residuals for UDSC are about 0.2 mm/s for 2-way Doppler, and 8 mm/s for 4-way Doppler. The higher 4-way Doppler residual can be attributed to the currently unmodelled gravity anomaly on the far-side. The RMS for the GN is about 0.5 mm/s, which is due to the fact that the station has smaller antenna diameter than UDSC. The range residuals are 0.7 m for Rstar and 0.1 m for the Main satellite for this particular arc.

Strategy for a new gravity field solution: We are continuing to collect the tracking data so that good far-side data coverage is achieved. With such coverage the first SELENE gravity field model will be estimated up to degree and order around 60, still with an aid of Kaula-type constraint and a short arc-length. The arc-length for R/Vstar can get longer based on the updated gravity field and multiple-satellite arcs are planned next, e.g., a week or longer arc for R/Vstar and a half-day arc for the Main satellite, processed at once by regarding each of the Main satellite arc as a separate satellite. The correlation of the VLBI data is a time consuming process, but the differential phase delay as the outcome is converted to doubly differenced 1-way range, which will place a strong constraint on determining R/Vstar orbit and will help to improve the quality of 4-way Doppler data for which Rstar orbit plays a roll of reference and also to improve the lunar k2 value. Finally all the SELENE tracking data will be combined with the historical tracking data for a more complete lunar gravity field solution.