CURRENT STATUS OF ACQUISITION AND PROCESSING OF TRACKING DATA FROM SELENE (KAGUYA) SATELLITES FOR LUNAR GRAVITY FIELD ESTIMATION. K. Matsumoto[1], S. Goossens[1], Q. Liu[1], T. Iwata[2], N. Namiki[3], H. Noda[1], H. Hanada[1], F. Kikuchi[1], Y. Ishihara[1], N. Kawano[1], S. Tsuruta[1], K. Asari[1], T. Ishikawa[1], and S. Sasaki[1], [1]RISE Project Office, NAOJ (2-12 Hoshigaoka, Mizusawa, Oshu, Iwate 023-0861, Japan, matumoto@miz.nao.ac.jp), [2]JAXA (3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan), [3]Kyushu University (6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan)

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) [1] and VRAD (artificial radio sources for VLBI) [2]. 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 [3]. A global lunar gravity field with unprecedented accuracy is expected to be estimated through precision orbit determination by using these tracking data [4].

After the end of the initial check out of Rstar and Vstar on November 5, 2007, the tracking data are being acquired on a regular basis. This paper presents the current status of the data acquisition scheduling and the initial result of orbit determination.

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 duration of a single 4-way pass is from several minutes to about 40 minutes, and we can have one to four 4-way passes during one-day operation, with the amount of 4-way data depending on the link condition. We also plan to acquire some 4-way Doppler data during so-called face-on geometry where all the three satellites are visible from UDSC. This configuration allows us to observe radial Doppler component of the Main satellite to which the conventional line-of-sight 2-way Doppler has less sensitivity, although it needs a coordination with other mission instruments which needs huge amount of data downlink resources of UDSC. Figure 1 shows the 4-way Doppler data coverage achieved from October 31, 2007 to January 6, 2008. The 2-month coverage is encouraging and we can expect a nice far-side coverage by the end of the nominal mission period (October, 2008).

After giving the highest priority to the 4-way Doppler we still have room to choose which 2-way measurement for Rstar or Vstar is carried out. The Vstar 2-way observation is preferentially chosen when there is a chance for Radio Science occultation observation of Vstar to detect the lunar ionosphere [5] or for same-beam VLBI observation [6].

The differential VLBI data are collected by four Japanese domestic stations of VERA [7]. Antenna time of about 24 hours/week is assigned to SELENE. We currently give weight to carrying out the differential VLBI observation during the face-on geometry because it is also complementary observable to the conventional 2-way measurement. 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.

Doppler data pre-processing: It is well known that the Doppler tracking data for a spin satellite contain modulated signals due to the spin. In order to eliminate the R/Vstar spin effect (about 11 rpm), we have designed a digital low-pass filter (LPF) which conserve the Doppler spectrum for gravity field. The 0.1-sec Doppler data are subjected to the LPF and integrated to 10-sec data. A smaller residual level is achieved by the low-pass filtering compared to unfiltered case.

Orbit determination setting: The range and Doppler data were processed by GEODYN II [8] software. Force modeling on the satellites consisted of the LP150Q model [9] as a priori gravity field. The DE403 ephemeris were adopted for the computation of third-body perturbations, as well as the definition of the lunar librations and coordinate system. Solar radiation pressure was modeled as a cannonball model. The data weights were set as 2 m for 2-way range, 1 mm/s for 2-way Doppler, and 1.3 cm/s for 4-way Doppler. There are reaction wheel unloading events for the Main satellite which are scheduled about every 12 hours (but more frequently in the initial check out phase). The Main satellite arc is often split at the unloading timing.

Preliminary results of tracking data residual: Figure 2 shows, as an example, 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. As is discussed in [10], 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: As of this writing we have not yet solved for the lunar gravity field from the tracking data, but we are waiting until a good data coverage is achieved. With such a 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 [3] 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 k_2 value [11]. Finally all the SELENE tracking data will be combined with the historical tracking data for a more complete lunar gravity field solution.

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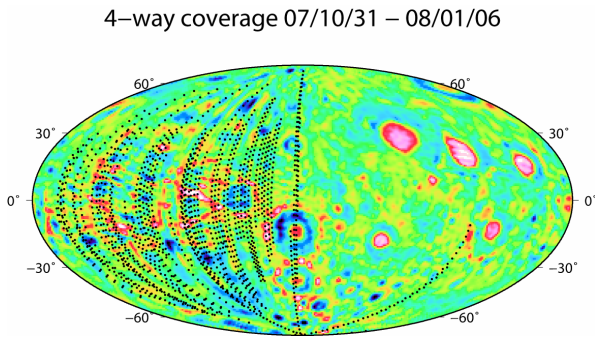

Figure 1. The 4-way Doppler coverage achieved from October 31, 2007 to January 6, 2008. Each black dot corresponds to the position of the Main satellite with 1 minute interval. The far-side is on the left-hand side of the map. The near-side 4-way data were collected during the initial check out of Rstar.

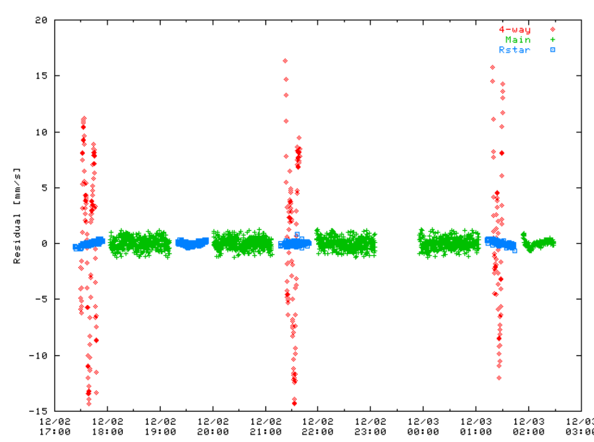

Figure 2. Doppler residuals for December 2-3 arc. Blue: Rstar 2-way, Green: Main satellite 2-way, Red: Main satellite 4-way. The 2-way Doppler data of the Main satellite are from the GN station except for the last pass starting at 02:00 December 3.