Arc continuation of SELENE main orbiter for an analysis of the lunar gravity field

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RSAT/VRAD teams in SELENE project are aiming an analysis of lunar gravity field. Planetary gravity field is studied from range and range rate (RARR) data of perturbed orbit of spacecraft. Therefore it is preferable that time length of free flight of the SELENE main orbiter is longer than 24 hours. However, because SELENE adopts 3-axes attitude control, momentum wheels in the main orbiter need to be unloaded every 12 to 18 hours. At the time of unloading, the main orbiter jets uncoupled thrusters. Consequently, the orbit makes a small change, and arc length is limited to be shorter than 18 hours. Matsumoto et al. has demonstrated by numerical simulation that the lunar gravity filed can be well resolved even from the series of short arcs, but it is possible that longer arcs decrease covariance between gravity coefficients. In this study, we attempt to model changes of the orbit by taking telemetry data for continuation of series of short arcs, and evaluate errors due to continuation.

Adopted telemetry data are time of thruster impulses and amounts of unloading of each momentum wheel. The thrusters jet impulses in every 10 seconds from 12 to 25 times in each unloading event. The time of thruster impulses are counted in every 1 second. Together with planned time of impulses, the time of impulses can be determined precisely. The amounts of momentum wheels are converted to velocity changes by satellite system of the SELENE project. Errors of this conversion are 1.2, 0.23, and 0.23 mm/sec for along-track, across-track, and radial directions, respectively, in each unloading event. Also we take into account random deviation of each impulse of 20%.

The velocity changes are modeled in three ways. First, we neglect the velocity changes and treat short arcs as one long arc for comparison with other two models. Second, we approximate a series of impulses as 1 big impulse. And third, we assume that every impulse is exactly same magnitude. We call these models as 0-impulse, 1-impulse, and multi-impulse models, respectively. For simplicity, perturbation other than secular variation by J2 term of lunar gravity field is not included in calculations. Initial orbit is adopted from nominal values of the SELENE project except for longitude of ascending node. The longitude of ascending node is assumed to be 85.5 (nominal), 45, or 0 degree. Accuracy of RARR observation is assumed to be 1 km and 1 mm/sec. We use Kalman filter for most likelihood estimates of normalized J2 until the change of the J2 is less than 10**-10. The time length of the continued arc is set to be 30 hours and RARR observation are included in the first and last 6 hours.

Resulted errors of the estimated J2 are 10**-4~-5, 10**-5~-6, and 10**-5~-8 for the 0-impulse, 1-impulse, and multi-impulse models, respectively. Obviously telemetry data increase accuracy of the estimate, while the difference between 1-impulse and multi-impulse models is not significant. Besides, accuracy is best for the longitude of ascending node of 0 degree and is worst for that of 85.5 degree. This result can be well explained by orbital dynamics of secular variation. The secular variation appears as rotation of perigee within orbital plane. A motion of orbital plane is 2 orders of magnitude smaller, because the SELENE main orbiter is in polar orbit. For longitude of ascending node of 0 degree, a line of site of RARR observations is parallel to the orbital plane. Therefore the secular variation is distinct in the RARR data. On the other hand, for longitude of ascending node of 85.5 degree, a line of site is perpendicular to the orbital plane. The RARR data are insensitive to the secular variation. In all cases, resulted errors are larger than that of the most recent lunar gravity model, LP100J. Further improvement of algorithm is necessary for practical use of arc continuation.