Reassessment of SELENE (KAGUYA) Doppler Bias

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The SELenological and ENgineering Explorer "KAGUYA" (SELENE), the first lunar explorer that successfully made observations of the gravity field on the far side of the Moon, was launched by the H-IIA rocket on September 14, 2007. Since the initial check-out phase of SELENE and up to the present day, JAXA has been developing a series of lunar gravity field models called SGMT (SELENE Gravity Model Tsukuba) using 2-way and 4-way SELENE Doppler data in order to improve the orbit determination and propagation accuracy. In this paper, we focus on describing the quality assessment of SELENE Doppler data, especially the results of Doppler bias estimation.

Key Words: Kaguya, SELENE, Doppler, bias, Orbit Determination

1. Introduction

KAGUYA was launched by the H-IIA Launch Vehicle on September 14, 2007 from the Tanegashima Space Center in Japan. KAGUYA was injected to lunar elliptical orbit at apolune altitude of 12,000 km, perilune altitude of 100 km on October 3. KAGUYA decreased its altitude gradually and was put on a final circular polar orbit at about 100 km altitude around the Moon on October 18. KAGUYA consisted of the Main Orbiter and two small spin-stabilized satellites, "OKINA" (Relay Satellite) and "OUNA" (VRAD Satellite). OKINA was placed in an elliptic orbit at an apolune altitude of 2400 km to relay communications between the Main Orbiter and the ground network on the Earth for measuring satellite-to-satellite (4-way) Doppler when the KAGUYA was flying on the far side of the Moon. OUNA which was in an elliptic orbit at an apolune altitude of 800 km, played a role of measuring the gravity field around the Moon by sending radio waves3). KAGUYA was descended to a circular polar orbit at 50km altitude from February 1, 2009 and then was descended again to lower orbit at perilune altitude of 10-30km from April 16, 2009. Finally, KAGUYA made a controlled impact with the lunar surface on June 10, 2009.

Besides NAOJ has been studying new lunar gravity model called SGM (SELENE Gravity Model) Using tracking data of KAGUYA and historical data such as Apollo 2,3), JAXA has been studying lunar gravity model called SGMT (SELENE Gravity Model Tsukuba) using KAGUYA tracking data only and applied it to the actual operation of the extended mission4). The purpose of improving SGMT is to realize more accurate orbital design methodology in tracking satellites at low lunar orbit in next generations, and secondarily to provide more precise experimental figures for such scientific work as lunar interior structure study5).

Since SGMT is derived from SELENE tracking data only, it is supposed to be susceptible to quality of SELENE tracking data. So JAXA has started reassessment of quality of SELENE tracking data especially Doppler bias.

2. Reassessment of Doppler bias

2.1. First recognition of 4-way Doppler bias existence

The initial check-out of first 4-way tracking revealed the existence of bias in 4-way Doppler. The first 4-way tracking started at 22:00 on 31 October 2007 (UT). Figure 1 shows residuals of 4-way Doppler data in the first iteration, the observed data minus data computed from initial orbit using LP100J as the a priori gravity model, for a measurement pass starting at 23:17 on 5 November and ending at 0:12. The initial orbit of the Main Orbiter and “OKINA” were estimated respectively using 2-way tracking data in advance.

During this pass, the Main Orbiter was initially over the near side when the 4-way link was established. The residuals when the Main Orbiter was over the near side may be bias in data, whereas the long-wavelength, large amplitude features of the residuals when the Main Orbiter was over the far side of the Moon is considered as difference between the actual gravity and LP100J.

2.2. 4-way Doppler bias estimation

Although there are significant Doppler bias, the early SGMT models were derived estimating Range bias, but without estimating Doppler bias. Since 2009, JAXA has been trying to estimate of Doppler bias and to make clear its potential influence on orbit determination and lunar gravity field estimation.

The theoretical value of Doppler bias of spin-stabilized satellite is known to be calculated considering the turn-around ratio of the satellite transponder, the wavelength of the ground-based transmitter, and the spin rate of the satellite6). Figure 2 shows the examples of estimated 4-way Doppler
bias, estimated with fixed 2-way Doppler bias of OKINA as theoretical value and estimated variable 2-way Doppler bias. OKINA has its antennas both on South side and North side. Two peaks in distribution of estimated value may be depend on which side antenna was used for communication link. There is no significant difference in estimated 4-way Doppler bias depend on difference of approach of 2-way Doppler bias calculation, but 4-way Doppler residuals slightly decreases with fixed 2-way Doppler bias of OKINA.

3. Summary

As a part of activity of improving orbit determination and propagation accuracy and lunar gravity field model, JAXA has started reassessment of SELENE tracking data quality mainly Doppler bias caused by spin of the OKINA. With theoretical value of 2-way Doppler bias of OKINA and estimated 4-way Doppler bias, 4-way Doppler residuals a little decreases. It seems that the ideal approach is to fix 2-way Doppler bias and also 4-way Doppler bias as theoretical value considering the effect of spin of OKINA, so next step is to confirm theoretical 4-way Doppler bias value.

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References


Fig. 1. 4-way Doppler residuals in pass from 23:17 on 5 November to 0:12 on 6 November 2007 (UT).

Fig. 2. Example of estimated 4-way Doppler bias, with theoretical 2-way Doppler bias and with variable 2-way Doppler bias of OKINA.