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Updated lunar gravity results of Kaguya (SELENE) and new lunar gravimetry by inverse VLBI method for SELENE-2

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In Japanese lunar explorer project Kaguya, we carried out the lunar gravimetry by using conventional 2-way range and Doppler, 4-way Doppler, and VLBI methods. In the presentation, results from incorporating all Kaguya Doppler tracking (including all collected 4-way data over the farside) are presented. We determined spherical harmonics expansion of the lunar gravity filed up to degree and order 100. They will be evaluated in terms of geophysical content, correlations with topography, and orbit determination performance. As a result, it is shown that unconstrained solutions can be obtained up to degree and order 70 without loss of correlations with topography. We also present a preliminary high-resolution 150 degrees and order model for low-lunar orbit determination. Preliminary results of the analysis of same-beam differential VLBI data are also included. It shows the contribution of VLBI measurements for improving the accuracy of orbit for the sub-satellites. The VLBI data will also contribute to a precise determination of the lower-degree gravity coefficients.

Now, we plan to apply new VLBI technique for next Japanese lunar mission. The iVLBI instrument, which consists of inverse VLBI and same-beam VLBI units, is proposed for lunar landing mission SELENE-2. The purpose of the instrument is to improve the accuracy of lower-degree coefficients of the lunar gravity field.

In the case of inverse VLBI, artificial radio source is loaded on one orbiter and one lunar landing unit (a small survival module on the lunar surface). These transmit three S-band carrier wave signals and the difference of the distance between radio sources and ground VLBI station is measured. This differential range measurement is sensitive to the motion of the orbiter relative to lunar landing unit. The 2-way ranging between the orbiter and the lunar landing unit is also carried out by using three S-band signals. The range is accurately determined from the phases of the radio signals.

We also apply the heritage of VRAD mission of Kaguya, same-beam VLBI technique. The radio source loaded on the orbiter and the lunar landing unit transmits three or four S-band singal and one X-band signal to the earth. These signals are received at a pair of VLBI stations. A doubly differenced range between two lunar radio sources and VLBI stations are measured within the error of less than 1 mm. This measurement will also contribute to determine the position of the orbiter and the lunar landing unit.

In the presentation, the principle of inverse VLBI, detail of the instrument for SELENE-2, and recent status are shown.