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VLBI radio sources on a lander and an orbiter for study of lunar internal structure proposed for SELENE-2 mission

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VLBI (Very Long Baseline Interferometry) radio sources were on board the SELENE two sub-satellites, Rstar and Vstar. The radio waves from the radio sources (called VRAD) were received at multiple ground stations which forms a type of tracking data, i.e. delay in arrival times of the wave of a radio source at two different stations forming a baseline carries information about the angular position of the radio source. Differential VLBI data between Rstar and Vstar, when both the radio sources were within the beamwidth of the ground antennas, were of particular importance because they are highly accurate with atomospheric and ionospheric disturbances almost cancelled out by the simultaneous observation. Such tracking data, i.e. "same-beam differential VLBI data" were used to develop an improved lunar gravity field model SGM100i [1].

The Japanese future lunar mission SELENE-2 will carry both a lander and an orbiter. We propose to put the VRAD-type radio sources to these spacecraft in order to accurately estimate lunar potential Love number k_2 and low-degree gravity coefficients through precision orbit determination of the orbiter with respect to the lander by using the same-beam VLBI tracking technique. We also propose a new type of observation called inverse VLBI [2] in order to further improve the k_2 estimate.

The same-beam VLBI observation is only possible when the separation angle between the two radio sources is smaller than the beamwidth of the ground antennas. The relatively large shape of Rstar's orbit (100 km x 2400 km) did not allow the same-beam observation all the time, but the situation can be improved by adequetly setting the orbit. For example, the Vstar-like orbit (100 km x 800 km) will almost always keep the separation angle smaller than the S-band beamwidth of domestic VERA stations since one of the radio sources is fixed on the near-side lunar surface.

A preliminary simulation study has been conducted under the condition of 2-week arc length, 12-week mission length, 6 hours/day 2-way Doppler observation plus S-band same-beam VLBI observation with the 4 VERA stations. The k_2 uncertainty is evaluated as 10 times the formal error considering the errors in solar radiation pressure modeling and in lander position. The results show that, when combined with the historical tracking data including SELENE and when the orbiter inclination was 90 degrees, the k_2 uncertainty is below 1 %. The Love number k_2 is sensitive to the structure in deep interior. According to a model calculation, the k_2 value changes by about 5 % depending on the state of the core, liquid or solid, when the size of the core is 350 km in radius. Thus the SELENE-2 VLBI mission will constrain the lunar deep interior through the estimation of k_2 Love number.

References: [1] Goossens et al., Journal of Geodesy, in press. [2] Kawano et al., Journal of Geodetic Society of Japan, 45, 181-203, 1999.