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Simulation analysis of differential phase delay estimationby same beam VLBI Method

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The size and density of the lunar core estimated from the moment of inertia of the Moon are important constraints for investigating the origin of the Moon. However, the lack of accurate gravity field information especially for the far side and the limb region of the Moon restricted the accuracy of the moment of inertia of the Moon to be around 1 %. In order to estimate the lunar gravity field accurately especially for the far side and the limb region of the Moon, the differential VLBI observation in the VRAD (the differential VLBI RADio sources) mission will be carried out, next to the 2-way and 4-way Doppler observations in the RSAT (the Relay SAtellite Transponder) mission of the Japanese lunar explorer SELENE (SELenological and ENgineering Explorer).

In the VRAD mission, the multi frequency VLBI (MFV) method will be used to estimate the differential phase delay. The lunar orbiting two spacecraft transmit the four carrier wave signals, three in S-band and one in X-band. These signals are used to derive the differential phase delay of the X-band signal. However, there are two severe conditions for deriving the differential phase delay without the cycle ambiguity. These conditions are for the phase error of the differential residual fringe phase (DRFP) and for the error of the total electron content (TEC) included in the DRFP. These conditions can not be satisfied by the conventional switching VLBI method when the tropospheric fluctuation is large and/or the traveling ionospheric disturbance (TID) happens in the ionosphere above the VLBI station. In order to resolve this problem, the differential phase delay estimation by the same beam VLBI observation is proposed as a new method. Most of the error sources in the VRAD mission such as the tropospheric delay and the ionospheric delay are evaluated. As the results of the evaluations, it is shown that the conditions of the MFV method can be satisfied by applying the same beam VLBI observation method even if the tropospheric fluctuation is large and/or the TID happens. It is also shown that the accuracy of the delay depends on the average elevation angle and the elongation between the two spacecraft.

Moreover, a method for estimating the differential phase delay of the X-band signal in the case of the switching VLBI observation is developed. As long as there is at least one occasion of the same beam VLBI observation in the continuous observation path, the differential phase delay can be obtained for whole of this path by referring to that obtained in the period of the same beam VLBI observation. This method can be performed in more than 90 % of the total paths. The accuracy of the differential phase delay of the X-band signal is expected to be a few tens of ps. From this result, it can be expected that the low degree coefficients of the lunar gravity field can be derived with an increase in accuracy of more than one order of magnitude than previous results and an increase in accuracy of one order for high degree coefficients.