Same-beam differential VLBI technique using two sub-satellites of SELENE

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The Japanese SELENE project consists of three satellites; a main satellite in a circular polar orbit of 100-km altitude, a relay sub-satellite (Rstar) with altitude of 100-2400 km, and a VLBI sub-satellite (Vstar) with altitude of 100-800 km. The first direct observation of the far-side gravity field will be made in terms of 4-way Doppler tracking of the main satellite via Rstar, and long-wavelength as well as lunar-rim gravity fields will be precisely determined by differential VLBI tracking of the orbits of two sub-satellites. Rstar and Vstar only transmit three-pair carriers of 2212, 2218, 2287 MHz at S-band and one-pair carriers of 8456 MHz at X-band, and the difference in phase delay between Rstar and Vstar will be obtained from the relation between correlation phase and frequency of four carriers. In this case, the difference in the correlation phase at each frequency has to be estimated without 360-degree ambiguity, for which some strict conditions should be satisfied, e.g., the error of correlation phase must be lower than 4.3 degrees and the error of differenced total electron contents (Ds) in ionosphere along the signal propagation paths must be less than 0.23 TECU. In order to resolve the 360-degree ambiguity problem, we propose a new VLBI technique, called as same-beam differential VLBI, in which Rstar and Vstar are observed simultaneously within the same beam of the receiving antenna. In this case, the influence of atmosphere, ionosphere and receivers can be nearly canceled in the difference of correlation phases. In this report, we estimate the possible duration of same-beam differential VLBI observation by simulating orbits of Rstar and Vstar, and find that it is about 80 percent among all paths. We also estimate the errors of atmosphere, ionosphere and receivers, and propose methods to decrease these errors. For example, phase errors in the receiver are lower than 1 deg. Phase fluctuations caused by thermal noise are 0.7 deg for S-band and 1.1 deg for X-band. Ds can be measured from X- and S-band correlation phases with an accuracy of 0.1 TECU. Phase fluctuations caused by atmosphere at S-band are less than 0.7 deg estimated from 26 m baseline VLBI observation results. Influence of phase characteristic of on-board transmitting antenna and spin of satellites can be reduced to 0.02 deg by using a low pass filter. These results show that the conditions for removing 360-degree ambiguity are satisfied by using the same-beam differential VLBI. Using the new technique, difference in delay time can be obtained with an accuracy of several ps, and the relative position between Rstar and Vstar can be measured with an accuracy of as high as several tens of cm.