HAYABUSA VLBI observation for the Positioning of the Interplanetary Spacecraft using VLBI

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Precise spacecraft positions (5-10 nrad) can be obtained with differential spacecraft-quasar VLBI observations that directly measure the angular position of the spacecraft relative to nearby quasars. We performed more than 30 VLBI experiments for the two Japan's spacecrafts, NOZOMI and HAYABUSA from September 2002 until November 2003. These VLBI experiments are aimed to establish the positioning technology for the interplanetary spacecrafts in realtime.

We use nine VLBI antennas in Japan to perform the VLBI experiments at X-band. Algonquin 46-m of Natural Resources Canada (NRCan) also participate in several experiments in collaboration with the Space Geodynamics Laboratory (SGL) of CRESTech. We equipped the state of the art 'K5 VLBI system' to these stations. The K5 system is the multiple PC-based VLBI system equipped with a PCI-bus Versatile Scientific Sampling Processor (VSSP) board on the FreeBSD and Linux operating system. The K5 system includes the original software packages which are data sampling and acquisition, real-time IP data transmission, and correlation analysis. For the purpose of analyzing the VLBI observables we are developing the specific VLBI delay model for finite distance radio source. The model is already implemented in the VLBI software package. The package will include the VLBI observation scheduling to take account of the passage of the spacecraft near the quasar line of sight and the propagation delay estimating for the ionosphere and the neutral atmosphere.

The final products obtained from the NOZOMI VLBI experiments were available with approximately 30 hours latency. The obtained group delays were compared with the NOZOMI orbit using range and range rate (R&RR) observables. Preliminary results demonstrate that the VLBI delay residuals are consistent with R&RR observables. However, the rms scatter between them are relatively large up to several tens nanoseconds. We consider these large scatters are caused by low signal to noise ratio of the NOZOMI VLBI group delays.

NOZOMI VLBI experiments are insufficient to develop the VLBI tracking technique due to some problems such as signal weakness, narrow band width and so on. Thus, we perform another VLBI experiments. The one of the candidate targets is HAYABUSA, which was developed to investigate asteroids. HAYABUSA was launched on May 9 2003, and has been flying steadily towards an asteroid named 'Itokawa', after the late Dr. Hideo Itokawa, the father of Japan's space development program [JAXA, 2003].

First, we evaluated the signal intensities of the candidate quasars to perform the differential VLBI experiments. We selected 24 quasars from the ICRF catalog considering the HAYABUSA trajectory during September 1 to December 31, 2003. The separation angles between the HAYABUSA and the quasars are less than 5 degrees at each epoch. The first HAYABUSA VLBI experiment was successfully carried out November 26, 2003. The group delay fringes of HAYABUSA range and telemetry signals are successfully detected. In addition, the phase delay signals are also detected by using the revised VLBI correlation software including the infinite VLBI model[Sekido et al., 2003]. We are now evaluating the estimated positions obtained from HAYABUSA group and phase delays by comparing with the R&RR results.