VLBI Observation by Receiving Narrow Bandwidth Signal from NOZOMI

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1.Introduction

An orbit of a spacecraft (s/c) is usually determined by using coherent 2-way range and range-rate (R&RR) measurements. In addition to R&RR, the VLBI (Very Long Baseline Interferometry) technique can be also used for positioning of the s/c. By measuring the difference of arriving time of same wave front of radio signal from the s/c at two separated antennas, VLBI can determine the angular position of the s/c in space. VLBI is sensitive to the direction perpendicular to line-of-sight LOS) direction to the s/c from the tracking station in contrast to the R&RR. Combination of two kinds of observations can improve the accuracy of orbit determinations.In order to make above technique a common method for the s/c orbit determination, we observed the first Japanese Mars explorer NOZOMI by using a regional VLBI network and a new s/c VLBI tracking method.

2. Back-end system and correlation software In radio astronomical and/or geodetic VLBI surveys, usually wide bandwidth signals from several MHz to GHz) are recorded by fast sampling-rate systems. In contrast with above systems, when applying the VLBI technique for the s/c orbit determination, it is not effective for the s/c to generate and emit such a wide bandwidth signal or for ground system to record and real-time process such a wide bandwidth signal. Usually, the s/c transmits narrow bandwidth downlink carrier wave and/or the modulated carrier wave.　The group delay and delay rate should be obtained from the narrow bandwidth signals so as to get the instantaneous angle of the s/c and the angle variation in space.　For this reason, we have developed a narrow bandwidth VLBI sampling and recording system, called S-RTP station, for the s/c VLBI tracking. The sampling rate of our system is very slow, therefore the amount of sampling data is small enough for correlation by a common used PC. For this system, correlation software has been also developed.

3. Signals of NOZOMI

The downlink signal from NOZOMI was consist of a carrier wave, two range tones, and some ambiguity tones. In order to resolve the ambiguity of phase measurement by using group delay, the carrier wave and two range tones were separately recorded in 3 channels of S-RTP station. Moreover, to compensate the phase difference between channels of the video converter, the phase calibration signals at every 60kHz were mixed with the IF signals in front of the video converter. For calibrating the clock offset and clock rate between two VLBI stations, several QSOs with position precisely known were also observed before and after the tracking of NOZOMI.

4. Results of Correlation

The correlation was done by software of FX mode. In NOZOMI mission, a C/N of the signal recorded at the ground station was too low, so we use only 30Hz around the center frequency of the signals to increase the signal-to-noise ratio (SNR). After this correction, SNR of carrier wave was 21 and that of range tones was 13.

After the corrections of clock offset and clock rate, the geometric delay obtained by group delay analysis well accorded with the delay determined by the R&RR measurement. Average difference was less than 2nsec and which was within the bounds of error of group delay analysis. If we assume that the baseline is 200km and the distance between NOZOMI and ground station is 6000000km, the position error of NOZOMI was 18km. Due to the very low C/N, this result is not accurate enough for orbit determination of NOZOMI precisely, but we confirmed the validity of our new hardware and software VLBI systems. It is also confirmed that our new VLBI system has a capability of precise s/c tracking within the error of a few nsec when SNR is about 100.