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7.6 TIE OF THE KSP VLBI NETWORK TO THE TERRESTRIAL REFERENCE SYSTEM

By

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ABSTRACT

To determine accurate site coordinates of the Key Stone Project Very Long Baseline Interferometry stations on a global terrestrial reference frame, a series of tie experiments have been carried out with the 34-m antenna station in the Kashima Space Research Center. By using the site coordinates of the 34-m antenna on the ITRF96 reference frame, positions of the four Very Long Baseline Interferometry stations in the Key Stone Project Network have been tightly connected to the global reference frame.
Keywords: VLBI, Geodesy, Terrestrial reference frame

1. Introduction

In usual analyses of data from geodetic Very Long Baseline Interferometry (VLBI) experiments, site coordinates of one observation station have to be fixed to *a priori* values and the site coordinates of the other stations have to be estimated. In principle, the site coordinates of the reference station are not necessarily accurate as far as the baseline lengths and relative positions are concerned. However, consistency between site coordinates of the reference station and the terrestrial reference system has to be ensured if the results are to be compared with results obtained by other techniques. Consistency of the terrestrial reference frame, in which the site coordinates of the reference station are defined, with the celestial reference frame and the earth rotation parameters is also important for obtaining reliable results. This is especially true in the case of VLBI data analyses in the Key Stone Project (KSP), where source positions and earth rotation parameters are fixed to a priori information.[1] To ensure consistency between the terrestrial reference frame, the celestial reference frame, and earth rotation parameters, it is best to conform to the standards of the IERS Convention 1996 defined by the International Earth Rotation Service (IERS).[2] IERS is an organization which is responsible for maintaining accurate and consistent reference frames, theoretical models, and constants, which are all essential for obtaining reliable results from space geodetic measurements. The IERS Convention 1996 is the latest set of definitions of these quantities. In the IERS Convention 1996, the terrestrial reference system and the celestial reference system are defined, and the ITRF96[3] and RSC (WGRF) 95R01[4] are the conventional realizations of these reference systems constructed based on the IERS Convention 1996. IERS has computed a series of earth rotation parameters EOP (IERS) 97C04 based on these two reference frames and is continuously extending the series with monthly and semi-weekly bulletins. In routine analyses of the KSP VLBI data, positions of radio sources and the earth rotation parameters are respectively fixed to the RSC (WGRF) 95R01 and EOP (IERS) 97C04. Therefore, it is necessary to determine the precise position of the reference station on the ITRF96.

We considered that the KSP VLBI station at Kashima is the most suitable as the reference station for the KSP

Table 1 List of seven tie VLBI experiments with the 34-m antenna VLBI station at Kashima and KSP VLBI stations.

Experiment Experiment	Date	Participating VLBI Stations
95JAN19	January 19, 1995	Kashima (34-m), Kashima (KSP), Koganei (KSP) Kanozan (2.4-m), Koganei (3-m)
97MAY01	May 1, 1997	Kashima (34-m), all KSP stations
97OCT07	October 7, 1997	Kashima (34-m), all KSP stations
97NOV18	November 18, 1997	Kashima (34-m), all KSP stations
98FEB16	February 16, 1998	Kashima (34-m), all KSP stations
98MAY01	May 1, 1998	Kashima (34-m), all KSP stations
98JUN19	June 20, 1998	Kashima (34-m), all KSP stations

VLBI data analysis since the other two VLBI stations at the Kashima Space Research Center (KSRC) are included in the ITRF96. The 34-m antenna VLBI station and the 26-m antenna VLBI station have been included in many international VLBI experiments and their site coordinates and common velocity are accurately defined in the ITRF96. Since these two antennas are located very close to the KSP Kashima VLBI station, it is reasonable to assume that the site velocity of the KSP Kashima VLBI station is the same as the site velocities of the 34-m and 26-m antenna VLBI stations. Consequently, we only have to determine accurate site coordinates of the KSP Kashima VLBI station at an arbitrary time epoch. To determine these coordinates, we have carried out seven geodetic VLBI experiments with the KSP VLBI stations and the 34-m antenna station at KSRC. This paper describes details and results of the experiments.

2. Experiments

Seven geodetic VLBI experiments were performed to determine accurate site coordinates of the Kashima KSP VLBI station in the ITRF96 terrestrial reference frame. Table 1 lists the dates and participating stations of these experiments. Except for the 95JAN19 experiment, these experiments were performed with the four KSP VLBI stations and the 34-m antenna VLBI station in KSRC. At the time of the 95JAN19 experiment, KSP VLBI stations at Miura and Tateyama had not yet been constructed and only two stations at Kashima and Koganei were operational. Instead, the 3-m antenna mobile VLBI station at Koganei and the 2.4-m antenna mobile VLBI station at Kanozan participated in the experiment. To obtain a sufficient signal-to-noise ratio for these two small aperture VLBI stations, each observation had to be longer than in the routine KSP VLBI experiments. Consequently, the number of observations in the experiment was only about half of the number in the other experiments. In the 97OCT07 and 97NOV18 experiments, a frequency reference distributor unit used at the 34-m antenna VLBI station at KSRC did not function properly and did not provide sufficient frequency stability, so the results of these experiments were not as good as usual. Therefore, only data obtained from the other four experiments (97MAY01, 98FEB16, 98MAY01, and 98JUN19) have good quality.

The observations of the seven experiments were performed with the tape-based VLBI observation mode at a recording speed of 64 Mbps (megabits per second) unlike routine KSP VLBI experiments.[5] Moreover, the frequency assignments of the observation channels were different from the setup used for routine KSP VLBI experiments to fit the frequency range of the 34-m antenna receivers.

3. Results

Recorded data on the observation tapes were processed by the KSP VLBI Correlator system at Koganei[6]. The processed data were then analyzed by using Calc 8.2 and Solve 5.00094[7]. Source coordinates and earth rotation parameters were fixed, respectively, to *a priori* information from RSC(WGRF)95R01 and EOP(IERS)97C04. Site coordinates of the 34-m antenna VLBI station at KSRC were calculated from the site coordinates and velocity of the station defined in the ITRF96 terrestrial reference frame. The site coordinates of the other stations were estimated along with the clock offsets and atmospheric delays. Fig. 1 shows the estimated positions of the KSP VLBI station at Kashima expressed in the horizontal plane and in the vertical plane. The site positions at the epoch of January 1, 1997 were calculated from the estimated results from the seven experiments using the site velocity of the 34-m antenna VLBI station defined in the ITRF96. Ellipses are the one-sigma uncertainties of the estimated results.

Error ellipses of three of the experiments (95JAN17, 97OCT07, and 97NOV18) are relatively large compared with the other four experiments, reflecting the poor quality of the data of the three experiments. The RMS (root mean square) repeatability of the estimates of the site coordinates from other four good-quality VLBI data is less than $\pm$1mm for horizontal components and $\pm$5mm for a vertical component. The origins in Fig. 1 are the averages of the results from these four experiments. The site coordinates of the Kashima KSP VLBI station are considered to be reliably determined in the ITRF96 terrestrial reference frame from the position averaged from the four good-quality experiments. The site coordinates of the

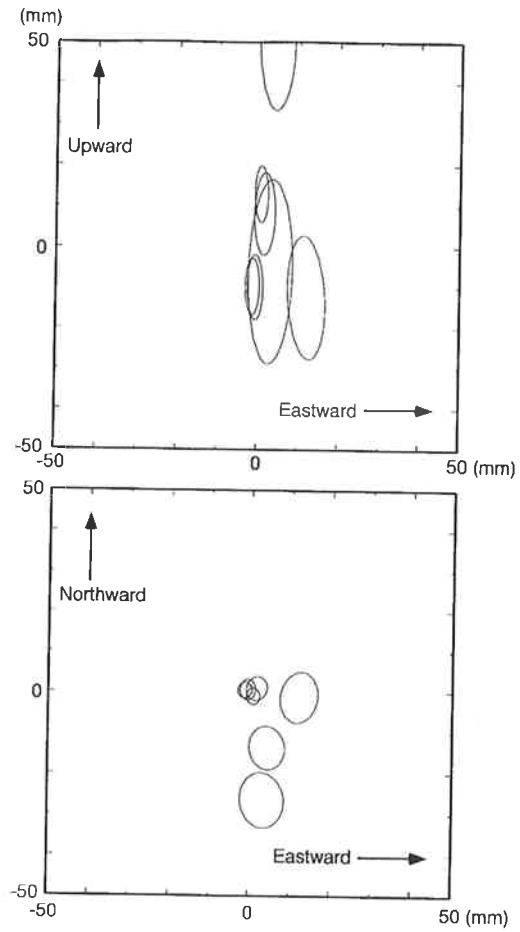

Fig. 1 Estimated site position of the KSP Kashima VLBI station. Error ellipses are 1σ formal errors.

Table 2 Estimated site coordinates of the KSP VLBI stations on the ITRF96 terrestrial reference frame at the epoch of January 1, 1997.

Site	X (mm)	Y (mm)	Z (mm)
Kashima	−3997505658.31	3276878393.29	3724240695.69
Koganei	−3941937433.67	3368150896.10	3702235287.62
Miura	−3976129956.66	3377927877.39	3656753837.14
Tateyema	−4000983402.88	3375275950.81	3632213183.01

Table 3 Estimated site velocities of the KSP VLBI stations on the ITRF96 terrestrial reference frame.

Site	X (mm/year)	Y (mm/year)	Z (mm/year)
Kashima	−1.30	2.40	−12.90
Koganei	−2.79	2.01	−7.83
Miura	12.43	−1.17	−5.18
Tateyema	11.32	−0.03	−0.06

other three sites on ITRF96 were then determined from the accumulated data obtained by routine KSP VLBI experiments performed between August 1994 and June 1998. Table 2 shows the estimated site coordinates of four KSP VLBI stations on ITRF96 at the epoch of January 1, 1997. Table 3 shows the site velocities on ITRF96 estimated for the four KSP VLBI stations. The site velocity of the KSP VLBI station at Kashima is assumed to be the same as the site velocity of 34-m antenna station at KSRC given in ITRF96.

4. Discussions and Remarks for the Future

The Key Stone Project VLBI Network has been tied to the ITRF96 coordinate system through the four good-quality VLBI experiments with 34-m antenna VLBI station at KSRC and KSP VLBI stations. The obtained site coordinates of the KSP VLBI station at Kashima are now used as the reference in the analysis of data from routine KSP VLBI experiments. Since the estimated site coordinates of three other KSP VLBI stations are based on the ITRF96 terrestrial reference frame, the coordinates can be compared with the other results obtained by different space geodetic techniques such as Global Positioning System (GPS) and Satellite Laser Ranging (SLR).

To improve the reliability and the accuracy of the tie, periodical geodetic VLBI experiments with the KSP VLBI stations and other VLBI stations of which the site coordinates and the site velocity are accurately defined in the ITRF96 are essential. Comparizons of the results with the conventional ground survey measurements are also important. Ground survey measurements have been performed at four sites of the KSP network and detailed comparizons will become possible soon. The observed data will have to be analyzed again when either the IERS Conventions or the reference frames are refined in the future. Although the tie of the KSP VLBI Network to the terrestrial reference system has been achieved through the 34-m antenna VLBI station at KSRC, the accuracy of the tie will improve if more VLBI stations are included in the tie experiments. Thus, several VLBI experiments with Fairbanks, Wettzell, and Urumqi are being planned. The recording speed of 64 Mbps will be increased to 256 Mbps and it will increase the number of observations in an experiment.

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