Analysis Center at Communications Research Laboratory

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Abstract

This report summarizes the activities of the Analysis Center at the Communications Research Laboratory (CRL) for the year 2003. By using the newly developed PC-based data acquisition and data processing system (K5 VLBI system), we performed the international e-VLBI sessions twice and we demonstrated a rapid estimation of UT1-UTC in less than one day after the observations on June 27, 2003. We also 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.

1. General Information

The CRL analysis center is located in Kashima, Ibaraki Japan. It is operated by the Radio Astronomy Applications Group, Kashima Space Research Center of CRL. VLBI analyses at CRL are being mainly concentrated on experimental campaigns for developing new techniques such as differential VLBI (DVLBI) for the spacecraft orbit determination and e-VLBI measurements for the real-time EOP determination. In addition we are now preparing to perform the feasibility experiment of GPS and VLBI data transmission using a satellite communication link through the TCP/IP protocol from the South Pacific to Japan. We are also conducting a water vapor radiometer (WVR) observation in Kashima and an numerical simulation of atmospheric parameters (equivalent zenith wet delay and linear horizontal delay gradients) estimated by ray-tracing through the non-hydrostatic numerical weather prediction model (NHM).

2. Staff

The staff members who are contributing to the Analysis Center at the CRL are listed below:

- KONDO Tetsuro, Responsible for overall operations and performance.
- KOYAMA Yasuhiro, Development of data analysis software for the geodetic experiment.
- SEKIDO Mamoru, Development of data analysis software for the DVLBI.
- OHSAKI Hiro, Development of data analysis software for the DVLBI.
- ICHIKAWA Ryuichi, Development of data analysis software for the DVLBI and atmospheric modeling.

3. Current Status and Activities

3.1. Geodetic VLBI experiments

Two geodetic VLBI sessions were carried out to evaluate the performance and functions of the K5 VLBI system[Koyama et al.,(2003a)[1]]. The first session was performed for about 24 hours from January 31, 2003 by using Kashima34-Koganei baseline. The second experiment was performed for about 24 hours from July 14, 2003 by using five VLBI stations at Kashima (34m),

Tsukuba (32m), Tomakomai (11m), Gifu (11m), and Yamaguchi (32m). The example of the results are shown in Table 1. The comparison of the RMS residuals of delay and delay rates suggests the performance of the K5 systems is better than the K4 systems.

Table 1. Comparison of Kashima 11 - Koganei 11 baseline lengths estimated from the data obtained with K4 and K5 systems on Jan. 31, 2003.

	No. of valid data	Baseline Length (mm)	RMS Residual Delay(psec)	Rate(fsec/sec)
K4	112	109099657.0±6.7	76	136
K5	159	109099641.2±3.2	33	92

3.2. Real-time EOP measurements

We performed a test e-VLBI session for two hours from 16:00 UT on March 25, 2003 with the Kashima-Westford baseline[Koyama et al.,(2003b)[2]]. The 34-m antenna VLBI station at Kashima and the 18-m antenna station at Westford were used for the observations. This was the fourth test in the series of e-VLBI test observations. During the previous tests, successful detections of the fringes from the e-VLBI observations were demonstrated and the software developments have been continued with the data sets obtained. The estimated UT1-UTC value is shown in the Table 2 as well as the values published in the IERS Bulletin B.

Table 2. Estimated value of UT1-UTC from the Kashima-Westford e-VLBI session and reported values from IERS Bulletin B 183, May 2, 2003.

	Epoch (UT)	**UT1-UTC(μsec)**
e-VLBI	20:00 on Mar. 25	-338727.0±23.9
IERS	00:00 on Mar. 25	-337951
IERS	00:00 on Mar. 26	-338610

The next e-VLBI session was performed for two hours beginning at 13:00 UT on June 27, 2003. The observation mode, configuration of the observing systems, and the baseline were identical to the previous e-VLBI session performed in March, 2003. The purpose of the session was to demonstrate how fast the UT1-UTC can be actually estimated from the international e-VLBI session.

Table 3 shows the actual time sequence of the observations, file transfers, and data processing during the e-VLBI session. As shown in the Table 3, the UT1-UTC was estimated within 21 hours and 20 minutes after the session finished. Thus the rapid estimation of the EOP in less than one day was successfully demonstrated by the international e-VLBI observations and data analysis.

3.3. Differential VLBI

Precise spacecraft positions (5-10 nrad) can be obtained with differential spacecraft-quasar VLBI (DVLBI) observations that directly measure the angular position of the spacecraft relative

Table 3. Time sequence from the observations to the data analysis. Time is in Japanese Standard Time and start from 22:00 on June 27, 2003

TIME(UT)	**Event**
Time	Event
22:00	Observations Start
00:00	Observations End
∼04:20	File extraction and transmission From Kashima to Westford:
	107Mbps (41.54GByte in 51m 35s)
	From Westford to Kashima:
	44.6Mbps (41.54GByte in 2hr 04m 02s)
∼08:10	File Conversion (Mark5 to K5)
∼20:30	Software Correlation
∼21:20	Bandwidth Synthesis Processing, Database Generation, Data Analysis

to nearby quasars. We performed more than 30 VLBI experiments for the two Japan's spacecrafts, NOZOMI("Hope") and HAYABUSA("Falcon") from September 2002 until November 2003 [see Ichikawa et al., 2003[3] and Sekido et al., 2003[4] in detail]. These VLBI experiments are aimed to establish the positioning technology for the interplanetary spacecrafts in realtime.

The final products obtained from the NOZOMI VLBI experiments were available with approximately 30 hours latency as shown in Figure 1. On the other hand, the removable data hard disks at other stations (Tomakomai, Tsukuba, Yamaguchi, and Algonquin) were mailed to Kashima. Thus, the latency to product the group delays using these satation data were up to several days.

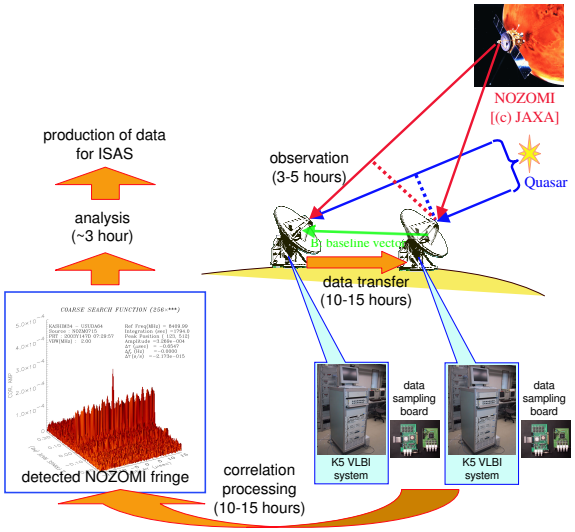

Figure 1. **Schematic image showing NOZOMI VLBI data flow and analysis**

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 are now evaluating our VLBI group delays by comparing with the R&RR results more

deeply.

We are now preparing to 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 [JAXA, 2003][5]. The first HAYABUSA VLBI experiment was successfully carried out November 26, 2003. We are now evaluating the obtained HAYABUSA group delays by comparing with the R&RR results.

3.4. Evaluation of Atmospheric Model

Observations of atmospheric slant delay using water vapor radiometer (WVR) nearby the Kashima 11-m antenna are carried out for detecting and characterizing water vapor variations. We are also evaluating atmospheric parameters (equivalent zenith wet delay and linear horizontal delay gradients) and positioning errors derived from slant path delays obtained by ray-tracing through the non-hydrostatic numerical weather prediction model (NHM) with 1.5 km horizontal resolution.

4. Future Plans

During the year 2004 the plans of the Analysis Center at CRL include:

- Several international and domestic VLBI experiments for the real-time EOP determinations using the e-VLBI and K5 system (both IP-VLBI system and PC/VSI system).
- Development of the analysis software for the spacecrafts positioning using phase delay observables
- Improvement of processing speed and efficiency for the VLBI data correlation using multiprocessor and high speed network
- Comparisons of the tropospheric parameters derived from VLBI, GPS, WVR and non-hydrostatic numerical weather prediction data.

In addition KSP data sets are still available at the URL http://ksp.crl.go.jp/index.html. General information about VLBI activities at the CRL is provided at

http://www2.crl.go.jp/ka/radioastro/index.html.

References

[1] Koyama et al., Evaluation of the K5 system in geodetic VLBI experiments, IVS CRL/TDC News, No. 23, pp 26-30, 2003.

[2] Koyama et al., Rapid Turn Around EOP Measurements by VLBI over the Internet, IUGG proceedings, 2003.

[3] Ichikawa et al., An evaluation of VLBI observations for the positioning of the NOZOMI Spacecraft and the future direction in research and development of the deep space tracking using VLBI, IVS CRL/TDC News, No.23, pp 31-33, 2003.

[4] Sekido et al., VLBI Application for Spacecraft Navigation (NOZOMI) -follow-up on Model and Analysis, IVS CRL/TDC News, No.23, pp 34-35, 2003.

[5] JAXA web site, http://www.muses-c.isas.jaxa.jp/English/index.html, 2003.