# Analysis Center at National Institute of Information and Communications Technology

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**Abstract**

This report summarizes the activities of the Analysis Center at National Institute of Information and Communications Technology (NICT, former CRL) for the year 2004. By using the state-of-art e-VLBI systems, we performed the international EOP session between Westford and Kashima, differential VLBI measurements for the precise tracking the spacecraft HAYABUSA and geodetic experiments. In particular, we achieved the most rapid estimation of UT1-UTC with a latency of four and half hours. In addition, we performed ionospheric studies, the development of automatic GPS data processing system, and satellite communication experiments.

## 1. General Information

The NICT analysis center is located in Kashima, Ibaraki, Japan. It is operated by the Radio Astronomy Applications Group, Kashima Space Research Center of NICT. VLBI analyses at NICT are mainly concentrated on experimental campaigns for developing new techniques such as e-VLBI measurements for the real-time EOP determination and differential VLBI (DVLBI) for spacecraft orbit determination. In addition we carried out monthly IVS-T2 sessions, the feasibility experiment of GPS and VLBI data transmission using a TCP/IP satellite communication link. We are also developing an automatic GPS analysis system named "APPS (Advanced Precise Positioning System)" to provide the precise positioning for non-geodesist users.

## 2. Staff

The staff members who are contributing to the Analysis Center at the NICT are listed below (in alphabetical order):

- ICHIKAWA R., Development of data analysis software for the DVLBI and atmospheric modeling.
- KONDO T., Responsible for overall operations and performance.
- KOYAMA Y., Development of data analysis software for the geodetic experiment.
- SEKIDO M., Development of data analysis software for the DVLBI.
- TAKEUCHI H., Development of distributed processing system.
- T. HOBIGER, Analysis of ionospheric effects on space geodesy.

## 3. Current Status and Activities

### 3.1. Real-time EOP measurements

On June 29, 2004, one hour e-VLBI session between Westford and Kashima stations was performed to obtain UT1 estimation as soon as possible [1]. After the observations, the data

recorded at Westford station with the Mark 5 system were extracted and transferred to Kashima through Abilene/TransPAC/JGNII networks. 13.5 GBytes of data were transferred in about 1 hour and 15 minutes and the average data transfer rate was 24 Mbps. The transferred data were then converted to the K5 file format. As soon as the data format conversion was completed, the software correlation was started using both NFS-based distributed processing system on Linux and FreeBSD and the VLBI@home on Windows 2000 and XP [2]. Immediately after all the correlation processing was completed, database files were generated and the data analysis was performed by using CALC and SOLVE software developed by the Goddard Space Flight Center of NASA. The data analysis was completed in about 4 hours and 30 minutes after the last observation of the session. Table 1 shows the time sequence from the observations.

Table 1. Time sequence from observations through the data analysis of the e-VLBI session on June 29, 2004

| Events | Time in UT (Date) |
|---|---|
| Observing session started | 19:00 (June 29) |
| Observing session finished | 20:00 |
| File transfer started | 20:13 |
| File transfer completed | 21:28 |
| Correlation processing completed | 00:16 (June 30) |
| Data analysis completed | 00:30 |

Following the success, an extra intensive session series between Tsukuba and Wettzell that observes every Sunday was initiated to fill the remaining day of the week for the intensive sessions. By establishing the Sunday intensive sessions, UT1 estimation from VLBI observations have become possible everyday.

### 3.2. Differential VLBI

We performed VLBI experiments for tracking the HAYABUSA spacecraft. HAYABUSA, which means "Falcon" in Japanese, 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. The first HAYABUSA VLBI experiment was performed at X-band (8.4 GHz) using six VLBI stations in Japan on November 26, 2003.

We also performed HAYABUSA VLBI experiment on October 16 and 18, 2004 in order to evaluate reduction of propagation delays due to the ionosphere and neutral atmosphere using differential VLBI technique. In this experiment, we acquired the VLBI data using both K5 system and state-of-art Gigabit system. The hybrid correlation processing based on the Gigabit system and the DBBC (Digital Baseband Converter) filtering technique is very efficient to detect fringes of weak radio sources which have small separation angle from the spacecraft [2].

### 3.3. Ionospheric Study

Mr. Hobiger (research fellow of the Japan Society for the Promotion of Science (JSPS) since July 1st, 2004) was conducting research on the determination of ionospheric parameters from VLBI observations. He has enhanced a method, first developed at NICT (Kondo, 1991, [4]), to

According to the comparison between group delays and R&RR results, large residuals of more than 100 nanoseconds have been found as shown in Figure 1[3].

The large scattering of the group delays is shown at the first four epochs and after about 07:30UT in Figure 1. On the other hand, the relatively small scattering, less than 10 nanoseconds, is shown during the period between 05:00UT and about 07:30UT. It is considered that the difference is caused by the characteristic of the radio signals transmitted from HAYABUSA. The group delays with large residuals are obtained using the telemetry signal, which has narrow bandwidth less than 1 MHz. The other group delays are obtained by the range signal which has a bandwidth of more than 1.5 MHz.

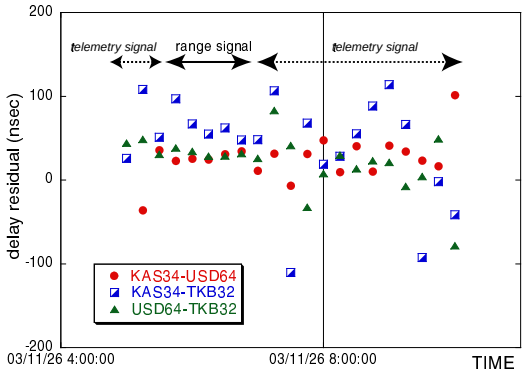


Figure 1. Residual delays between determined position using R&RR data by ISAS/JAXA and VLBI group delay observables

gain absolute ionospheric values from dual frequency VLBI measurements and applied it to the whole IVS database and several other data sources. The results may validate existing theoretical or measurement-based ionospheric models. Furthermore his studies provide useful information about long-term trends in the ionosphere ([5]) and allow direct comparison to results from other space geodetic techniques, like GPS or satellite altimetry missions. Moreover he is investigating effects on ionospheric corrections caused by the receiving system and by correlation processes.

### 3.4. Geodetic Data Transmission Through the Satellite TCP/IP Link

Full-time observations at globally distributed VLBI stations are desirable for real-time monitoring of the earth orientation. However, pacific and southern hemisphere coverage is not sufficient. If we are able to use a high speed TCP/IP data link using an optical fiber network or wideband satellite communication at the South Pacific Islands, the state-of-art e-VLBI system, which we are developing, will be able to fill a gap in the VLBI observation network. Thus, we started to perform satellite data transmission experiments[6].

Our first experiments were successfully carried out during the periods of February 9-14, 2004 and January 16-21, 2005 at the University of South Pacific (USP), SUVA, Fiji. In the 2004 experiment we evaluated the throughput rate using the new satellite router which can improve the maximum throughput of a TCP connection to avoid the time delay due to the round trip time (RTT). The peak data throughput was slightly more than 1440 Kbps, which is up to about 94% of the nominal maximum throughput. In the 2005 experiment we successfully performed the K5 software correlation of VLBI data sets using the VLBI@home between Japan and Fiji via satellite link.

### 3.5. APPS

We are developing an automatic GPS analysis system named “APPS (Advanced Precise Positioning System)”. APPS enables everybody to obtain accurate GPS solutions without requiring geodetic understanding, the operation of the sophisticated GPS software, or complicated data handling. Users can submit static single point or multi-station network GPS data to the APPS

analysis server by e-mail and receive the analyzed results back by e-mail after a few minutes. At present we allow access to the mail-based APPS analysis server only to a limited number of users in order to help to revise the system and we are developing the web site service of APPS.

### 3.6. Evaluation of Atmospheric Model

Observations of atmospheric slant delay using water vapor radiometer (WVR) near the Kashima 34-m antenna continue 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

For the year 2005 the plans of the Analysis Center at NICT 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).
- Differential VLBI experiments for spacecraft tracking
- Development of the analysis software for the spacecraft positioning using phase delay observables
- Improvement of the processing speed and efficiency of the VLBI data correlation using multiprocessor and high speed network
- Evaluation of simulated positioning errors due to the tropospheric parameters derived from the non-hydrostatic numerical weather prediction data.

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

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

(Please note that these URLs were changed from those given in the 2003 annual report).

## References

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[2] Takeuchi et al., VLBI@home - VLBI Correlator by GRID Computing System, in IVS GM 2004 Proceedings, NASA/CP-2004-212255, 2004.

[3] Ichikawa et al., HAYABUSA VLBI Observations for Development of Deep Space Tracking -Preliminary Report-, NICT TDC report, No.24, 7-8, 2004.

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[5] Schuh H., et al., Vienna IGG Special Analysis Center Annual Report 2004, this volume

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