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) for the year 2009.

1. General Information

The NICT Analysis Center is located in Kashima, Ibaraki, Japan and is operated by the space-time standards group of NICT. Analysis of VLBI experiments and related study fields at NICT are mainly concentrated on experimental campaigns for developing new techniques such as e-VLBI for real-time EOP determination, prototyping of a compact VLBI system, time and frequency transfer, atmospheric path delay studies, and improvement of the accuracy of space geodetic techniques.

2. Staff

Members who are contributing to the Analysis Center at the NICT are listed below (in alphabetical order, with their working locations in parentheses):

- HOBIGER Thomas (Koganei, Tokyo), Atmospheric and ionosphere research using VLBI and GPS, studies on the improvement of the accuracy of space geodetic techniques
- ICHIKAWA Ryuichi (Kashima), Compact VLBI system development and Atmospheric Modeling
- KONDO Tetsuro (Kashima and Ajou Univ., Korea), Software Correlator
- KOYAMA Yasuhiro (Koganei, Tokyo), International e-VLBI
- SEKIDO Mamoru (Kashima), International e-VLBI and VLBI for spacecraft navigation
- TAKIGUCHI Hiroshi (Kashima), Time-transfer experiments, international e-VLBI, and loading effects

3. Current Status and Activities

3.1. Time and Frequency Transfer via VLBI

As a new frequency transfer technique, which enables the comparison of highly stable frequency standards, we proposed the geodetic VLBI technique using our MARBLE system. We carried out inter-comparison experiments between VLBI, GPS, and DMTD (Dual Mixer Time Difference) on the local Kashima-34-m—Kashima-11-m baseline in order to show that VLBI is able to measure the correct time difference. The experiment included proof of the clock difference measurement capability, whereby the length of a reference signal transmission cable was artificially changed by using a line stretcher. Usually, geodetic VLBI alternately observes multiple sources that are uniformly covering the sky. Moreover, usually clock and atmosphere parameters as well as station coordinates are estimated within the geodetic analysis. However in this experiment, as we observed only one source and due to the short baseline, we estimated only clock parameters. The results reveal that the artificial delay changes measured by VLBI and DMTD show good agreement (within 10 ps). In general the VLBI results match the DMTD results better than GPS does. From this experiment, we confirmed the capability of the geodetic VLBI technique for time transfer application [8]. Further investigations of this application will be carried out.

3.2. Ultra-rapid UT1 Experiments

Data transfer via Internet protocols allows reduction of the latency of UT1 measurements obtained from VLBI. Such experiments, known as e-VLBI, were conducted in cooperation with colleagues from Metsähovi, Onsala, Wettzell, and GSI in order to demonstrate that the estimates of UT1 can be obtained shortly after the last scan has been observed [7]. By the usage of the UDP-based Tsunami protocol, data were sent to Kashima, converted to K5 format, and handed over to our software correlator, which is operated in distributed computing mode. In cooperation with Geographical Survey Institute (GSI) it was possible to obtain UT1 estimates, which have been proven to be as accurate as the IERS Bulletin-A results, as soon as four minutes after the last observation was made. Additionally application of real-time data transfer for 24-hour VLBI experiments has been tested on the Tsukuba—Onsala baseline. The experience gained from these experiments is going to be applied to the weekly Intensive VLBI sessions and is expected to improve the latency and accuracy of the IERS products.

3.3. MARBLE

We are developing a compact VLBI system with a 1.6 m diameter aperture dish in order to provide reference baseline lengths for calibration. We named the system "Multiple Antenna Radio-interferometry for Baseline Length Evaluation (MARBLE)" [4]. On December 9, 2008, we installed the first prototype of the compact VLBI system on the top of the building near the Kashima 34 m antenna and successfully detected the first fringe between the first prototype of the compact VLBI system and the Kashima 34 m on February 9, 2009 [5]. Moreover, we performed the first VLBI geodetic experiment between the first prototype and the Tsukuba 32 m of GSI on June 25, 2009. In this experiment, data acquisition at the Kashima 11 m was also performed. We estimated the baseline length between the first prototype and the Kashima 11 m (about 194 m) using the indirect method (see 'MARBLE concept [5]'). The formal error of its estimation is about 23% smaller than that of the conventional estimation. At the end of 2009, we installed the second prototype of the compact VLBI system and performed a geodetic experiment with the first prototype and the Tsukuba 32 m on December 23, 2009. We are now processing the obtained data sets.

3.4. Ray-traced Troposphere Slant Delay Correction

As numerical weather models have been constantly improved with respect to their accuracy and resolution, it became feasible to utilize them for the purpose of computing troposphere delay corrections from ray-tracing [3], considering that residual delays are still estimated within the geodetic adjustment process. A software package, named Kashima Ray-tracing Tools (KARAT), has been developed with the ability to transform numerical weather model data sets to geodetic reference frames, compute fast and accurate ray-traced slant delays [2], and correct geodetic data on the observation level. The impact of such corrections on UT1 estimates has been investigated by Boehm et al.[1] and is displayed in Figure 1.

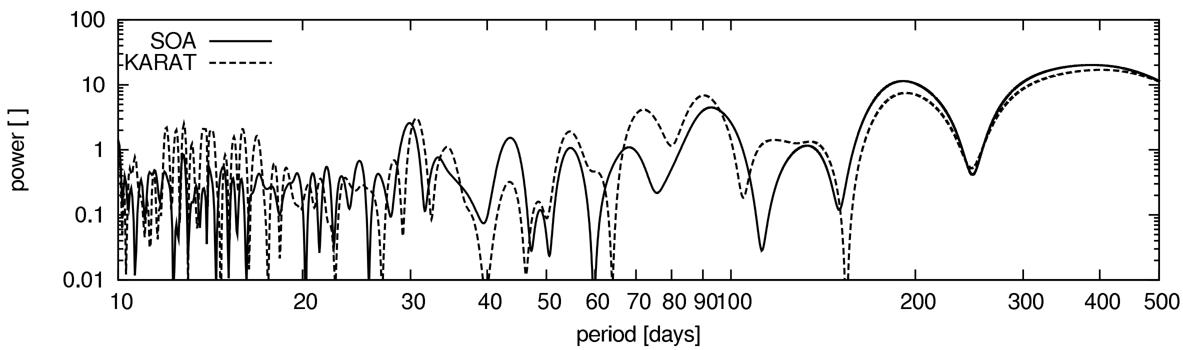

Figure 1. Lomb-Scargle periodogram of INT2 UT1 estimates w.r.t. IERS 05 C04 obtained from state-of-the-art (SOA, solid line) processing and after ray-traced corrections have been applied to station Tsukuba. The power at about fortnightly periods is clearly increased using the delays from direct ray-tracing with KARAT (dashed line). Details of this study can be found in Boehm et al.[1].

3.5. Kashima Ray-tracing Service - KARATS

In order to enable users of space geodetic techniques to take advantage of KARAT without the need to access numerical weather models on their own, it was decided to provide ray-tracing as a service. Thus the ray-tracing tools will be embedded in an automatic processing chain, called Kashima Ray-Tracing Service (KARATS), which can be started via a Webinterface. Once a user has taken his observations, he can send the data in a common format via the Internet to KARATS. Thereafter the Web server will do a rough data check and compute the geometry from the observation file. As soon as a ray-tracing client becomes available it will send the geometry file to that machine. The client performs the ray-tracing and sends the tropospheric delays back to the server. Thereafter the ray-traced delays are subtracted from the user's data and a "reduced" observation file is sent back to the user. KARATS is free of charge and can be accessed via *http://vps.nict.go.jp/karats/*. Although currently only GPS corrections can be computed online, VLBI is expected to be supported within 2010.

3.6. Development of a Multi-technique Space Geodetic Analysis Software Package

An analysis software package based on Java and named CONCERTO [6] enabled the user to consistently process SLR, GPS, and other satellite tracking data. The next version of this program package will also include VLBI as an additional space geodetic technique. As the software is currently being redesigned and completely re-written in C++, the requirements for complete VLBI data analysis (i.e. from ambiguity resolution through parameter estimation) can be taken into account. Considering the demand of VLBI2010, a focus will be set on automated and unattended processing of observations, which has been already implemented for SLR. A variety of observation formats, including raw correlator output, is supported by the VLBI module of C5++, allowing consistent processing of VLBI data. Since CONCERTO was originally designed for satellite techniques, existing modules and models can also be utilized to do spacecraft tracking either by VLBI or by a combination of several techniques, which monitor the satellite.

4. Future Plans

For the year 2010 the plans of the Analysis Center at NICT include:

- Further time and frequency transfer experiments
- Development of a multi-technique space geodetic analysis software, allowing automated and unattended processing of VLBI experiments
- Improvement of processing speed and efficiency for VLBI data correlation using multi-processors/multi-cores and high-speed networks
- International and domestic VLBI experiments for real-time EOP determination using e-VLBI and the K5 system
- Differential VLBI experiments for spacecraft tracking and its analysis

References

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