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 the National Institute of Information and Communications Technology (NICT) for the year 2008.

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):

- HOBIGER Thomas, Atmospheric and ionospheric research using VLBI and GPS, and studies on the improvement of the accuracy of space geodetic techniques
- ICHIKAWA Ryuichi, Compact VLBI system development and atmospheric modeling
- KONDO Tetsuro, Software correlator
- KOYAMA Yasuhiro, International e-VLBI
- SEKIDO Mamoru, International e-VLBI and VLBI for spacecraft navigation
- TAKIGUCHI Hiroshi, Time-transfer experiments, international e-VLBI, and loading effects

3. Current Status and Activities

3.1. 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 [6]. 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 three minutes after the last observation has been made. 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.

3.2. 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. The 10-km reference baselines are used to validate surveying instruments maintained by GSI, such as GPS and EDM. The compact VLBI system will be installed at both ends of the reference baseline. We named the system "Multiple Antenna Radio-interferometry of Baseline Length Evaluation (MARBLE)" [5]. We have tested the front-end of the compact VLBI system with a wide-band quad-ridged horn antenna (QRHA) before installing it on the 2.4 m diameter dish at Kashima. We performed three single-band and two geodetic (S/X) VLBI experiments on a 54 km baseline between the 2.4 m dish equipped with the QRHA and the Tsukuba 32 m antenna of GSI (see Figure 1). The results of the determined baseline length agree well with experiments which used only an X-band feed on the 2.4 m dish.

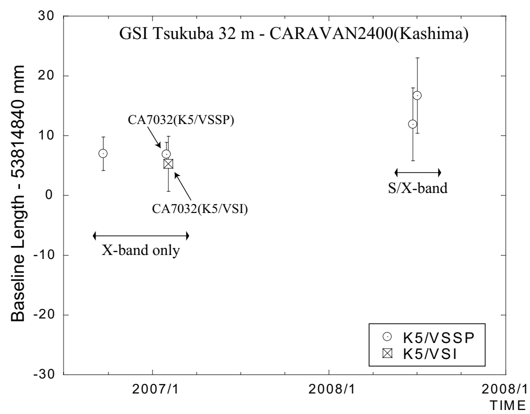

Figure 1. Results of experiments using the QRHA on a 2.4 m antenna.

3.3. Time and Frequency Transfer via VLBI

We are planning to use MARBLE for time and frequency transfer, as one of its applications. In order to confirm the potential of current VLBI time and frequency transfer, we have compared the results of VLBI and GPS carrier phase frequency transfer using the Kashima-Koganei baseline. First results revealed that VLBI is more stable than GPS [7]. Also, we compared VLBI and GPS using data from the IVS and the International GNSS Service (IGS) for the same purpose. The results of the VLBI frequency transfer show that the stability follows a $1/\tau$ law very closely, and it surpasses the stability of atomic fountains at 10^3 seconds or longer. Moreover, it could be shown that the stability has reached about 2×10^{-11} (20 ps) at 1 second. These results verify that the geodetic VLBI technique has the potential for precise frequency transfer [8].

3.4. MK3TOOLS

A set of programs, summarized under the name MK3TOOLS, allows the creation of Mark III databases from post-correlator output without any dependency on CALC/SOLVE libraries. NetCDF files are utilized as intermediate data storage, and either Mark III compatible databases or NGS files are generated for follow-on analysis. Since all routines can be controlled from the command line, MK3TOOLS enables the realization of a processing chain without human interactions and allows the generation of databases for applications with a high demand for low latency (e.g. e-VLBI). In interactions with OCCAM, MK3TOOLS is capable of automatically resolving ambiguities and computing ionosphere-free observables from dual-frequency experiments.

3.5. Kashima Ray-tracing Tools—KARAT

For all space geodetic techniques operating with radio frequency signals that are emitted outside the Earth's atmosphere, delays caused by the troposphere have to be considered properly in order to remove bias from the arrival times of the incoming signals. Since the troposphere constituents, and thus the index of refraction, are highly variable with time and space, it is common to estimate troposphere delays within space geodetic analysis rather than modeling its effect a priori. As numerical weather models have been constantly improved with respect to their accuracy and resolution, it has become feasible to utilize them for the purpose of computing troposphere delay corrections from ray-tracing [2], considering that residual delays are still estimated within the geodetic adjustment process. Kashima has developed a software package named Kashima Ray-tracing Tools (KARAT) that is able to transform numerical weather model data sets to geodetic reference frames, compute fast and accurate ray-traced slant delays [1], and correct geodetic data on the observation level. Currently VLBI and GPS, as well as InSAR observations, can be corrected for atmosphere path delays by KARAT.

3.6. 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 automated processing chain, called Kashima Ray-Tracing Service (KARATS), which can be started via a Web interface. Once a user has taken his observations, he can send the data in a common format via the Internet to KARATS. Then 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, the server will send the geometry file to that machine. The client performs the ray-tracing and sends the tropospheric delays back to the server. Then the ray-traced delays are subtracted from the user's data and a "reduced" observation file is sent back to the user. KARATS will be free of charge and is currently undergoing a beta-test phase before it is opened to the public.

3.7. Phase Ambiguity Resolution Within Next-generation VLBI

For next-generation VLBI systems, it is necessary not only to deploy improved technology, but also to revise analysis strategies to take full advantage of the observations taken. With the new systems, it should be feasible to resolve phase ambiguities directly from post-correlation data, providing roughly an order of magnitude improvement in the precision of the delay observable. As the unknown ambiguities are of integer nature, methods of analytically resolving them have been investigated [4]. Furthermore, it has been shown that other nuisance parameters can be solved simultaneously with the analytically relevant delay observables.

3.8. Effect of Formatter Clock Offsets on UT1 Estimates from INT2 Sessions

INT2 observation networks are equipped with different hardware components, which require different processing strategies when the data are correlated. As the timing units at each station are usually offset with respect to universal time (UTC), this effect should be considered during correlation processing. Thus, the theoretical impact of neglecting these offsets on the estimation of UT1 has been investigated. Moreover, studies have been made into how formatter clock offsets affect UT1 time series and how such missing corrections can be applied a posteriori [3]. Although the discussed effect is smaller than the formal error of the estimates for most of the UT1 experiments, it is important to consider station clock offsets properly in next-generation VLBI systems, which are expected to improve the accuracy of the results by about one order of magnitude.

4. Future Plans

For the year 2009 the plans of the Analysis Center at NICT include:

- Several international and domestic VLBI experiments for real-time EOP determination using e-VLBI and the K5 system
- Further development of the automated processing of UT1 experiments and extension of the processing to multi-baseline experiments
- Time and frequency transfer experiments
- Opening KARATS for public use and further development of troposphere ray-tracing methods
- Differential VLBI experiments for spacecraft tracking and their analysis
- Improvement of processing speed and efficiency of the VLBI data correlation using multi-processors and high-speed networks

References

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