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 2011.

1. General Information

The NICT Analysis Center is operated by the space-time standards group of NICT and is located in Kashima, Ibaraki, Japan as well as at the headquarters in Koganei, Tokyo. In April 2011 the space-time standards group, to which the VLBI group belongs, was re-organized under the Applied Electromagnetic Research Institute of NICT. Analysis of VLBI experiments and related study fields at our group are mainly concentrated on experimental campaigns for developing new techniques such as time and frequency transfer, e-VLBI for real-time EOP determination, analysis software development, prototyping of a compact VLBI system, and atmospheric path delay studies.

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): Analysis software development, time and frequency transfer, and atmospheric research
- ICHIKAWA Ryuichi (Kashima): Compact VLBI system and atmospheric modeling
- KONDO Tetsuro (Kashima): Software correlator
- KOYAMA Yasuhiro (Koganei, Tokyo): e-VLBI
- SEKIDO Mamoru (Kashima): International e-VLBI and VLBI for spacecraft navigation

3. Current Status and Activities

After the big earthquake on 11 March 2011, post-seismic crustal deformation has been regularly monitored by the Kashima (11 m) - Koganei (11 m) baseline since 7 May 2011. More details about these monitoring observations are described in [3].

3.1. Ultra-rapid EOP Experiments

In cooperation with Geospatial Information Authority of Japan (GSI), Onsala Space Observatory, and University of Tasmania, several ultra-rapid UT1 and EOP experiments were carried out. Since the single baseline between Onsala and Tsukuba only allows the determination of UT1 in real-time, first tests with a three-station network including Hobart were made in order to test the potential of obtaining all three Earth orientation parameters in near-real time. Therefore, the automated analysis software (see section 3.3) needed to be adopted to handle automated ambiguity resolution of multi-baseline sessions and to allow for a robust estimation of the three EOP components. In addition to the dedicated ultra-rapid experiments, GSI regularly automatically submits c5++ processed UT1 results (see [2] for details on the processing strategy) from INT2 sessions to the IERS for test purposes.

3.2. Time and Frequency Transfer via VLBI

Space geodetic techniques like GNSS have been proven to be a useful tool for time and frequency transfer purposes. Besides SLR, which is currently tested under the name T2L2, VLBI could be another space geodetic technique that can be utilized for time and frequency transfer. Unlike GNSS, VLBI does not require any orbital information, as it directly refers to an inertial reference frame defined by the location of the quasi stellar objects. As summarized in [5], current VLBI systems can provide a frequency link stability of about 2 x 10-15 @ 1d (ADEV). But due to the fact that geodetic VLBI networks do not observe for more than 24h continuously, no statement about long-term stability can be made. Moreover, as VLBI only provides one observation per epoch, troposphere and station clocks need to be de-correlated in space geodetic analysis by estimating these parameters from a batch of several scans. Thus, VLBI can only contribute to frequency transfer with clock estimates made every 30 minutes or longer. In order to overcome this drawback, NICT's Space-Time Standards Laboratory has started to work on the realization of a time and frequency transfer system based on the principles of VLBI, whereas developments from the upcoming geodetic VLBI2010 system are expected to help to reach these goals. VLBI2010 is designed to provide observables with a few picoseconds of uncertainty, and once a global station network is deployed, it is expected to operate 24h/7d which would allow to access long-term frequency stability on intercontinental links. The VLBI2010 short-term frequency transfer limitation is thought to be overcome when VLBI is combined with GNSS (or TWSTFT) in the analysis processing. Based on simulation data (see Figure 1) we have started to evaluate the frequency transfer performance of the future VLBI2010 network. In parallel, system development has started at the Kashima Space Research Center facility.

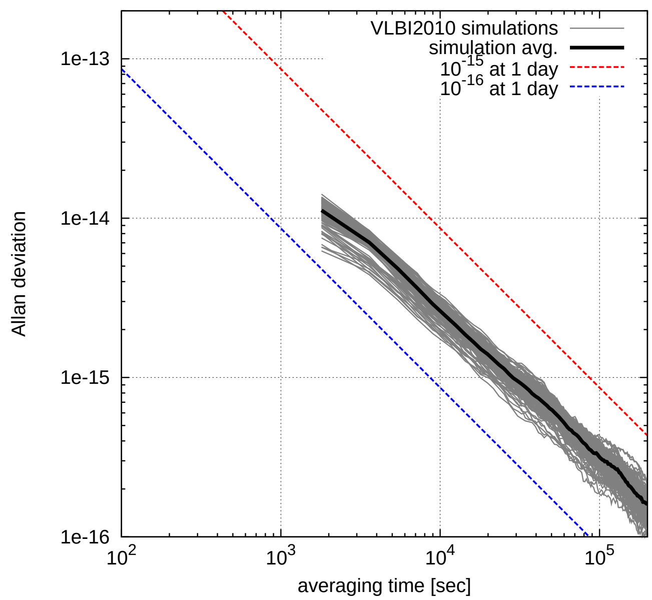

Figure 1. Frequency transfer performance over an 18 station global network of VLBI2010-like stations using a combination of 3 m and 10 m dishes. Simulated observations were kindly provided by the Vienna University of Technology.

3.3. Development of a Multi-technique Space-geodetic Analysis Software Package

c5++, which is a space-geodetic analysis software that includes SLR, GNSS and VLBI, has undergone several modifications and updates in the year 2011. First of all, the software has been made compatible with the IERS Conventions 2010 (see [4]), and its processing speed was improved. In addition, a SINEX interface has been added in order to output data for inter-comparison and submission of results. This interface can also be used to read a priori information (TRF, CRF, EOPs, etc.) which are also given in SINEX format. The VLBI module has been extended to handle unattended multi-station experiments, whereas a new simple and robust ambiguity resolution method has been implemented in order to ensure automated processing. This feature has been tested with three-station EOP experiments (see Section 3.1) and is currently undergoing an evaluation using large global VLBI networks. Further software updates include new features for real-time UT1 experiments [2] as well as a support for VMF1. In addition to the currently used least-squares estimation method, a Kalman filter is being implemented in c5++. Moreover,

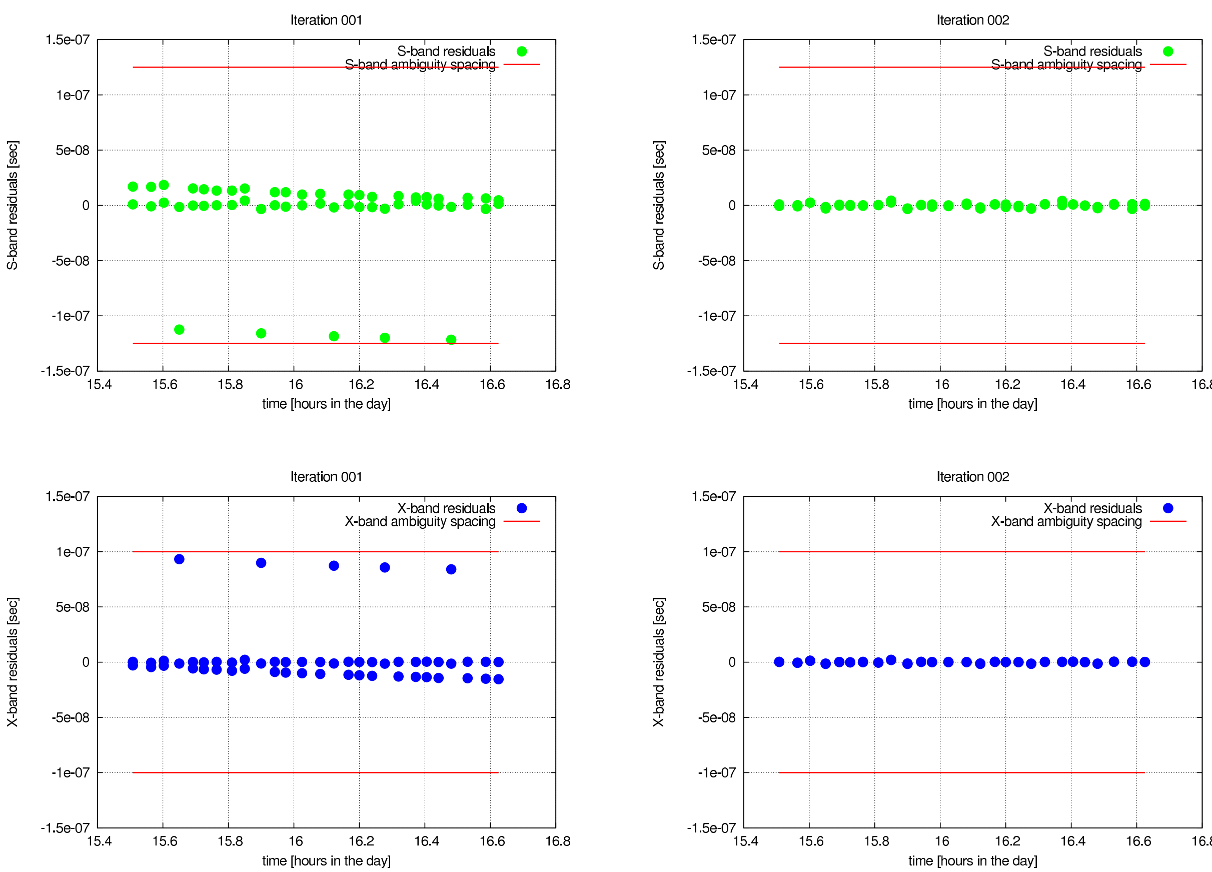

Figure 2. S-band (top) and X-band (bottom) residuals after the first (left) and second (right) iteration using the automated ambiguity resolution strategy applied to data from a three-station experiment (Onsala, Tsukuba, and Metsahovi) on September 4, 2007. For this example one can see that all ambiguities are resolved properly after two iterations.

dedicated time and frequency transfer and spacecraft navigation modules are being developed in order to support the research activities of NICT's VLBI project.

3.4. Ray-traced Troposphere Slant Delay Correction for Space Geodesy

A software package, called Kashima Ray-tracing Tools (KARAT), has been developed, and it is capable of transforming numerical weather model data sets to geodetic reference frames, computing fast and accurate ray-traced slant delays, and correcting geodetic data on the observation level. A thorough comparison of ray-traced troposphere delays with results from other space-geodetic techniques during CONT08 has been made by Teke et al. (2011, [6]). KARAT has been extended to support frequency dependency of the refractivity following the Liebe model [1] with the goal of finding out whether modern space-geodetic microwave techniques (including VLBI2010 and higher dual-frequency VLBI configurations) should be corrected for dispersive troposphere delays.

4. Future Plans

For the year 2012 the plans of the Analysis Center at NICT include:

- Time and frequency transfer simulations and experiments by VLBI and combination with other techniques like GPS or TWSTFT
- Further improvement of the multi-technique space-geodetic analysis c5++ software
- Experiments and analysis of multi-baseline network which allows the determination of all three EOPs in real-time
- Usage of multi-processors/multi-core processing platforms for the acceleration of space geodetic applications
- VLBI experiments for spacecraft tracking and its analysis

References

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