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 2012.

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. The Analysis Center focuses on the processing of VLBI experiments which are related to NICT's research goals. Effort is spent on developing new VLBI technology for time and frequency transfer, the development of a modern multi-technique analysis software package, prototyping of a compact VLBI system, real-time EOP determination, and atmospheric path delay studies.

2. Staff

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

- HOBIGER Thomas (Koganei, Tokyo): analysis software development, time and frequency transfer, and software correlator development
- ICHIKAWA Ryuichi (Kashima): compact VLBI system and atmospheric modeling
- KONDO Tetsuro (Bangkok/Thailand and Kashima): software correlator development
- KOYAMA Yasuhiro (Koganei, Tokyo): time and frequency transfer experiments
- SEKIDO Mamoru (Kashima): development of VLBI systems and coordination of activities

3. Current Status and Activities

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

In a cooperation between several Japanese institutes the multi-technique space geodetic analysis software "c5++" [3] has been developed over recent years. The software provides consistent geodetic and geophysical models which can be accessed by single technique space-geodetic applications or can be used to combine several techniques on the observation level (Figure 1). Satellite Laser Ranging (SLR) and Very Long Baseline Interferometry (VLBI) stand-alone applications have been realized in the last two years. With the introduction of an option to utilize local tie information as well as the possibility of estimating common parameters (clock, troposphere, orbits) the software enables rigorous combination of space geodetic techniques on the observation level. Moreover, the inclusion of GNSS as a third space geodetic technique since 2012 has increased the choice of analysis strategies tremendously. However, rigorous combination of space geodetic data on the observation level depends on proper handling of inter-technique biases and other offsets in order to make this approach work well. Moreover, the large number of unknown parameters requires sophisticated algorithms, as well as a large enough PC memory in which huge matrices can be stored temporarily.

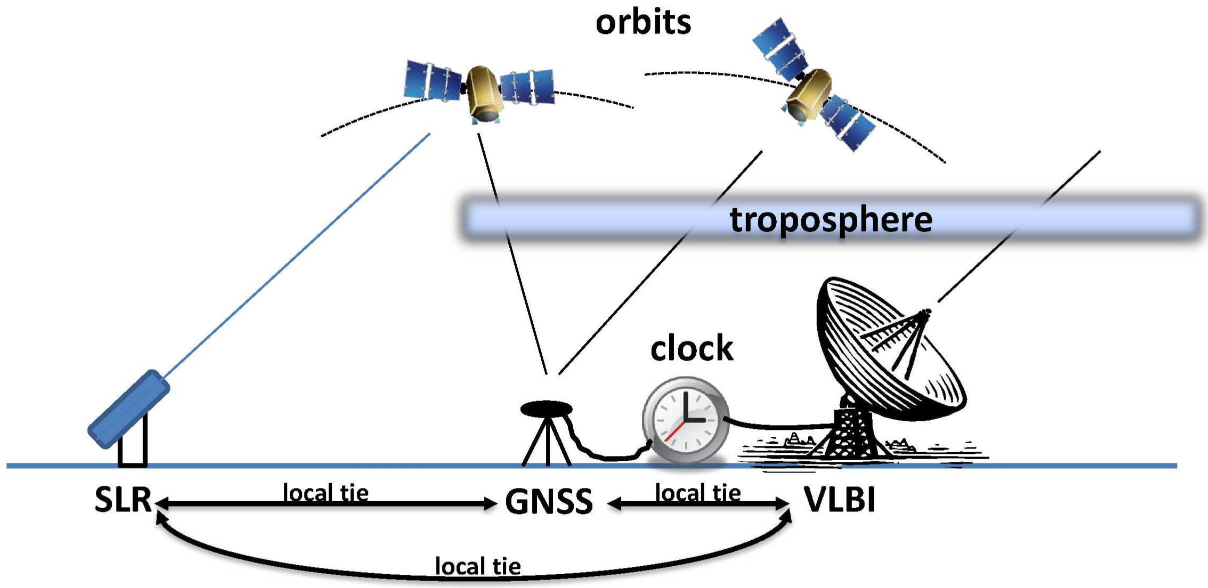

Figure 1. Combination of space geodetic data on the observation level requires the knowledge of precise local tie information. Co-located VLBI and GNSS technology often shares the same frequency standard, which allows estimation of a single clock model for both techniques. In addition troposphere delays are thought to be identical except for a constant bias (so-called "troposphere tie").

3.2. Frequency Transfer by Means of VLBI

Space geodetic techniques such as 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 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 by [4], 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 24 hours 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 these drawbacks, NICT's Space-Time Standards Laboratory has started to work on the realization of a frequency transfer system based on the principles of VLBI, whereas developments from the upcoming geodetic VLBI2010 system are expected to help in reaching 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 access to long-term frequency stability on intercontinental links. The VLBI2010 short-term frequency transfer limitation is thought to be improved when VLBI is combined with GNSS (or TWSTFT) in the analysis processing (see prior section). Our software c5++ has been prepared to combine VLBI and GNSS data on the observation level. Thereby, the concept of a reference clock within the VLBI station network needs to be dismissed when VLBI data is combined with GNSS information, which is processed in precise point positioning (PPP) mode. Thus, when combining both techniques, GNSS data are expected to provide the absolute clock information at each site and contribute to the short-term frequency stability. On the other side VLBI will provide good long-term stability and compares station clocks over long baselines.

3.3. Ultra-rapid EOP Experiments

Geospatial Information Authority of Japan (GSI), Onsala Space Observatory, University of Tasmania, and the Hartebeesthoek Radio Astronomy Observatory carried out several ultra-rapid EOP experiments which were automatically analyzed with c5++. The analysis process had to be adopted to handle automated ambiguity resolution of a multi-baseline session and to allow for a robust estimation of the three EOP components. First results demonstrated that all three EOPs can be estimated from such a dedicated ultra-rapid observation network. However, small software updates and bug fixes are still necessary in order to make the automated multi-baseline ambiguity resolution algorithm work with low SNR data or outliers. In addition to the dedicated ultra-rapid experiments, GSI regularly submits UT1 results from INT2 sessions that have been automatically processed by c5++ on an operational basis (see [3] for details on the processing strategy).

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

A software package, called Kashima Ray-tracing Tools (KARAT), has been developed. 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. 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. By the use of this model it is possible to compute the complex refractivity based on atmosphere quantities such as pressure, temperature, and relative humidity. Although the frequency dependent delay contribution appears to be of small order, one has to consider that signals are propagating through few kilometers of troposphere at high elevations to hundreds of kilometers at low elevations. Thus, it has been investigated whether such an effect has a magnitude above the noise floor of current space geodetic instruments or if it can be safely neglected. It could be shown [2] that dispersive troposphere delays grow inversely proportional to the cosine of the zenith distance (like any other troposphere delay) and will be absorbed into the estimated zenith delays during post-processing. Thus frequency dependent troposphere delays should not affect the geodetic results on a significant level. However, for X/Ka-VLBI the question remains of the level to which troposphere products are comparable to other estimates from other space geodetic techniques when a frequency dependent troposphere contribution is neglected.

4. Future Plans

For the year 2013 the plans of the Analysis Center at NICT include:

- Time and frequency transfer experiments by VLBI and combination with other techniques such as GNSS or TWSTFT
- Combination of multi-technique space-geodetic data on the observation level with c5++
- Implementation of an interface for c5++, which allows reading and creation of OpenDB data
- Experiments and analysis of multi-baseline networks 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

References

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[4] Rieck C., R. Haas, R.T.K. Jaldehag, and J.M. Johansson, VLBI and GPS-based time-transfer using CONT08 data, IVS 2010 General Meeting Proceedings, 365-369, NASA/CP-2010-215864, 2010.