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 2007.

1. General Information

The NICT analysis center is located in Kashima, Ibaraki, Japan and is operated by the VLBI 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, ionospheric and atmospheric path delay studies and differential VLBI (DVLBI) for spacecraft orbit determination. In addition we carried out monthly IVS-T2 sessions.

2. Staff

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

- HOBIGER Thomas, Postdoctoral fellow of the Japan Society for the Promotion of Science (JSPS)/Atmospheric and ionosphere research using VLBI and GPS
- 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, International e-VLBI and loading effects

3. Current Status and Activities

3.1. Ultra-rapid UT1 experiments

Data transfer via Internet protocols allows to reduce 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. 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 [2] which is operated in distributed computing mode. Thus it was possible to obtain UT1 estimates, which are proven to be as accurate as the IERS Bulletin-A results, already 30 minutes after the last observation has been made [3]. 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.

Table 1. e-VLBI sessions for rapid UT1 measurement performed since April 2007. Station codes are as follows, 'Ks':Kashima34, 'Ts':Tsukuba 32, 'On':Onsala, 'Mh':Metsähovi, 'Wz':Wettzell.

Date 2007	**Baseline**	**Data rate** (Mbps)	**UT1-UTC** (ms)	**UT1-c04** (μ sec.)	**Error** (μ sec.)	**Latency**
03 April	Ks – On	256	-69.6044	-38.5	8	–
23 April	Ks – On	128	-98.4422	15.0	41	1 h 55 min.
02 May	Ks – On	128	-110.0189	-30.4	16	–
18 May	Ks – Mh	128	-130.5832	67.5	98	2 h 38 min.
30 May	Ks – On	128	-143.2703	-14.7	9	28 min.
31 May	Ks – On	128	-143.7011	-83.5	8	–
04 June	Ks – On	256	-144.6447	13.1	6	31 min.
14 July	Ks-On, Ks-Wz	256	-162.0879	6.2	6	–
	Ks – On		-162.1017	-7.6	10	
	Ks – Wz		-162.0715	22.6	8	
	Ts – Wz, On-Ts		-162.0674	26.7	8	
	On – Ts		-162.0725	21.6	7	
	Ts – Wz		-162.0585	35.6	5	
	Ts – Wz(INT2)		-162.0974	-3.3	7	
15 July	Ks – On	256	-162.0186	-30.7	6	–
	Ts – Wz(INT2)		-162.0017	-13.8	8	
25 Oct	Ks – On	256	-208.4180	95.8	640	–
26 Nov	Ks – On	128	-240.0781	75.8	8	–
		256	-240.1118	78.2	16	–
		512	-240.1134	82.5	29	–
		128	-240.1621	76.9	8	25 min.
		128	-240.2628	-2.3	14	27 min
		512	-240.3020	-8.8	30	–

3.2. CARAVAN2400

We are currently developing a "Compact Antenna of Radio Astronomy VLBI Adapted for Network" with a 2.4 m diameter dish, which is named CARAVAN2400. A geodetic VLBI experiment between the CARAVAN2400 and the GSI 32 m antenna at Tsukuba was performed from Jan 31 until Feb 1, 2007. In this experiment, the K5/VSI system was used with a bandwidth of 512 MHz in order to evaluate the performance of an even smaller VLBI system with a 1.6 diameter. The obtained results were well consistent with the one from a previous test using the K5/VSSP system. In addition, another VLBI experiment between Kashima 34 m and Koganei 11 m was performed on July 19, 2007. At Kashima, the Cs gas-cell atomic frequency standard was used instead of the hydrogen maser in order to evaluate its capability for geodetic VLBI experiments. Although the Allan variance of the Cs gas-cell is worse than that of the hydrogen standard by a factor of about

ten, the baseline length results were in quite good agreement with the previous experiment.

3.3. MK3TOOLS

A set of programs, summarized under the name MK3TOOLS, allow to create MK3 databases from post-correlator output without any dependency on CALC/SOLVE libraries [1]. NetCDF files are utilized as intermediate data-storage and either MK3 compatible databases or NGS files are generated for follow-on analysis (figure 1). Since all routines can be controlled from the command-line MK3TOOLS enables the realization of a processing chain without human interactions and allows to generate databases for applications with a high demand on low latency (e.g. e-VLBI). Currently only K5 post-correlation format is supported by MK3TOOLS.

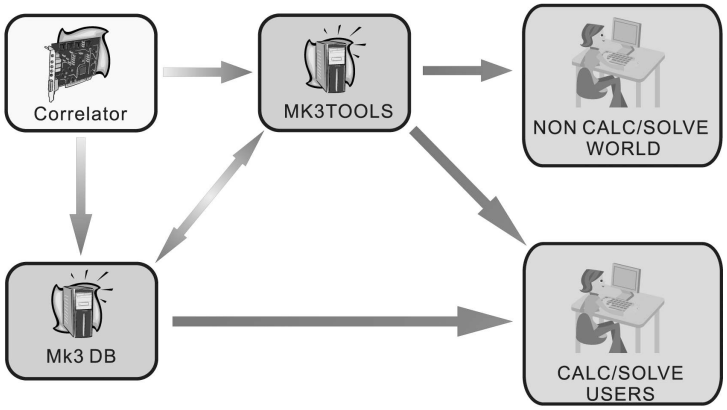

Figure 1. The role MK3TOOLS between correlator output and analysis

3.4. Differential VLBI for Spacecraft Tracking

Together with JAXA/ISAS, Japan the HAYABUSA satellite has been tracked on March 7th, 2007 with the purpose to test a phased-array tracking system within Japan.

3.5. Kashima Ray-tracing Tools - KARAT

Numerical weather models (NWM) have undergone an improvement of spatial and temporal resolution which makes it possible to utilize them for the computation of electro-magnetic wave propagation characteristics. Until now such models have been used to create mapping functions, which relate slanted observations to vertical ones. In our studies we have tried to handle numerical weather models to obtain directly the troposphere total slant delays in any arbitrary direction by ray-tracing methods. Thus a set of programs, subsumed under the name Kashima Ray-Tracing Tools (KARAT), has been developed which allows to carry out fast and accurate ray-tracing tasks and output the information to standard formats. All modules are designed to fulfill the requirements for real-time processing, but are capable to run in post-processing mode as well. Numerical weather models from the Japanese Meteorological Agency (JMA), covering East Asia (including Japan, Korea, Taiwan and parts of Russia and China), can be input directly to KARAT.

First tests using GPS have revealed that more than 99% of total troposphere can be modeled by KARAT and that only a simple mapping function is needed to account for the remaining symmetric troposphere delay. Application within VLBI analysis and usage for space-craft tracking is planned for the close future. Moreover KARAT can be used to simulate/evaluate positioning errors of space geodetic techniques associated with water vapor inhomogeneities.

3.6. Phase Ambiguity Resolution Within Next-generation VLBI

Next-generation VLBI system designs are aiming at one mm global position accuracy. Thus, it is not only necessary to deploy improved VLBI systems, but also to revise analysis strategies that 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 precision of the delay observable. As the unknown ambiguities are of integer nature, it has been investigated how they the can be resolved analytically using algorithms which have been developed for GNSS applications. Furthermore, it has been shown that other nuisance parameters can be solved simultaneously with the analytically relevant delay observables. In order to test this, artificial observations were created using parameters from actual design studies and these were used to test the developed algorithms.

4. Future Plans

For the year 2008 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 (both VSSP system and PC/VSI system)
- Unattended generation of MK3 databases and automated processing of UT1 experiments
- Differential VLBI experiments for spacecraft tracking and its analysis
- Development of the analysis software for spacecraft positioning using phase delay observables
- Improvement of processing speed and efficiency for the VLBI data correlation using multi-processor and high speed network
- Implementation of KARAT in a multi-processor/multi-core environment and establishment of an on-line ray-tracing service

References

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[3] Sekido M., H. Takiguchi, Y. Koyama, T. Kondo, R. Haas, J. Wagner, J. Ritakari, S. Kurihara and K. Kokado, Ultra-rapid UT1 measurements by e-VLBI, submitted to Earth, Planets and Space, 2008.