4-station ultra-rapid EOP experiment with e-VLBI technique and automated correlation/analysis

S. Kurihara, K. Nozawa, R. Haas, J. Lovell, J. McCallum, J. Quick, T. Hobiger

Abstract Since 2007, the Geospatial Information Authority of Japan (GSI) and the Onsala Space Observatory (OSO) have performed the ultra-rapid dUT1 experiments, which can provide us with near real-time dUT1 value. Its technical knowledge has already been adopted for the regular series of the Tsukuba-Wettzell intensive session. Now we tried some 4-station ultra-rapid EOP experiments in association with Hobart and HartRAO so that we can estimate not only dUT1 but also the two polar motion parameters. In this experiment a new analysis software c5++ developed by the National Institute of Information and Communications Technology (NICT) was used. We describe past developments and an overview of the experiment, and conclude with its results in this report.

Keywords ultra-rapid, EOP, UT1-UTC, e-VLBI, c5++

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1 Background

In 2007, the Geospatial Information Authority of Japan (GSI), the National Institute of Information and Communications Technology (NICT), the Onsala Space Observatory (OSO), and the Metsähovi Radio Observatory started the Japan-Fennoscandia ultra-rapid dUT1-project by using e-VLBI technique. The purpose of the project is to derive UT1-UTC as soon as possible. In order to realize this, data transfer to correlator should be real-time or near real-time, and some following processes; data format conversion, correlation processing, and analysis, should be automated and made closer to real-time.

So far a few dozens of experiments have been implemented. We succeeded in deriving dUT1 within 4 minutes after the end of the last scan from observed data of Tsukuba-Onsala east-west stretching baseline shown in Fig. 4 (Matsuzaka et al., 2008). Since 2009, the method has been applied to the regular IVS sessions and consecutive dUT1 time series has been obtained (Matsuzaka et al., 2010). In CONT11 campaign performed in 2011, also from Tsukuba-Onsala baseline, a 15-day continuous dUT1 time series was derived. After that, a multi-baseline experiment with Tsukuba-Hobart north-south baseline was also implemented in order to estimate not only dUT1 but also polar motion parameters (Kokado et al., 2012).

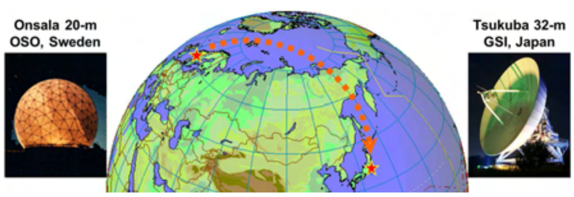

Fig. 1 The data transfer from Onsala to Tsukuba.

2 Data flow and analysis strategy

Fig. 2 shows the data flow of the experiment. The data from Sweden and Australia were transferred to Tsukuba correlator in real-time by Mark5A/PCEVN or in near real-time every scan. Since the system of Tsukuba correlator processes with K5 data format, the format conversion to Mark5 is required. The conversions are processed on eight servers distributedly. After K5 data makes a pair of baseline, a distributed correlation processing starts with 48 processing sockets in 16 servers. Since these servers access their data disk drives in the format conversion and the correlation processing, our system is adopting not NFS but Lustre File System to avoid the bottleneck of the disk accessing. The correlator outputs were reduced and the solutions were derived using fully automated VLBI analysis software c5++ (Hobiger et al., 2010). In order to automate and stabilize the whole sequence of processes, we developed some management programs shown in Table 1. The "rapid" program family is written in Perl, and users can execute the ultra-rapid data processing by issuing easy commands with the experiment code and the name of involved stations. A solution at the middle of the designated time window (ex. 6 hours) was derived from the analysis for the correlator outputs in the window. Once a correlator output comes up, the window slides forward, and the next solution is derived from next dataset in this window. It is so-called "sliding window approach". By repeating this process, a dataset of the sequential solutions is yielded.

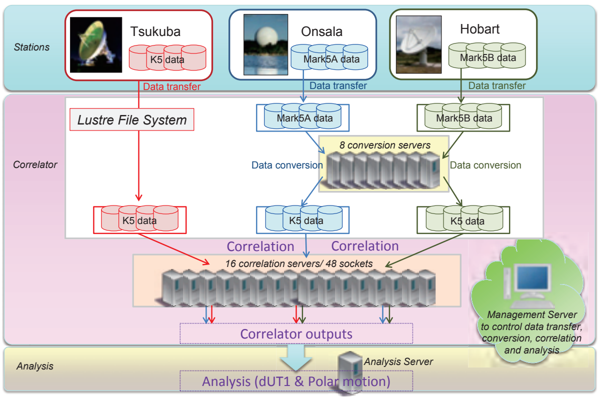

Fig. 2 Data flow of the ultra-rapid e-VLBI experiment.

Table 1 The "rapid_" series of programs to manage the automated data processing.

Name	Summary
rapid_transfer	executes tsunami/tsunamid and transfers data from station to correlator.
rapid_conv	converts the data from Mark5 to K5 if needed.
rapid_cor	runs fringe search and main correlation processing sequentially.
rapid_komb	generates the bandwidth synthesis outputs.

3 4-station/6-baseline experiments

Since 2011, the 4-station/6-baseline experiments adding HartRAO (26-m or 15-m) into Tsukuba-Onsala-Hobart network have been implemented (Fig. 3). The c5++ software has been upgraded to the version of 2012 July in order to estimate not only dUT1 but also polar motions. This version supports a multi baseline network, favorite parameterization, and SINEX output too. In case of dUT1 estimation so far, since the polar motion parameter is dealt with as known parameter, the error of polar motion would be unnecessary offset for the estimated dUT1 with respect to the probable value. It is desirable for avoiding the issue to estimate the whole three EOPs simultaneously.

So far the 11 regular IVS sessions that include at least three stations of four (Tsukuba, Onsala, Hobart, and HartRAO) were implemented as the ultra-rapid EOP experiment. The six sessions of them added Hobart or HartRAO 15-m by so-called "tag-along", which is a function of SKED to add stations into an original VLBI schedule (Table 2). When the whole processes were carried out smoothly, 90% of the total solutions were derived within 10 minutes (Fig. 4).

As concerns the evaluation of estimated parameters, the poor network geometry of the set of observed baseline data in the sliding window causes some large outliers or uncertainties. It is because the IVS original schedule is not optimized for Hobart and the number of the scans of Hobart is quite a few. Then the ratio of east-west baseline and north-south baseline inclines to either of them. It is improved to some degree by making the dedicated schedule for these four stations. The five experiments with the dedicated schedule were done from November 2012 to February 2013 (Table 3). In the UR1301 in January, which was a 2.5-day long schedule, the EOP was estimated with 2-hour sliding window strategy. Fig. 5 shows the EOP time series of the near real-time c5++ solutions and the 1-hour piece wise liner Calc/Solve solutions, and Fig. 6 shows the network geometry of each solution represented as the rate of the number of observations for east-west baseline, north-south baseline, and the others. Partially, the rate of east-west baseline extremely low, and then the c5++ solution deviates from the prediction. On the other hand, in the periods that include both east-west and north-south baselines with a well-balanced rate, the solutions are consistent with the prediction and Calc/Solve solution. Therefore, in order to estimate whole three EOPs, the 4-station/6-baseline network is a bit poor in geometry, and for more stable sequential EOP solutions, the network like the IVS-R series including globally-distributed at least 8 stations is needed.

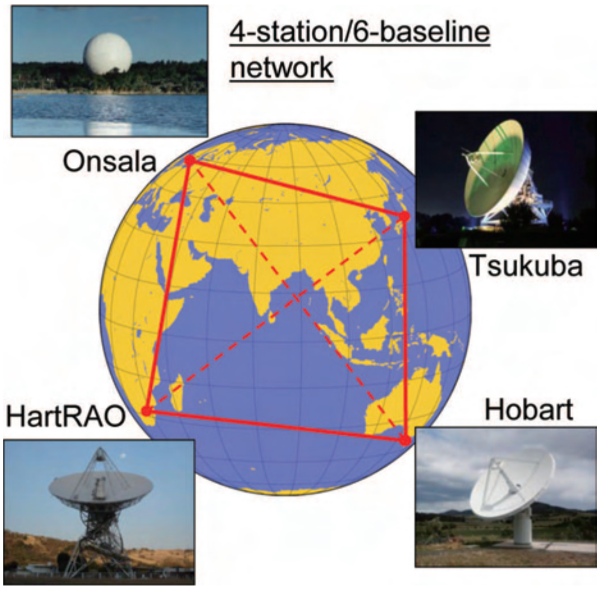

Fig. 3 The 4-station/6-baseline network consists of Tsukuba, Onsala, Hobart, and HartRAO.

Table 2 Recent ultra-rapid EOP experiments behind the IVS regular session.

Session	Date	Time	Stations
IVS-R1554	OCT10	17:00	HhOnTs +Hb
IVS-R1555	OCT15	17:00	HhOnTs +Hb
IVS-R1561	NOV26	17:00	HhOnTs +Hb
IVS-R1563	DEC10	17:00	HhOnTs
IVS-RD1210	DEC11	17:30	HhOnTs
IVS-R1564	DEC18	17:00	HhOnTs
IVS-R1569	JAN22	17:00	HbHhOnTs
IVS-R1570	JAN28	17:00	HhOnTs
IVS-RD1301	JAN29	17:30	HhOnTs +Hb
IVS-R1573	FEB18	17:00	HbOnTs +Ht
IVS-T2088	FEB19	17:30	HhOnTs +Hb

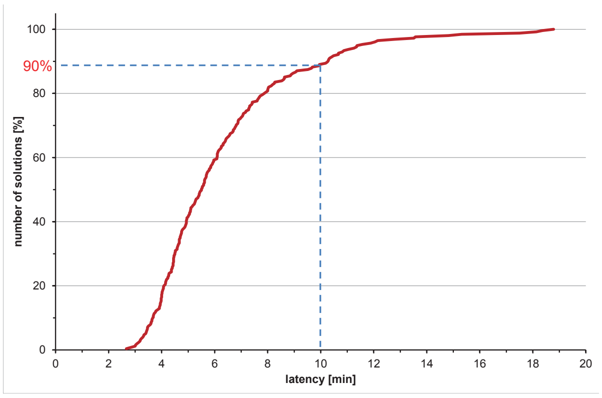

Fig. 4 Latency - Number of solutions in % in the session IVS-R1555 on October 15.

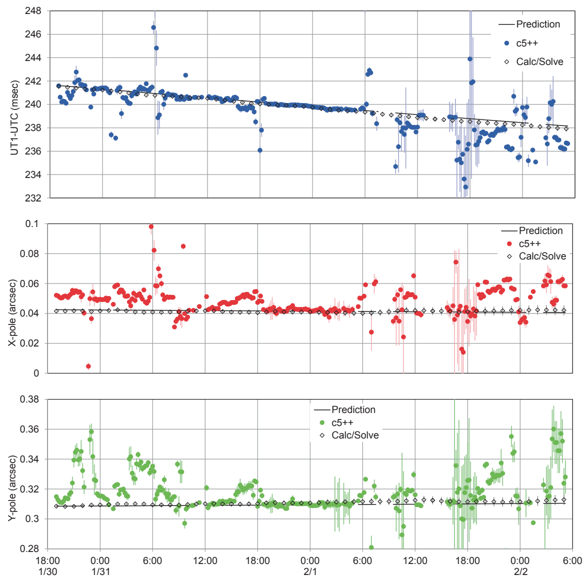

Fig. 5 Estimated EOP with comparison between c5++ and Calc/Solve

Table 3 Recent ultra-rapid EOP experiments with dedicated schedule.

Session	Date	Time	Dur.	Stations	#obs. (cor/skd)
UR1201	NOV29	18:00	24	HbHtTs	382/ 822 (46.5%)
UR1202	DEC06	18:00	24	HbHtTs	363/ 482 (75.3%)
UR1203	DEC17	07:30	35	HbHtOnTs	978/1033 (94.7%)
UR1301	JAN30	18:00	61	HbHtOnTs	1326/1467 (90.4%)
UR1302	FEB05	17:30	48.5	HbHtTs	815/ 943 (86.4%)

4 Summary and future plan

For the purpose of near real-time EOP estimation, some 4-station/6-baseline ultra-rapid EOP experiments with the dedicated schedule were implemented. On

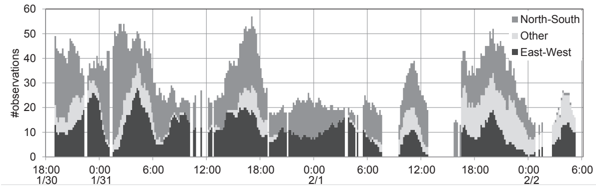

Fig. 6 The network geometry represented as the rate of observations.

the whole, we succeeded in the smooth and near real-time data processing and analysis. Besides, in the periods of poor network geometry in schedule, the solution diverges and it does not seem to estimate EOP correctly. More stations and baselines may resolve this issue, but it is not easy in terms of the capacity of the simultaneous data transfer and the throughput of the Tsukuba correlator, and whether the 5th and 6th stations connected to broad-band network were found or not. After this, some improvements like reconsidering of analysis strategy, upgrade of c5++ for Kalman filter, and real-time transfer of the Mark5B data, are expected.

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