Near real-time monitoring of UT1 with geodetic VLBI

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Abstract We give a short overview on the current status of near real-time monitoring of UT1 with geodetic VLBI. The use of real-time data transfer together with automated correlation and data analysis makes it possible to derive final dUT1-results with very low latency. The agreement with IERS C04 results is on the level of 30 μsec. It is even possible to determine time series of dUT1 during ongoing 24 h IVS-sessions. The concept is highly relevant for future VLBI2010 operations.

Keywords near real-time UT1, e-VLBI, VLBI2010

1 Introduction

In 2007 the VLBI research groups at Onsala (Sweden), Metsähovi (Finland), Kashima (Japan) and Tsukuba (Japan) started the Fennoscandian-Japanese ultra-rapid dUT1-project. The overall goal of this project is to determine dUT1 with very low latency using e-VLBI and automated data processing (Sekido et al., 2008). Figure 1 shows a map with the VLBI stations involved and the long and almost parallel east-west baselines that can be formed.

Different kind of observing sessions were and are performed in the project. In the beginning during 2007 and 2008, the focus was on dedicated 1-baseline intensive-style sessions that lasted about 1 to 1.5 hours. Since 2009 the focus moved to 24 h long sessions during standard IVS-sessions when Tsukuba and Onsala are participating. During these network sessions the baseline Tsukuba-Onsala is used during 24 hours for dUT1-determination on one baseline. Additionally, several hour long intensive-style sessions are scheduled and observed when additional observing time is available after standard IVS-sessions.

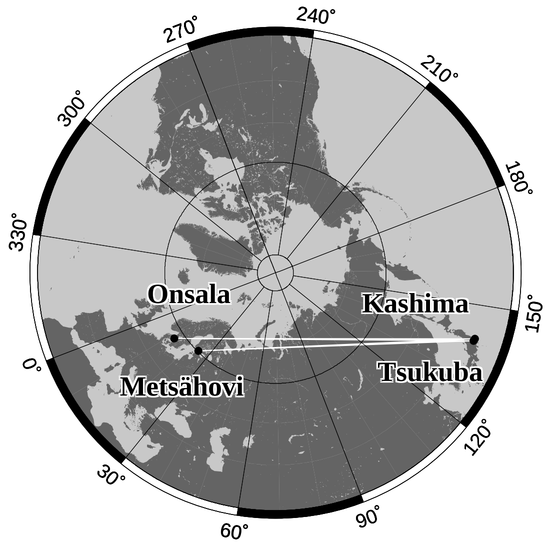

Fig. 1 The network of four stations used for the ultra-rapid dUT1-sessions

The project tried to address the effect of different data rates on the dUT1-results and the question of consistency of dUT1-results that are determined simultaneously on almost parallel baselines.

Figure 2 gives a schematic description of the ultra-rapid setup. The Fennoscandian VLBI stations acquire data with the Mark4 data acquisition system. The observational data are recorded on Mark5 units and PCEVN computers, and in parallel send the data in real-time via optical fibre to the correlator station in Japan where the data are also recorded. The real-time data transfer uses the Tsunami data transfer protocol. The

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Japanese VLBI stations acquires data with the VSSP system and record on K5-recorders, and transfer the data to the correlator. At the correlator the Fennoscandian VLBI data are first converted from Mark4-format to K5-format, and than correlated with the Japanese data. The whole process chain is automatized, as well as the post-processing of the correlation results (Hobiger et al., 2010).

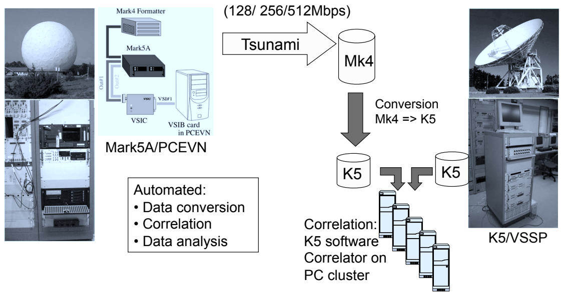

Fig. 2 Schematic description of the setup for ultra-rapid dUT1-sessions.

2 Ultra-rapid intensive-style dUT1-sessions

The series of ultra-rapid intensive-style dUT1-sessions started in March 2007. During 2007 and 2008 in total 41 successful 1 hour long sessions were conducted, see e.g. Haas et al. (2010). The latency of the final dUT1-results improved dramatically from several hours to a couple of minutes after end of observations. The world record was achieved in February 2008 on the baseline Onsala-Tsukuba when the final dUT1-results were derived within 3.5 minutes after the end of the observing session (Matzusaka et al., 2008).

The comparison to IERS C04-results show that the ultra-rapid dUT1 values show the same level of agreement with C04 as the IERS-rapid solutions (about 30 μsec) (Haas et al., 2010). However, the latency of the ultra-rapid dUT1 results is much lower.

Unfortunately there were only very few simultaneous sessions on almost parallel baselines. The reasons were that it was difficult to get telescope time and/or that equipment failed. However, for one session in July 2007 we found an RMS-agreement of 16.7 μsec.

The majority of the sessions was observed with a data rate of 256 Mbps. Only a few session did use 128 or 512 Mbps, so that a rigorous assessment of the effect of data rates on the precision of the dUT1-results was not easy possible. However, there is some indication that higher data rates give lower formal error for the dUT1-results, which might indicate a higher precision.

Since the intensive-style ultra-rapid sessions were successful and reduced the latency of the dUT1-results significantly, the concept was adopted for the standard IVS sessions INT-2 and INT-3. The data transfer for these sessions also used offline or real-time data transfer, and the INT-2 sessions correlated at Tsukuba are since 2010 done in ultra-rapid mode.

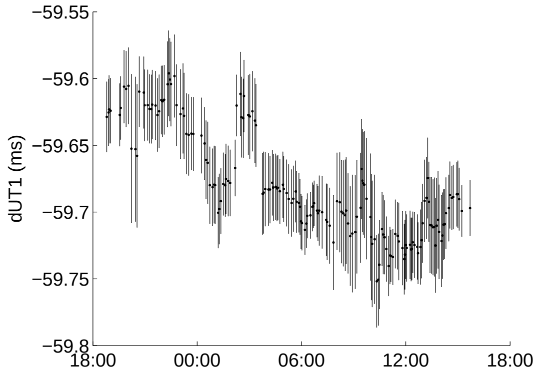

Fig. 3 Ultra-rapid 24 h dUT1 during R1.450 on September 27/28, 2010.

3 Ultra-rapid 24 h dUT1-sessions

Since 2009 almost all standard 24 h IVS-sessions where both Onsala and Tsukuba are involved are operated as ultra-rapid sessions. The sessions include e.g. R1-, RD- and T2-experiments. The observational data from Onsala are real-time transferred to the Tsukuba correlator where the data are converted and correlated. Once 35 scans are collected, a data analysis is performed and dUT1 determined. During the 24 h session the data are analyzed in a sliding-window-approach. This means that when a new scan comes in the oldest is left out and a new analysis is performed. The results is a time series of dUT1 that is produced during the ongoing IVS-session. The results are available with very low latency and the progress of the analysis can be monitored on the webpage `http://www.spacegeodesy.go.jp/vlbi/dUT1/`.

The data are analyzed in an automatic mode with two independent software packages, an automated version of OCCAM, and the software C5++ (Hobiger et al., 2010). The results are close and do for most cases agree within their formal errors, but they are so far not identical. Figure 3 shows as an example the ultra-rapid 24 h dUT1-results during R1.450 on September 27/28, 2010.

Figure 4 depicts the residuals with respect to the IESR C04 dUT1 values. Shown are the residuals of the INT-series as analyzed by BKG, the IVS-R-series as analyzed by BKG, the combined IVS-results of the IVS-R-series, and the ultra-rapid 24 h observations. The agreement expressed in bias and RMS is depicted in Figure 5. The ultra-rapid results show a larger bias than the other series and the RMS scatter is on the same level as the IVS-INT results. The larger bias is probably due to that the observing schedules of standard 24 hour network session are not optimized for one-baseline determination of dUT1. A degradation of the dUT1-results is thus to be expected compared to dedicated one-baseline experiments. Furthermore, is the 'sliding-window' analysis approach probably not the best strategy to analyze the data. A filter-based analysis strategy promises to give more robust results.

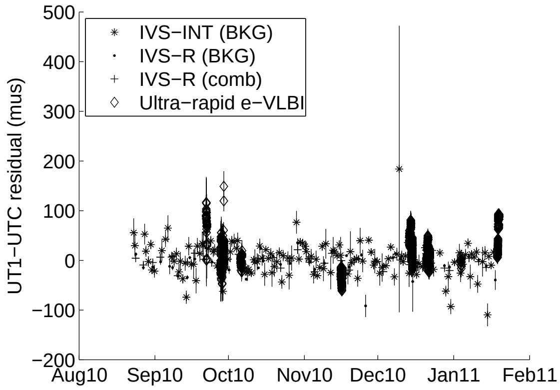

Fig. 4 Residuals with respect to IERS C04 series.

4 Summary and outlook

Real-time e-VLBI including near-real-time correlation and data analysis is possible. Low latency for dUT1-results can be achieved, even within minutes after the end of the observations. The agreement with C04 on the same level as the IERS rapid solutions.

Simultaneous observations on almost parallel baselines agree on the order of better than 16.7 μsec. There is an indication that higher data rates give reduced formal errors of the dUT1-results.

The results from ultra-rapid-24h sessions show a larger biases with respect to C04 than dedicated INT-sessions. This is probably due that the 24 hour network schedules are not optimized for one-baseline dUT1-determination. The RMS-agreement with respect to C04 is comparable to standard INT-sessions. The INT-2 and INT-3 series have thus adopted the ultra-rapid approach, respectively e-transfer, to achieve low latency dUT1-results. This is important since low latency has been shown to improve dUT1-predictions considerably (Luzum and Nothnagel, 2010).

The sliding-window analysis approach of the ultra-rapid 24 h dUT1-sessions is not ideal. A filter-based analysis strategy is under development (Hobiger, 2011). The results from the two software packages used for the automated data analysis do not agree completely, but for most of the cases within the formal errors. It appears that a unified analysis strategy is necessary and currently the IVS Task Force for Intensives is working on this topic.

The plans for 2011 are to perform the complete CONT11 in a ultra-rapid mode and to determine dUT1 continuously for 15 days. Additionally, we want to continue with the 24 h ultra-rapids and 'long-intensives'.

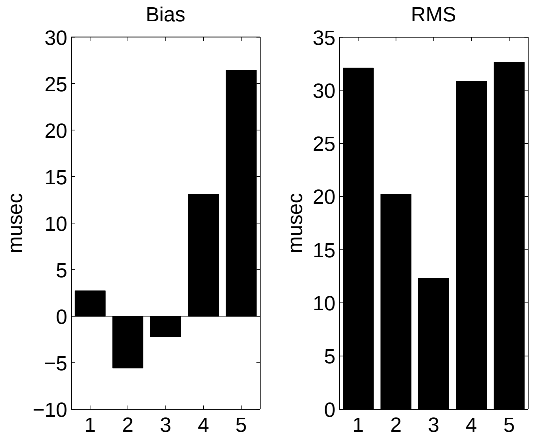

Fig. 5 Bias (left) and RMS-scatter (right) for the comparison with IERS C04. Presented are bias and RMS-scatter for 1 – IVS-INT (BKG), 2 – IVS-R (BKG), 3 – IVS-R (IVS combined), 4 – ultra-rapid (OCCAM), 5 – ultra-rapid (C5++).

For the future one can expect that the ultra-rapid concept will be well suited for VLBI2010. It is plausible that VLBI201 could be operated with distributed correlation. Single baselines could be correlated in near real-time already during the ongoing sessions. Complete databases that include all individual baselines could be merged and complete networks could be analyzed partly already during or latest directly after the end of an observing session. This will allow to determine all EOP in near-real-time.

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