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Developments of Automated Data Processing System for Ultra Rapid dUT1 e–VLBI Sessions

Yasuhiro Koyama, Mamoru Sekido, Thomas Hobiger, Hiroshi Takiguchi, Tetsuro Kondo

Kashima Space Research Center, National Institute of Information and Communications Technology, Japan

Abstract. Timeliness of the data processing of the international VLBI observations has been continuously improved in the past decades. In particular, e–VLBI technique has proved that it has the capability to shorten the latency by transferring the observed data to the correlator by using high speed communication networks. The method has been introduced to routine intensive VLBI sessions to monitor dUT1. To improve the timeliness even further, we started an initiative to develop automated data transfer and data processing systems using Europe-Japan baselines. On Feb. 21, 2008, we succeeded to demonstrate the effectiveness of the developed systems and estimated the dUT1 parameter 3 minutes 45 seconds after the last scan of the one hour intensive style e–VLBI session. This achievement was realized by the developments of the K5/VSSP32 data acquisition terminal, automated data processing and analysis software.

1. Introduction

Improving the timeliness of the analyzed results from global VLBI sessions is one of the important and challenging themes for IVS. Since UT1-UTC, or dUT1, randomly varies reflecting dynamic phenomena on the surface and the interior of the Earth, the accuracy of the predicted dUT1 values deteriorates with time. Therefore, it is expected that the accuracy of the predicted dUT1 can be improved by shortening the delay time from the observations to the data processing for global geodetic VLBI sessions. The report of the IVS Working Group 2 for Product Specification and Observing Program pointed out that it is very important to shorten this processing time delay to improve the accuracy of the Earth Orientation Parameters (EOP) including dUT1. The report also sets the goal of the IVS observing program to make the time delay from observation to product less than one day by the year 2005. This goal was partially realized by introducing e–VLBI scheme to the routine intensive VLBI sessions.

Currently, both INT-2 and INT-3 regular intensive sessions are performed in a similar way. The observed data are transferred to the correlator site after the session. After all the data are transferred, file format conversion, correlation, and data analysis processing are performed manually by an operator at the correlator site. We considered that it is possible to further improve the latency to obtain the results if we can transfer data in parallel with the observations and process the data automatically without manual interactions. By developing necessary hardware and software, we successfully demonstrated the concept. In the following sections, details of these developments will be explained.

2. Developments of K5/VSSP32 System

The developments of the K5 recording terminal began with the developments of a specialized A/D sampling board called K5/VSSP board. The board was designed to be installed in a PCI expansion bus slot of a commodity PC running FreeBSD or Linux operating system. Each board is capable to sample 4 channels of analog inputs from VLBI base band converters by referring to the external 10 MHz standard signal from a Hydrogen Maser system. One K5/VSSP recording terminal is composed of four rack-mounted PC systems with one K5/VSSP board for each PC system, and it can record 16 channels of baseband signals for usual geodetic VLBI sessions. The K5/VSSP terminals were introduced at Kashima (34 m and 11 m), Koganei, Tsukuba, and Syowa IVS stations from 2002 and were used for regular IVS sessions since then. Each PC systems of the K5/VSSP terminal is equipped with an on-board commodity network interface, so that it became possible to transfer the observed data over the high speed networks right after the VLBI sessions for e–VLBI operations. However, it was not possible to transfer the data files while the recording is on-going at very high speed data rate. To improve this situation, we started to develop new data acquisition terminal K5/VSSP32. The pictures of the new K5/VSSP32 terminal are shown in the Fig. 1.

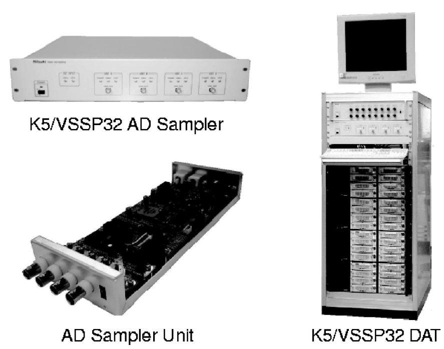

Figure 1. Pictures of the K5/VSSP32 data acquisition terminal (right) and K5/VSSP32 USB 2.0 external AD sampler unit (left)

In the K5/VSSP32 data acquisition terminal, the A/D sampling unit was designed as an independent external unit which is interfaced with a commodity PC system using USB 2.0. Each unit can sample 4 baseband channels. 4 units are configured in one rack mountable chassis to support 16 input channels. Since each unit is designed as an external device from the PC system, it became very simple to install the unit under the Linux PC systems. The K5/VSSP32 terminal is composed of 4 Linux PC systems with one K5/VSSP32 unit connected to each PC. Comparing the previous K5/VSSP terminal, the new K5/VSSP32 terminal can support observing data rate up to 1024 Mbps (256 Mbps per unit) whereas the old K5/VSSP system can only support up to 512 Mbps. It also became possible to read and transfer recorded data files even while another scan is being recorded. The K5/VSSP terminals at five IVS stations have been replaced with the new K5/VSSP32 terminal system gradually since 2007. By using this terminal, it now became possible to process the observed data for file format conversion and correlation processing even if the recording of the other scan is happening as illustrated in the Fig. 2.

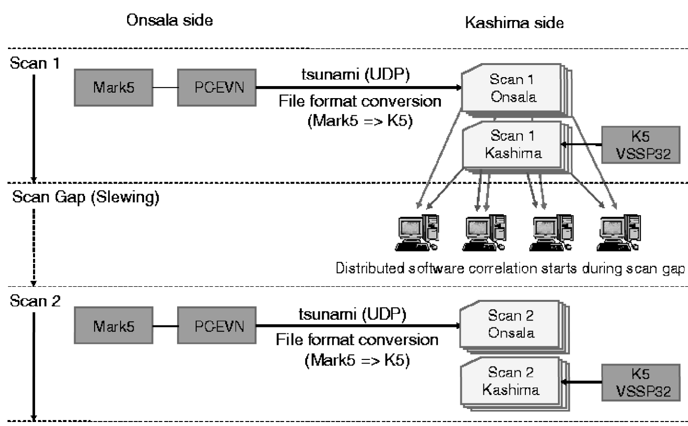

Figure 2. The processing flow of the ultra rapid e–VLBI intensive sessions

3. Automated Data Processing and Analysis

As shown in Fig. 2, a set of programs have been developed to perform the distributed data correlation processing. PC-EVN system is installed at Onsala station to transfer the observed data in real-time to the correlation site at Kashima using Tsunami data transfer protocol. The same configuration is set up at Metsähovi and Tsukuba stations, respectively. The Tsunami protocol is a UDP-based protocol designed to transfer high speed digital data effectively over the long distance high speed networks. A format conversion program from Mark 5 file format to K5 file format has been implemented to the Tsunami receiver client program, so the K5 format data files are created on the Tsunami receiver client at Kashima after each scan is completed. At the same time, K5/VSSP32 terminal at Kashima generates the K5 format data files. As soon as the scan has been completed, the K5 data files, one from the Onsala station and the other from the Kashima station, are accessed by the K5 software correlation program for correlation processing. Since four K5 data files are usually generated from one geodetic VLBI scan, it is easy to distribute the correlation processing tasks to four independent CPUs. Usually, the correlation processing finishes before the next scan starts. But even if the next scan starts before the correlation processing of the previous scan, it does not cause any problem. In the next scan, the data from Onsala station is transferred to Kashima no matter whether the correlation processing of the previous scan is finished or not, and the correlation processing of the next scan starts as soon as the data transfer completed.

Typically, 20 to 30 scans are observed within one ultra-rapid dUT1 intensive VLBI session, and the last correlation processing finishes after a few minutes from the last scan. By applying this method alone, the required time to process the data is tremendously reduced from about an hour to a few minutes by transferring the data in parallel with the observation session. As soon as the correlation processing of all scans finishes, the Mark 3 format database files will be generated and the data are analyzed automatically (Fig. 3).

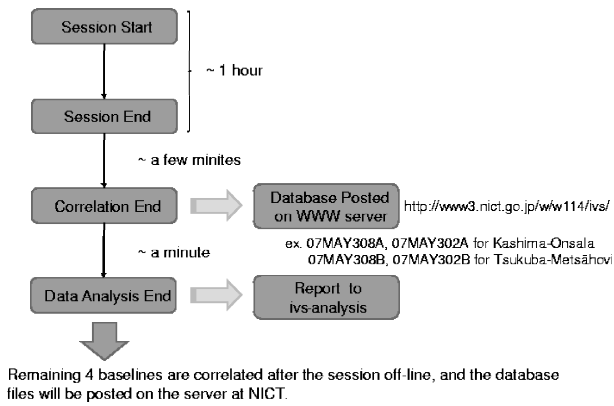

Figure 3. Typical data flow for the ultra rapid dUT1 e–VLBI intensive sessions

To realize this data flow, we have developed a set of programs to interface between bandwidth synthesis output files and database files in various formats as illustrated in Fig. 4. To support both CALC/SOLVE and OCCAM data analysis software, a new database based on the NetCDF architecture has been designed. From the NetCDF database, it is possible to generate the Mark 3 database files for CALC/SOLVE software and NGS-card data files for OCCAM software. It is also possible to produce NetCDF database files from Mark 3 database files. To obtain the estimated value of the dUT1, it is necessary to resolve group delay ambiguities caused by the bandwidth synthesis processing. The procedure to resolve ambiguities is also automated by integrating the

OCCAM data analysis software and scripts to perform iterative processes to resolve ambiguities. Once the ambiguities are resolved, the estimated results of dUT1 will be posted on a Web server to make it available to the wide user community, and the NetCDF database and Mark 3 database files are updated with the correct group delay information to make them free from group delay ambiguities.

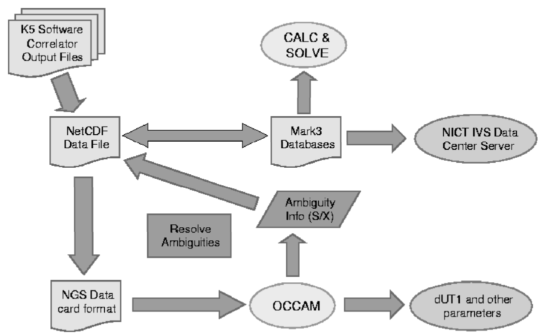

Figure 4. Relationship between the newly designed NetCDF database file and other format database files, analysis software, and output files from bandwidth synthesis processing

4. Conclusions and Future Plan

By using the newly developed hardware and software systems described in the previous sections, we succeeded in estimating dUT1 only 3 minutes 45 seconds after the intensive style e–VLBI session between Onsala and Tsukuba stations performed on Feb. 21, 2008. Although this results from a special R&D setup, it will be a straight forward process to introduce the same method to the routine intensive dUT1 VLBI sessions like INT-2 in the near future. To make this transition from R&D stage to the routine operation stage, we are planning to continue similar e–VLBI sessions until this procedure of the ultra rapid e–VLBI intensive sessions become reliable and robust. In the future, it will also become possible to process the large scale global VLBI sessions if all of the network stations are connected each other by high speed research networks.

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