Tsukuba VLBI Correlator

Shinobu Kurihara [1], Tetsuya Hara [1,2]

Abstract This report summarizes the activities of the Tsukuba VLBI Correlator during 2014. The weekend IVS Intensive (INT2) and the Japanese domestic VLBI observations (JADE) were regularly processed using the K5/VSSP correlation software.

1 Introduction

The Tsukuba VLBI Correlator, located in Tsukuba, Japan, is hosted and operated by the Geospatial Information Authority of Japan (GSI). It is fully devoted to processing geodetic VLBI observations of the International VLBI Service for Geodesy and Astrometry (IVS). All of the weekend IVS Intensive (INT2) for UT1-UTC (= dUT1) determination and the Japanese domestic VLBI observations for geodesy called JADE organized by GSI were processed at the Tsukuba VLBI Correlator. The K5/VSSP correlation software developed by the National Institute of Information and Communications Technology (NICT) is used for all processing.

1. Geospatial Information Authority of Japan
2. Advanced Engineering Service Co., Ltd.

2 Component Description

2.1 e-VLBI

The Tsukuba VLBI Correlator has been connected to a broadband network, and most of observed VLBI data is delivered via the network. The Tsukuba VLBI Correlator has a 10 Gbps dedicated link to the SINET4 operated by the National Institute of Informatics (NII), which is connected to some research networks in the world such as Internet2 in the U.S., GÉANT2 in Europe, and TEIN4 at Singapore. It enabled us to transfer massive amounts of data between the Tsukuba VLBI Correlator and the overseas IVS Components. In March, the Ishioka VGOS Station was also connected to the Tsukuba VLBI Correlator and SINET4 with a 10 Gbps dedicated cable.

2.2 K5/VSSP Correlation Software

The K5/VSSP correlation software consists of several programs for the calculation of a priori values of delay and delay rate (*apri_calc*), for the correlation processing for all observations (*fx_cor or cor*), and for monitoring the results of the correlation processing by performing a so-called “coarse search” (*sdelay*), following several utilities such as *Komb* for bandwidth synthesis [1]. All of these programs were developed and have been maintained by NICT. The K5/VSSP correlation software can be used not only for K5 data processing but also for the Mark 5 data processing by using the data format conversion program (*m5tok5*).

Table 1 Correlator Hardware Capabilities.

	Main system	**Second System**
Number of servers	16 - 14 for correlation processing - two for controlling correlation processing	44 - 16 for correlation processing - two for controlling correlation processing - 26 for data storage
Operating System	Red Hat Enterprise Linux 6.3	CentOS version 5.5
CPU	Intel Xeon X5687 @3.60GHz quad CPU x 2	Intel Xeon X3360 @2.83 GHz quad CPU Intel Xeon 5160 @3.00 GHz dual CPU x 2 Intel Xeon X3480 @3.07 GHz quad CPU Intel Xeon @3.80 GHz CPU x 2
Total storage capacity	Data Direct Networks storage: 513 Tbytes	Lustre File System: 30 Tbytes
Network	10 Gbps dedicated line connected to SINET4 by NII	

The following are processes of the K5 correlation and programs used in each process:

1. Transferring data from network stations to the correlator (*tsunami and tsunamid*).
2. Data format conversion from Mark 5 to K5 (*m5tok5 or m5btok5*).
3. Preparation of a priori parameter files (*apri_calc*).
4. Fringe search to find a clock offset at each pair of stations (*fx_cor or cor*).
5. Running correlation processing for all observations (*fx_cor or cor*).
6. Coarse search for estimating residual delay and delay rate, and plotting them on a 3-D diagram (*sdelay*).
7. Bandwidth synthesis to derive a multi-band delay (*komb*), and making Mark III databases by *MK3TOOLS* to be submitted to the IVS Data Center.

The correlation and analysis management programs developed by GSI can run the above processes consecutively and ultra-rapidly. The program for the management of data transfer *rapid_transfer* accesses a data server in an observing station, executes *tsunamid* there, and then executes *tsunami* to transfer data automatically at the correlator side when an observation starts. The data is converted from Mark 5 to K5 format by a program *rapid_conv* as necessary. *Rapid_cor* is a program to search for a fringe for each baseline according to the clock information of each station written in the FS log. Once the fringe is detected, the main correlation processing is run sequentially with the clock offset and rate found in the fringe search until the last observation. *Rapid_komb* executes *komb* one after another for bandwidth synthesis process. The fully automated VLBI analysis software *c5++* developed by NICT can read the komb output files directly and derives a VLBI solution [2]. *Rapid_c5pp*, which gives a *c5++* interface, makes a configuration file for *c5++* automatically and executes analysis.

2.3 Correlator Hardware Capabilities

The hardware supporting the activities of the Tsukuba VLBI Correlator is summarized in Table 1. All of these pieces of equipment are general purpose and commercially available products. It means that no dedicated hardware is required in the K5 correlation processing. In 2014, IBM System X3650 servers and a Data Direct Networks storage system with a capacity of 513 TB were incorporated into the main correlation processing (Figure 1). It shortens correlation time by half. The existing system is also available as the second processing system (Figure 2). There was no other hardware modification in this year.

3 Staff

The technical staff at the Tsukuba VLBI Correlator are:

- **Shinobu Kurihara** — correlator/analysis chief, management.
- **Tetsuya Hara** (AES) — correlator/analysis operator, software development.

Fig. 1 View of the data processing servers and storage system at the Tsukuba VLBI Correlator.

4 Correlator Operations

4.1 IVS Intensives for UT1-UTC

In 2014, 106 Intensive sessions that were observed on weekends in total were processed at the Tsukuba Correlator. The details are described in Table 2. The observed data at Wettzell is transferred to the Tsukuba Correlator in near real-time with the Tsunami UDP protocol and is converted to the K5 format immediately. The observed data at the Tsukuba station is also transferred to the correlator at once. The whole process from data transfer through analysis is implemented by the *rapid_* programs (see Section 2.2), and a dUT1 solution of the Tsukuba–Wettzell baseline can be derived within a few minutes after the end of the last scan of the session.

Table 2 Intensive sessions processed at the Tsukuba Correlator. One session K14040 on February 9 was canceled and not processed due to heavy snow at the Tsukuba Station.

	Baseline	Period	# of sessions
Intensive 2	TsWz	Jan 04 – Dec 28	101
	KkWz	Jan 05 – Jan 19	3
	KbWz	Oct 25 – Oct 26	2
Total			106

4.2 JADE and JAXA

JADE is the domestic geodetic VLBI series involving three GSI stations (Tsukuba, Aira, and Chichijima), three NICT stations (Kashima 34-m, Kashima 11-m, and Koganei 11-m), and two VERA stations of the National Astronomical Observatory of Japan (NAOJ) located in Mizusawa and Ishigakijima. Five JADE sessions were correlated in 2014. The JAXA session is separately conducted from JADE including JAXA stations, such as Usuda, in order to determine the global positions of the stations in the ITRF. One JAXA session was processed in this year.

Fig. 2 View of the existing data processing servers.

4.3 Ultra-Rapid dUT1 Experiment

This experiment is the joint project with Sweden, Australia, and South Africa continued since 2007. During five regular IVS 24-hour sessions and CONT14 sessions, the ultra-rapid dUT1 experiments were implemented and processed at Tsukuba Correlator. For details, refer to the report "Tsukuba VLBI Analysis Center" in this volume.

5 Outlook

We will continue to process the IVS Intensive sessions. For more stable operation, we will make further improvements to the *rapid_* programs and maintain hardware and network. When the Asia-Oceania VLBI Group for the Geodesy and Astrometry (AOV) coordinates and conducts regional VLBI observations, we will process the observed data and play a major role of a correlator in the Asia-Oceania region.

References

1. Kondo, T., et al.: Development of the K5/VSSP System, *Journal of the Geodetic Society of Japan*, **54**(4), 233-248, 2008.
2. Hobiger, T., et al.: Fully automated VLBI analysis with c5++ for ultra-rapid determination of UT1, *Earth Planets Space*, **62**, 933-937, 2010.