Tsukuba VLBI Correlator

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

Abstract This report summarizes the activities of the Tsukuba VLBI Correlator during 2013. 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. 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. The ultra-rapid EOP experiment (see Section 4.3) is also performed by this network.

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 [1]. *Komb* is a bandwidth synthesis software that was developed on an HP-1000 series minicomputer by using the FORTRAN program language when the K-3 VLBI system was being developed. It has been ported to a Linux operating system by using the C language. All these programs were developed and have been maintained by NICT. The K5/VSSP correlation software can be used not only for

Fig. 1 Processing servers and Lustre File System at the Tsukuba VLBI Correlator.

K5 data processing but also for the Mark 5 data processing by using the data format conversion program (*m5tok5*).

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.

We developed several management programs to run the above processes consecutively and ultra-rapidly. The program for the management of data transfer *rapid_transfer* accesses the hosts in observing stations, executes *tsunamid* there, and then at the correlator side, executes *tsunami* to transfer data automatically 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 fringes of 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].

2.3 Correlator Hardware Capabilities

The hardware supporting the activities of the Tsukuba VLBI Correlator is summarized in Table 1. All these pieces of equipment are general purpose and commer-

Fig. 2 New high performance servers and storage at the Tsukuba VLBI Correlator.

cially available products (Figure 1). It means that no dedicated hardware is required in the K5 correlation processing. In the correlator, mass data storage is required. Moreover, since some executed correlation processes access a data file simultaneously, the processing capability of correlator depends on the Read I/O of the data storage. The Lustre File System enables us to use numerous HDDs mounted on a lot of servers like one partition as if it were a large virtual disk. Thus, the I/O performance is dramatically improved compared with NFS.

Additionally, a set of high performance servers and huge storage was newly installed (Figure 2). The new system was originally purchased for the new VGOS station Ishioka, but it can be used for operational correlation processing too. The specification of the new system is also shown in Table 1. The new system can shorten the time of correlation processing.

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.

4 Correlator Operations

4.1 IVS Intensive for UT1-UTC

In 2013, 72 Intensive sessions in total were processed at the Tsukuba Correlator. The details are described in Table 2. In April, because the Kokee Park station antenna was repaired, the Intensives on weekdays were done as INT2 sessions with the Tsukuba—Wettzell baseline and processed at the Tsukuba Correlator. Just after that, we found that there was a fatal flaw in the pedestal of the track of the Tsukuba antenna. Since then all Intensive sessions that included the Tsukuba station were canceled, and Kokee was substituted for Tsukuba in the Intensives on Sunday. Wettzell, Ny-

Table 1 Correlator Hardware Capabilities.

	Current system	**New System**
Number of servers	43 - 16 for correlation processing - 1 for controlling correlation processing - 26 for data storage	18 - 16 for correlation processing - 2 for controlling correlation processing
Operating System	CentOS version 5.3, 5.4 or 5.5	Red Hat Enterprise Linux 6.3
CPU	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	Intel Xeon X5687 @3.60GHz quad CPU x 2
Total storage capacity	Lustre File System: 24.9 Tbytes	Data Direct Networks storage: 513 Tbytes
Network	10 Gbps dedicated line connected to SINET4 by NII	

Ålesund, and Svetloe made a baseline with Kokee alternatively.

The observed data at Wettzell is transferred to the Tsukuba Correlator in real-time with the VDIF/SUDP protocol and is recorded on a data storage device in the K5 format directly. The observed data at the Tsukuba station is also transferred to the correlator immediately. Since the whole process from data transfer through analysis is implemented by the *rapid_* programs (see Section 2.2), 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. In the case of the Kokee baselines, because the observed data at Kokee was transferred via the U.S. Naval Observatory (USNO), it took a few hours to derive a solution.

Table 2 Intensive sessions processed at Tsukuba Correlator.

	Baseline	Period	# of sessions
Intensive 1	TsWz	Apr 22 – Apr 30	7
Intensive 2	TsWz	Jan 05 – Apr 28	34
	KkWz	May 12 – Jul 07 Oct 06 – Dec 29	19
	KkNy	Jul 14 – Jul 28 Aug 25 – Sep 29	9
	KkSv	Aug 04 – Aug 18	3
Total			72

4.2 JADE

JADE is the domestic geodetic VLBI series involving four GSI stations (Tsukuba, Aira, Chichijima, and Shintotsukawa), 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. Nine JADE sessions were correlated in 2013.

4.3 Ultra-Rapid EOP Experiment

This experiment is the joint project with Sweden, Australia, and South Africa having been continued since 2007. Several ultra-rapid EOP 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 and JADE correlation. For more stable operation, we will make further improvements to the *rapid_* programs and start to use the new high performance servers and storage for our routine processing.

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.