

# Tsukuba VLBI Correlator

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## Abstract

The Tsukuba VLBI Correlator is invested by the Geospatial Information Authority of Japan (GSI). The K5/VSSP correlation software is regularly used, and the IVS-INT2, JADE, and other various sessions are correlated.

## 1. Introduction

The K5/VSSP software correlator (Figure 1), located in Tsukuba, Japan, is operated by the Geospatial Information Authority of Japan (GSI). It is fully dedicated to processing the geodetic VLBI sessions of the International VLBI Service for Geodesy and Astrometry. All of the week-end IVS Intensives (INT2) and the Japanese domestic VLBI observations organized by GSI were processed at the Tsukuba VLBI Correlator.



Figure 1. Tsukuba VLBI correlator.

## 2. Component Description

### 2.1. e-VLBI

Nowadays when the Internet is spread throughout the world, it seems that the physical transportation of the magnetic media on which the observed VLBI data is recorded is a bit outdated.

Most of the observed VLBI data processed at the Tsukuba VLBI Correlator is delivered via networks. 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 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 IVS Components overseas. The ultra-rapid EOP experiment (see section 4.3) is also brought about 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 baselines (*fx\_cor* or *cor*), and for monitoring the results of the correlation processing by performing a so-called “coarse search”, following several utilities [1]. *Komb* is a bandwidth synthesis software that was developed on an HP-1000 series minicomputer using the FORTRAN program language when the K-3 VLBI system was being developed. It has now been ported to a Linux operating system using the C language. All these programs were developed and have been maintained by the National Institute of Information and Communications Technology (NICT), which are available not only for the 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 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 station (*fx\_cor* or *cor*).
5. Running correlation processing for all baseline (*fx\_cor* or *cor*).
6. Coarse search for residual delay and delay rate and plotting a 3-D diagram to indicate the delay and fringe-rate axis (*sdelay*).
7. Bandwidth synthesis to derive a multi-band delay (*komb*) and generation of a Mark III database to be submitted to the IVS Data Center (*MK3TOOLS*).

We developed various management programs to run the above processes consecutively and ultra-rapidly. A 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. The solution, a triad of the Earth Orientation Parameter (EOP), is derived from a set of the bandwidth synthesis outputs generated by *rapid\_komb* that executes *komb* one after another. The fully automated VLBI analysis software *c5++* developed by NICT estimates EOPs, clock parameters with respect to a reference station, and atmospheric delays for each station according to the configuration of parameterizations defined in advance [2]. The 3-D diagrams of the fringes of each baseline and the graphs of the time series

of EOP are available on the GSI Web page and updated by the minute during an ultra-rapid experiment.

### 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 commercially available. It means that no dedicated hardware is required in the K5 correlation processing. In a correlator, mass data storage is required. Moreover, since some executed correlation processes access a file simultaneously, the capability of the 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.

In 2012, some aging servers crashed and were removed from the correlation system. It has had little impact on the overall capability of the correlator.

Table 1. Correlator Hardware Capabilities.

Number of servers	49 - 16 for correlation processing - 2 for controlling correlation processing - 31 for data storage
Operating System	CentOS version 5.4 or 5.5
CPU	Intel Pentium4 3.0 GHz / Intel Xeon 3.4 GHz dual CPU / Xeon 3.06 GHz dual CPU / Intel Xeon 3.07 GHz quad CPU
Total storage capacity	Lustre File System: 27.9 Tbytes individual RAIDs: 102 Tbytes in total
Network	10 Gbps dedicated line connected to SINET4 by NII

### 3. Staff

The technical staff members at the Tsukuba VLBI Correlator are

- **Shinobu Kurihara**: correlator/analysis chief, software design and development.
- **Kentaro Nozawa** (AES): correlator/analysis operator, software development.
- **Takashi Nishikawa** (AES): correlator/analysis operator.
- **Toshio Nakajima** (I-JUSE): system engineer.

Kensuke Kokado, who had been the correlator/analysis chief until the end of May 2012, moved to another division on April 1.

## 4. Correlator Operations

### 4.1. IVS-INT2 and IVS-INT3

In 2012, 107 IVS-INT2 sessions were correlated. 83 of them observed the Tsukuba-Wettzell baseline, and the other 24 observed the Kokee-Wettzell baseline. The observed data at Wettzell is transferred to the correlator in real-time with the VDIF/SUDP protocol and is recorded on data storage in the K5 format directly. Since the whole processes from correlation to analysis are implemented by the *rapid\_* programs (see section 2.2), a dUT1 solution can be derived within two minutes after the end of the last scan of the session. In case of Kokee-Wettzell baseline, since the observed data at Kokee was transferred via the U.S. Naval Observatory (USNO), it took a few hours to derive a solution.

Besides, one IVS-INT3 observed on February 20 (k12051) was correlated instead of the Bonn correlator.

### 4.2. JADE and JAXA

JADE is the domestic geodetic VLBI series involving four GSI stations (Tsukuba, Aira, Chichijima, and Shintotsukawa), two 11-m stations at Koganei and Kashima owned by NICT, and two VERA stations of the National Astronomical Observatory of Japan (NAOJ) located in Mizusawa and Ishigakijima. Eight JADE sessions were correlated in 2012. A JAXA session involving Usuda 64-m to provide precise geodetic coordinates required in the tracking of the deep space probes was processed as well.

### 4.3. Ultra-Rapid EOP Experiment

This experiment is the joint project with Sweden, Australia, and South Africa, having been continued since 2007. The HartRAO 26-m and 15-m antennas newly joined in the experiments, and the automated ultra-rapid processing was implemented with a four-station/six-baseline network. For details refer to the report “Tsukuba VLBI Analysis Center”, this volume.

## 5. Outlook

For more stable operation, we will make some improvements to *rapid\_* programs.

## 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.