VLBI Correlators in Kashima

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Abstract

Software correlator systems developed at Kashima Space Research Center are used for data processing of R&D VLBI experiments. Major correlation tasks processed in 2008 were the following three: e-VLBI project for rapid UT1 measurement, CARAVAN2400 project for reference baseline determination with small diameter antennas, and a project for time standards comparison with VLBI. An automatic data processing scheme, which distributes correlation tasks to a cluster of PCs for parallel processing, has been extensively used for this geodetic VLBI processing.

1. General Information

The VLBI group of Kashima Space Research Center (KSRC) of National Institute of Information and Communications Technology (NICT: Fig.1) has been contributing to the VLBI community by developing the VLBI data acquisition system (DAS) and the correlation systems. Both systems are named K5.

The complete 16 channel set of the K5/VSSP DAS system has been used at the Kashima 34m, Tsukuba 32m, and Mizusawa 20m VERA station of National Astronomical Observatory of Japan (NAOJ) for geodetic VLBI observations. Also a subset of the DAS has been installed at Gifu Univ.'s 11m station, Hokkaido Univ.'s 11m station, and Yamaguchi Univ.'s 32m station, and they are used for astrophysical line spectrum observations.

e-VLBI technology has been intensively developed in recent years. International e-VLBI experiments for ultra-rapid UT1 measurements have been conducted as a pilot project for testing the stability of operation. Also we have participated in several e-VLBI demonstration events, and the K5 DAS system's compatibility with foreign DAS systems has improved through those international experiments.

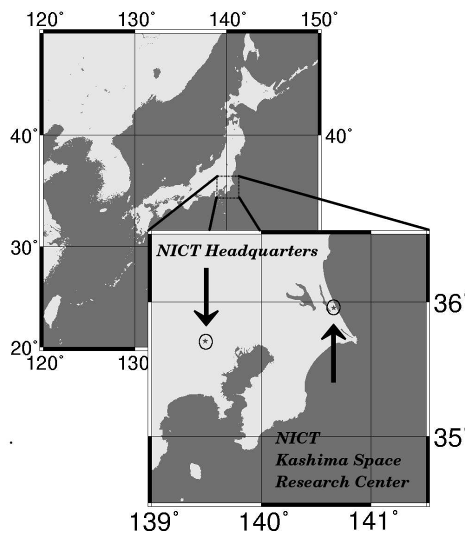

Figure 1. Location of NICT/KSRC.

2. Component Description

NICT has developed two kinds of DASs, and they are named K5/VSI and K5/VSSP [1, 2], respectively. Two sorts of software correlators have been developed for each of them. Table 1 summarizes the differences between the two sorts of DAS systems and the corresponding software correlator packages. T. Kondo has developed the K5 software correlator [3] for the correlation of K5/VSSP data. Hereafter "K5 software correlator" means "cor & fx_cor" system, except for wherever "K5/VSI correlator" is clearly stated. The "cor & fx_cor" system has been used for geodetic data processing such as UT1 measurements. This software package includes a data format converter between K5/VSSP and Mark 5A [4]. Thus the K5 software correlator can perform not

Table 1. Two kinds of K5 software correlators and the corresponding DAS systems.

Name of Module	Corresponding DAS System	Number of Data Channels	Processing Speed	Main Developer	Applications
cor & fx_cor	K5/VSSP, K5/VSSP32	4 x 4ch	Medium	T.Kondo	Geodesy UT1
GICO3	K5/VSI	1ch (∼ N)	Fast	M.Kimura	Astronomy VERA Project

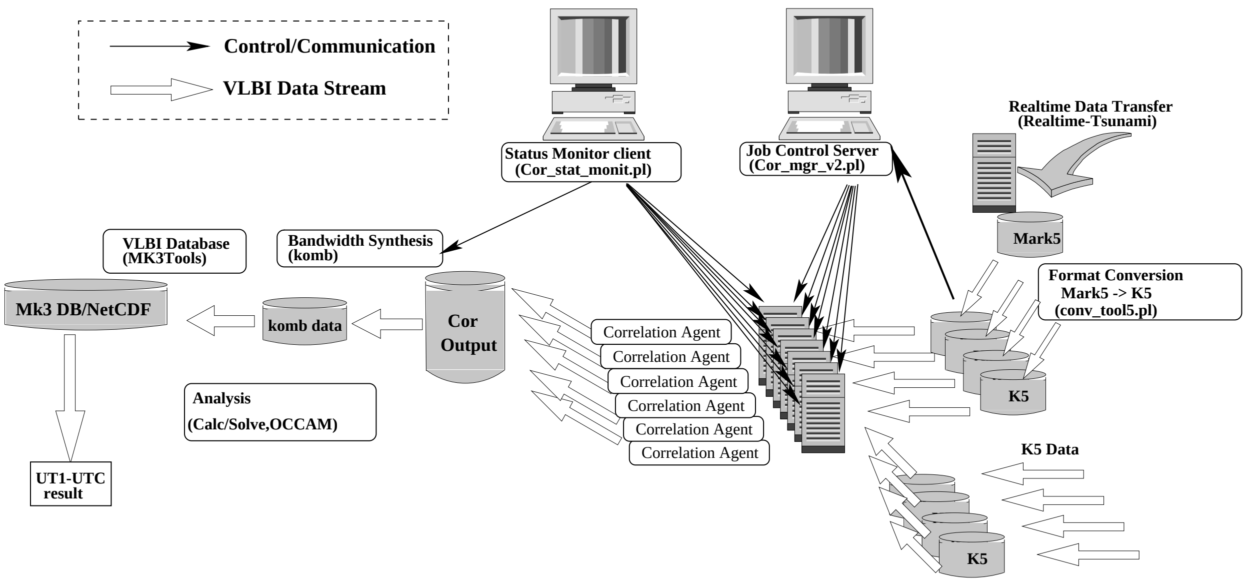

Figure 2. Distributed software correlation system with a cluster of PCs.

only native correlation processing of K5/VSSP data but also mixed correlation with Mark 5A and K5 via data conversion. This function has been used in International e-VLBI observation for ultra-rapid UT1 measurements [5].

A subsidiary software package for distributed correlation processing has been written in Perl. Figure 2 shows the schematic diagram of the data processing system. The software modules written in Perl scripts communicate with each other, and they accomplish the distributed data processing. The data conversion (Mark 5A→K5) and correlation processing tasks are invoked from the scripts. This correlation system has been used for e-VLBI experiments for ultra-rapid UT1 measurements [6] and for the other geodetic VLBI experiments, as well.

3. Staff

- Tetsuro Kondo is in charge of development and maintenance of software correlator package (cor & fx_cor). Also he is in charge of development of PC-based VLBI sampler K5/VSSP32 [2]. He has been working now at Ajou University in Korea on the construction of a geodetic VLBI system in Korea, since April 2008.
- Yasuhiro Koyama is Group leader of "Space-Time Application Group" and is in charge of

overall activity in our group. He moved to NICT Headquarters in Tokyo in August 2008.

- Ryuichi Ichikawa has been the leader of the VLBI project in Kashima since August 2008. He is in charge of the MARBLE project, in which a small-size VLBI station has been developed for providing length-standards for GSI.
- Mamoru Sekido is in charge of the e-VLBI activity.
- Moritaka Kimura is working on the development of a high speed Gigabit software correlator. He is in charge of development of software correlators for the VERA project.
- Thomas Hobiger is developing a new VLBI database system by using NetCDF. He also performs research into atmospheric path delay calibration with the ray tracing technique.
- Eiji Kawai is in charge of maintenance of the 34m telescope and is responsible for the operation of the 34m telescope and DAS for IVS VLBI sessions.
- Masanori Tsutsumi is working as a system engineer for computer maintenance.

4. Current Status and Activities

4.1. Ultra-rapid UT1 Measurements

Rapid UT1 measurements have been conducted under the collaboration of NICT, Geographical Survey Institute (GSI) Japan, Onsala Space Observatory (Sweden), and Metsähovi Radio Observatory (Finland). The aim of this project is testing and improving the software correlation system with e-VLBI to achieve minimum latency in VLBI UT1 sessions. UT1 estimation has become available within 30 minutes of session termination by using a mixture of K5 and Mark 5 systems on international baselines. A record minimum latency of less than 4 minutes was achieved on February 22 on the Tsukuba-Onsala baseline with a 256 Mbps data rate. The observation and correlation were performed by Onsala and GSI. NICT contributed to this by providing an automatic correlation system, automatic Mark III database creation via NetCDF[1] (MK3TOOLS [7]), and an automatic UT1 analysis scheme with OCCAM developed by T.Hobiger. A list of our e-VLBI UT1 experiments is available on the Web[2].

4.2. e-VLBI Development

Data format/interface compatibility with Mark 5B has significantly improved with the combination ADS-2000 sampler and K5/VSI DAS. A software package for real-time data stream transmission with a protocol of UDP/IP has been developed. The first realtime e-VLBI experiment with ATNF was realized in June. Further improvement has continued and has contributed to an e-VLBI demonstration for the International Year of Astronomy in 2009 conducted by JIVE.

4.3. GICO3 Correlator for K5/VSI

A software correlation system using high speed correlation software named GICO3 is under development for NAOJ's VERA project [8]. The system is designed for processing 10 baselines by

[1] http://www.unidata.ucar.edu/software/netcdf/

[2] http://www2.nict.go.jp/w/w114/stsi/research/e-VLBI/e-VLBI-frame.html

Table 2. Picture and Specification of Software Correlator for VERA Project

Specification parameters of the Software Correlator	
Stations	5
Baselines	10
Processing Rate	512 - 1024 Mbps/station
Lags Number	64 - 64000 points
Output	10 cross and 5 auto correlations
Output rate	1 - 100Hz
Output format	CODA, FITS

cross-correlation and 5 stations by auto-correlation, simultaneously [9]. The maximum data rate is 1 Gbps for each station. A picture of the K5/VSI correlation system is displayed in Table 2.

5. Future Plans

Geodetic application of the GICO software correlator will be one target, and it will expand the capability of co-observation with Mark 5B stations. Software to adopt to VDIF (VLBI Data Interchange Format) will be developed.

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