VLBI Correlators in Kashima

Mamoru Sekido, Moritaka Kimura

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 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. Automatic data processing scheme, which distributes correlation tasks to cluster of PCs for parallel processing, has been extensively used for those geodetic VLBI processing.

1. General Information

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

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

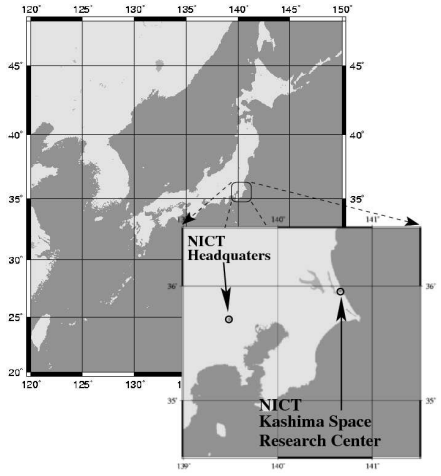

Figure 1. Location of NICT/KSRC.

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

2. Component Description

NICT has developed two kinds of DASs, and they are named K5/VSI and K5/VSSP[1, 3], respectively. Two sorts of software correlators have been developed for each of them. Table 1 summarizes the difference of the two sorts of DAS systems and coresponding software correlator packages. T. Kondo has developed the K5 software correlator[2] for correlation processing of K5/VSSP data. Hereafter 'K5 software correlator' means 'cor & fx_cor' system, except for clearly stating K5/VSI correlator. The 'cor & fx_cor' system has been used for geodetic data processing such as UT1 measurements. This software package includes data format converter between K5/VSSP and Mark5A[**?**]. Thus the K5 software correlator can perform not only native K5 correlation processing of K5/VSSP data but also mixed correlation with Mark5A and K5 via data

Table 1. Two kinds of K5 software correlators and correspndig DAS sytems.

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 ($\sim$ N)	Fast	M.Kimura	Astronomy VERA Project

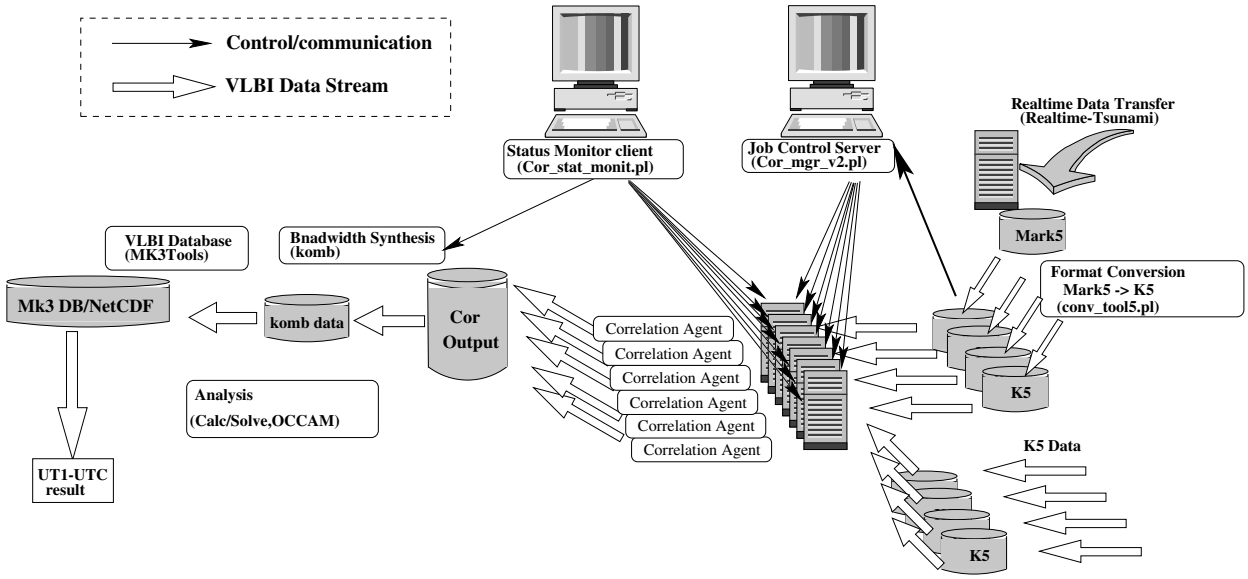

Figure 2. Distributed software correlation system with a cluster of PCs.

conversion. This function has been used in International eVLBI observation for Ultra rapid UT1 measurements[5].

Addtional software package for distributed correlation processing has been written in Perl language. Figure 2 shows the schematic diagram of data processing system. The software modules written in Perl scripts communicate each other and they realize the distributed data processing. The data conversion (Mk5A-¿K5) and correlation processing task are invoked from the scripts. This correlation system has been used for eVLBI experiment for ultra-rapid UT1 measurement[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[3]. He has been working now at Ajou University in Korea for construction of 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 has moved to NICT Headquarter in Tokyo since August

2008.

- Ryuichi Ichikawa is leader of VLBI project in Kashima since August 2008. He is in charge of the MARBLE project, in which 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 Giga bit software correlator. He is in charge of development of software correlators for VERA project.
- Thomas Hobiger is developing a new VLBI database system by using NetCDF. Also he as activity in research of atmospheric path delay calibration with ray tracing technique.
- Eiji Kawai is in charge of 34m telescope maintenance and responsible for operation of 34m telescope and DAS for IVS VLBI sessions.
- Masanori Tsutsumi is working as system engineer for maintenance of computers.

4. Current Status and Activities

4.1. Ultra-rapid UT1 measurements

Rapid UT1 measurement has been conducted under the collaboration among NICT, Geographical Survey Institute (GSI) Japan, Onsala Space Observatory (Sweden), and Metsähovi Radio Observatory (Finland). The aim of this project is testing and improvement of software correlation system with eVLBI for minimum latency in UT1 observation by VLBI. UT1 estimation has become available within 30 minutes of latency by using mixture of K5 and Mark5 systems on international baselines. A record of the minimum latency has been achieved within 4 min. on 22 Feb. on Tsukuba-Onsala baseline with 256Mbps data rate. The observation and correlation has perfromed by Onsala and GSI on that experiment. NICT has contributed to it by prviding automatic correlation system, automatic Mk3 database creation via NetCDF[1] (MK3TOOLS[7]), and automatic UT1 analysis scheme with OCCAM developed by T.Hobiger. List of our eVLBI experiments conducted for UT1 is available on the web[2].

4.2. E-VLBI Development

Data format/interface compatibility with Mk5B 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 developed. The first realtime eVLBI experiment with ATNF was realized in June. Further improvement has been continued and has contributed eVLBI demonstration of International Year of Astronomy in 2009 conducted by JIVE.

4.3. GICO3 correlator for K5/VSI

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

[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

of cross correlation and 5 stations auto-correlation simultaneously[9]. The 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 GICO software correlator will be made, and it will expand ability to co-observation with Mark5B stations. Software development to adopt to VDIF(VLBI Data Interchange Format) will be made.

References

[1] T. Kondo, et al.: Technology Development Center at NICT, International VLBI Service for Geodesy and Astrometry 2007 Annual Report, this issue,2008.

[2] Y. Koyama, et al.: Evaluation of the K5 system in geodetic VLBI experiments, Technical Development Center News CRL, No.23, 26-30, 2003.

[3] T. Kondo, et al.: Development of a New VLBI Sampler Unit (K5/VSSP32) Equipped with a USB 2.0 Interface, IVS 2006 General Meeting Proceedings, edited by Dirk Behrend and Karen Baver, NASA/CP-2006-214140, p.195-199, 2006

[4] Whitney, A.R.: Mark IIIA/IV/VLBA Tape Formats, Recording Modes and Compatibility *Supercedes Memo #205 + Revisions, Mark4 Memo Series, *http://www.haystack.edu/geo/mark4/memos.html*, **230A**, 2005.

[5] Sekido. M., et al.: Ultra-rapid UT1 measurement by e-VLBI, Earth Planets and Space, **60**, pp,865-870, 2008

[6] Sekido, M. et al.: Development of e-VLBI Technologies for Ultra-rapid UT1 Measurement, IVS NICT-TDC News,*http://www2.nict.go.jp/w/w114/stsi/ivstdc/news-index.html*, **No.29**, pp. 28-30, 2008.

[7] Hobiger, T. et al.: MK3TOOLS & NetCDF – storing VLBI data in a machine independent array oriented data format–, Proceeding 18th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting April 12, 2007, Vienna, Austria, *http://mars.hg.tuwien.ac.at/evga/*, P03, 2007.

[8] M. Honma et al.:Multi-Epoch VERA Observations of H_2O Masers in OH 43.9 – 0.1, Publ. Astron. Soc. Japan Vol 57 pp. 595-603, 2005

[9] M. Kimura: Development of the software correlator for the VERA system, Technical Development Center News NICT, No.26, 26-27, 2005.