VLBI Correlators at Kashima

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Abstract

The software correlator systems developed at Kashima Space Research Center are used for data processing of R&D VLBI experiments. In 2007 the correlation tasks processed were an e-VLBI project for rapid UT1 measurements, the CARAVAN2400 project for reference baseline determination with small diameter antennas, and a project for comparison of time standards with VLBI. An automatic data processing scheme was newly introduced and it has drastically reduced the latency of UT1 determination. The rapid UT1 measurement with e-VLBI was demonstrated at the JGN2 symposium 2008. The automated correlation processing scheme also works efficiently in the other projects. The implementation of the high speed correlation software package GICO3 into the correlation system for the VERA project is in progress under contract with NAOJ.

1. General Information

The VLBI group of Kashima Space Research Center (KSRC) of National Institute of Information and Communications Technology (NICT) has been developing software correlators and the disk-based data acquisition system called K5. The software correlator system works on a cluster of personal computers (PCs), and it has the capacity for automation and for modification of the correlation configuration for specific data processing.

2. Component Description

NICT has developed two kinds of data acquisition systems (DAS): K5/VSI and K5/VSSP [1]. Software correlator adaptations have been developed for each of them. To clearly distinguish the two software correlator packages, Table 1 summarizes their differences. Mainly the 'cor & fx_cor' system has been used for geodetic data processing such as UT1 measurements and the CARAVAN2400 project. In the following, 'K5 software correlator' means 'cor & fx_cor' system, except when clearly stated otherwise (e.g., K5/VSI correlator).

Table 1. Two kinds of K5 software correlators developed at KSRC.

Name of Module	Corresponding DAS System	Number of Data Channel	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

2.1. Software Correlator for K5/VSSP ('Cor & Fx_cor')

The K5 software correlator system has been developed by T. Kondo [2] with the aim of geodetic VLBI data processing. It has been originally dedicated for processing the data of K5/VSSP(VSSP32) [3], which is a disk-based VLBI data recording system developed at NICT.

The K5 software correlation package includes the format converter between K5/VSSP and Mark 5 system. Thus it can be used for correlation processing of Mark 5 data via data format conversion. Now the K5 software correlation system has been exported to JIVE under a license agreement and it has been routinely used for fringe detection for VLBI observations of the European VLBI Network.

Some perl script package wrapping for the correlator core software ('cor & fx_cor') was developed in 2007. They provide a communication function to the correlator core which enables an automatic correlation processing with distributed computation on a PC cluster. This capability contributed to the improvement of the latency of the ultra-rapid UT1 measurement. The rapid UT1 measurement has been conducted in a collaboration among NICT, Geographical Survey Institute (GSI) Japan, Onsala Space Observatory (Sweden), and Metsähovi Radio Observatory (Finland). UT1 estimation has become available with 30 minutes of latency by using multiple technologies such as high speed network, data transport protocol 'tsunami', disk-based data recording systems K5/VSSP32 and Mark 5 [4], and PC interface VSI-B [5]. One target of the rapid-UT1 measurement project is the evaluation of the operational stability of pseudo-realtime e-VLBI as well as the stability of the solution. The 'tsunami' protocol [6] made the real-time transfer of observed VLBI data in Mark 5 format possible over intercontinental distances (Onsala, Metsähovi to Kashima,Tsukuba). Then data format conversion from Mark 5 to K5 and cross correlation processing are performed. For utilizing this automated processing, only the clock parameters need to be fixed before the experiment.

Figure 1. A view of the observation room of the Kashima 34m antenna. The K5 system in this room is used both for observation and correlation processing.

A VLBI database system based on NetCDF[1] has been developed by T. Hobiger (MK3TOOLS) [7, 8]. After the correlation processing, the MK3TOOLS have been used for the creation of Mark III databases for the analysis with the CALC/SOLVE system. The NetCDF database file is used as intermediate database to generate a Mark III database. Since the MK3TOOLS have a function to generate NGS card format as well, this is used for the analysis with OCCAM analysis system. Automatic analysis procedure for UT1 estimate is being developed by T. Hobiger by using the MK3TOOLS, NGS databases, and the OCCAM software.

Besides UT1 observations, the correlation system has been used for the CARAVAN2400 project [1], a project of time standards comparison with VLBI [1], and some fringe test experiments for supporting VLBI stations of JAXA/ISAS.

2.2. GICO3 Correlator with K5/VSI

GICO3 is a high speed correlation software developed by M. Kimura for the K5/VSI system. Under a contract with National Astronomical Observatory of Japan (NAOJ), a correlation pro-

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

Table 2. e-VLBI sessions for rapid UT1 measurement performed since April 2007. Station codes are as follows, 'Ks':Kashima34, 'Ts':Tsukuba 32, 'On':Onsala, 'Mh':Metsähovi, and 'Wz':Wettzell. The effective band width for the experiments from 3rd April to 4th June are 140.2MHz and 33.1 MHz for X and S-band, respectively. And those for experiments from 14 and 15 July are respectively 280.4 MHz and 48.8 MHz for X and S-band. The experiments on 14 and 15 July were performed by add on to the INT-2 sessions of Tsukuba-Wettzell baseline.

Date 2007	**Baseline**	**Data rate** (Mbps)	**UT1-UTC** (ms)	**UT1-c04** (μ sec.)	**Error** (μ sec.)	**Latency**
03 April	Ks – On	256	-69.6044	-38.5	8	–
23 April	Ks – On	128	-98.4422	15.0	41	1 h 55 min.
02 May	Ks – On	128	-110.0189	-30.4	16	–
18 May	Ks – Mh	128	-130.5832	67.5	98	2 h 38 min.
30 May	Ks – On	128	-143.2703	-14.7	9	28 min.
31 May	Ks – On	128	-143.7011	-83.5	8	–
04 June	Ks – On	256	-144.6447	13.1	6	31 min.
14 July	Ks-On, Ks-Wz	256	-162.0879	6.2	6	–
	Ks – On		-162.1017	-7.6	10	
	Ks – Wz		-162.0715	22.6	8	
	Ts – Wz, On-Ts		-162.0674	26.7	8	
	On – Ts		-162.0725	21.6	7	
	Ts – Wz		-162.0585	35.6	5	
	Ts – Wz(INT2)		-162.0974	-3.3	7	
15 July	Ks – On	256	-162.0186	-30.7	6	–
	Ts – Wz(INT2)		-162.0017	-13.8	8	

cessing system using the software correlator is being developed for the VERA project [9]. The system is designed for processing 10 baselines of cross correlation and 5 stations autocorrelation, simultaneously [10]. The data rate is 1 Gbps for each station. A picture of the correlation system composed of 5 PCs is displayed in Table 3

3. Staff

- Tetsuro Kondo is working for development and maintenance of software correlator package (cor & fx_cor). Data format converter between Mark 5 and K5 is included in the package. He also is in charge of the development of the PC-based VLBI sampler K5/VSSP32 [3].
- Yasuhiro Koyama is project leader of the "Space-Time Application Project" and is in charge of overall activity in our group.
- 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 the development of software correlators for the VERA project.
- Thomas Hobiger is developing a new VLBI database system using NetCDF. He also is active in research of atmospheric path delay calibration with ray tracing technique.
- Masanori Tsutsumi is working as system engineer for maintenance of computers.

Table 3. 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

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