VLBI Correlators in Kashima

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Abstract

Correlators at Kashima have been used for processing of experimental VLBI observations. The KSP correlation system has been used for domestic VLBI observations for geodesy in 2004. Instead of the decreasing frequency of using those hardware correlators, occasions to use disk-based recording system (K5) are getting more frequent. Two different disk-based recording systems have been developed. One is a multi-channel VLBI system named K5/VSSP and the other is a single channel Giga-bit system called K5/VSI. Data recorded with either of these disk-based recording system are processed by software correlators. The correlation processing rate with software correlator is already in the range of practical use.

1. General Information

Kashima Space Research Center of National Institute of Information and Communications Technology (NICT; formerly Communications Research Laboratory) has developed VLBI hardware correlators as IVS technical development center. Now the field of technology development in correlation processing is shifting from hardware to software owing to quick growth of computing power of personal computers. A software correlator has great benefit for VLBI community in several points of view. (1) It has wide flexibility in configuration of the specification. The lag number and frequency resolution can be modified very easily. (2) Also the cost of maintenance and bug fixing is lower. (3) Multiplication of the quantity of correlator is enabled simply by purchasing additional personal computers and by copying the software. (4) It is good from an educational point of view and for the expansion of the VLBI community to universities, since correlator software can be written by university students, giving experience in correlation processing. Actually, some universities in Japan have started to work for VLBI data processing with IP-sampler board, which is 4ch sampler component of K5 system.

By the way, we are still going to operate hardware correlators for processing the data recorded on conventional tape-based systems. Here we introduce our VLBI correlators and our activity in the development of correlation processing software.

2. Correlators

2.1. KSP-Correlation System

The JADE series VLBI experiments are omni-bus type geodetic VLBI service coordinated by the GSI of Japan. The 11m antenna at Gifu University, 32m Yamaguchi University, and 34m Uchinoura and 64m Usuda deep space tracking stations of ISAS/JAXA have participated in some of those experiments to determine their terrestrial coordinates. Data processing of JADE experiments is sometimes shared with GSI-correlators and the KSP correlators in Kashima. Correlation processing was performed on JADE0403, JADE0404, and JADE0407 experiments to process the data on GIFU-11m antenna related baselines. Also two VLBI experiments for ionospheric TEC measurements, in which Kashima-34m, Gifu-11m, and Mizusawa-20m antennas participated, were processed with the KSP correlator.

Figure 1. KSP Correlator room. The KSP hardware-correlation system, which is capable of processing 4 stations and 6 baselines of tape-based VLBI data, is sometimes operated for domestic geodetic VLBI data processing.

2.2. Software Correlation System

2.2.1. K5/VSSP Correlation System

Correlation process of the K5/VSSP disk-based recording system is performed by a software-correlation package for geodesy, which has been developed by Kondo (Kondo et al. 2003). It runs on standard personal computer (PC) and performs correlation of two data sets of VLBI data in the form of binary files on hard disk (HD). Figure 2 shows the K5/VSSP system, the K5/VSI system is described in the next paragraph. The K5/VSSP system is used for e-VLBI experiment

Figure 2. K5/VSSP VLBI system (right in the left panel) consists of 4 PCs. Each PC is equipped with one IP-sampler board, which has 4 channels of data input. Sampled data are recorded on their HDs as binary files. The maximum recording rate is 128 Mbps per PC. These recording PCs are also used for data processing purposes as correlators. K5/VSI VLBI system (left in the left panel) has capability of 1 Gbps recording rate per PC. Its data is fed from Giga-bits sampler (right) in VSI format.

for rapid UT measurements (Koyama et al. 2003, Koyama et al. 2004). The processing speed of the K5/VSSP software correlator is typically 2 Msps/CPU with Pentium III processor. This software correlator package is also used at JIVE for quick fringe detection before observations with

the EVN.

2.2.2. K5/VSI system

The K5/VSI system consists of a data recording interface board equipped in a PC with RAID-HD system (Figure 2 left) and Giga-bit sampler with VSI output. The K5/VSI system is going to be used for the Huygens VLBI observation in collaboration with EVN, VLBA, ATNF, and Chinese VLBI institutions. Specified frequency channels of data are extracted from the data records by using a digital filtering technique (Takeuchi et al. 2004), and it is converted to Mark 5 data.

Kimura has developed ultra high-speed correlation software for the K5/VSI. Its processing rate is 0.5 Gsps/PC with PowerPC 970FX(2GHz) processor at present. The rate is limited by data transfer speed of LAN, which connects the K5/VSI. A peer-to-peer cross correlation processing scheme, by which the processing rate can be made independent of the number of baselines, was proposed (Kimura 2002). Processing rate of the software correlator as a function of FFT points is displayed in Figure 3.

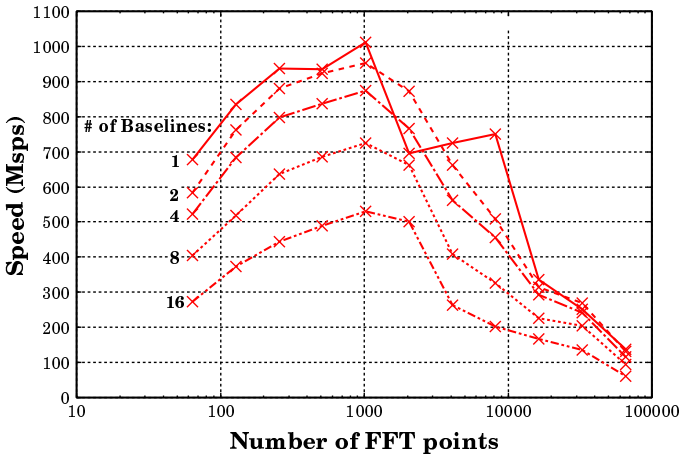

Figure 3. Processing rate of ultra-high-speed FX-type software correlator is plotted as a function of number of FFT points. The first rise of plot along the x-axis is due to increasing efficiency in data transfer from disk to the CPU. The drop of efficiency in the second half along the x-axis is due to shortage of cache memory in the CPU.

2.2.3. Other Software Correlators

Correlation processing of VLBI data of spacecraft signal is slightly different from the standard one at least at two points. Firstly, curvature of the wavefront has to be taken into account in the delay model, since the distance from the baseline to the spacecraft is at finite distance. For this purpose, a newly developed a priori delay model (Sekido & Fukushima 2003, 2004) is implemented and used for a priori delay computation. Secondly, because a modulated signal with limited bandwidth is transmitted from the spacecraft, correlation processing with spectral frequency filtering may be effective to enhance the SNR. Thus filtered correlation process is applied for post-correlation data for extraction of group delay. When phase delay is used for spacecraft navigation, extraction of Fourier component of the carrier signal with high frequency resolution

is the main task to be done in the processing. For this purpose, a special correlation package for phase delay extraction was developed.

A realization of distributed correlation processing system is in progress. One is a client-server system working on unix system, in which dedicated client computers are deployed. Currently it is realized by using remote-shell. Another is screen-saver mode processing system named "VLBI@home". The latter one is based on the idea that most time of PC resource are idle. Actually, these distributed correlation systems were used in a Japan-US e-VLBI experiment and supported the rapid UT1 estimation in 4.5 hours.

3. Staff

- Tetsuro Kondo is responsible for overall operations and performance. He is also developing software correlators for geodetic purposes.
- Yasuhiro Koyama is in charge of correlation processing system and is working on e-VLBI on intercontinental baseline.
- Mamoru Sekido is in charge of KSP correlation system and is working on VLBI applications for spacecraft navigation.
- Moritaka Kimura is working on the development of a hardware Giga-bit correlator and a high speed Giga bit software correlator.
- Hiroshi Takeuchi is working on software digital filter and the next generation high speed sampler.

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