

# VLBI Correlators in Kashima

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## Abstract

Kashima Space Technology Center (KSTC) is making use of two kinds of software correlators, the multi-channel K5/VSSP software correlator and the fast wide-band correlator ‘GICO3,’ for geodetic and R&D VLBI experiments. Overview of the activity and future plans are described in this paper.

## 1. General Information

The Kashima Space Technology Center (KSTC) of the National Institute of Information and Communications Technology has developed two types of VLBI systems. The multi-channel VLBI system called ‘K5/VSSP’ [1, 2] and the wide band data acquisition system ‘K5/VSI’ [3, 4] were developed for applications of geodesy and astronomy, respectively. Software correlators for each of the systems have been developed and used for geodetic observing and R&D VLBI experiments.

The current main mission of our group is the development of transportable VLBI systems for frequency comparison over intercontinental distances. To gain better sensitivity with small diameter antennas, a wide-band observation system is employed in the system. Linear and dual polarization observing for the frequency range of 3-15 GHz almost meet the VLBI2010 specifications. The computation load of correlation is estimated to increase about two orders of magnitude over the conventional VLBI system; thus a new software correlator with a distributed computation design named KFC is planned.

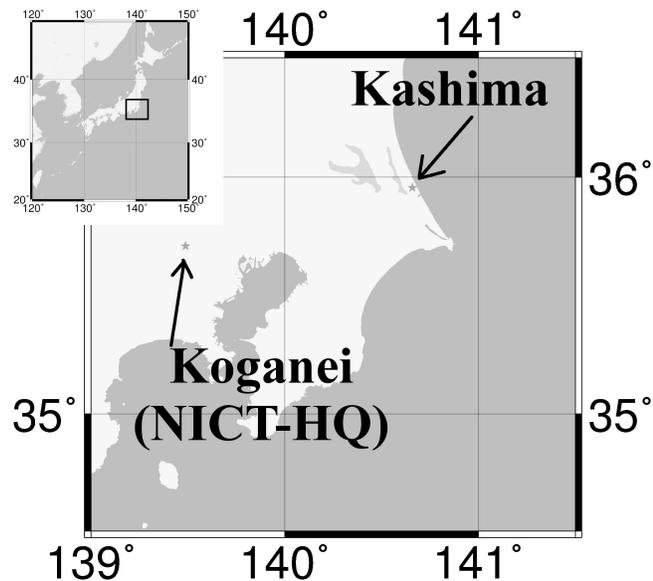


Figure 1. Locations of NICT Headquarters and KSTC.

## 2. Component Description

The KSTC correlator is mainly used for processing geodetic and R&D VLBI experiments organized by NICT. Two types of software correlators have been used.

### 2.1. K5/VSSP Software Correlator

**Correlation Type:** Both FX-type and XF-type software correlators are available in the K5/VSSP software suite [2]. The FFT algorithm used in the FX-type correlator has advantages in correlation with a large lag (delay) window, so it is mainly used for the clock

parameter search in the beginning of routine processing. The XF-type correlator is relatively faster than FX-type in the processing of 1-bit quantization data with a small lag number. Because a small lag number is sufficient for geodetic applications, the XF-type correlator is mainly used in routine 1-bit quantization data processing for geodesy. Except for the case above, the XF-type software is used.

**Processing unit:** The K5/VSSP32 DAS is designed with one or four channel inputs per unit, so four channels is designed to be the maximum number of data streams to be fed to a single correlation task. This is a benefit for distributed processing with this software correlator, because correlation tasks are divided by the unit of channels and can be processed independently with multiple CPUs.

**Processing speed:** The single four-channel processing rate is three to six times slower than the data acquisition rate, when a single task is run on an Intel(R) Core2 Duo 3GHz processor, for example. The total processing rate is compensated by multiple run of the tasks on a cluster of computers in routine operation. This software correlator code is compiled with the GNU gcc compiler and can work on any CPU.

**Other functions:** The correlation product includes all the necessary information such as phase calibration information for further reduction of geodetic VLBI. In the next step, the correlator output files are synthesized by the bandwidth synthesis ‘komb’ software [5] to extract precise group delays from the data.

## 2.2. GICO3 Software Correlator

**Correlation Type:** FX-type correlator that uses an FFT algorithm. The optimum lag window is around 1024 lags, which is determined by the overhead of the function calls and the size of the fast access cache memory [6].

**Processing unit:** Processing with an arbitrary number of channels is made possible by the initial configuration.

**Processing speed:** The processing rate of 2 Gbps is a few times slower than the real-time data acquisition rate in the case of processing with an Intel(R) Xeon(R) CPU with a 2.33GHz clock, for example.

**Other functions:** Cross correlation and auto-correlation results are obtained at the same time, so that it is suitable for astronomical applications. The extraction of precise delay observables and the creation of Mark III databases is available through using Mk3Tools [7].

## 3. Staff

The names of the staff members who contribute to the correlator at NICT/Kashima and their tasks are listed below in alphabetical order.

- HASEGAWA Shingo (Kashima): in charge of maintenance and troubleshooting of K5 system computers, tasks of the data conversion from K5/VSSP format to Mark 5 format in IVS sessions.

- HOBIGER Thomas (Koganei, Tokyo): development of a new VLBI database system based on NetCDF, research on atmospheric delay calibration with the ray tracing technique, and development of the new software correlator KFC for the wide-band VLBI systems.
- KONDO Tetsuro (Bangkok, Thailand): maintenance of the software correlator package and documentation of the K5/VSSP32 system.
- KOYAMA Yasuhiro (Koganei, Tokyo): the Leader of the International Cooperation Office of NICT. Conductor of VLBI experiments for frequency comparison.
- SEKIDO Mamoru (Kashima): Coordination of VLBI experiments and development of the new VLBI system for frequency comparison.
- TAKEFUJI Kazuhiro (Kashima): Development of the new wide-band VLBI system with the small diameter antenna MARBLE and processing of experiment data with the GICO3 software correlator.
- TSUTSUMI Masanori (Kashima): maintenance of K5 system computers and the network.

#### 4. Current Status and Activities

Table 1 shows a list of the experiments processed by the K5 software correlator. Because Time and Frequency comparison is the main project, some experiments for feasibility testing were made with the 11-m antennas. These data were processed with the K5/VSSP software correlator running on multi-core PCs (e.g., CPU Intel Core i7 920 2.67 GHz cache 8192 KB, Processor 4 (Hyper Threading Total Core8), Memory 12 GB).

Table 1. Correlation tasks processed with the K5/VSSP correlator in 2012.

Project	Exp code	Date	Stations	baseline x scans x days	Data rate (Mbps)
Freq. Comp.	K1203x	2-6 Feb.	K1,Kg	1 x 4723 (4 days)	512
Freq. Comp.	K12050	19-21 Feb.	K1,Kg	1 x 2295 (2 days)	512
Freq. Comp.	K12052	21-22 Feb.	K1,Kg	1 x 1349 (1 day )	512
Freq. Comp.	K122nx	28-31 Jul.	K1,Kg	1 x 4723 (3 days)	512
Freq. Comp.	K122wx	31 Jul.-4 Aug.	K1,Kg	1 x 3593 (3 days)	512
Sgr-A*	sg1218x	28 Jun.-8 Jul.	K1,Kg	1 x 35 x 10 days	512
Sgr-A*	sg1228x	11-15 Oct.	K1,Kg	1 x 35 x 6 days	512
Sgr-A*	sg12362	27 Dec.	K1,Kg	1 x 35 x 1 day	512

K1:Kashima-11m, Kg:Koganei-11m

Except for the frequency comparison, monitoring of Sgr-A\* with S/X-band was organized with K5/VSSP32. Since it is predicted that a bunch of material will fall into the massive black-hole at the center of our galaxy by the summer in 2013, huge energy is expected to be emitted in the form of electromagnetic radiation in a wide frequency range. This monitoring observation will be continued in 2013 under collaboration with Keiou University, Ibaraki University, and the National Astronomy Observatory of Japan.

In addition to these experiments, fringe test and performance test experiments for a small diameter antenna with the K5/VSI (ADS3000+) data acquisition system were conducted. The GICO3 software correlator was used for this processing.

## 5. Future Plans

The project mission of the VLBI group in NICT is to establish a VLBI system for Time and Frequency comparison. For this purpose, we are developing the transportable wide-band VLBI system, which is semi-compliant with the VLBI2010 specifications. A new software correlator with distributed computation design is planned for this project [8].

## References

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