VLBI Correlators in Kashima

Mamoru Sekido, Tetsuro Kondo, Yasuhiro Koyama, Moritaka Kimura

Abstract

Correlators at Kashima have been developed for data processing of experimental VLBI observations for geodesy, spacecraft navigation and astronomy. A new PC-based VLBI sampler K5/VSSP32 is under development. Real-time data processing with software correlator was demonstrated with intercontinental baseline (Kashima – Westford) at JGN2 symposium in January 2007. Construction of software correlator as backup correlator for VERA project has been in progress as a 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 contributing to the VLBI community by development of VLBI technologies. In April 2006, the name of our group was changed from "Radio Astronomy Applications Section" to "Space-Time Application Project".

The hardware correlator developed for the Key Stone Project [1] is still available at KSRC, though it was not used in 2006. Instead, software correlator running on personal computers (PC) is mainly used for data processing of geodetic and spacecraft VLBI observations. Figure 1 shows a view of the observation room of the 34m station. The cluster of PCs are used for both VLBI data acquisition and correlation processing. VLBI data obtained at other stations are transferred to Kashima through the network or by sending hard disk drives (HDD) via usual mail. The cluster of PCs is used for correlation processing by sharing the data via Local Area Network (LAN). For the practical use of the software correlator, we have a contract with National Astronomical Observatory of Japan (NAOJ) to build a correlator system by using software correlator as a backup system for the VERA project [2].

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

A demonstration of real-time correlation processing of intercontinental baseline was successfully performed in the JGN2 symposium held in Hiroshima, Japan in January 2007. That success was achieved by strong support from staff of Haystack Observatory and Network people of JGN2 [3], Internet2 [4] and Dragon project [5].

2. Component Description

2.1. Data Processing for Geodesy

New version of PC-based sampling system K5/VSSP32 [6] is under development by Nitsuki Co Ltd under supervision of T.Kondo. The new observation and correlation software compatible with

K5/VSSP32 sampler is being prepared by T.Kondo.

A project named "Caravan" to build a prototype of a small VLBI antenna system with wide-band data acquisition system [7] is in progress. A 2.4m diameter antenna equipped with a gigabit recording system was tested with geodetic VLBI experiments between the 2.4 m station and Tsukuba 32m diameter telescope. The first test observation was 16 MHz sampling 8 channel only for X-band by using the K5/VSSP data acquisition system. Correlation was performed with software correlator. Further test experiments are planned for February 2007.

2.2. Data Processing of Spacecraft Observation

A series of VLBI observations of spacecraft HAYABUSA were organized in November 2005; at that time HAYABUSA made touch down to the asteroid ITOKAWA. A limit in precision of delay measurement was caused by spacecraft signal, since Japanese space missions have not been designed to transmit multi-tone signals with large frequency separation for VLBI spacecraft navigation. The phase delay observable has the potential for much higher precision of delay measurement, though absolute delay measurements are difficult due to phase ambiguity. The occasion of HAYABUSA's approach to ITOKAWA was a good chance to evaluate the calibration precision of Delta-VLBI technique with phase delay. Because the orbit of Itokawa is given with enough precision by other techniques (radar and optical measurement), it is possible to use phase delay observable assuming zero ambiguity by using Itokawa's orbit as a priori position of HAYABUSA. In this case, the purpose of the measurement is not orbit determination, but evaluation of the Delta-VLBI calibration technique. For this purpose, correlation processing to extract phase delay was performed with software correlator developed by M.Sekido. The excess delay correction with Delta-VLBI was confirmed to be successful in the order of 0.1 nanoseconds.

In 2007, the Japanese and Chinese space agencies will launch a lunar mission, which will use the VLBI technique extensively for measuring the lunar gravity field. China operates four VLBI stations for this lunar mission. As a test experiment, Japanese spacecraft GEOTAIL was observed jointly with Japanese and Chinese VLBI stations in December 2006. The data were recorded with Mark 5 system in China and with K5 system in Japan. Data conversion is in progress for data exchange and correlation processing in both countries. The ease of data conversion between different data acquisition systems is a benefit of PC-based recording systems. Realization of VSI-E will completely remove the troubles of data conversion between different VLBI systems in the near future.

2.3. E-VLBI Demonstrations

NICT is a unique institute which has specialists both in network research and in VLBI research. We are collaborating with Network Architecture Group and JGN2 group within NICT. The JGN2 is a high-speed network test-bed for encouraging the network research funded by Ministry of Internal Affairs and Communications. We are participating in JGN2 as a user and have performed e-VLBI demonstrations in conferences. The international conference of "Super Computing 2006" was held in Tampa in Florida in November 2006. Since a high-speed network connection to the Haystack Observatory was not available at the time, we performed pseudo VLBI data transfer to Kashima from a server placed in Chicago. Then the correlation results were output to a display in Tampa. The data transfer rate was 512 Mbps. At the JGN2 symposium held in Hiroshima in January 2007, we demonstrated real-time VLBI

data processing with distributed software correlators. Thanks to support from people of the Haystack Observatory, we could use Westford 18m diameter radio telescope as a counter part. Since a high speed dedicated network connection through GROWNET and BOSSNET was not ready at that time, we used a shared network for the connection from Haystack to Chicago. The stable network performance with TCP/IP was unfortunately less than 64 Mbps; hence we wrote a program to extract one channel of the 16 Mbps 2bit data stream from 16MHz × 32 bit parallel data stream provided by VSI-H standard interface. Then the single channel of data was transferred to software correlators in Tokyo. The software correlator is composed of three PCs located at Akihabara, Otemachi, and Koganei, which are interconnected by an optically linked network. The fringe of 3C84 was successfully detected with real-time correlation processing with software correlator, and the result was transferred to Hiroshima for display. The successful achievement of these demonstrations was due to support from staff of Haystack, JGN2, Internet2 DRAGON project, and network group of NICT.

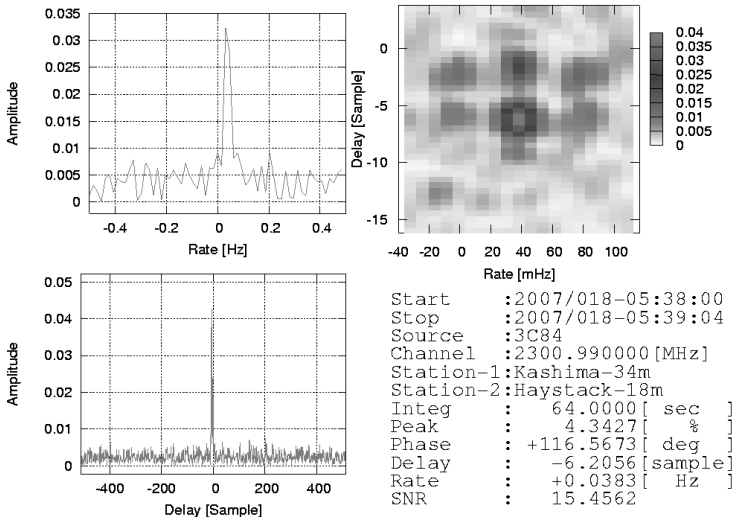

Figure 2. Fringe for 3C84 detected in real-time software correlation on Westford (18m)–Kashima (34m) baseline

2.4. Construction of Software Correlator for VERA Project

Our group has a contract with NAOJ to build a software correlator for the VERA project [2]. The VERA project already operates an FX-correlator, which was originally developed for VSOP project [8]. The software correlator system is being prepared [9] for replacement or as a backup of the current correlator. The specifications of the software correlator are given in Table 1. This system is going to be complete in 2007.

Table 1. Picture and specifications 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

3. Staff

- Tetsuro Kondo is working on the development and maintenance of the software correlator for K5/VSSP [10]. Data format converter between Mark 5 and K5 is included in his package. Also he is in charge of new version of PC-based VLBI sampler K5/VSSP32 [6].
- Yasuhiro Koyama is project leader of "Space-Time Application Project" and is in charge of overall activity in our group.
- Mamoru Sekido is in charge of the e-VLBI activity and writing software for data transfer over the network. He is also working on VLBI applications for spacecraft navigation [11, 12].
- Moritaka Kimura is working on the development of a high speed Gigabit software correlator. He is in charge of development of software correlators for VERA project of NAOJ.
- Masanori Tsutsumi is working as system engineer for maintenance of PCs.

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