VLBI Correlators in Kashima

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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 the development. Real-time data processing with software correlator has been 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

VLBI group of Kashima Space Research Center (KSRC) of National Institute of Information and Communications Technology (NICT) has been contributing to VLBI community by development of VLBI technologies. In April 2006, name of our group has been changed from "Radio Astronomy Applications Section" to "Space-Time Application Project".

Hardware correlator developed for Key Stone Project[1] is still available at KSRC, though it was never used in 2006. Instead, software correlator running on personal computer (PC) is mainly used for data processing of geodetic and spacecraft VLBI observations. Figure 1 shows a view of 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 transfered to Kashima through the network or by sending hard disk drive (HDD) via usual mail. The cluster of PCs are used for correlation processing by sharing these data via Local Area Network (LAN). For practical use of software correlator, we have an contract with National Astronomical Observatory of Japan (NAOJ) to build an correlator system by using software correlator as an backup system for VERA project[2].

Figure 1. A view of 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 has been achieved by strong support by 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 the development by Nitsuki Co Ltd under supervision by 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 small VLBI antenna system with wide-band data acquisition system [7] is in progress. Diameter of 2.4m antenna equipped with gigabit recording system has been 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 K5/VSSP data acquisition system. Correlation has been performed with software correlator. Further test experiment is being planed in February 2007.

2.2. Data Processing of Spacecraft Observation

A series of VLBI observation of spacecraft HAYABUSA have been organized in November 2005, at that time the HAYABUSA made touch down to the asteroid ITOKAWA. An limit in precision of delay measurement has been caused by spacecraft signal, since Japanese space missions have not been designed to transmit multi tones signal with large frequency separation for VLBI spacecraft navigation. Phase delay observable has a potential of much higher precision of delay measurement, though absolute delay measurement has been hard 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 technique (radar and optical measurement), then we can use phase delay observable with 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 has been performed with software correlator developed by M.Sekido. The excess delay correction with delta-VLBI has been confirmed to be successful in the order of 0.1 nano seconds.

In 2007, Japanese and Chinese space agency will launch a lunar mission, which uses VLBI technique extensively for measurement of lunar gravity field. Now China has been operating four VLBI stations for this lunar mission. As an test experiment, Japanese spacecraft GEOTAIL has been observed jointly with Japanese and Chinese VLBI stations in December 2006. The data were recorded with Mark5 system in China and with K5 system in Japan. Data conversion is in progress for data exchange and correlation processing at both countries. The easiness in data conversion between different data acquisition systems is a benefit of PC-based recording system. Realization of VSI-E will completely remove such troublesomeness in data conversion among different VLBI systems in near future.

2.3. e-VLBI demonstrations

NICT is an unique institute which has both specialists 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 JGN2 as a user and have performed e-VLBI demonstrations in conferences. International conference of "Super Computing 2006" has held at Tampa in Florida in November 2006. Since high-speed network connection to the Haystack Observatory was not available at this time, we performed pseudo VLBI data transfer to Kashima from a server placed at Chicago. Then the correlation results was output to Tampa for display. The data transfer rate was 512 Mbps. In JGN2 symposium held at 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 high speed dedicated network through GROWNET and BOSSNET was not ready at this time, we used shared network for connection from Haystack to Chicago. The stable network performance of with TCP/IP was unfortunately less than 64 Mbps, then we wrote a program to extract one channel of 16 Mbps 2bit data stream from 16MHz $\times$ 32 bit parallel data stream provided by VSI-H standard interface. And the single channel of data was transfered to software correlators in Tokyo. The software correlator is composed of three PCs located at Akihabara, Otemachi, and Koganei, which are connected each other by optically linked network. The fringe of 3C84 was successfully detected with real-time correlation processing with software correlator, and the result was transfered to Hiroshima for display. The successful achievement in these demonstrations were owing to support from staff of Haystack, JGN2, Internet2, DRAGON project, and network group of NICT.

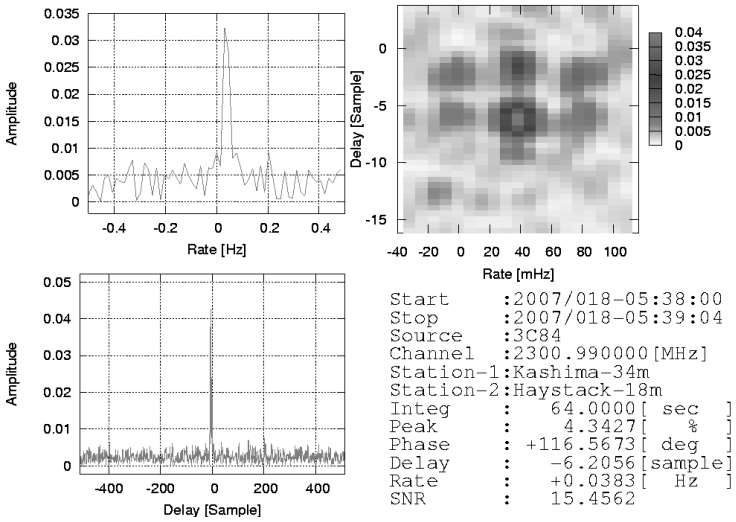

Figure 2. Fringe for 3C84 detected in real-time software correlation on Westford 18m- Kashima 34m baseline

2.4. Construction of Software correlator for VERA project

Our group have a contract with NAOJ to build a software correlator for VERA project[2]. Already the VERA project has been in operation with FX-correlator, which was originally developed for VSOP project[8]. For replacement or as a backup of current correlator, software correlator system is being prepared[9]. The specification of the software correlator is in table 1. This system is going to be complete in this year.

Table 1. 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

3. Staff

- Tetsuro Kondo is working for development and maintenance of software correlator for K5/VSSP[10]. Data format converter between Mk5 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 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 Giga bit 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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