Kashima 34-m VLBI Network Station Report for 2015-2016

Mamoru Sekido [1] and Eiji Kawai [1]

Abstract The NICT Kashima 34-m diameter radio telescope has been regularly participating to VLBI sessions organized by the IVS with standard S/X band receiver. The station is maintained by VLBI group of Space Time Standards Laboratory of NICT. VLBI application for precision frequency transfer is the main project of this group. Broadband feed of narrower beam width was originally developed for the 34-m antenna of Cassegrain optics. Broadband VLBI experiments for evaluation of receiver and data acquisition system have been conducted with Kashima 34m antenna of NICT, Ishioka 13m station of GSI, and with two small diameter VLBI stations located NMIJ(Tsukuba) and NICT(Koganei). In addition to geodetic and time transfer VLBI observation, the Kashima 34m antenna has been used for astronomical VLBI observations with radio telescopes of NAOJ and domestic universities, and for single dish observation for Jupiter and Pulsar.

Fig. 1 The Kashima 34-m radio telescope.

1 General Information

The 34-m diameter radio telescope has been maintained and operated by the VLBI group of Space Time Standards Laboratory (STSL) in the National Institute of Information and Communications Technology (NICT). It is located in the Kashima Space Technology Center (KSTC), which is at the east coast of the main island of Japan. The STSL includes groups of Japan Standard Time, and Atomic Frequency Standard. They are engaed in keeping national time standard JST and development of advanced optical frequency standard, respectively. The other group of STSL is working for frequency transfer by using communication satellite and GNSS observations. Our VLBI group is sharing the task of development of precision time transfer technique by means of VLBI. A new broadband VLBI system is being developed for application of time transfer and to be compatible with the VGOS system for future joint observation.

1. NICT Space-Time Standards Laboratory/Kashima Space Technology Center

Table 1 Antenna performance parameters of the Kashima 34-m telescope.

Receiver	Pol.	Frequency	SEFD [Jy]
L-band	RHCP/LHCP	1405-1440MHz 1600-1720 MHz	$\sim$ 300
S-band	RHCP/LHCP	2210-2350 MHz	$\sim$ 350
X-band	RHCP/LHCP	8180-9080 MHz	$\sim$ 300
Wideband	V-Linear Pol.	3.2-11 GHz	$\sim$ 1000 – 2000
K-band	LHCP	22 - 24 GHz	$\sim$ 2000
Q-band		42.3-44.9 GHz	$\sim$3000

2 Component Description

2.1 Receivers

The Kashima 34-m antenna has multiple receiver systems from 1.4 GHz up to 43 GHz. The performance parameters for each frequency are listed in Table 1. Receiving bands are changed by exchanging receiver systems at the focal point of the antenna. Each receiver is mounted on one of four trolleys, and only one trolley can be at the focal position. The focal point is adjusted by the altitude of the sub-reflector with five axes actuators.

Fig. 2 Broadband NINJA feed has been installed in the receiver room of the Kashima 34-m telescope.

2.2 Data Acquisition System

Three types of data acquisition systems (DAS) have been developed and installed at the Kashima 34-m station.

K5/VSSP32 is a multi-channel data acquisition system with narrow frequency width up to 32 MHz[1]. One unit of K5/VSSP32 sampler (Fig.3) has four analog inputs. Analog data is digitized by 64 MHz sampling rate in the first stage, then frequency shaped by digital filter at the second stage. Variety of sampling rate (0.04 - 64 MHz) and quantization bits (1 - 8 bit) are selectable. Four units of K5/VSSP32 compose one set of geodetic VLBI DAS with 16 video channels. Observed data is recorded in K5/VSSP data format. Software tools for observation and data conversion to Mk5A/B format are freely available. Please visit the web site [1] for details on K5/VSSP sampler specification and software resources.

Fig. 3 One unit of K5/VSSP32 sampler has four video signal inputs. Data output and remote control is made via USB2.0 interface. One geodetic terminal of 16 video signals is composed of four units of this device.

K5/VSI is a data recording system composed of a computer with 'PC-VSI' data capture card, which receives VSI-H data stream as input and transfers it to CPU of the computer via PCI-X interface (Fig.4). Thankso the standardized VSI-H interface specification, this system can be used to record any data stream of VSI-H interface[2]. NICT Kashima 34-m station is equipped with three kinds of VSI-H samplers (ADS1000, ADS2000[2], and ADS3000+[3]). The ADS3000+ sampler is capable of both broadband observations (1024

[1] http://www2.nict.go.jp/sts/stmg/K5/VSSP/index-e.html

[2] http://vlbi.org/vsi/

Msps/1ch/1bit, 128 Msps/1ch/8bit) and multi narrow channels observation by using digital BBC function, where one of 2, 8, 16, or 32 MHz video band widths are selectable.
The K5/VSSP32 samplers and analog frequency video converter had been used for observations of IVS sessions at NICT. Since 2016, Kashima 34-m station has began to use ADS3000+ with DBBC function for IVS sessions.

Fig. 4 Upper panel shows PC-VSI card, which captures VSI-H data stream. Up to 2048 Mbps data stream is captured by one interface card. Lower panel shows ADS3000+, which is capable to extract 16 channels of narrow band signals via DBBC function, and it outputs data stream though VSI-H interface.

K6/GALAS is the new high speed sampler for broadband VLBI observation project GALA-V[4]. Analog input data converted to digital data by 16.384 GHz sampling rate. Four digital data streams of 1024 MHz frequency width at requested frequencies are extracted by digital frequency conversion and filtering function of the sampler. Output data comes out via 10 Gbit-Ether-net interface with VDIF/VTP/UDP packet streams. A new aspect of K6/GALAS is so called 'RF-Direct Sampling', in which radio frequency (RF) signal is directly captured without frequency conversion. This 'RF-Direct Sampling' technique has advanced characteristic in precision delay measurement by VLBI.

3 Staff

Members who are contributing to keep and to run the Kashima 34-m station are listed below in alphabetical order:

- HASEGAWA Shingo is the supporting engineer for IVS observation preparation and maintenance of file servers for e-VLBI data transfer.
- ICHIKAWA Ryuichi is in charge of keeping GNSS stations.
- KAWAI Eiji is the main engineer in charge of the hardware maintenance and the operation of the 34-m station. He is responsible for routine geodetic VLBI observations for IVS.
- KONDO Tetsuro is mainting K5/VSSP software package and working for implementation of ADS3000+ control function to FS9.
- SEKIDO Mamoru is responsible for the Kashima 34-m antenna as the group leader. He maintains FS9 software for this station and operates the Kashima and Koganei 11-m antennas for IVS sessions.
- TAKEFUJI Kazuhiro is a researcher using the 34-m antenna for the GALA-V project and the Pulsar observations. He worked for installation of the broadband IGUANA and NINJA receivers, and made the subreflector position adjustiment and perfomance measurement of the new receiver.
- TAKIGUCHI Hiroshi is a researcher for analysis of T&F transfer and geodesy with GNSS observations.
- TSUTSUMI Masanori is the supporting engineer for maintenance of data acquisition PCs and computer network.
- UJIHARA Hideki is a researcher designing the new broadband IGUANA-H and NINJA feeds.

4 Current Status and Activities

4.1 VLBI Sessions for IVS, AOV, and JADE

Kashima 34-m station is participating VLBI sessions (CRF, RV, T2, and APSG) conducted by IVS. Asia-Oceania VLBI Group for Geodesy and Astrometry(AOV) has been established since 2014, and started local VLBI sessions. Kashima 34-m station has been

participating AOV session and JADE session, which is Japanese domestic VLBI session conducted by geographical survey institute (GSI) to keep station coordinates . The JADE session was terminated in 2014.

As described above, data acquisition terminal K5/VSSP32 or ADS3000+ have been used for data recording in K5/VSSP data format. For exporting data to foreign correlation center, the data is converted to Mk5B format by using tools of K5/VSSP package. All the data provision to correlation center is made by e-Transfer though data servers listed in Table 2. Thanks to collaboration with Research Network Testbed JGN, 10 Gbps network connection is available to Kashima Space Technology Center. Server *k51c* is capable to transfer the data with 10 Gbps, though *k51b* is limited to 1 Gbps due to network interface card in it.

Table 2 VLBI data servers for exporting data by e-Transer to correlation centers.

Server name	Data capacity	Network Speed
k51b.jp.apan.net	27 T Byte	1 Gbps
k51c.jp.apan.net	46 T Byte	10 Gbps

4.2 Broadband VLBI experiments

The main mission of the VLBI project of NICT is the development of broadband VLBI systems for application of distant frequency transfer. This project named GALA-V [4] is targeting to make precision frequency comparison between small diameter VLBI stations, which are equipped with broadband VLBI observation system compatible with VGOS. Originally developed broadband IGUANA-H feed[5] was mounted in the end of 2013 and first international VLBI observation was successfully performed with Haystack Observatory in January 2014. Another broadband NINJA feed was mounted at the 34-m telescope in July 2014, then frequency range 3.2 — 13 GHz has become available. VLBI experiments for development of data acquisition system and signal processing have been conducted with Ishioka 13m station of GSI in the summer of 2015 and 2016. Wideband bandwidth synthesis software [6] has been developed, and sub-pico second precision delay measurement was achieved by the broadband system. A series of test VLBI sessions over 24 hours long have been conducted with GALA-V system in 2016. More detail of the observations and example of the results are reported in "NICT VLBI Analysis Center Report" [7].

4.3 Observations under Collaborations

Under collaboration with National astronomical observatory of Japan(NAOJ) and domestic universities, this 34-m radio telescope has been used for VLBI observations and single dish observations.

Pulsar observation: Under collaboration with Prof. Terasawa of RIKEN Japan, Tohoku Univ. and JAXA, multi frequency observations for Crab pulsar have been conducted[8]. Kashima 34-m antenna has been used for this observation with L-band receiver. **Jupiter Observation:** For investigation of Jovian Synchrotron radiation, S-band receiver of Kashima 34-m antenna has been used. **Astronomical VLBI Observations:** Under collaboration with NAOJ, Yamaguchi Univ., Ibaraki Univ., and Tsukuba Univ., Kashima 34-m station is participating domesitic astronomical VLBI observations with X-band, K-band, and Q-band receivers.

5 Future Plans

Implementation of function for remote setup and data recording control over ADS3000+ from FS9 is in progress by Dr. T. Kondo. That might be suported in standard FS9 release in future.

Progress of corrosions at the backup structure of the 34-m station was found in 2016. Repair work as counter measure to the corrosion is being planned for some months in the latter half of 2017.

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