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

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

Fig. 1 The Kashima 34-m radio telescope.

1 General Information

The 34-m diameter radio telescope is 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 the Japan Standard Time and the Atomic Frequency Standard groups. They are engaged in keeping the national time standard JST and in the development of an advanced optical frequency standard, respectively. The other group of STSL is working for frequency transfer by using communication satellites and GNSS observations. Our VLBI group is sharing the task of precision time transfer technique development 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 observing.

NICT Space-Time Standards Laboratory/Kashima Space Technology Center

NICT Kashima 34-m Network Station

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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 axis actuators.

Fig. 2 A broadband NINJA feed was 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 a narrow frequency width up to 32 MHz [1]. One unit of the K5/VSSP32 sampler (Figure 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. A variety of sampling rates (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 Mark 5A/B format are freely available. Please visit the Web site[1] for details on K5/VSSP sampler specifications 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 a 'PC-VSI' data capture card, which receives a VSI-H data stream as input and transfers it to the CPU of the computer via a PCI-X interface (Figure 4). Thanks to the standardized VSI-H interface specification, this system can be used to record any data stream of the VSI-H interface[2]. The 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

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

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

(1024 Msps/1ch/1bit, 128 Msps/1ch/8bit) and multi narrow channel observing by using the digital BBC function, where one of the 2, 8, 16, or 32 MHz video band widths can be selected.
The K5/VSSP32 samplers and analog frequency video converter had been used for observing IVS sessions at NICT. Since 2016, the Kashima 34-m station has begun to use ADS3000+ with the 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 the broadband VLBI observation project GALA-V [4]. Analog input data are converted to digital data at a 16.384 GHz sampling rate. Four digital data streams of 1024 MHz frequency width at requested frequencies are extracted by digital frequency conversion and the filtering function of the sampler. Output data comes out via a 10 Gbit-Ethernet interface in VDIF/VTP/UDP packet streams. A new aspect of K6/GALAS is so called 'RF-Direct Sampling', in which a radio frequency (RF) signal is directly captured without frequency conversion. This 'RF-Direct Sampling' technique has advanced the characteristic of precision delay measurements by VLBI.

3 Staff

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

- HASEGAWA Shingo is the supporting engineer for IVS observing preparation and maintenance of file servers for e-VLBI data transfer.
- ICHIKAWA Ryuichi is in charge of maintaining GNSS stations.
- KAWAI Eiji is the main engineer in charge of hardware maintenance and the operation of the 34-m station. He is responsible for routine geodetic VLBI observations for IVS.
- KONDO Tetsuro maintains the K5/VSSP software package and is working to implement the ADS3000+ control function in FS9.
- SEKIDO Mamoru is responsible for the Kashima 34-m antenna as the group leader. He maintains the 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 on the installation of the broadband IGUANA and NINJA receivers and made the subreflector position adjustment 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 the 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

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

started local VLBI sessions. The Kashima 34-m station has been participating in AOV sessions and JADE sessions, which are Japanese domestic VLBI sessions conducted by the Geographical Survey Institute (GSI) to maintain station coordinates. The JADE sessions were terminated in 2014.

As described above, the K5/VSSP32 or ADS3000+ data acquisition terminals were used for data recording in the K5/VSSP data format. To export data to a foreign correlator, the data is converted to Mark 5B format using tools from the K5/VSSP package. All of the data provision to the correlator is made by e-Transfer through data servers listed in Table 2. Thanks to collaboration with Research Network Testbed JGN, a 10 Gbps network connection is available to the Kashima Space Technology Center. The server *k51c* is able to transfer the data at 10 Gbps, although *k51b* is limited to 1 Gbps due to the network interface card in it.

Table 2 VLBI data servers for exporting data by e-Transfer to correlators.

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

4.3 Observations under Collaborations

In collaboration with the 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 observations: In collaboration with Prof. Terasawa of RIKEN Japan, Tohoku University, and JAXA, multi-frequency observations of the Crab pulsar have been conducted [8]. The Kashima 34-m antenna has been used for this observing with an L-band receiver.

Jupiter Observations: For the investigation of Jovian Synchrotron radiation, the S-band receiver of the Kashima 34-m antenna has been used.

Astronomical VLBI Observations: Under collaboration with NAOJ, Yamaguchi University, Ibaraki University, and Tsukuba University, the Kashima 34-m station is participating in domestic astronomical VLBI observing with its X-band, K-band, and Q-band receivers.

5 Future Plans

Implementation by Dr. T. Kondo of remote setup and data recording control over ADS3000+ from FS9 is in progress. This might be supported in the standard FS9 release in the future.

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

Acknowledgements

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