Kashima 34-m VLBI Network Station Report for 2017–2018

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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. The VLBI application for precision frequency transfer is the main project of this group. The broadband feed of narrower beam width was originally developed for the 34-m antenna with Cassegrain optics. Broadband VLBI experiments for the evaluation of the receiver and data acquisition system have been conducted with the Kashima 34-m antenna of NICT and with two small diameter VLBI stations located in Medicina (Italy) and NICT (Koganei, Japan). In addition to geodetic and time transfer VLBI observing, the Kashima 34-m antenna has been used for astronomical VLBI observing and for single dish observing of Jupiter and pulsars.

1 General Information

The 34-m diameter radio telescope (Figure 1) 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 about 100 km east of Tokyo, Japan. The STSL includes groups of Japan Standard Time and Atomic Frequency Standard. They are engaged in keeping the national time standard JST and development of advanced optical frequency standard, respectively. The other group of STSL is working on frequency transfer using communications satellites 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.

NICT Space-Time Standards Laboratory/Kashima Space Technology Center

NICT Kashima 34-m Network Station

IVS 2017+2018 Biennial Report

Fig. 1 The Kashima 34-m radio telescope.

2 Component Description

2.1 Receivers

The Kashima 34-m antenna has multiple receiver systems from 1.4 GHz up to 22 GHz. A Q-band (43 GHz) receiver is mounted, although it has not been available since 2017 due to a phase-locked oscillator problem. The performance parameters for each frequency are listed in Table 1. The receiving bands are changed by exchanging receiver systems at the focal point of the

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	∼ 300
S-band	RHCP/LHCP	2210-2350 MHz	∼ 350
X-band	RHCP/LHCP	8180-9080 MHz	∼ 300
Wideband	V-Linear Pol.	3.2-11 GHz	∼ 1000 – 2000
K-band	LHCP	22 - 24 GHz	∼ 2000
Q-band **		42.3-44.9 GHz	∼3000

** Q-band is currently not available.

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 subreflector with five axes actuators.

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 the K5/VSSP32 sampler (Figure 3) has four analog inputs. Each analog signal is digitized at a 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 the K5/VSSP32 compose one set of geodetic VLBI DAS with 16 video channels. The observed data is recorded in K5/VSSP data format. Software tools for observation and data conversion to the Mark 5A/B format are freely available. Please visit our Web site[1] for details on the K5/VSSP sampler specification and software resources.

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

Fig. 3 One unit of the K5/VSSP32 sampler has four video signal inputs. Data output and remote control are made via a 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 a VSI-H interface[2] [2]. The NICT Kashima 34-m station is equipped with three kinds of VSI-H samplers (ADS1000 and ADS3000+ [3]). The ADS3000+ sampler is capable of both broadband observations (1024 Msps/1ch/1bit, 128 Msps/1ch/8bit) and multi narrow channel observations using the 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 was used for observations of IVS sessions at NICT. Since 2016, the Kashima 34-m station has begun to use ADS3000+ with the DBBC function for IVS sessions.

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

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 through VSI-H interface.

K6/GALAS is the new high speed sampler for the broadband VLBI observation project GALA-V [4]. An analog radio frequency signal is converted to digital data at a 16.384-GHz sampling rate. Four digital data streams of 1024-MHz frequency width at any frequencies selected by 1-MHz step resolution are extracted by digital frequency conversion and filtering function of the sampler. This is a new aspect of K6/GALAS, 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 characteristic in precision delay measurement by VLBI. Output data comes out via a 10 Gbit-Ethernet interface with VDIF/VTP/UDP packet streams.

3 Staff

The staff members contributing to running and maintaining 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 the routine geodetic VLBI observations for IVS.
- KONDO Tetsuro is maintaining the K5/VSSP software package and working on the implementation of the ADS3000+ control function in FS9.
- MIYAUCHI Yuka is in charge of the data acquisition software.
- SEKIDO Mamoru is responsible for the Kashima 34-m antenna as the group leader. He maintains the FS9 software 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 pulsar observations. He worked on the installation of the broadband NINJA feed system, and made subreflector position adjustments and performance measurements of the new receiver.
- TSUTSUMI Masanori is the supporting engineer for the 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 IVS Sessions

The Kashima 34-m station is participating in geodetic VLBI sessions (T2, CRF, RD, APSG, AOV, and R1). All the data provision to the correlator is made via e-transfer using the data servers listed in Table 2.

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

Server name	Data capacity	Network Speed
k51b.jp.apan.net	44 TByte	1 Gbps
k51c.jp.apan.net	22 TByte	10 Gbps

Thanks to collaboration with Research Network Testbed JGN, a 10-Gbps network connection is available to Kashima Space Technology Center. The server *k51c* is able to transfer the data at 10 Gbps, while *k51b* is limited to 1 Gbps due to its network interface card.

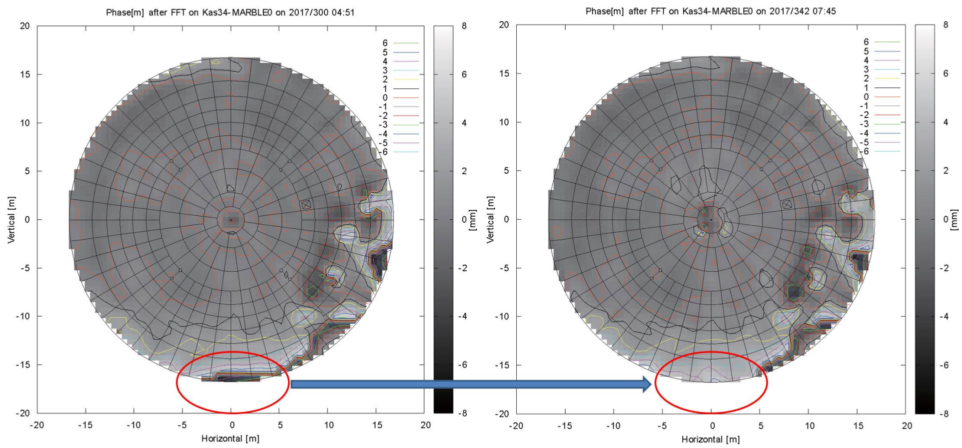

Fig. 5 Contour map of surface height distribution obtained by holography test in 2017. The large deviation of flatness found in the initial measurement (left) was adjusted (right). We confirmed the accuracy of the holographic measurement in preparation of the repair work in 2018.

4.2 Broadband VLBI Experiments

As the mission of our project, we have been conducting broadband VLBI experiments for frequency transfer. Broadband VLBI is performed by using the Kashima 34-m antenna (O), a small diameter broadband VLBI antenna (A) installed at National Metrology Institute of Japan (NMIJ), and another one (B) at headquarters of NICT at Koganei. From the VLBI delay data of OA and OB baselines, that of AB baseline is computed by closure delay relation. This observation scheme is named 'Node-Hub' Style (NHS) VLBI [5]. After testing this NHS VLBI, one of the small antennas was exported to Medicina observatory in Italy in July 2018. Under collaboration with Italian National Metrological Research Institute INRiM and INAF, we have started an optical clock frequency transfer experiment between the Yb optical clock at INRiM in Italy and the Sr optical clock at the headquarters of NICT (Koganei) in Japan.

4.3 Maintenance Work

Holographic Reflector Surface Measurement and Adjustment

Repair work of the main reflector backup structure damaged by corrosion was made in the period between June and September 2018. Damage due to rust was found via inspection with an aerial vehicle by ourselves in October 2016. Then we made an effort to keep a budget and design and finally carried this out in 2018. Because it was supposed that some part of the steel angle supporting the main reflector needs to be replaced during the work, we have to prepare for reflector height adjustment after the work. In 2017, we did test observing with a 12.5 GHz geostationary satellite signal and confirmed the accuracy of the measurement (Figure 5) [6].

Fig. 6 The Kashima 34-m antenna in holographic observing after reflector adjustment. We carried out the reflector adjustment during day time and the holography observing in the evening. We repeated this procedure for a week. For safety, we watched the antenna during the holography observing for about 1.5 hours to avoid an accidental smash with the scaffolding.

Just after the repair work in September 2018, we carried out reflector height adjustment using scaffolding for repair work in 2018. Surface height measurement by holography and adjustment of the panel was repeated by ourselves. Figure 6 shows the scaffolding standing on the north side of the 34-m antenna. Reflector flatness (pp 12.7 mm, RMS 1.2 mm) just after the repair work was improved (pp 2.3 mm, RMS 0.3 mm) by the holographic measurement and adjustment.

Helium Gas Leakage Trouble Shooting

A helium gas leak was found in February 2017. The cause of the leak was identified on one pipe running at the elevation cable wrap section. Finally we fixed the leakage by replacing four 25-m length helium tubes in October 2017. For some part of this period, the cooled receiver system had to be operated at room temperature.

5 Future Plans

We have started an optical clock time transfer experiment between the Yb optical clock at INRiM in Italy and the Sr optical clock at the headquarters of NICT (Koganei) for the period between 2018–2019. The small telescope at Medicina will be returned back to Japan by August 2020.

We are really regretful that the Kashima 34-m antenna has been planned to be dismantled from the middle of 2020. The background reasons are aging of the antenna, maintenance costs, and difficulty in obtaining repair parts.

Acknowledgements

We thank H. Mikoshiba and K. Handa of NAOJ for advice on holographic reflector surface measurement. The high-speed network environment is supported by the High Speed R&D Network Testbed JGN. We thank K. Namba and Y. Okamoto of the Information System Group of NICT for support for network security and a high-speed LAN environment.

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