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

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 34-m antenna of NICT and with two small diameter VLBI stations located Medicina(Italy) and NICT(Koganei, Japan). In addition to geodetic and time transfer VLBI observation, the Kashima 34-m antenna has been used for astronomical VLBI observations and for single dish observation for Jupiter and Pulsar.

1 General Information

The 34-m diameter radio telescope (Fig. 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 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.

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

NICT Kashima 34-m Network Station

IVS 2015+2016 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. Q-band (43GHz) receiver is mounted, though it is not available due to phase-locked oscillator problem since 2017. 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

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~~ N.A.

receiver is mounted on one of four trolleys. 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.

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 signal 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). Thanks to the standardized VSI-H interface specification, this system can be used to record any data stream of VSI-H interface[2][2]. 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 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.

K6/GALAS is the new high speed sampler for broadband VLBI observation project GALA-V[4]. Analog radio frequency signal is converted to digital data by 16.384 GHz sampling rate. Four

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

[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 though VSI-H interface.

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 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. Output data comes out via 10 Gbit-Ethernet interface with VDIF/VTP/UDP packet streams.

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 maintaining K5/VSSP software package and working for implementation of ADS3000+ control function to FS9.
- MIYAUCHI Yuka is in charge of data acquisition software.
- 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 NINJA feed system, and made the subreflector position adjustment and performance measurement of the new receiver.
- 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 IVS Sessions

Kashima 34-m station is participating geodetic VLBI sessions (T2, CRF, RD, APSG, AOV, and R1). All the data provision to correlator 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-Transfer to correlation centers.

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

4.2 Broadband VLBI Experiments

As the mission of our project, we have been conducting a broad band VLBI experiments for frequency transfer. Broadband VLBI is performed by using 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 antenna was exported to Medicina observatory in Italy in July 2018. Under the collaboration with Italian National Metrological Research Institute INRiM and INAF, we have started optical clock frequency transfer experiment between Yb optical clock at INRiM in Italy and Sr optical clock at headquarters of NICT(Koganei) in Japan.

4.3 Maintenance Work

Holographic Reflecter Surface Measurement and Adjustment

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

Just after the repair work in Sep. 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. Fig. 6 shows the scaffolding standing in north side of 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 Feb. 2017. Cause of the leak was identified on one pipe running at the elevation cable wrap section. Finally we fixed the leakage by replacing four 25m length helium tubes in Oct. 2017. Some part of this period, cooled receiver system has to be operated in room temperature.

5 Future Plans

We have started optical clock time transfer experiment between Yb optical clock at INRiM in Italy and Sr optical clock at 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 regret that Kashima 34-m antenna has been planned to be dismantled from middle of 2020. Background reasons are aging of the antenna, maintenance cost, and difficulty in obtaining repair parts.

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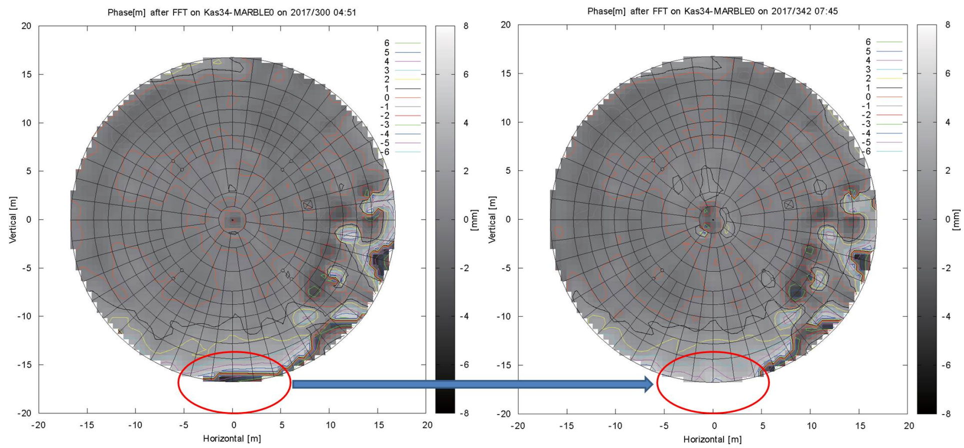

Fig. 5 Contour map of surface height distribution obtained by holography test in 2017. Large deviation of flatness found in the initial measurement (left) was adjusted (right). We confirmed the accuracy of the holographic measurement for preparation to the repair work in 2018.

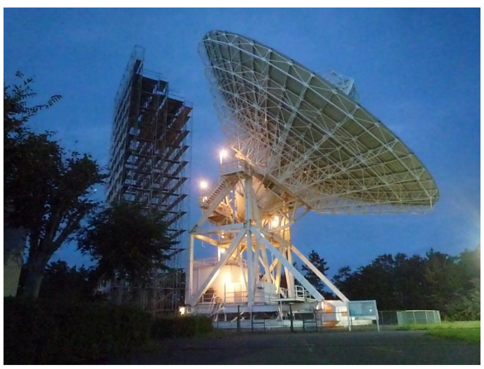

Fig. 6 Kashima 34-m antenna in holographic observation after reflector adjustment. We carried out reflector adjustment in day time and holography observation in the evening. We repeated this procedure for a week. For safety, we have watched the antenna during the holography observation about 1.5 hours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

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