Status Report of Koganei 11-m VLBI Station for 2021–2022

Mamoru Sekido

Abstract The Koganei 11-m station participated in T2, APSG, and AOV sessions conducted by the IVS and Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV)[1]. The antenna's operations were interrupted from May to August 2021 due to multiple troubles. We fixed the causes of these problems by ourselves and resumed observation in August 2021. The trees adjacent to the antenna are suspected to be a cause of lower SNR in X-band. At the end of 2022, pruning the trees and bamboos around the station was performed. We now expect productivity improvement in IVS sessions in 2023. We confirmed strong radio frequency interference (RFI) for S-band receiver. We are planning to insert a bandpass filter in front of LNAs to mitigate the RFI, even though this will cause an increase in the receiver noise temperature.

1 General Information

The Koganei 11-m diameter VLBI station is operated by the geodesy group of the Space-Time Standards Laboratory (STSL) of the National Institute of Information and Communications Technology (NICT). The antenna site is located at the northern campus in the headquarters of NICT in Koganei, Tokyo (Figure 1). These 11-m VLBI antennas were built together with three other VLBI stations for the Key Stone Project (hereafter referred to as KSP). The aim of the KSP [1] was monitoring crustal deformation around the Tokyo metropolitan area by using multiple space geodetic techniques: VLBI, GPS, and SLR. That project was operated in the period between 1995 and 2001. After the KSP project was terminated in 2001, two 11-m antennas at Miura and Tateyama were transferred to Gifu University and Hokkaido University, respectively, for radioastronomy. The two antennas of Kashima and Koganei had been used as a tool for technology developments and participated in international and domestic geodetic VLBI observations. Unfortunately, the Kashima 11-m antenna was damaged in May 2019 by rain water leakage to the waveguide system including the LNAs. That happened through holes in the feedome membrane, which might have been made by the pecking of birds. In September of the same year, the Kashima 34-m antenna was seriously damaged by the strong winds of typhoon Faxai [3]. Finally, the Kashima 34-m and 11-m antennas were dismantled in 2020 [4]. And the Kashima Space Technology Center

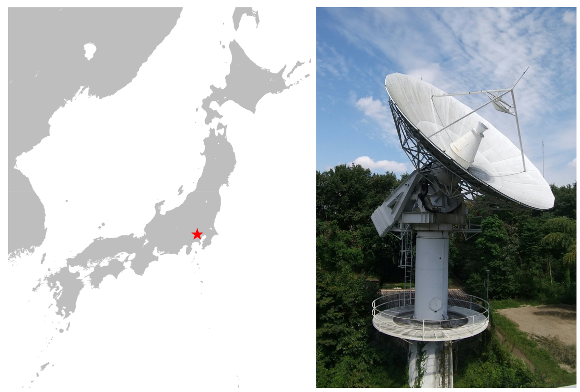

Fig. 1 Left: Location of NICT-Koganei. Right: Koganei 11-m VLBI station.

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NICT Koganei-11m Network Station

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[1] https://auscope.phys.utas.edu.au/aov/index.html

VLBI group, which had contributed to Japanese VLBI technology development since the 1970s, was formally dissolved in March 2021.

The remaining Koganei 11-m antenna is continuing VLBI observations, participating in the IVS and AOV sessions.

2 Component Description

2.1 Koganei 11-m Antenna

Parameters of the Koganei 11-m antenna are listed in Table 1.

Table 1 Specification of the Koganei 11-m antenna. The system temperature and SEFD values at S-band are not listed, because the measurement values are not appropriate due to RFI.

Mount Type	Azimuth / Elevation
Diameter [m]	11.0
Optics	Cassegrain
Slew Speed [deg/sec]	Az: 1.0 / El: 1.0
Az/El Range [deg]	Az: 90.0–630.0 / El: 7.0–89.0
Receiving Freq. [MHz]	S: 2,212–2,360 X-1: 7,700–8,200 X-2: 8,100–8,600
Local Freq. [MHz]	S: 3,000 / X-1:7,200 / X-2: 7,600
Typical T_{sys} [K]	S:– / X: 110
Typical SEFD [Jy]	S:– / X: 5000
Aperture Efficiency [%]	approx. 60

The System Equivalent Flux Density (SEFD) values depicted in Figure 2 show that the performance of the X-band receiver system has not significantly degraded since 2014. Those for S-band scattered since 2020, and it may represent that the radio frequency interference (RFI) to S-band receiver system became more severe since then. More detail on the status of the S-band receiver is discussed later in this paper.

2.1.1 Maintenance Events

Increase of drive resistance

Antenna operations were frequently interrupted by a thermal relay trip in May 2021. It was caused from an increase of mechanical resistance of the azimuthal roll bearing, which enabled smooth azimuthal rotation with supporting all antenna weight. The Koganei 11-m antenna has been working with a high utilization rate for VLBI and STEREO downlink data acquisition. However, maintenance work for the mechanical greasing was stopped in 2016 due to a shortage in the budget. We did the greasing of the Az/El bearing and exchanging the transmission lubrication oil ourselves. Finally, mechanical resistance was reduced, and the issue of thermal relay trip was solved in early summer of 2021. During the period from May to July, we stopped antenna operations and IVS observations.

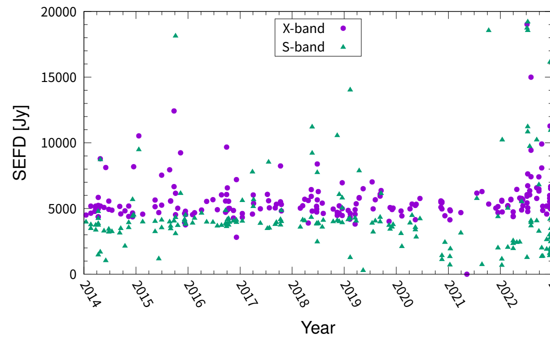

Fig. 2 SEFDs of S/X-band are plotted for the period 2014–2022.

Damage caused by thunderstorm

A strong thunderstorm hit the Koganei region on 30 July 2021. Lightning strikes in the storm damaged the Azimuth encoder, antenna controller unit (ACU), and DC power amplifier (DCPA). Fortunately, we have spare parts for these devices; we replaced the damaged equipment and resumed antenna operations on 12 August 2021.

2.1.2 X-band

Although the receiver performance at X-band does not show obvious changes, IVS Correlation Centers have reported that the fringe detection rate of the Koganei 11-m station was degrading in recent years. Since the antenna site is surrounded by tall trees, one possible cause is the blocking of the line of sight by the trees. Though the antenna height was 12.5 m, which was raised up by additional foundation, the surrounding

Fig. 3 Panoramic view around the Koganei 11-m antenna in February 2023. The picture covers 0–180 degrees (upper panel) and 180–360 degrees (lower panel) of azimuthal direction.

trees were even taller than the antenna. We performed tree pruning at a 40-m radius circular area around the antenna in the winter of 2021. Additional pruning was conducted for an extended area at the end of 2022 by another unrelated project, by chance. Figure 3 displays the panoramic view around the Koganei 11-m antenna after the pruning.

System temperature (T_{sys}) contour maps of the sky before (12 September 2022) and after (21 December 2022) the pruning are presented in Figure 4. Higher temperatures below 20 degrees of elevation in the top panel represents that line of sight was blocked at low elevation angle. T_{sys} was significantly reduced for east-south directions after the pruning, although trees in the west were not reduced sufficiently. Then T_{sys} is still high below 20 degrees of elevation in the west direction. For improving the productivity of VLBI sessions, we are going to submit revised horizontal mask information to the IVS to adjust observation schedules. Since T_{sys} is approximately expressed by linear combination of optical thickness τ and temperature T_{atm} of the atmosphere by the following equation:

$$\begin{aligned} T_{sys} &= T_{rx} + T_{atm}[1 - \exp\{-\tau/\sin(El)\}] \quad (1) \\ &\simeq T_{rx} + T_{atm} \cdot \tau/\sin(El), \end{aligned}$$

receiver noise temperature T_{rx} and τ can be estimated by assuming the atmospheric temperature (here we assumed 200 K for atmosphere at several km height). The bottom panel of Figure 4 shows the T_{sys} plot versus $1/\sin(El)$ for the east direction, where sky clearance was improved after tree pruning. Although the reason of deviation of data from linear trend at El=60 and 90 degrees is not known yet, the model of Equation 1 gives a fairly good approximation of data. That implies that the antenna is observing the sky without blockage at high to low elevation angles.

Antenna operation time is shared with the Space Environment Laboratory (SPEL). When the antenna is free from VLBI observation, the down-link signal of the STEREO satellite[2] is acquired for the monitoring of solar activity.

2.1.3 S-band

The pruning of trees surrounding the antenna improved the environment at S-band as well. Figure 5 compares S-band T_{sys} maps on the sky before and after the pruning. Decreasing temperature in the southeast direction was observed. However, the T_{sys} and SEFD measurements are unstable, and it is attributed to RFI.

We investigated LNA output in January 2022, and found serious contamination of radio frequency envi-

[2] http://www.nasa.gov/mission_pages/stereo/main/index.html

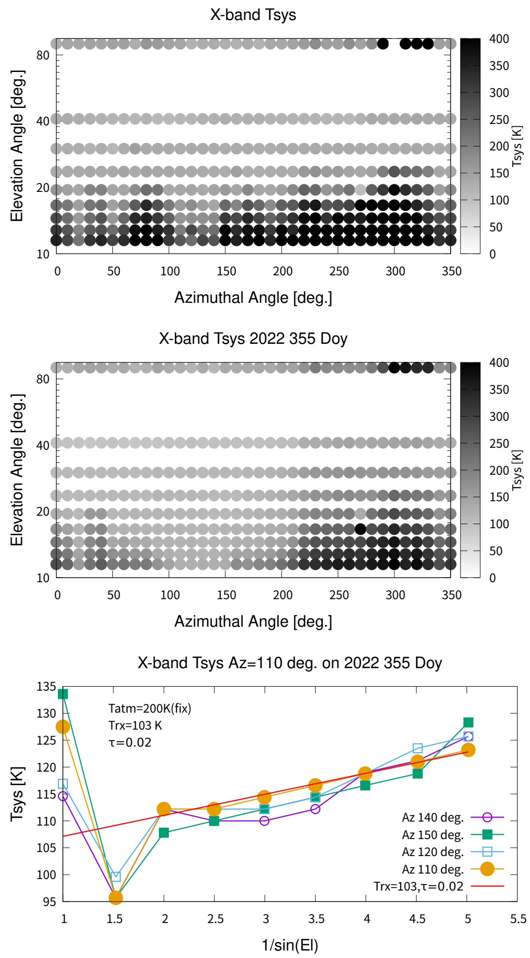

Fig. 4 Contour map of X-band T_{sys} in the sky before (top) and after (middle) the tree pruning in 2022. Bottom: Plot of T_{sys} (X-band) vs $1/\sin(El)$ gives estimate of optical thickness τ and Receiver noise temperature (T_{rx}).

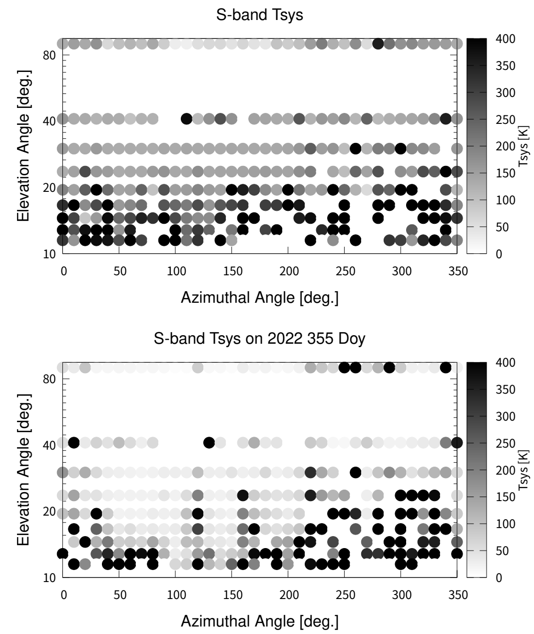

Fig. 5 S-band T_{sys} sky map before (top: 12 September 2022) and after (bottom: 22 December 2022) tree pruning.

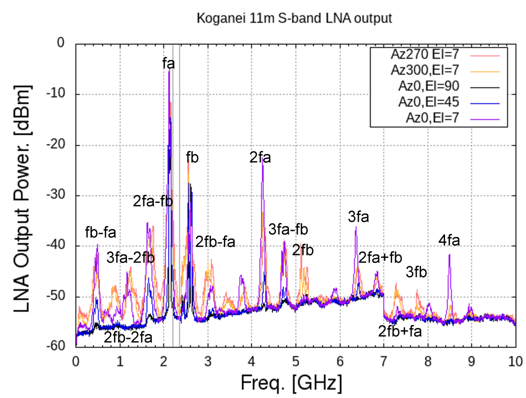

Fig. 6 The S-band LNA output of the Koganei 11-m antenna measured on 14 January 2022. Two strong signal at 2.11–2.17 GHz (referred to as ’fa’) and 2.55–2.57 GHz & 2.60–2.64 GHz (referred to as ’fb’) are generating mixed harmonics up to the fourth order.

ronment in S-band. Figure 6 shows LNA is working at a non-linear region and is generating a fourth-order mutual modulation of signal at 2.11–2.17 GHz (hereafter referred to as fa) and at 2.55–2.57 GHz, 2.60–2.64 GHz (hereafter referred to as fb). These signals are assumed to be coming from the base station for mobile phones. This sort of serious condition is due to the location of Koganei station in the metropolitan area of Tokyo, and it could be one of the worst-case locations of any IVS station in the world. We are planning to introduce a bandpass filter to mitigate the saturation of S-band LNA.

2.2 Data Acquisition Systems

Data acquisition for legacy mode geodetic VLBI sessions is performed with four units of the K5/VSSP32 [5] system, where each unit has four video signal inputs. Observed data is recorded on a standard Linux file system in K5/VSSP32 format[3]. Then, format conversion from the K5/VSSP32 to Mark-5B is performed by using the K5/VSSP32 software tool[4]. All the VLBI data acquired by NICT were exported to Correlation Centers over a 10-Gbps network provided by the High Speed R&D Network Testbed JGN.

The IVS and AOV sessions observed by the Koganei 11-m antenna are listed in Table 2.

Table 2 VLBI sessions for Koganei 11-m stations in 2021–2022.

Year	**2021**: 14 sessions	**2022**: 21 sessions
IVS & AOV	T2P144, AOV055, T2145, T2146, AOV059, T2147, AOV061, APSG48, T2148, APSG49, AOV064, T2149, T2P150, AOV066	T2P151, AOV067, AOV068, AOV069, T2152, AOV070, T2153, AOV071, AOV072, APSG50, T2154, AOV073, AOV074, T2155, AOV075, T2156, AOV076, AOV077, T2P157, AOV078, APSG51

3 Staff

SEKIDO, Mamoru (STSL): Working on operation and maintenance of the Koganei 11-m antenna.

ICHIKAWA, Ryuichi (STSL): Working on operation and maintenance of the GNSS station and gravimeter.

ISHIBASHI, Hiromitsu (SPEL): Working on operation of the 11-m antenna for acquiring STEREO downlink data. Supporting maintenance work of the 11-m antenna.

4 Future Plans

The Koganei 11-m antenna will keep operations to participate in IVS and AOV VLBI sessions. The modification of the S-band receiver system to mitigate the RFI is an important task to be performed.

[3] https://www2.nict.go.jp/sts/stmg/K5/VSSP/vssp32_format.pdf

[4] http://vlbi.sci.ibaraki.ac.jp/K5WWW/index-e.html

4.1 Local Tie Information

Responding to the call for participation to ITRF2020, local survey data for 1996–1999 and 2013 were submitted to the ITRF Combination Center in 2021 [2].

A new local survey was conducted in 2022 by a project of another group (Space communication system laboratory) of NICT. This survey contains locations of the 11-m VLBI station, a 1.5-m optical SLR telescope, a KSP-SLR telescope, and an IGS station. The survey data is still in the process of compilation. After summarizing the local tie information, it will be submitted to the IERS for the future improvement of the ITRF.

Acknowledgements

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