Status report of Koganei 11-m VLBI Station for 2021-2022

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Abstract The Koganei 11-m stations have been participating T2, APSG, and AOV sessions conducted by the IVS and Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) [1]. The antenna was interrupted operation during May to August 2021 due to multiple troubles. We fixed the causes of problems by ourselves and resumed observation from August 2021. The surrounding tree around the antenna is suspected to be a cause of lower SNR in X-band. In the end of 2022, pruning trees and bamboos around the station was performed. Then, we expect productivity improvement in IVS session in 2023. We confirmed strong radio frequency interference (RFI) for S-band receiver. We are planning to insert bandpass filter in front of LNA to mitigate the RFI, though that will cause increase of receiver noise temperature.

1 General Information

Koganei 11-m diameter VLBI station is operated by 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 the NICT in Koganei Tokyo (Figure 1). This 11-m VLBI antennas was built together with three other VLBI stations for Key Stone Project (hereafter referred as KSP). The aim of the KSP [1] was monitoring of 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 has terminated in 2001, two 11-m antenna at Miura and Tateyama were transferred to Gifu University and Hokkaido University respectively for radioastronomy. Two antennas of Kashima and Koganei had been used as tool for technology developments and participated to international and domestic geodetic VLBI observations. Unfortunately, Kashima 11m antenna was damaged in May 2019 by rain water leakage to the waveguide system including LNA. That happened by holes on the feedome membrane, which might be made by bird's pecking. In September of the same year, the Kashima 34m antenna seriously damaged by attack of strong wind typhoon Faxai[3]. Finally, Kashima 34m and 11m antenna were dismantled in 2020[4]. And VLBI group of Kashima Space Technology Center, which had contributed to

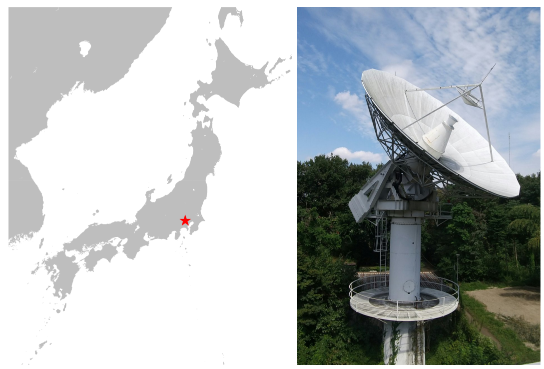

Fig. 1 Left: Location of NICT-Koganei, Right: Koganei 11-m VLBI station.

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NICT Koganei-11m Network Station

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

Japanese VLBI technology development since 1970s, was formally dissolved in March 2021.

Remaining Koganei 11-m antenna is continuing VLBI observations participating to the IVS and AOV sessions.

2 Component Description

2.1 Koganei 11-m Antenna

Parameters of Koganei 11-m antenna is listed in Table 1. The plot of System Equivalent Flux Density (SEFD)

Table 1 Specification of Koganei 11m Antenna. System temperature and SEFD of S-band is not presented, because 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
	S: 2212-2360
Receiving Freq. [MHz]	X-1: 7700-8200
	X-2: 8100-8600
Local Freq. [MHz]	S: 3000 / X-1:7200 / X-2: 7600
Typical T_{sys} [K]	S:– / X: 110
Typical SEFD [Jy]	S:–/X: 5000
Aperture Efficiency [%]	approx. 60

in the top panel of Fig. 2 shows that performance X-band receiver system does not significantly degrade 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 severer since then. More detail on the status of the S-band receive is discussed in latter section.

2.1.1 Maintenance events

Increase of drive resistance

Antenna operation was frequently interrupted by thermal relay trip in May 2021. It was caused from increase of mechanical resistance of azimuthal roll bearing, which enable smooth azimuthal rotation with supporting all antenna weight. Koganei 11-m antenna have

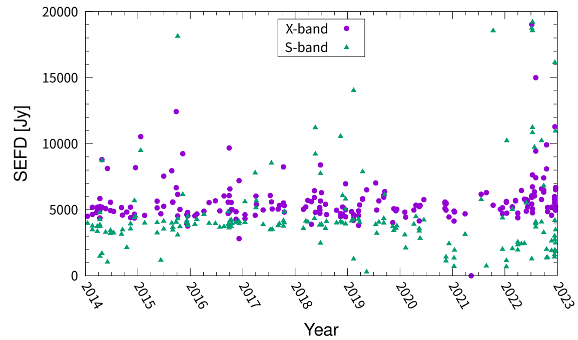

Fig. 2 SEFDs of S/X-band are plotted for the period 2014-2022.

been working with high utilization rate for VLBI and STEREO downlink data acquisition. However, maintenance work for mechanical grease up stopped since 2016 due to shortage of budget. We made grease up for Az/El bearing and exchanged transmission lubrication oil by ourselves. Finally mechanical resistance was reduced, and the issue of thermal relay trip was solved in early summer of 2021. During this period from May to July, we stopped antenna operation and IVS observation.

Damage caused by thunderstorm

Strong thunderstorm attacked to Koganei region on 30 July 2021. Lightning strike 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 the antenna operation from 12 August 2021.

2.1.2 X-band

Although the receiver performance of X-band does not show obvious changes, IVS correlation center has been reported that fringe detection rate of Koganei 11-m station was degrading in recent years. Since the antenna site is surrounded by toll trees, one of possible cause will be blocking of line of sight by trees. Though the antenna height was 12.5-m, which was built with raised up by additional foundation, surrounding trees had been even toller than the antenna. We performed tree pruning at 40-m radius circular area around the antenna in the winter of 2021. Additional pruning was conducted for extended area by a project of other section in the end of 2022, by chance. Fig. 3 displays panorama view around the Koganei 11-m antenna after the pruning.

System temperature (T_{sys}) contour maps of the sky before (12 Sep. 2022) and after (21 Dec. 2022) the pruning are presented in Fig. 4. Higher temperature 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 reduces 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:

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

receiver noise temperature T_{rx} and τ can be estimated by assuming atmospheric temperature (here we assumed 200 K for atmosphere at several km height). The bottom panel of Fig. 4 shows plot of T_{sys} versus $1/\sin(El)$ for 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, model of Eq. (1) gives fairly good approximation of data. That implies that antenna is observing sky without blocking till to low elevation angle.

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

2.1.3 S-band

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

We investigated LNA output in Jan. 2022, and found serious contamination of radio frequency environment in S-band. Fig. 6 shows LNA is working at non-linear region, and is generating fourth order mutual modulation of signal at 2.11-2.17 GHz (hereafter refereed as fa) and at 2.55-2.57 GHz, 2.60-2.64 GHz (hereafter refereed as fb). These signals are supposed to be coming from base station for mobile phones. This sort of serious condition is due to location of Koganei station in the metropolitan area of Tokyo, and it must be one of the worst case in the IVS stations in the world. We are planning to introduce bandpass filter to mitigate the saturation of S-band LNA.

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

2.2 Data Acquisition Systems

Data acquisition for legacy mode geodetic VLBI sessions is performed with four units of 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 K5/VSSP32 software tool [4]. All the VLBI data acquired by NICT were exported to correlation centers over 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.

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

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

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

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

3 Staff

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4 Future plan

Koganei 11-m antenna will keep operation for participation to VLBI sessions of IVS and AOV. Modification of S-band receiver system to mitigate the RFI is important task to be performed.

4.1 Local tie information

Responding to the call for participation to ITRF2020, local survey data for 1996-1999 and 2013 were submitted to 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 location of 11-m VLBI station, 1.5-m optical SLR telescope, KSP-SLR telescope, and IGS station. The survey data is still in process of compilation. After summarizing the local tie information, it will be submitted IERS for future improvement of ITRF.

Acknowledgements

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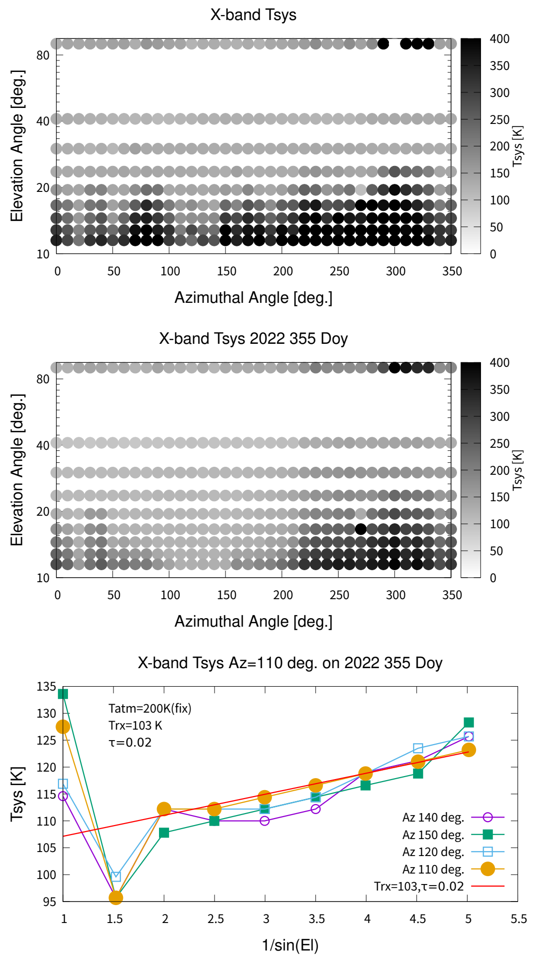

Fig. 4 Contour map of X-band T_{sys} in the sky before (top) and after (middle) the tree pruning in 2022. Bottom: Plot of T_{sys} (X-band) vs $1/\sin(El)$ gives estimate of optical thickness τ and Receiver noise temperature (T_{rx}).

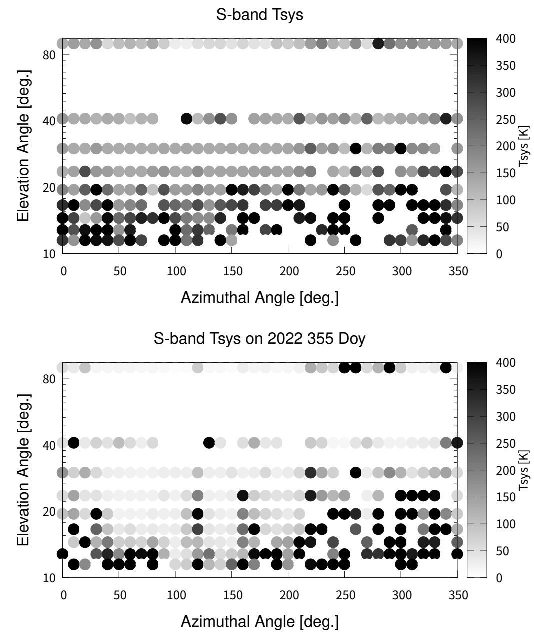

Fig. 5 S-band T_{sys} sky-map before (top:12 Sep. 2022) and after (bottom:22 Dec. 2022) tree pruning.

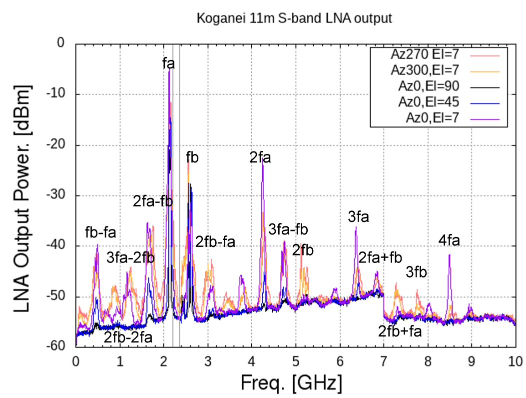

Fig. 6 S-band LNA output of Koganei 11-m antenna measured on 14 Jan. 2022. Two strong signal at 2.11-2.17 GHz(refereed as 'fa') and 2.55-2.57 GHz & 2.60-2.64 GHz (refereed as 'fb') are generating mixed harmonics up to fourth order.

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