Status Report of Koganei 11-m Antenna and Local Tie Survey

M. Sekido[1], T. Morinaga[2], M. Satomura[2], J. Nakazono[1], R. Ichikawa[1], H. Kunimori[3]

Abstract The status of the Koganei 11-m VLBI station is described with a brief history. Although this station has participated in IVS sessions with legacy S/X-band, degradation of the radio frequency environment and troubles of the antenna drive system have been getting serious in recent days. The Koganei site accommodates multiple space geodetic techniques, so local tie surveys have been performed several times. In those surveys in the past, total station and leveling data was analyzed separately and used to determine horizontal and vertical coordinates, respectively. In 2022, we conducted a geodetic local tie survey and performed least squares analysis by using a full data set via the “pyaxis” software developed by LINZ. This local tie result will be submitted to the ITRF center for the next update.

Keywords Status report, Local tie

1 Koganei 11-m VLBI Station

1.1 Antenna Parameters and Brief History

The Koganei 11-m antenna is a dedicated VLBI station with a legacy S/X receiver system built in 1995 [1]. NICT (formerly named CRL, RRL) has been active in the development of space geodetic techniques including VLBI, SLR, and GPS since the 1970s. VLBI technology development was mainly performed at Kashima, and the SLR was investigated with a 1.5-m diameter optical telescope at Koganei. The Koganei 11-m antenna was built in a project with the aim of monitoring crustal deformation around Tokyo with multiple space geodetic techniques (Key Stone Project: KSP), and it was routinely operated for geodetic VLBI in the period 1995–2001. After the KSP was terminated, the station was used for R&D and has regularly participated in IVS geodetic VLBI sessions since 2011. Even after the Kashima VLBI group was formally dissolved in 2021, observing has been continued via limited resources. The participation rate in IVS sessions was about twice in a month on average. The rest of the time, the antenna is used by Space Environment Laboratory for receiving downlink data from the STEREO spacecraft for the space weather forecast project. Table 1 shows people supporting the Koganei VLBI station, and Table 2 lists the antenna parameters.

Table 1 Human resources related to the Koganei Station.

Name (Affiliation)	**Areas where in Charge**
SEKIDO Mamoru (STL)	IVS Observing, Maintenance of Koganei 11-m station
ICHIKAWA Ryuichi (STL)	GNSS observing and maintenance, Gravimeter observations
ISHIBASHI Hiromitsu (SEL)	Downlink data acquisition of STEREO solar observation spacecraft

STL: Space-Time Standards Laboratory,
SEL: Space Environment Laboratory

Thanks to the room temperature LNA design, the receiver system of the antenna has been stable without particular maintenance work. The Koganei 11-m sta-

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[1] National Institute of Information and Communications Technology

[2] Nippo Co. Ltd.

[3] Astro Terrace Inc. Japan

Table 2 Parameters of the Koganei 11-m VLBI station.

Antenna Type	Cassegrain focus AZ/EL mount
Diameter	11-m
Slew Speed	1 deg/s for AZ/EL
Receiving Band	S-band: 2.212–2.36 GHz X-band1: 7.70–8.20 GHz (not for IVS) X-band2: 8.10–8.60 GHz
Receiver LNA Type	Room Temp. Waveguide LNA
Local Frequency	S-band : 3000 MHz X-band1: 7200 MHz (not for IVS) X-band2: 7600 MHz
Backend	K5-VSSP32, 16ch, 1/2-bit, 1/2/4/8/16/32 Msps
Recording Rate	Up to 1024 Mbps
Pcal Frequency	5 MHz interval
Network Connection	10 Gbps via JGN

tion has been participating in about 20 geodetic VLBI sessions in a year. Because the Koganei site is surrounded by a residential area of Tokyo with a large population, mobile phone base stations as an infrastructure of citizen life have extended their locations and their transmission power. The radio environment has been getting worse, especially in S-band. Degradation of the receiver performance has been reported from the IVS Correlation Center since 2017. We suppose that the main reason for this is Radio Frequency Interference (RFI). Figure 1 shows SEFDs of S/X-band for ten years since 2014. The drop in SEFD appearing in the plot since 2020 might be an indication of LNA saturation getting more serious. We observed strong RFI causing saturation and inter-modulation from the frequency spectrum of S-band LNA output in 2019.

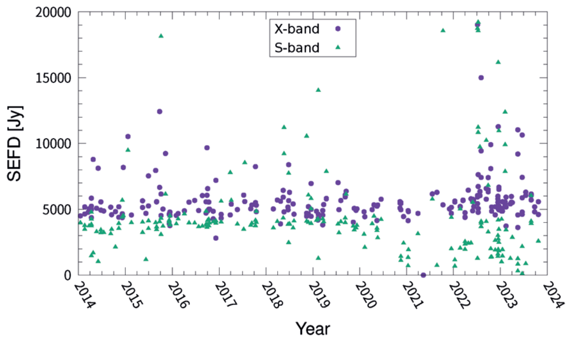

Fig. 1 SEFDs of the Koganei 11-m antenna for the period between 2014 and 2024.

1.2 Radio Frequency Interference

The strong RFI at 2.1 GHz and 2.55–2.65 GHz causing saturation of the LNA (Figure 2) comes from mobile phone base stations. We could see 1) inter-modulation is larger at lower elevations, and 2) RFI signals at 2.1 GHz, 2.5 GHz, and 2.6 GHz appear constant regardless of the elevation angle. As a workaround for this issue, we were preparing an insertion of a band-pass filter (2.2–2.4 GHz) in front of the LNA to exclude this RFI. However, antenna drive system trouble has occurred additionally in November 2023, and antenna operation has stopped since then. The prospect of the recovery is unclear yet.

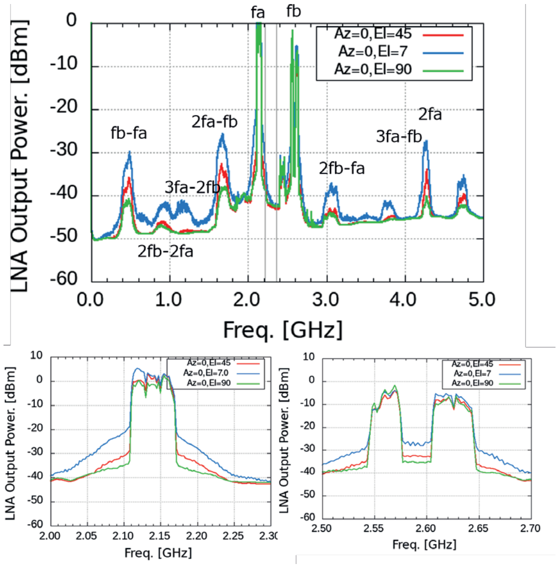

Fig. 2 Frequency spectrum of the S-band LNA output monitored in 2022. LNA output signals at different elevation angles were monitored by spectrum analyzer. The power level was amplified by an amplifier (G=30dB), but we confirmed that saturation/inter-modulation originated from the LNA instead of the external amplifier.

2 Local Tie Geodetic Survey

2.1 Local Tie Survey in 2022

Local tie measurement is increasingly important for improvement of the ITRF. Because KSP utilized multiple space geodetic techniques, local tie surveys were performed several times in the project. Especially, the Koganei site has accommodated an SLR observation facility since the late 1980s and a VLBI facility from 1995. So it has a long observation history contributing to the ITRF (Figure 3).

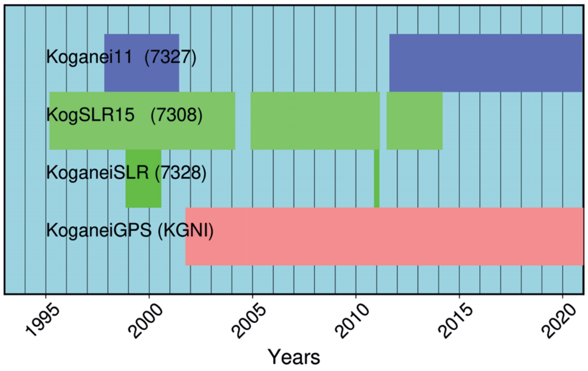

Fig. 3 Contributions to the ITRF2020 from the Koganei VLBI, SLR, and GNSS stations.

Geodetic local tie surveys were performed every year in the period 1996 through 1999 (hereafter referred to as "Survey-199x", where x is in the range of 6–9). Then another one was performed in 2013. Recently, we conducted a geodetic local tie survey in the period between October and November 2022 (hereafter referred to as "Survey-2022"). Figure 4 shows the map of the local survey network in 2022. The main targets of the survey are reference points of the 11-m VLBI station, GNSS antenna: "PGPS", 75-cm SLR telescope: "SLR-CP0", 1.5-m SLR telescope: "1.5m-CP0", 1.0-m telescope: "1m-CP0", and reference short pillar: "S2RT", which is the reference point of "SLR-CP0" connected by an eccentric vector registered in the ILRS. The point "S2RT" is indicated as "KS2" in the map of Figure 4. Because the "Survey-2022" and "Survey-199x" (x=6–9) were performed by different contractors, the point names were distinguished from the former survey with the prefix character "K". Many of the stable geodetic monuments and ground markers used for former surveys were re-used in this survey. However, the 1.0-m diameter optical telescope: "1m-cp0" was a new target included in this survey for the first time; thus new ground marker points with the name of KNX are newly introduced. Equipment used in this survey is listed in Table 3.

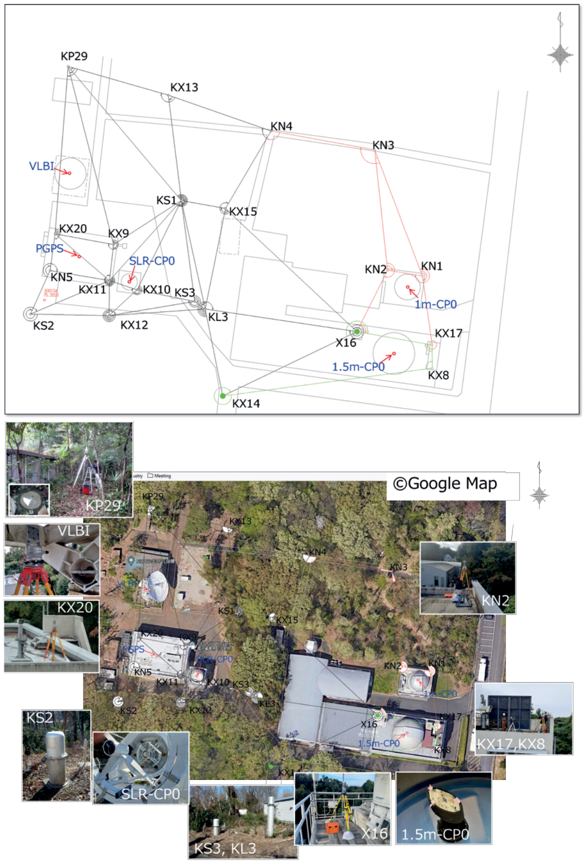

Fig. 4 Map (upper) and pictures of monuments (lower) at the Koganei site of Survey-2022.

The reference point of the 11-m antenna was measured via a target marker placed at the AZ-EL cross point location with the total station (see Figure 4), instead of observations of a target marker attached to the antenna at many different Az-El angles.

2.2 Local Tie Analysis with Pyaxis

We used least squares 3D geometrical analysis by using software *"pyaxis"* [2], developed by Land Information New Zealand (LINZ). Three kinds of data sets were used for the input of the analysis: 1) 154 total station observations, which output horizontal angle, zenith angle, and slant distance, 2) 22 leveling data, and 3) GNSS observations for 24 hours at points X16, KX11, KX20, and KN2. The GNSS observation data

Table 3 Equipment used in the Survey-2022.

Equipment	Model	Performance
GNSS Receiver	Trimble R12	Horizon: 3mm ± 0.1 ppm, Vertical: 3.5 mm ± 0.4 ppm
Leveling Equipment	Trimble Navigation DiNi 0.3	0.3 mm (1 km round)
Leveling Bar	Tamaya LD-13S	Thermal exp. 0.2 ± 0.03 ppm/deg
Total Station	Leica Nova MS60	Distance: 1 mm, Angle: 1 arc sec

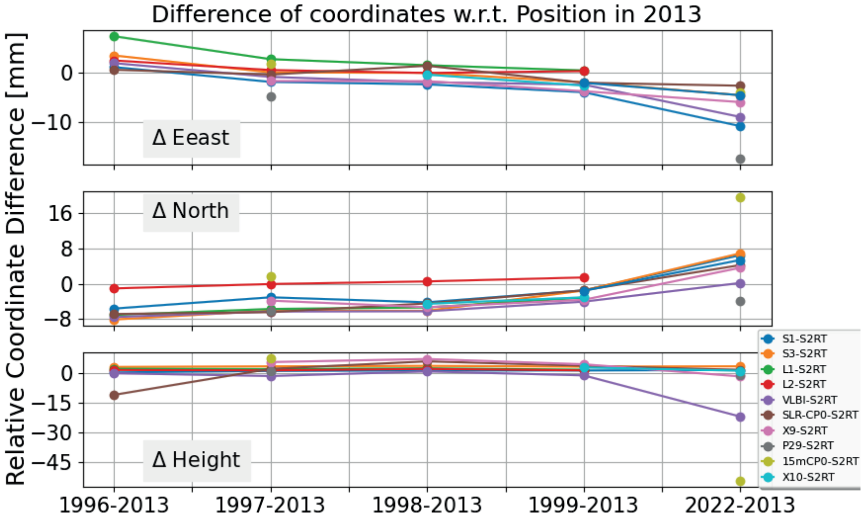

Fig. 5 As an indicator of repeatability, the relative coordinates of reference points with respect to “S2RT” (KS2) obtained by surveys in 1996–1999 and 2022 are plotted with respect to those of 2013.

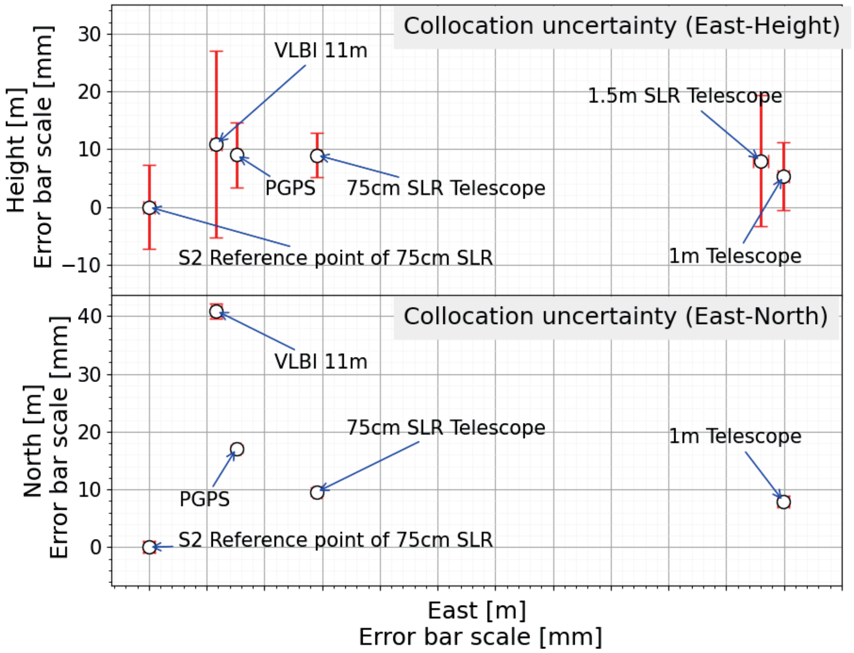

Fig. 6 Results of the geodetic local tie survey in 2022. Relative vectors of target points with respect to that of “S2RT” (KS2) are plotted with their error bars in the East-Height (upper) and East-North (lower) planes, respectively. The error bars are indicated in the “mm” scale for visibility, whereas their coordinates are in the “m” scale.

were analyzed with the GPS processing service provided by Geoscience Australia [3].

Local geodetic surveys have been conducted in the period 1996–1999 [4] and 2013 in the past (hereafter each survey is referred to as Survey-*year*). These surveys and analysis before 2013 were made by the same contractor, and joint analysis with total station and leveling data were not performed, but instead the data were treated separately following the procedures of standard geodetic surveys. To check the repeatability and compare the latest survey, Survey-2022, with those in the past, the relative coordinates of the reference points are plotted in Figure 5, taking the coordinates of “S2RT” in 2013 as the common origin. From this figure, repeatabilities before 2013 are less than 10 mm and 15 mm for horizontal and vertical respectively. And those in 2022 were 20 mm and 50 mm, respectively. The reason for these larger differences may be attributed to differences of data analysis procedures and interpretation of reference points due to different contractors.

The relative vectors of Survey-2022 analyzed by pyaxis are displayed in Figure 6, where reference point “S2RT” (KS2) is used as the origin. The horizontal and vertical one sigma uncertainties are 1–2 mm and 6–16 mm, respectively. The smaller uncertainty in the horizontal plane is regarded as due to constraint by the network spread in the horizontal plane. Although height is mostly measured from the bottom but not measured from the top direction, this asymmetry of constraint conditions will lead to a larger height uncertainty than the horizontal one. After further refinement, the local tie results are going to be submitted to the ITRF center for the next update of the terrestrial reference frame.

Acknowledgements

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