Ishioka Geodetic Observing Station – 13.2-m Radio Telescope

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Abstract The Ishioka Geodetic Observing Station is operated by the Geospatial Information Authority of Japan (GSI). The Ishioka 13.2-m radio telescope at this station contributed to regular S/X and VGOS observations during 2019 and 2020. During a five-months period in 2020, the station could not participate in international observations because of antenna trouble. This is a report on activities of the Ishioka station during 2019 and 2020.

1 General Information

The Ishioka Geodetic Observing Station (Figure 1, hereafter called Ishioka station) is located at about 70 km northeast of Tokyo and 17 km northeast of the Geospatial Information Authority of Japan (GSI) headquarters in Tsukuba (Figure 2) and operated by GSI. Ishioka station has a 13.2-m radio telescope, which was designed by MT Mechatronics (MTM) to fulfill the VGOS requirements.

The Ishioka 13.2-m radio telescope started observation in 2016 as the successor of the Tsukuba 32-m radio telescope, which was located in Tsukuba, and has participated in S/X sessions coordinated by IVS. Furthermore, it has also participated in the VGOS sessions as a VGOS station.

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Ishioka Network Station

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Fig. 1 Ishioka 13.2-m radio telescope in the Ishioka Geodetic Observing Station.

2 Component Description

The specifications of the Ishioka 13.2-m radio telescope are summarized in Table 1. Ishioka station has two types of feeds: a tri-band feed and a QRFH feed. We use these two feeds depending on the types of observation: a tri-band feed for legacy S/X observation and a QRFH feed for broadband observation. It takes about one week to switch the feeds and adjust the equipment.

The signal is recorded in the following way for both observations. First, radio waves received with the antenna are converted to radio signals at the feed. Then, the signal is amplified and converted to an optical signal to be transferred to the observation building. In the building, it is again converted to RF and then to IF signal by frequency conversion. Finally, it is digitalized and recorded. Field System ver. 9.10.5 (FS9) is used to control the antenna and surrounding devices.

Table 1 Specifications of the Ishioka 13.2-m radio telescope.

Parameter	Ishioka 13.2-m radio telescope
Owner and operating agency	GSI
Latitude	N36°12′33″
Longitude	E140°13′08″
Altitude	112.8 m
Year of construction	2014
Radio telescope mount type	Az-El
Antenna optics	Ring focus
Diameter of main reflector	13.2 m
Azimuth range	180° ± 250°
Elevation range	0–100°
Azimuth drive velocity	12°/sec
Elevation drive velocity	6°/sec
Tsys at zenith (X/S)	50 K / 300 K
Tsys at zenith (Broadband)	H-pol: [*1] 216 K (3-GHz band) 138 K (5-GHz band) 139 K (6-Hz band) 243 K (10-GHz band) V-pol: N/A[*2]
SEFD (X/S)	1500 Jy / 2200 Jy
SEFD (Broadband)	H-pol: [*1] 4,040 Jy (3-GHz band) 3,854 Jy (5-GHz band) 3,900 Jy (6-GHz band) 9,368 Jy (10-GHz band) V-pol: N/A[*2]
RF range (X)	8,192–9,104 MHz
RF range (S with BPF)	2,170–2,425 MHz
RF range (Broadband with BPF)	2–14 GHz
Recording terminal	ADS3000+ sampler & K5/VSI data recording terminals
Data capacity	89 TB
Hydrogen maser	VCH-1003M (VREMYA-CH)

[1]The average value in observing frequency band for VGOS observation (3-GHz band: 3,000.4–3,480.4 MHz, 5-GHz band: 5,240.4–5,720.4 MHz, 6-GHz band: 6,360.4–6,840.4 MHz, 10-GHz band: 10,200.4–10,680.4 MHz).
[2]V-polarization of broadband is very noisy (described in section 4.2.3). Tsys and SEFD could not be measured as of January 22, 2021.

Fig. 2 Location of Ishioka station.

3 Staff

Ishioka station is operated by eight members and a contract operation staff member belonging to the VLBI group of GSI as of December 2020. The member list is shown in Table 2.

Table 2 Member list of the VLBI group of GSI (as of December 2020).

Name	Main Function	Remarks
Tomokazu Kobayashi	Supervisor	Apr. 2020
Toru Yutsudo	Management	Apr. 2019
Katsuhiro Mori	Observation facility management & Co-location	Apr. 2020
Yu Takagi	Research	Apr. 2020
Kyonosuke Hayashi	Research	Apr. 2019
Haruka Ueshiba	Operation & Co-location	
Tomokazu Nakakuki	Operation & Research	Apr. 2019
Saho Matsumoto	Operation & Research	
Kentaro Nozawa	Operation (AES)	

4 Current Status

4.1 Observation

Observation is automated and basically operated remotely from GSI headquarters in Tsukuba. It is unmanned operated at night and holidays, and error e-mails are sent when problems occur. Because of the spread of COVID-19, a state of emergency was declared in Japan from April to May 2020. Although most of the staff worked from home, it did not affect operations. Note that all staff continued to be required to work from home once a week as of the end of 2020. However, Ishioka station had stopped operations for about five months due to antenna trouble (described in Section 4.3).

4.1.1 S/X Observation

Ishioka station participated in the S/X sessions from January to November 2019 and from March to June 2020 (Table 3). It participated in one-hour sessions to contribute to dUT1 and 24-hour sessions for obtaining EOP with high frequency. AOV sessions, which are designed for enhancing positioning accuracy in the Asia-Oceania region, were held once a month and GSI contributed as a scheduler in some of them. Furthermore, Ishioka participated in "AOV Mixed-mode" observations, in which S/X and VGOS stations observed at the same time, beginning in March 2020.

Ishioka station could not participate in the scheduled S/X sessions from July to September 2020 because of antenna trouble.

4.1.2 Broadband Observation

From December 2019 through February 2020 and after November 2020, Ishioka station participated in broadband observations with the QRFH feed. Ishioka station participated in the bi-weekly VGOS-O (VGOS-T before 2020) sessions. In December 2019, we started to participate in EU-VGOS sessions as the only station in Asia. In addition, VGOS Intensive sessions with Onsala (ONSA13NE (Oe) and ONSA13SW (Ow)) also started. These are one-hour sessions conducted at the same time as the S/X Intensive sessions and are conducted once a week.

We also participated in one of the mixed-mode R&D sessions, coordinated by IVS, as a VGOS station in 2020.

During the broadband observations from December 2019 to February 2020, Ishioka's antenna and QRFH feed were also used for test observations for frequency comparison conducted by the National Institute of Information and Communications Technology (NICT).

Table 3 Number of regular sessions in 2019 and 2020.

System	Sessions	2019	2020
S/X	IVS-R1	41	14
	IVS-R4	43	14
	IVS-T2	6	1
	APSG	2	2
	AOV	11	3
	IVS-CRF	2	1
	IVS-INT1	30	3
	IVS-INT2	93	29
	IVS-INT3	41	14
	Total	*269*	*81*
VGOS	VGOS-O (VGOS-T)	2	6
	EU-VGOS	2	5
	VGOS-B	4	12
	IVS-R&D	–	1
	Total	*8*	*24*
Total		**277**	**105**

4.2 Introduction of the Superconducting Filter

As mentioned in Section 2, Ishioka station participates in the S/X and VGOS sessions with a different feed. To participate in both of the sessions continuously, we started to discuss the possibility of observing with the QRFH feed without interruption. To realize this, it is required to observe S- and X-band with the QRFH feed. However, because of the strong Radio Frequency Interference (RFI) caused by the artificial noise around Ishioka station, we had to cut less than 3 GHz with the high-pass filter installed in the QRFH feed. Therefore, we considered to introduce the filter to cut only artificial noise in S-band. First, we conducted an RFI survey in July and October of 2019, and we determined the frequency to cut with the filter. According to these results, the superconducting filter was developed and installed in the QRFH feed (both H- and V-polarization) in March 2020. We adopted the superconducting filter because it has steep cut-off characteristics and is able to cut the noise avoiding the frequency needed for observation. From June to July 2020, we conducted the RFI survey to check the effect of the filters and confirmed that the filters have the expected performance. Furthermore, we conducted test observations with the cooperation of NICT, University of Tasmania (UTAS), and Shanghai Astronomical Observatory (SHAO) in July 2020. We confirmed that fringes could be detected [1].

4.3 Troubles

Some troubles had a large impact on the operation of Ishioka station.

4.3.1 Trouble in Antenna Elevation Driving System

In June 2020, the antenna suddenly stopped with errors during observation. It repeated frequently, occurring only when driving in elevation direction, and the antenna always stopped around EL 60 degrees. We asked the manufacturer to investigate this problem and we were forced to cancel almost all planned observation during that time. The cause of this trouble has not been clearly detected yet. After some treatments, Ishioka station restarted the observation at the end of November 2020 with the follow-up check by the manufacturer. Because of this trouble, we could not participate in the planned S/X and VGOS observations for five months.

4.3.2 Internal Noise in QRFH Feed

In the QRFH feed, a high-frequency noise has occurred in the V-polarization since January 2020. We investigated the cause of this noise several times and confirmed that the noise was detected at the output of the receiver LNA, so it is sure the noise is caused inside the receiver. Although this problem has not been solved yet, it is possible to detect fringes with this noisy data for VGOS observations. We will conduct further investigation to fix this problem.

4.3.3 Other Troubles

During the term of S/X observations in 2019, several sessions were missed because the antenna's emergency lock activated suddenly due to the trouble of the antenna control unit and could not be unlocked remotely. In addition, during the term of VGOS observation in 2020, some data were missed because of the trouble of the recording server. We dealt with this trouble by changing the PC-VSI (interface) board or updating the driver of the RAID controller.

4.4 Co-location Survey

At Ishioka, we also operate a GNSS Continuously Operating Reference Station (CORS) which is registered as an IGS station. To contribute to building the ITRF, we regularly conduct co-location surveys. To determine the local-tie vector between the VLBI antenna and the GNSS antenna (Figure 3), we did the first co-location survey in 2016 and have conducted further co-location surveys once a year since 2018. In 2018, we applied two methods to estimate the VLBI antenna invariant point: legacy one called *Outside method* and another one called *Inside method*. *Inside method* was expected to be more efficient and accurate than *Outside method* and it was confirmed by comparing the results for both methods [2, 3] and we adopted the *Inside method* instead of the *Outside method* in the 2019 and 2020 surveys. We are preparing to submit the results to the IERS.

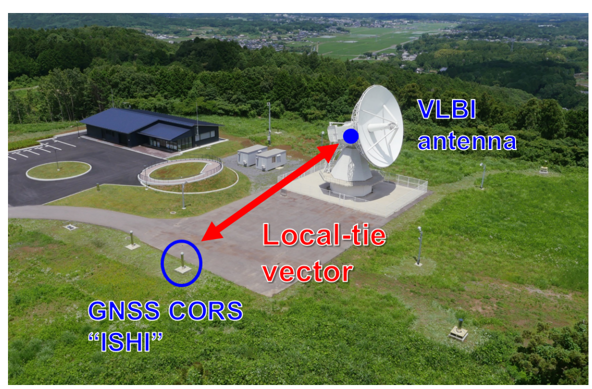

Fig. 3 VLBI–GNSS local-tie in Ishioka station.

5 Outlook

Ishioka station will continue to participate in the S/X and the VGOS observations coordinated by the IVS. In parallel with that, we will progress with the consideration for participating in both broadband and S/X observations with the QRFH feed. At the moment, the circular polarized signal is treated in S/X observation and the linear polarization signal is treated in broadband observation. To participate in S/X observations with the QRFH feed, it is required to convert the polarization from linear to circular in the process of signal from receiver to recorder. Furthermore, we are setting up the new sampler DBBC3 for our operating system. In addition, we will continue to conduct co-location surveys regularly.

References

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