Implementation of Ishioka VGOS Station

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Abstract

The Geospatial Information Authority of Japan (GSI) started a new project to construct a VGOS (VLBI Global Observing System) station in Japan. Construction of the antenna (radio telescope) is complete, and the necessary equipment (Front-end, Back-end, H-maser, and so on) has been delivered. The name of the new site is the Ishioka Geodetic Observing Station. It is located 16.6 km away from the Tsukuba 32-m antenna. We briefly report on the implementation of the new station, especially the initial receiving performance of the new antenna, and the first geodetic results of VLBI observations carried out after February 2015.

1. Introduction

The Geospatial Information Authority of Japan (GSI) has carried out Very Long Baseline Interferometry (VLBI) observations since 1981. In the first period, from 1981 to 1994, we developed transportable VLBI systems with a 5-m antenna and a 2.4-m antenna, and used them to carry out domestic observations. Eight sites in Japan were observed, and their precise positions determined. In addition, joint Japan-Korea VLBI observations were carried out using a transportable 3.8-m antenna in 1995. In these observations, the Kashima 26-m antenna, which was removed in 2002, was used as the main station. Next, in the second period from 1994 to 1998, GSI established four permanent stations: the Tsukuba 32-m, Shintotsukawa 3.8-m, Chichijima 10-m, and Aira 10-m antennas. Regular VLBI observations using the four stations are being done. In particular, the Tsukuba 32-m antenna is a main station not only for domestic but also for international VLBI observations.

In 2011, GSI started a project to construct a new antenna following the VLBI2010 concept (Petrachenko et al., 2009), which is recommended by the International VLBI Service for Geodesy and Astrometry (IVS) as the next-generation VLBI system. ‘VLBI2010’ is now called VGOS (VLBI Global Observing System).

This paper gives an outline of the project, the initial receiving performance of the new antenna, and the first geodetic results of VLBI observations that have been carried out since February 2015.

2. Observing Facilities

In the new project, observing facilities were constructed. The conceptual design, consisting of six components, is depicted in Figure 1. As of October 1, 2015 temporary operation rooms are installed instead of the Operation Building, which will be completed by the end of February 2016.

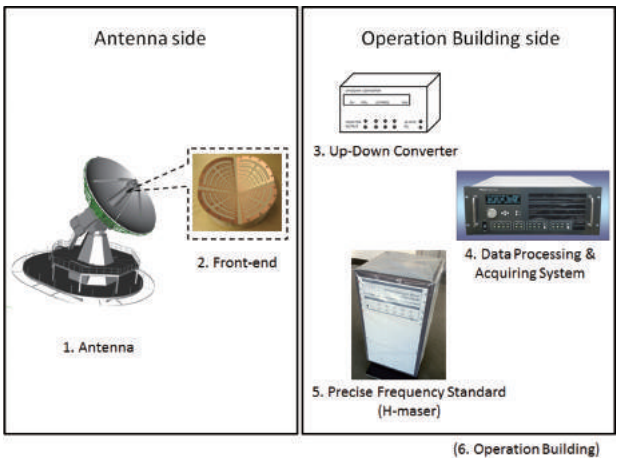

Fig. 1 Conceptual design of the new observing facilities

3. Site Information

The site is located in Ishioka in Ibaraki prefecture, which is near Tsukuba (about 16.6 km-NE from GSI). GSI rents the land from Ibaraki prefecture, and the station is installed in the grounds of the Ibaraki Prefectural Livestock Research Center. The site's name is the Ishioka Geodetic Observing Station (iGOS), because there is not only a VLBI, but also a Global Navigation Satellite System (GNSS) observation point and a Gravity measurement room. The location of the new station is shown in Figure 2. According to the results of a soil investigation of the site, the bedrock lies near to the surface, at a depth of less than 3 meters. This fact suggests that the groundwater effect, which has been the cause of the vertical movements at the Tsukuba station, may be avoidable (Munekane et al., 2010).

Fig. 2 Location of the new station

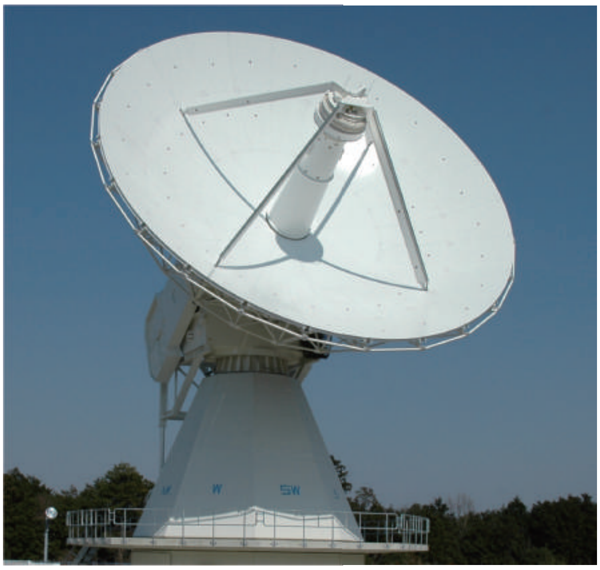

Fig. 3 Photo of the new antenna

Table 1 Specifications of the new antenna

Parameter	Value
Diameter	13.2 m
RF frequency range	2-14 GHz
Optics	Ring Focus
Surface accuracy	$\leqq$ 0.1 mm(rms)
AZ maximum slew rate	12°/sec
EL maximum slew rate	6°/sec
AZ maximum acceleration rate	3°/sec^2
EL maximum acceleration rate	3°/sec^2
Special features	Reference point can be measured directly from the ground for co-location.

4. Antenna and Front-end

4.1 Antenna

The antenna (radio telescope) is the main part of the observing system (Figure 3). Since a single antenna is employed, very high slew rates are specified, to comply with the VGOS concept. In addition, Ring Focus optics was applied for the antenna design to match the beam pattern of the broadband feed. The specifications of the antenna are listed in Table 1.

4.2 Front-end

According to the VGOS concept, a broadband feed is necessary to achieve high aperture efficiency over 2-14 GHz. Because the Eleven feed, which has been developed at Chalmers University of Technology in Sweden, and the Quadruple-Ridged Flared Horn (QRFH), which is developed at the California Institute of Technology (Caltech), are both practical as a broadband feed, both feed systems were purchased. Which of these two feeds to employ will be determined after evaluation of the antenna receiving performance with the two feeds.

In both cases, each feed and its Low Noise

Amplifiers (LNAs) is installed in a separate cryogenic system whose physical temperature is less than 20 K. The measured receiver noise temperatures for the QRFH system are less than approximately 30 K for both polarizations (see Fig. 4.).

In addition, to achieve compatibility with the legacy S/X band observation, a tri-band feed system was also purchased. The initial receiving performance was measured using the tri-band feed system (see the following section).

A phase and cable calibration system was also installed. A new type of P-cal unit, designed by the Haystack observatory, has been developed and employed. In addition, instead of the present D-cal unit, a new cable calibration system developed by the National Institute of Information and Communications Technology (NICT) is also employed. The specifications of the front-end are shown in Table 2.

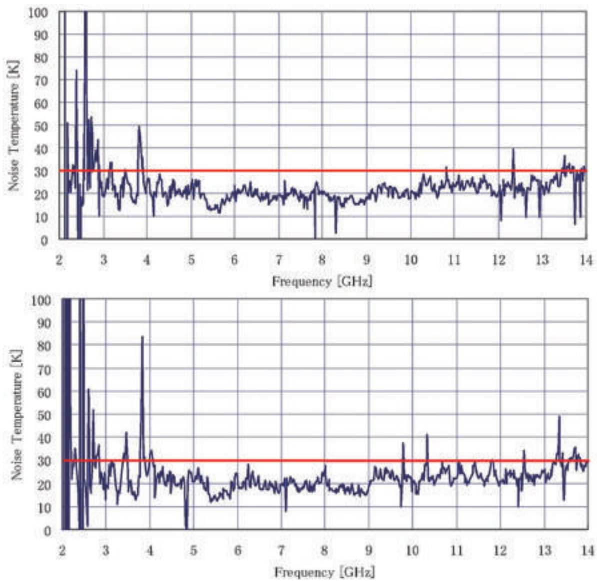

Fig. 4 Receiver noise temperatures for QRFH system (Upper: Horizontal polarization, Lower: Vertical polarization)

Table 2 Specifications of the front-end

Parameter	Value
RF frequency range	2-14 GHz
Polarization	Dual linear polarization
Feed	Eleven feed or QRFH
Dewar	Feed, LNAs, and other devices should be included and cooled by cryogenic system.
Physical temperature	≦ 20 K
Receive noise temperature	≦ 30 K
Total gain	≧ 45 dB
Output frequency range	2-14 GHz
Number of outputs	2 (for dual linear polarization)
Phase and delay calibration	New P-cal unit designed by Haystack Observatory, New cable calibration system developed by NICT
Injection of P-cal/noisesource	Pre-feed (Eleven feed) or pre-LNA (QRFH)

5. Receiving Performance

First of all, the receiving performance of the new antenna with tri-band feed system was tested by measuring radio signals from some strong radio stars (Cas-A, Taurus-A, Virgo-A). The SEFD values for the X and S bands were approximately 1,250 Jy and 1,700 Jy, respectively. This means that the aperture efficiencies for the X and S bands are 77% and 59% respectively, if the system noise temperature is assumed to be 50 K. High receiving performance for the X band was confirmed as a feature of the Ring Focus optics. The receiving performance for the Ka band has not been measured yet.

As a next step, the receiving performance with QRFH system was measured. Unfortunately only the sun was detectable, and it was realized that modification of the cryogenic dewar would be necessary to improve the sensitivity of QRFH. We are planning to improve the cryogenic dewar by the end of March 2016.

Finally, the receiving performance with Eleven feed was measured by receiving radio signals from some strong radio stars (Cas-A, Taurus-A, Cygnus-A). The SEFD values in the frequency range from 3 to 14 GHz are shown in Figure 5. The SEFD values less than 9 GHz are acceptable (less than 2,000 Jy), but unfortunately SEFD values greater than 10 GHz get worse and reach 7,500 Jy at 14 GHz.

On the other hand, radio frequency interference (RFI) is more serious than expected because of a feature of Ring Focus optics. In the case of Ring Focus optics, the aperture efficiency is better, but artificial radio signals can reach the feed more easily than the usually-used optics like Cassegrain. At the new station, the RFI caused by the radio signals for cellular phones is so strong in the frequency range less than 2.1 GHz that saturation of the amplifiers for the S band occurs. In order to avoid the saturation of the S band amplifiers, three types of filters, High Pass Filter (cut less than 2.2 GHz), Notch Filter (cut 2.1 GHz), and Band Pass Filter (pass 2.2-2.4 GHz), are installed in the signal chain of the antenna, and VLBI observation can be carried out normally at present.

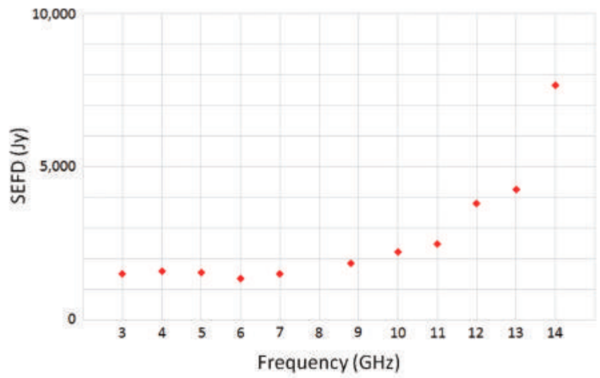

Fig. 5 SEFD values of the new antenna with Eleven feed

6. First Geodetic Result

The first geodetic VLBI observation at Ishioka station was carried out in February 2015 in the Japanese domestic network including GSI's VLBI stations (Tsukuba 32-m, Aira 10-m, and Chichijima 10-m antenna). By the end of June 2015, the Ishioka station had participated in two types of VLBI sessions. One is the Japanese domestic session JADE (JApanese Dynamic Earth observation by VLBI) and the other is AOV (Asia-Oceania VLBI group for Geodesy and Astrometry) session, which started in 2015 for the Asia-Oceania region. In total ten 24-h VLBI sessions were observed at Ishioka station, and the precise geodetic results were successfully obtained for JADE sessions, which were analyzed by GSI. The results of baseline length between Ishioka and the Tsukuba 32-m antenna are listed in Table 3. The standard deviation for each session is the range 1-2 mm, which is reasonable for the Ishioka-Tsukuba baseline.

Table 3 Results of baseline length between Ishioka and Tsukuba

Session	Date	Baseline Length
JD1502	Feb. 19	16,606,288.71 ± 1.58mm
JD1503	Mar. 05	16,606,290.88 ± 1.04mm
JD1504	Mar. 12	16,606,285.38 ± 1.39mm
JD1505	Apr. 23	16,606,291.41 ± 1.31mm
JD1506	May. 14	16,606,293.14 ± 1.50mm
JD1507	Jun. 04	16,606,290.03 ± 1.27mm
JD1508	Jun. 11	16,606,291.17 ± 1.34mm

7. Future plan

Parallel observations with the Tsukuba 32-m station using the legacy S/X band mode will be performed by the end of 2016 in order to determine an accurate tie vector between Ishioka and the Tsukuba 32-m antenna, which is very important information to succeed the accurate coordinates of the Tsukuba 32-m antenna, which have been determined by observations over 20 years.

The Ishioka station will also participate in the VGOS session with VGOS stations in the world. The first VGOS session is scheduled in August 2016.

8. Summary

A new project for constructing a new antenna in Japan has started. The new station will be fully compliant with the VGOS concept. The construction of the antenna was completed by the end of March 2014. The measurement of the receiving performance of the antenna was performed, and high aperture efficiency for the X band was confirmed.

The first geodetic VLBI observation was carried out in February 2015, and ten VLBI observations were performed up to June 2015. Precise geodetic results were successfully obtained.

This station will play an important role as a main station in the Asian region instead of the Tsukuba 32-m station in the near future.

Acknowledgements

VLBI operation software developed by National Aeronautics and Space Administration (NASA) is employed at Ishioka station. Installation and customization of this software was performed by NICT under a joint research agreement between GSI and NICT.

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