# VERA Geodetic Activities

*Takaaki Jike, Seiji Manabe, Yoshiaki Tamura, Makoto Shizugami, VERA group*

**Abstract**

Geodetic activities of VERA in the year 2010 are briefly described. The regular geodetic observations are carried out both in K- and S/X-bands. The frequency of regular observations are three times a month—twice for the VERA internal observations in K-band and once in S/X-band. The networks of the S/X sessions are JADE of GSI and IVS-T2. The raw data of the T2 sessions are electronically transferred to the Bonn and Haystack correlators via Internet by using the Tsunami protocol.

Gravimetric observations are carried out at the VERA stations. The superconducting gravimeter previously installed at Esashi Earth Tides Station was moved to Mizusawa and placed in the vicinity of the VERA antenna in order to monitor vertical displacement at the end of 2008, and the observation continued throughout the year.

## 1. General Description

VERA is a Japanese domestic VLBI network consisting of Mizusawa, Iriki, Ogasawara, and Ishigakijima stations. Each station is equipped with a 20-m radio telescope and a VLBI backend. The Ishigakijima antenna is shown in Figure 1. The VERA array is controlled from the Array Operation Center at Mizusawa via Internet.

The primary scientific goal of VERA is to reveal structure and dynamics of our Galaxy by determining 3-dimensional force field and mass distribution. Galactic maser sources are used as dynamical probes, the positions and velocities of which can be precisely determined by phase referenced VLBI relative to extragalactic radio sources. The distance is measured as a classical annual trigonometric parallax. The observing frequency bands of VERA are S and X, K (22 GHz) and Q (43 GHz). Geodetic observations are made in S/X- and K-bands. Q-band is currently not used for geodesy. Only a single beam is used even in K-band in geodetic observations, although VERA can observe two closely separated ($0.2^\circ <$ separation angle $< 2.2^\circ$) radio sources simultaneously by using the dual beam platforms.

General information about the VERA stations is summarized in Table 1, and the geographic locations are shown in Figure 2. Lengths of baselines range from 1000 km to 2272 km. The skyline at Ogasawara station ranges from 7° to 18° because it is located at the bottom of an old volcanic crater. The north-east sky at Ishigakijima station is blocked by a near-by high mountain. However, the majority of the skyline is below 9°. The skylines at Mizusawa and Iriki are low enough to observe sources with low elevation. Since Ogasawara and Ishigakijima are small islands in the open sea and their climate is subtropical, the humidity in the summer is very high. This brings about high system temperatures in the summer, in particular in K and Q bands. Iriki station as well as these stations are frequently hit by strong typhoons. The wind speed sometimes reaches up to 60–70m/s.

## 2. Technical Parameters

Parameters of the antennas and front- and back-ends are summarized in Tables 2 and 3 respectively. Two observing modes are used in geodetic observations. One is the VERA internal observation in K-band with the recording rate of 1 Gbps. The other is the conventional S/X-

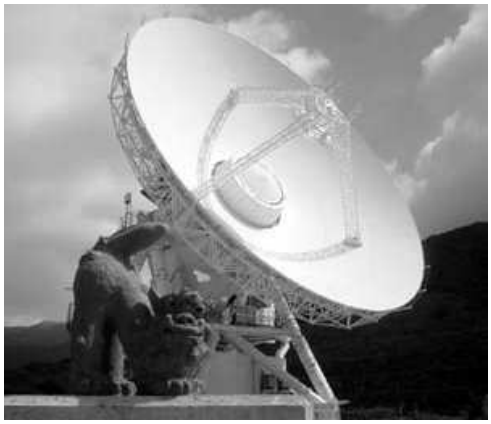

Figure 1. VERA Ishigakijima antenna.

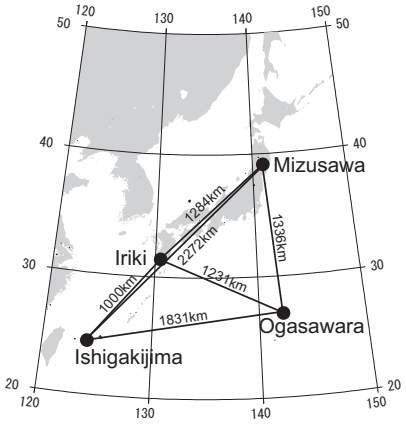


Figure 2. Location of the VERA stations.

Table 1. General information.

| | | |
|---|---|---|
| Sponsoring agency | Mizusawa VLBI Observatory,<br>National Astronomical Observatory of Japan | |
| Contributing type | Network observing station | |
| Location | Mizusawa | 141° 07’ 57”.199E, 39° 08’ 00”.726N, 75.7m(sea level) |
| | Iriki | 130° 26’ 23”.593E, 31° 44’ 52”.437N, 541.6m(sea level) |
| | Ogasawara | 142° 12’ 59”.809E, 27° 05’ 30”.487N, 223.0m(sea level) |
| | Ishigakijima | 124° 10’ 15”.578E, 24° 24’ 43”.834N, 38.5m(sea level) |

band observation with K5-VSSP. JADE, which is GSI’s domestic observation project, and IVS-T2 sessions belong to this class. Only Mizusawa and Ishigakijima participated in these sessions.

Table 2. Antenna parameters.

| | | | | |
|---|---|---|---|---|
| Diameter | 20m | Slew | Azimuth | Elevation |
| Mount | Az-El | range | -90° – 450° | 5° – 85° |
| Surface accuracy | 0.2mm(rms) | speed | 2.1°/sec | 2.1°/sec |
| Pointing accuracy | <12”(rms) | acceleration | 2.1°/sec$^2$ | 2.1°/sec$^2$ |

| | S | X | K |
|---|---|---|---|
| HPBW | 1550” | 400” | 150” |
| Aperture efficiency | 0.25 | 0.4 | 0.47 |

## 3. Organizational Change and Staff Members

Mizusawa VERA Observatory of NAOJ was reorganized to Mizusawa VLBI Observatory in April 2009. VERA and VSOP-2 were integrated into a unified project. Noriyuki Kawaguchi was inaugurated as Director in April 2010. The geodesy group consists of S. Manabe (chief, scientist), Y. Tamura (scientist), T. Jike (scientist), and M. Shizugami (software technician).

Table 3. Front-end and back-end parameters.

| Front-end | | | | | |
|---|---|---|---|---|---|
| Frequency band | Frequency range(GHz) | Receiver temperature | Polarization | Receiver type | Feed |
| S | 2.18–2.36 | 100°K | RHC | HEMT | Helical array |
| X | 8.18–8.60 | 100°K | RHC | HEMT | Helical array |
| K | 21.5–24.5 | 39±8°K | LHC | HEMT(cooled) | Horn |
| Back-end | | | | | |
| Type | channels | BW/channel | Filter | Recorder | Deployed station |
| VERA | 16 | 16MHz | Digital | DIR2000 | 4 VERA |
| K5-VSSP | 16 | 4MHz | VC | HDD | Mizusawa Ishigakijima |

## 4. Current Status and Activities

### 4.1. VLBI

VERA observes seven days a week except for the maintenance period in the summer. The nominal frequency of geodetic observations is three days a month. Among these three, VERA internal geodetic observations in K-band are performed twice a month and Mizusawa and Ishigakijima participate in JADE by GSI or IVS-T2 sessions in S/X-band on a once-a-month basis. The main purpose of the VERA internal geodetic observations is to determine relative positions of the VERA antennas accurate enough for astrometric requirements. The purpose the S/X sessions is to make the VERA coordinates refer to the IVS reference frame. The reason for the shift of the observing frequency band from S/X-band to K-band is to avoid the strong radio interference by cellular phone in S-band, particularly at Mizusawa. Interfering signal which has line spectra is filtered out. However, this filtering considerably degrades the system noise temperature. It is likely that the S-band observation will become impossible in the near future. On the other hand, VERA has the highest sensitivity in K-band as shown in Table 3. Thanks to the high sensitivity in this band the maximum number of scans in K-band is 800/station/24-hours, while that in S/X-band is 500 at most. It has been confirmed that the K-band observations are far more precise, although the ionospheric delay is not corrected for. In fact, standard deviations of the individual determinations of the antenna positions in K-band are less than half of those in S/X-band.

The error ellipsoid is fairly elongated in the vertical direction due to the insufficient network size for separating the vertical displacement from the zenith atmospheric delay variation. There seems no significant systematic difference in the estimated coordinates between S/X- and K-bands. This means that the majority of the ionospheric effect can be eliminated in the course of estimating the tropospheric delay, at least for the VERA network whose typical size is around 2300 km. However, the number of observations are not enough to derive a definite conclusion.

In order to link the VERA network to the international reference frame, VERA started participation in the IVS-T2 sessions by using Mizusawa and Ishigakijima stations in 2009. The observations at Ishigakijima were conducted by GSI. In September 2009, we successfully made

a test observation and electronic data transfer to the Haystack correlator via Tsunami protocol. In 2010, we participated in six T2 sessions and in three JADE sessions. VERA internal geodetic observations were carried out 28 times. The final estimation of the geodetic parameters are derived by using the software developed by VERA team.

### 4.2. Other Activities

Continuous GPS observations were carried out at each VERA station throughout the year. The observation of gravity tide with a LaCoste-Romberg gravimeter at Ogasawara was completed, and that at Ishigakijima is underway. The provisional result shows that there is no large discrepancy in the tidal amplitude and phase between the observations and those predicted by ocean models.

The superconducting gravimeter (SCG) was moved from the Esashi Earth Tides Station to Mizusawa in order to accurately monitor gravity change for the purpose of monitoring height change at VERA Mizusawa station. Four water table gauges surrounding the SCG were used for monitoring the water table height. The preliminary results show that gravity variation due to the variation of the water table can be corrected as accurately as the 1$\mu$gal level.

## 5. Future Plans

The internal K-band VLBI and the participation in the IVS-T2 sessions will be continued. Continuous GPS and gravimetric observations will also be carried out. Reconfirmation of local ties between GPS and VLBI has become an urgent task. The possibility of optical fiber links between Mitaka and the VERA stations is being pursued. Widening of the receiving and recording bandwidth is planned.