VERA Geodetic Activities

Takaaki Jike, Yoshiaki Tamura, Makoto Shizugami, VERA group

Abstract

This report briefly describes the geodetic activities of VERA in the year 2012. The regular geodetic observations are carried out both in K- and S/X-bands. The frequency of regular observations is three times a month—twice for the VERA internal observations in K-band. The networks of the S/X sessions are JADE of GSI and IVS-T2. The raw data of the T2 and JADE sessions are electronically transferred to the Bonn, Haystack, and GSI correlators via Internet.

Gravimetric observations are carried out at the VERA stations. An SG was installed at Mizusawa and placed in the vicinity of the VERA antenna in order to monitor vertical displacement at the end of 2008, and the observations continued throughout the year. Also at the VERA-Ishigakijima station, continuous operation of the SG started in 2012.

The crustal movements generated by the 2011 earthquake off the Pacific coast of Tohoku continued during 2012, and displacement of the VERA-Mizusawa position by post-seismic creeping continued.

1. General Information

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

The primary scientific goal of VERA is to reveal the structure and the dynamics of our galaxy by determining three-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 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 northeast sky at Ishigakijima station is blocked by a nearby 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. These stations, as well as Iriki station, are frequently hit by strong typhoons. The wind speed sometimes reaches up to 60–70 m/s.

2. Component Description

Parameters of the antennas and the 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

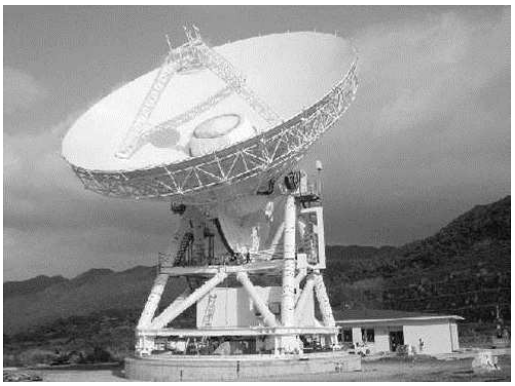

Figure 1. VERA-Ishigakijima 20-m antenna.

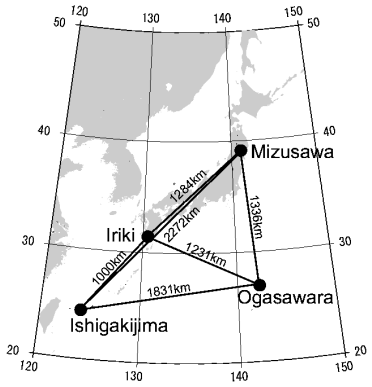

Figure 2. Locations of the VERA stations.

Table 1. General information.

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

mode in K-band with the recording rate of 1 Gbps. The other is the conventional S/X-band mode 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	20-m	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. Staff

Noriyuki Kawaguchi is the director of Mizusawa VLBI Observatory. The geodesy group consists of Seiji Manabe (scientist, retired in March 2012), Yoshiaki Tamura (scientist), Takaaki Jike (scientist), and Makoto Shizugami (engineer).

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	16 MHz	Digital	DIR2000	four VERA
K5-VSSP	16	4 MHz	Analog BBC	HDD	Mizusawa Ishigakijima

4. Current Status and Activities

4.1. VLBI

VERA observes seven days per week. The 24-hour geodetic sessions are allocated twice or three times in a month. Among these geodetic sessions, VERA internal geodetic observations in K-band are performed once or twice in 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 of the S/X sessions is to link the VERA coordinates into 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. The 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 observing 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 no correction is made for ionospheric delay. 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.

In order to link the VERA network to the international reference frame, VERA continues participation in the IVS-T2 sessions by using the Mizusawa and Ishigakijima stations. In 2012, a long maintenance period during October to December was allocated, during which the azimuth, elevation, and feed rotator motors were overhauled. Therefore, the period when VERA carried out regular VLBI observations was from January to September. We participated in six T2 sessions and in four JADE sessions. VERA internal geodetic observations were carried out 18 times. The final estimation of the geodetic parameters are derived by using the software developed by the VERA team.

4.2. Other Activities

Continuous GPS observations were carried out at each VERA station throughout the year. The superconducting gravimeter (SG) installed within the enclosure of the Mizusawa VLBI observatory, in order to accurately monitor gravity change for the purpose of monitoring height change at the VERA Mizusawa station, continued acquisition of gravity data. Four water level gauges surrounding the SG were used for monitoring the groundwater level. The preliminary results show that gravity variation due to the variation of the water table can be corrected as accurately as the 1μgal level. The SG was newly installed also in the VERA Ishigakijima station, and observing was started in January 2012. This observing aims at solving the cause of the slow slip event which occurs frequently around the Ishigaki island.

5. State of the Crustal Movement after the March 11, 2011 Earthquake at Mizusawa

After the 2011 earthquake off the Pacific coast of Tohoku (Mw=9.0) [Epoch=11 March 2011, 14:16:18 JST], VERA-Mizusawa was displaced by co-seismic crustal movement and post-seismic creeping. Also, during 2012, the creeping continued, although the speed declined (Figure 3). According to the newest analysis, the co-seismic steps are North=-1.274 m, East=2.337 m, and Up=-0.128 m in the horizontal coordinate system, and the displacement by creeping amounts to North=-0.258 m, East=0.756 m, and Up=0.067 m.

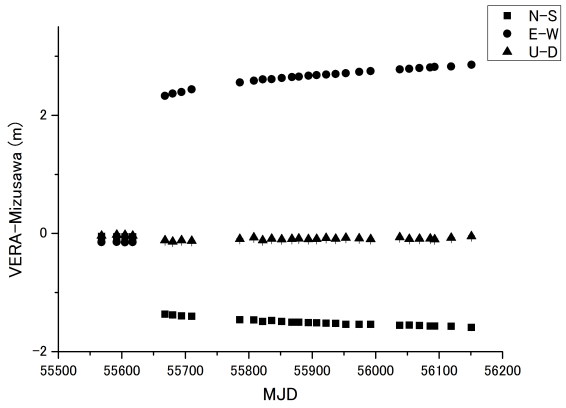

Figure 3. Movements of VERA-Mizusawa after 2011.

6. Future Plans

Now, the examination which increases the recording rate to 4 Gbps from 1 Gbps is being carried out. Furthermore, the examination for changing the recording system from tape recorder to HDD is also being implemented. With these changes, regular operation of a new software correlator is due to begin.