VERA Geodetic Activities

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Abstract

The geodetic activities of VERA in the year 2011 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. 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. 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.

The 2011 earthquake off the Pacific coast of Tohoku generated step-like and creeping-like movements to the VERAMZSW position.

1. General Description

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-Mizusawa antenna and the Mizusawa 10-m antenna are shown in Figure 1. In this figure, the antenna in the front is the Mizusawa 10-m antenna, and the one in the back is the VERA-Mizusawa antenna. The VERA array is controlled from the Array Operation Center at Mizusawa via Internet.

The primary scientific goal of VERA is to reveal the structure and the 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 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. Iriki station as well as these stations are frequently hit by strong typhoons. The wind speed sometimes reaches up to 60–70 m/s.

Figure 1. VERA-Mizusawa antenna and Mizusawa 10-m antenna.

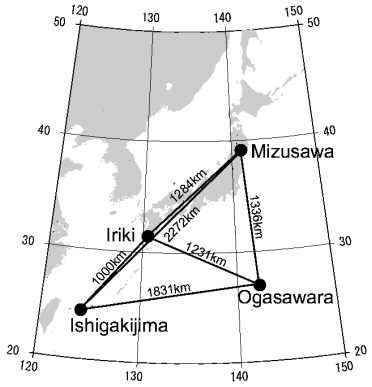

Figure 2. Location of the VERA stations.

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)

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-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

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

3. Current Status and Activities

3.1. 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 of 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. 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 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.

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 2011, we participated in seven T2 sessions and in three 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.

3.2. Other Activities

Continuous GPS observations were carried out at each VERA station throughout the year. 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 the VERA Mizusawa station. Four water table gauges surrounding the SCG were used for monitoring the water table height. SCG was installed also in the VERA Ishigakijima station in January 2012. The preliminary results show that gravity variation due to the variation of the water table can be corrected as accurately as the 1μgal level.

4. The 2011 Earthquake Off the Pacific Coast of Tohoku

The strong quakes by the 2011 earthquake off the Pacific coast of Tohoku (Mw=9.0) [Epoch=11 March 2011, 14:16:18 JST] damaged the VERA-Mizusawa 20-m antenna. Operations of the VERA-Mizusawa antenna stopped five weeks after the earthquake and for ten weeks of the repair period. VERAMZSW was displaced by co-seismic crustal movement and post-seismic creeping. These movements are clearly detected from VERA internal geodetic VLBI observations and continuous GPS observations. During the approximately three minutes of seismic motion, VERAMZSW was displaced 3.4 m at the maximum and shifted 2.4 m in the direction of east-northeast eventually. The co-seismic steps are X=-1.924 m, Y=-1.227 m, and Z=-1.062 m in the geocentric Cartesian coordinate system. The direction of the creeping is well agreed with the direction of co-seismic slip (Figure 3). Total length of the movement by the post-seismic creeping is 40.6 cm between 12 March and 31 December, 2011. This creeping is gradually decreasing but still continues.

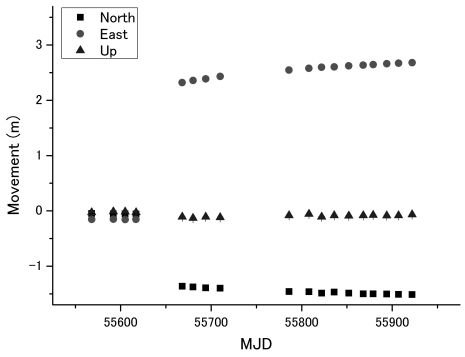

Figure 3. Movements of VERAMZSW after the 2011 earthquake.

5. Staff Members

The Mizusawa VERA Observatory of NAOJ was reorganized as the 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 (scientist), Y. Tamura (scientist), T. Jike (scientist), and M. Shizugami (software technician).