VERA 2015 and 2016 Geodetic Activities

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Abstract The geodetic activities of VERA in the years 2015 and 2016 are briefly described. The regular geodetic sessions were observed both in K- and S/X-bands. The frequency of regular sessions is three times a month—twice for the VERA internal sessions in K-band. The networks of the S/X sessions are AOV and IVS-T2. The raw data of the T2 and AOV sessions are electronically transferred to the Bonn, SHAO, and GSI correlators via Internet. Gravimetric observing is performed at the VERA stations. SGs are installed at Mizusawa and Ishigakijima in order to monitor precise gravity changes, and the observations continued for two years.

Fig. 1 The front view is of the Mizusawa 10-m antenna, and the back view is of the VERA Mizusawa 20-m antenna.

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 back-end. The VERA Mizusawa 20-m 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, C (6.4 GHz), 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. The lengths of the baselines range from 1,080 km to 2,272 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 allow sources to be observed at low elevations. Because Ogasawara and Ishigakijima are small

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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.

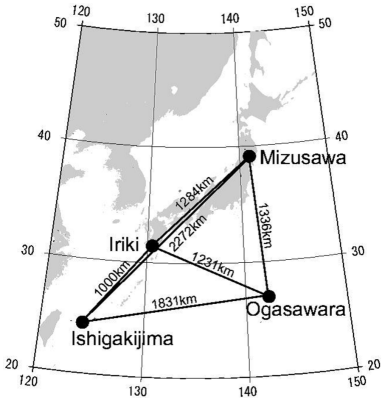

Fig. 2 Distribution of the stations in the VERA Network.

Table 1 Location.

Site name	Longitude	Latitude	Altitude
Mizusawa	141° 07' 57".199 E	39° 08' 00".726 N	75.7 m
Iriki	130° 26' 23".593 E	31° 44' 52".437 N	541.6 m
Ogasawara	142° 12' 59".809 E	27° 05' 30".487 N	223.0 m
Ishigakijima	124° 10' 15".578 E	24° 24' 43".834 N	38.5 m

2 Current Status

The parameters of the antennas and front- and back-ends are summarized in Tables 2 and 3, respectively. Two observing modes are used for geodetic observing. One is VERA internal observing in K-band with the recording rate of 1-Gbps. The other is conventional S/X-band observing with K5-VSSP. JADE, which is GSI's domestic observing project, and IVS-T2 sessions belong to this class. Only Mizusawa and Ishigakijima participated in these sessions.

Table 2 Antenna parameters.

Diameter of main reflector		20m	
Mount type		AZ-EL	
Surface accuracy		0.2mm (rms)	
Pointing accuracy		<12"(rms)	
	Azimuth	Elevation	
Slew range	-90° – 450°	5° – 85°	
Slew speed	2.1°/sec	2.1°/sec	
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 parameters			
Frequency band	S	X	K
Frequency range (GHz)	2.18–2.36	8.18–8.60	21.5–24.5
Receiver temperature	>100 °K	100 °K	39±8 °K
Polarization	RHC	RHC	LHC
Receiver type	HEMT	HEMT	cooled HEMT
Feed type	Helical array		Horn

Back-end parameters		
Observing type	VERA	T2, JADE, AOV
channels	16	16
BW/ch [MHz]	16	4 or 8
Filter	Digital	Analog video band
Recorder	OCTADISK	K5-VSSP
Rec. rate [Mbps]	1024	128
Deployed station	4 VERA	Mizusawa, Ishigakijima

3 Activities during the Past Two Years

VERA observes seven days a week, except for during a maintenance period from mid-June to mid-August. The 24-hour geodetic sessions are allocated two or three times in a month. Among these geodetic sessions, VERA internal geodetic sessions in K-band are performed once or twice in a month, and Mizusawa participates in JADE, AOV, or IVS-T2 sessions in S/X-band on a once-a-month basis. Ishigakijima participated in IVS-T2 or JADE sessions until February 2015. The main purpose of the VERA internal geodetic sessions is to determine the relative positions of the VERA antennas accurately enough for astrometric requirements. The purpose of the S/X sessions is to link the VERA coordinates into the IVS reference frame.

In the VERA internal geodetic sessions, the regularly-used frequency changed from S/X-band to K-band in 2007. 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 mobile phones in S-band, particularly at Mizusawa. The interfering signal which has line spectra is filtered out. But this filtering considerably degrades the system noise temperature. The interference zone is increasing, so it is likely that 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. 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 2015 and 2016, a long maintenance period from the middle of June to the middle of August was allocated for each year. Except for this period, VERA performed regular VLBI observing. Mizusawa participated in five T2 sessions, three JADE sessions, and two AOV sessions during 2015, and Ishigakijima participated in one JADE session and one T2 session in February 2015. In 2016, Mizusawa participated in five T2 sesions and three AOV sessions. VERA internal geodetic sessions were observed 15 times in 2015 and 18 times in 2016. The final estimates of the geodetic parameters are derived by using software developed by the VERA team.

Continuous GPS observing was performed 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 1 micro gal level. An SG was newly installed also at the VERA Ishigakijima station, and observing started in January 2012. The observing continued also during 2015—2016. The observing aims at solving the cause of the slow slip event which occurs frequently around the Ishigaki island.

4 Staff

Mareki Honma is the director of the Mizusawa VLBI Observatory. The geodesy group consists of Yoshiaki Tamura (scientist) and Takaaki Jike (scientist).

5 State of the Crustal Movement after Earthquakes

After the 2011 earthquake off the Pacific coast of Tohoku (Mw=9.0) [Epoch=11 March 2011, 14:16:18 JST], Mizusawa was displaced by co-seismic crustal movement and post-seismic creeping. Also from 2015 to 2016, the creeping continued, although the speed declined. According to the newest analysis, the co-seismic steps are X= -2.062 m, Y= -1.416 m, and Z= -1.064 m, and the displacement by creeping during two years, 2015 and 2016, is X= -0.182 m, Y= -0.105 m, and Z= -0.036 m. Due to the 2016 Kumamoto Earthquake (Mw=7.0) [Epoch=14 April 2016, 01:25:05 JST], crustal deformation changed the position of Iriki. The displacement of Iriki by co-seismic step and post-seismic creeping due to the Kumamoto Earthquake is more than 1 cm towards the south in total.

6 Recording, Correlation, and Future Plans

In 2015, we replaced our 1-Gbps recording system with a Hard Disk Recorder (OCTADISK) and our correlator with a Software Correlator. The examination of increasing a recording rate to 8-Gbps from 1-Gbps by using a high speed sampler (OCTAD) is being performed. Experimental geodetic VLBI observing was performed in February 2016 using the high speed sampler, and we can get geodetic solutions. It is planned that OCTAD will be placed in all of the VERA stations starting in 2017 and afterwards. Reconstruction of the S/X system is also planned, in accordance with the change to the specification of international VLBI Experiments. The received frequency of X-band will be widened to 8-9 GHz.