VERA Geodetic Activities

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Abstract

A general description of VERA is given from the standpoint of geodetic interest. Geodetic observations with VERA started in late 2002 and have been done routinely since late 2004. The frequency of regular observations are three times a month, that is, twice for VERA internal observations and once for participation in JADE of GSI. In 2006, alternating observations in S/X- and K-bands started in order to investigate the feasibility of observations in K-band. The results in 2006 show that precision of observations in K-band is twice as good as those of the S/X-band observations and there is no significant discrepancy between the S/X- and K-band observations when comparing day-to-day fluctuations. However, more observations are necessary to arrive at a final conclusion, such as the replacement of the S/X-band observations by the K-band observations. Future plans for 2007 are also described.

1. General Description

VERA is a Japanese domestic VLBI network consisting of Mizusawa, Iriki, Ogasawara and Ishigakijima stations. Each station is equipped with a 20m radio telescope and a VLBI backend. The Mizusawa 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 determinig 3-dimensional force field and mass distribution. Galactic maser sources are used as dynamical probes, 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. 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. 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, most part 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 summer is very high. This brings about high system temperature in summer, in particular in K and Q bands. These stations as well as Iriki station are frequently attacked by strong typhoons. The wind speed sometimes reaches 60–70 m/s.

2. Technical Parameters

Parameters of the antennas and front- and back-ends are summarized in Tables 2 and 3, respectively. The helical array antenna on one of the dual-beam platforms is shown in Figure 3. Two observation modes are used for geodetic observations. One is the VERA internal observation. The observing frequency bands are S/X and K and the recording rate is 1 Gbps. The other is the

Figure 1. Mizusawa VERA antenna (foreground)

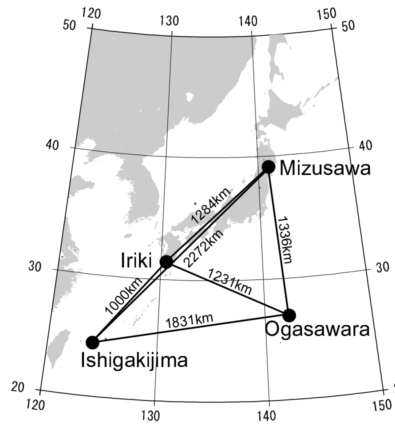

Figure 2. Location of VERA stations

Table 1. General information

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

joint observation with the Geographic Survey Institute (GSI) by Mizusawa's participation in GSI's domestic observation sessions called JADE. Its frequency band is S/X and the recording rate is 128 Mbps. A K5-VSSP data aquisition terminal is used.

3. Staff Members

The VERA team of NAOJ is led by Hideyuki Kobayashi and consists of 9 scientists, 10 technicians and 4 post-docs. Among them the members of the geodesy group are S. Manabe (chief, scientist), Y. Tamura (scientist), T. Jike (scientist), and M. Shizugami (software technician). The AOC is operated by VERA members independent of geodetic or astronomical staffing.

4. Current Status

VERA observes 6 days a week, except for a maintenance period in summer. Geodetic observations have been regularly scheduled 3 days a month since late 2004. VERA internal geodetic observations are performed twice a month and the monthly participation of Mizusawa in JADE with GSI is done on a once per month basis. The purpose of the JADE participation is to obtain VERA's coordinates in the terrestrial reference frame realized by the IVS. S/X- and K-band observations are alternately made within a framework of the VERA internal observations. The reason for the K-band observation is to avoid the strong radio interference by cellular phone in S-band,

Table 2. Antenna parameters

Diameter	20m			
Mount	Azimuth–Elevation			
Surface accuracy	0.2mm(rms)			
Pointing accuracy	<12h(rms)			
	S	X	K	
HPBW	1550”	400”	150”	5
Aperture efficiency	0.25	0.4	0.47	
Slew	Azimuth	Elevation		
range	-90°–450°	5°–85°		
speed	$2^{\circ}.1$/sec	$2^{\circ}.1/\mathrm{sec}^2$		
acceleration	$2^{\circ}.1/\mathrm{sec}^2$	$2^{\circ}.1/\mathrm{sec}^2$		

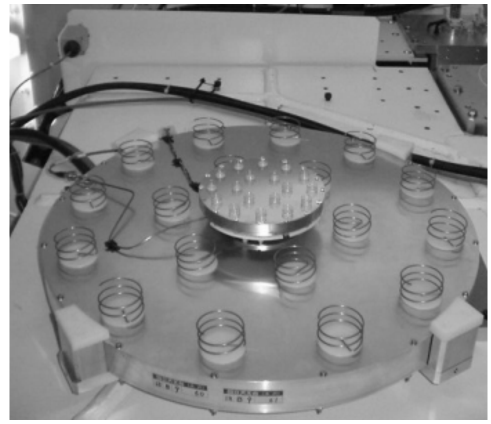

Figure 3. Helical array
Large and small disks are for S- and X-bands, respectively.

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	Miuzsawa

particularly at Mizusawa. An 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 becomes impossible in the near future. Experimental K-band observations are made in order to clarify how accuracy is improved by taking advantage of relatively high sensitivity and no interference in K-band. However, since the K-band observation uses only a single frequency band, there is the possibility that the effect of the ionosphere is considerably large even for a small network such as VERA. Besides this possibility, there might be unknown systematic differences between the conventional S/X-band and K-band observations.

The number of scans in S/X-bands is typically 500/station/24hours, while that in K-band is 800 thanks to the high sensitivity in this band. The precision of the site topocentric coordinates in the S/X-bands are 1–2 mm and 7–9 mm for the horizontal and vertical components, respectively. Those of the K-band observations are <1mm and 5mm. The error ellipsoid is strongly elongated in the vertical direction due to the insufficient network size for separating the vertical displacement from the atmospheric zenith delay variation. There seems to be no significant systematic difference in the estimated coordinates between S/X and K-bands. This means that the most part 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 2000 km. However, the number of observations is not enough to derive a definite conclusion.

VERA has a fifth DIR2000 besides the four at the VERA stations for recording purposes at Mitaka correlation center. This recorder is used to record data sent from Tsukuba 32m antenna linked to the Mitaka correlation center via optical fiber network. There were a few experiments where Tsukuba was treated as if it were the fifth VERA station. The experiments were successful. However, final comparison with JADE is not yet complete.

The raw data are correlated by Mitaka FX Correlator that has 5-station capability. Final results for the geodetic parameters are derived by using the software developed by VERA team.

A LaCoste-Romberg gravimeter was installed at Ishigakijima station in spring of 2006 in order to precisely determine the tidal characteristics of Ishigakijima station. The provisional result seems to indicate that there is no large discrepancy in the tidal amplitude and phase between the observation and the model calculation based on the latest ocean tide model, NAO.99Jb (Matsumoto et al., 2000 [1]).

5. Plans for 2007

Regular geodetic observations will be continued with the same frequencies as those in 2006. The S/X- and K-band observations will be alternately made until it becomes clear whether the K-band can replace the S/X-band or not. The participation in JADE will also be continued. Joint observations with the 11m telescope of Gifu University is planned to start in the spring. The Gifu telescope was formerly equipped with an S/X-band receiver. Last year the S/X-receiver was replaced by a K-band receiver. The telescope is linked to Mitaka via optical fiber and it is possible to record Gifu data by using a DIR2000 1Gbps recorder at Mitaka. Gifu is expected to join regularly the VERA internal observations in K-band and will be able to be regarded as the fifth station of VERA at least for geodetic purposes. Experimental observations with Tsukuba in the same mode will also be made. However, since VERA can only record 5-station data simultaneously, it is not possible to have both stations participate at the same time.

Gravimetric observations by LaCoste-Romberg gravimeter will continue at Ishigakijima in order to clarify tidal characteristics there. Three more LaCoste-Romberg gravimeters will be deployed in Iriki, Ogasawara and Mizusawa.

Plans other than observations are improvement of software, such as model update and GUI, and improvement and automization of data analyses.

References

[1] Matsumoto, K., Takanezawa, T. and Ooe, M.:2000, Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: a global model and a regional model around Japan, Journal of Oceanography, 56,567-581.