VERA Geodetic Activities

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Abstract This is a brief description of VERA's geodetic activities over the years 2023 and 2024. Both K-band and S/X-band were used for regular geodetic observations, with S/X-band used for IVS sessions and K-band for VERA internal geodetic VLBI sessions. Sampler/Recorders named OCTAD-OCTADISK2 were commonly used for IVS sessions, and the recorded raw data files were transferred electronically via the Internet to the correlator designated for each session. K-band sessions were domestic VLBI observations made on the VERA network, with recording rates of 2 Gbps. The data for this session type were processed and analyzed in Mizusawa from correlation to analysis. The Mizusawa antenna was out of operation for 15 months due to an EL motor failure, during which time geodetic observations within VERA decreased and participation in IVS sessions in particular stopped.

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 array is controlled from the Array Operation Center (AOC) at Mizusawa via Internet. Correlation processing of the data recorded by our VLBI array is performed by the software correlator at Mizusawa. Figure 1 shows the two parabola antennas at Mizusawa.

Fig. 1 Front view is the Mizusawa 10-m antenna and back is the VERA Mizusawa 20-m antenna.

The primary scientific goal of VERA by FY 2021 was to reveal the structure and the dynamics of our galaxy by determining a three-dimensional force field and mass distribution. Starting in 2022, a project called VLCOP has begun to conduct experimental VLBI observations, and proposals for observations with a variety of scientific objectives, not just radio astronomy, are widely invited. The first proposal was made in August 2022, and observations tentatively started in October 2022. This project has continued after 2023.

The observation frequency bands of VERA are listed with the S-, C-, X-, K-, and Q-bands as regular observation bands. S- and X-band are in operation only at Mizusawa. In addition, L- and W-band receivers have been installed in Mizusawa and Ishigakijima, and pilot experiments have begun. Geodetic observations are made in S/X- and K-bands. C- and Q-band are

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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 ($0.3^\circ <$ separation angle $< 2.2^\circ$) radio sources simultaneously by using the dual-beam platforms.

Table 1 Location of the VERA stations.

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

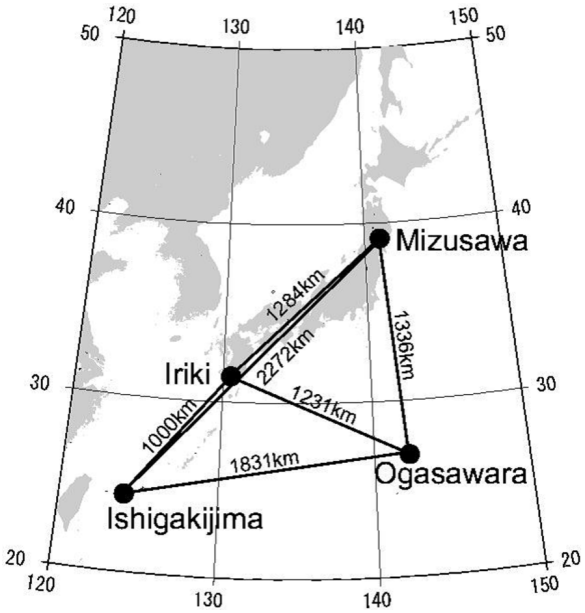

Fig. 2 Distribution of the stations in the VERA Network.

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 depression. 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. Because 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, Ogasawara, and Ishigakijima stations are frequently hit by strong typhoons. The wind speed sometimes reaches up to 60–70 m/s. Mizusawa often stops operating its antenna due to heavy snow in winter.

2 Current Status

The parameters of the antennas are summarized in Table 2, and front- and back-ends are summarized in Table 3, respectively. The Actual Receiver Temperature of S-band is much higher than the notation of the table due to the influence of interference. Two observing modes are used for geodetic observations. One is the VERA internal observation in K-band with the recording rate of 2 Gbps using VSREC. The other is the conventional S/X-band observation with OCTAD DBBC–OCTADISK2 (1 Gbps and 512 Mbps) [1]. AOV and T2P sessions belong to this class, and only Mizusawa participated in these sessions. OCTADISK was used for VERA's internal geodetic sessions until 2022, but due to the increased amount of data being recorded in shared use in EAVN sessions, the recording of geodetic observations was shifted to the use of VSREC to reduce the operational load on disk storage and correlator systems.

Table 2 Antenna parameters.

Diameter of main reflector	20 m
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

Freq. Band	S	X	K
HPBW	1550″	400″	150″
Aperture efficiency	0.25	0.4	0.47

The recorded data of the IVS session is transferred to the designated correlation station via the Internet after format conversion. Currently, the correlating

Table 3 Front-end and back-end parameters for Geodetic VLBI Observations.

Front-end parameters			
Frequency band	S	X	K
Frequency range (GHz)	2.18–2.39	8.18–9.10	21.4–23.6
Receiver temperature	$>$100 °K	100 °K	39$\pm$8 °K
Polarization	RHC	RHC	LHC
Receiver type	HEMT	HEMT	cooled HEMT
Feed type	Helical array		Horn

Back-end parameters			
Observation type	VERA Intl.	T2P	AOV
ADConv [MHz-bit]	1024-2	16-2	32-2
Channel	1	16	16
Sampler	ADS1000	DBBC	DBBC
HDD Recorder raid system	VSR	OCD2	OCD2
Recording rate [Mbps]	2048	512	1024
Deployed station	four VERA	Mizusawa	

VSR: VSREC, OCD2: OCTADISK2
DBBC: OCTAD Digital Baseband Converter

stations to which NAOJ has allowed forwarding of data are Bonn, University of Tasmania, Tsukuba, and Shanghai. The formats of the exported data files are k5vssp32 and mk5b.

The data correlation process for the K-band geodetic sessions is performed by the Software Correlator located in Mizusawa (Figure 3), and the geodetic analysis is completed within NAOJ. Specifications of correlation and geodetic analysis are shown in Table 4. Correlation output data are stored on NAOJ's data server.

Fig. 3 View of the Mizusawa Software Correlator and data servers in Mizusawa Correlation Office.

Table 4 Specifications and parameters of correlation and analysis.

Correlator	Software Corrlalator
Correlation Type	FX
Delay Tracking Time System	Geocentric
Number of Spectra	512 points
Accumulation Frequency	1 Hz
Correlation Output Format	CODA F/S and FITS-IDI
Delay Type	Group Delay
Delay Datafile Format	FITS binary table
Analysis Tools	calc and msolv package

3 Activities during the Past Two Years

VERA's antennas have been aging for more than 20 years since their construction, and this aging has led to serious failures and extended antenna outages in 2023–2024. Details are as follows. Ishigakijima was mostly shut down from January to July 2023 due to a power line failure caused by termites and ACU failure. Ogasawara was shut down in September 2023 due to an EL motor failure. Because the spare motor had also failed, the EL motor at Mizusawa was removed and attached to the antenna at Ogasawara, and with that treatment, Ogasawara returned to observation in October, while Mizusawa's antenna was shut down in September. This was due to the priority given to the operation of the three VERA southern stations and the repair of the motor at Mizusawa. In April 2024, the EL motor at Iriki suffered the same failure as the one at Ogasawara. Another EL motor that remained in Mizusawa was installed in Iriki, and antenna operation in Iriki resumed in May. Therefore, until two EL motors were restored, Mizusawa was completely out of operation.

The cause of the motor failure was determined to be a detached permanent magnet attached to the rotor. Pending the completion of repairs to the two motors, the Mizusawa antenna finally returned to operation at the end of October 2024. Mizusawa is one of the most important stations in VERA, responsible for coupling with the international reference system, but the failure completely halted observations for 15 months. Figure 4 shows the participation of each of the four stations for geodetic VLBI observations performed in the VERA network from 2023 to 2024. In the unlikely event that the antenna facilities of the VERA stations fail and operations cease, it must be more than considered that Mizusawa will take their place in the future.

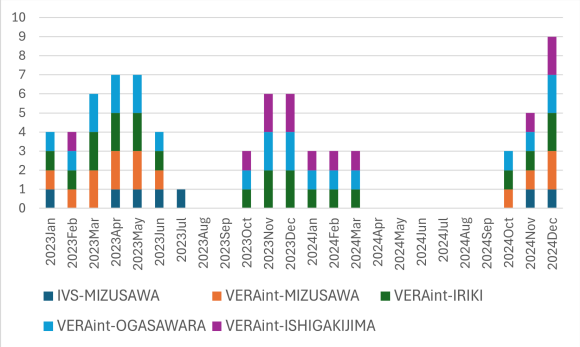

Fig. 4 Geodetic VLBI observations at each VERA station from 2023 to 2024.

Computer and network system updates occurred throughout NAOJ in May 2024. Data export of Mizusawa IVS sessions resumed in November 2024. The network connection for data export has been and continues to be rebuilt each time a correlation station is added to the export destination.

4 Future Plans

An SKA sub-project was established under the Mizusawa VLBI observatory in FY 2023. At the request of SKA Japan, VERA will provide a testing field to conduct basic experiments. We plan to add VDIF (release 1.1.1) to the format of recorded raw data for export and are currently testing the operation of data format conversion software. The experiment of relativistic geodetic observation using two "Optical Lattice Clocks" [2] was continued, and the application of Optical Lattice Clocks to VLBI, which began in 2024, will also continue.

5 Staff

Mareki Honma is the director of Mizusawa VLBI Observatory. The geodesy group consists of Yoshiaki Tamura (scientist) and Takaaki Jike (scientist). Jike is also responsible for the operation of the Mizusawa Correlation Office.

References

1. Y. Kono, T. Oyama, N. Kawaguchi, S. Suzuki, K. Fujisawa, H. Takaba, K. Sorai, M. Sekido, S. Kurihara, Y. Murata, H. Uose, "Real-time VLBI Network with 10GbE Connection, OCTAVE", in D. Behrend and K. Baver, editors, *International VLBI Service for Geodesy and Astrometry 2012 General Meeting Proceedings*, NASA/CP-2012-217504, pages 96–98, 2012.
2. H. Katori, https://doi.org/10.52926/JPMJMI18A1, 2018.