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Geodetic Observation System in VERA

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Abstract

VERA (VLBI Exploration of Radio Astrometry) consists of four VLBI stations. Each Station has a 20 m diameter antenna and is capable of observing at the frequencies of 2, 8, 22 and 43 GHz bands. The baseline length of VERA network is 1000–2270 km. The first VLBI fringe test in 22 GHz band was carried out in February 2002 between two stations. The geodetic observation system is under preparation to carry out the first observation in middle of 2002. Several observation modes are expected in the geodetic VLBI observations in VERA. One is VERA original mode which has a recording rate of 1 Gbps at the maximum. Another is so called K4 system whose recording rate is 128 Mbps. The latter system will be used for principally domestic compatible observations. The aimed accuracy of geodetic observation is 1–2 mm in 3 dimensions in VERA internal network, and 10 mm in the ITRF. This accuracy is required to obtain 10 micro arcsecond order astrometry purposes.

1. Introduction

VERA (VLBI Exploration of Radio Astrometry) is a new Japanese VLBI system dedicated to differential VLBI to measure the position and proper motion of maser sources in the Galaxy with 10 micro arcsecond level accuracy. VERA also aims at the Earth and planetary science such as studies on the tectonic motions around Japan, lunar geodetics by observing artificial radio sources loaded in satellites around the Moon (SELENE mission, launch in 2005). VERA project is being promoted by National Astronomical Observatory of Japan in collaboration with several domestic universities.

VERA network consists of four 20 m-diameter antennas. They are located at Mizusawa, Iriki, Ogasawara, and Ishigaki-jima. The range of the baseline length in the network is 1000 km to 2270 km. The provisional coordinates of VERA stations are listed in table 1.

In each station, dual receiver system of 22 GHz and 43 GHz bands are equipped to do differential VLBI observations for astrometry purpose. The dual receiver system is introduced in details by Kawaguchi et al. [1]. For the geodetic observations at 2 GHz and 8 GHz bands (S/X bands), ordinal single receiver system is adopted.

Table 1. Provisional coordinates of VERA stations.

Station	X	Y	Z	in meter
Mizusawa	-3857241.8	3108784.8	4003900.5	
Iriki	-3521719.4	4132174.6	3336994.3	
Ogasawara	-4491068.8	3481544.7	2887399.5	
Ishigaki-jima	-3263810.	4808265.	2619784.	(rough value)

2. Requirements in Geodetic Observations

The objective of geodetic observations is to attain as high precision as possible introducing wide band observation system which uses 1 Gbps recording system (SONY DIR2000 recorder). Construction of high precision coordinates is required not only for the studies of Earth science, but also for astrometric purpose. In astrometry, VERA is aiming to measure 10 micro arcsecond order annual parallax of radio sources by differential VLBI observation. In the case that the angular distance of two radio sources is 2 degree (maximum distance in VERA dual receiver system), the baseline accuracy of 10^{-9} is required. That is, to measure 10 micro arcsecond order annual parallax of radio sources, the VERA internal network should be constrained 1–2mm precision in 3 dimensions. Also, VERA network should be connected with global reference frame (ITRF) with the precision of 10 mm.

To obtain such precision, VERA internal geodetic observations are planed to carry out once a week at the maximum when the system is ready for regular operation. The observations to connect VERA network to ITRF will be carried out several times per year in collaboration with the Geographical Survey Institute (GSI), Japan.

In the early phase of VERA design, the measurements of the Earth orientation parameters (EOP) was one of the main targets. However, regular EOP observation is not intended to carry out at present. EOP will not regularly be estimated by VERA network itself. EOP producted by IERS will be used in the regular astrometric observation in VERA. It is estimated that the precision of IERS products is enough for astrometric purpose at present.

3. Geodetic Observation System

3.1. Specifications of S/X receivers

The specification of S/X band receivers are summarized in table 2. S/X bands are single receiver system, while dual system is equipped in 22GHz and 43GHz. The band width of down converter and intermediate frequency (IF) is limited within 400 MHz while that of radio frequency (RF) amplifier in X band is 900 MHz. This wide band extension is reserved for future reformation.

Table 2. Specification of S/X band front end.

1) S band	band width	2.2 GHz – 2.4 GHz
	system noise temp.	less than 150 K (considering radome loss)
	aperture efficiency	about 30 %
2) X band	band width	8.1 GHz – 9.0 GHz (within 400 MHz for one channel)
	system noise temp.	150 K – 170 K at present
	aperture efficiency	more than 40 %

3.2. Antenna Feeds

If we adopt a horn feed for S band, it becomes difficult to design cassegrainian focus area to share the space with other bands system, because of its large size. Moreover, it is difficult to obtain high aperture efficiency in S band. A micro strip antenna was designed at first, but it could

obtain only 20% aperture efficiency in S band. To avoid such problems in antenna feeds, helical array antenna of S and X bands are developed by a group in Hosei University. We obtained better aperture efficiency in S band, and wide band characteristic in X band. In each band, 6 helical antenna elements are arranged on an inner circle and 12 elements are arranged on outer circle (Figure 1). The diameter of array sizes are 60cm and 15cm in S and X bands respectively. The array of both bands are placed in co-axial.

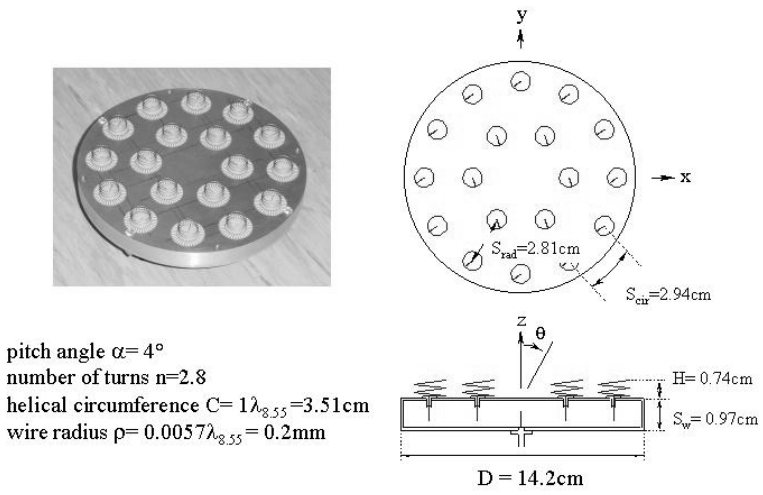

Figure 1. Design of X band feed by Hosei University group.

3.3. Digital and Analogue IFs

In S/X bands, RF amplifiers of room temperature type are used. The RF signals are converted to IF bands. The IF bands are 200-300MHz and 100-500MHz in S and X bands respectively. These bandwidths are traditional ones. Those IF signals are digitized at the front end (i.e. in the antenna focus room), and transmitted to the observation room using optical fibers. This digital IF system is used for VERA internal observations. The IF signals are applied to a digital band-pass filter in the observation room, and then they are stored in the 1 Gbps recorder.

The analogue IF signals are also transmitted to the observation room at the same time using co-axial cables or optical fibers. This analogue IF system is designed to keep compatibility in the observations with VERA external stations. In this case, recording system of 64 Mbps or 128 Mbps will be used.

3.4. Supposed Observation Modes

Many observation modes are equipped in VERA system. Typical observation modes which are available in geodetic observations are listed in table 3. In VERA original modes, the system of Giga bit sampler, digital filter and 1Gbps recorder are used. The observation modes can be

changed by selecting digital filter characters in VERA original mode. In VLBA applied mode, it has only logical compatibility at present. The recoding media differs from Mark III and Mark IV system, and bandwidth is limited to 512 MHz. Media conversion is required in practice.

Table 3. Typical observation modes in geodetic use. Modes for astrometric use are not listed here.

Mode	band	band width (MHz)	sampling (bit)	channels	data rate Mbps
VERA original	S	64	2	1	
mode A	X	64	2	3	1024
VERA original	S	32	2	1	
mode B	X	32	2	7	1024
K4 system	S	4	1	6	
	X	4	1	8	128
VLBA applied	any	8	1	16	256

3.5. Correlation, Analysis

The VSOP correlator (Mitaka FX correlator) will be used for the correlation processes. This correlator has the capacity to process 10 stations with 512 Mbps rate, and now upgraded to be able to process 5 stations with 1 Gbps rate at the maximum. The status of analysis software development is mentioned by Manabe et al. [2] in this proceedings.

4. Associated Observations

Colocated GPS observations are already started at Mizusawa and Iriki stations. It will start soon at remaining two stations. Trimble 4000SSE and 4000SSi receivers are used at those observations. GPS observation data in all stations is corrected in Mizusawa via network. The baseline change observed by GPS in the network will be compared with the results of VLBI observations.

Each station has a general purpose observation basement. It size is 1m×2m. Gravity tide observations using spring type gravimeters are planed. Absolute gravity measurements are also planed. The gravity changes will also compared with the vertical movements measured by VLBI and/or GPS.

References

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