VERA -new VLBI instrument free from atmosphere-

H.Kobayashi[1], T.Sasao[1], N.Kawaguchi[1], S.Manabe[1], T.Omodaka[2], O.Kameya[1], K.M.Shibata[1], T.Miyaji[1], M.Honma[1], Y.Tamura[1], T.Hirota[2], S.Kuji[1], K.Horiai[1], S.Sakai[1], K.Sato[1], K.Iwadate[1], Y.Kanya[1], H.Ujihara[1], T.Jike[1], T.Fujii[1], N.Motiduki[1], T.Oyama[3], H.Kurayama[3], R.Kamohara[2], H.Suda[3], T.Kasuga[4]

(1): VERA project, National Astronomical Observatory of Japan, Osawa, Tokyo, Japan, 181-8588,
E-mail;hkobaya@hotaka.mtk.nao.ac.jp
(2): Department of Physics, Faculty of Science, University of Kagoshima, Korimoto, Kagoshima, Japan,
(3): Department of Astronomy, Faculty of Science, University of Tokyo, Yayoi, Bunkyo-ku, Tokyo, Japan,
(4): Department of Precise Measurements and Control, Faculty of Engineering, Hosei University, Kajino-tyou, Koganei, Tokyo, Japan

ABSTRACT

VERA is the first VLBI array to be designed to be free from the atmosphere phase fluctuations. It has four VLBI station with 2,300 km maximum baseline length in Japan. To compensate phase fluctuations of interferometer visibilities, which are mainly caused by the atmosphere, VERA antenna has two receivers and observes two objects simultaneously. By the comparison the visibility phase between two beams, simultaneous phase referencing VLBI will be achieved. The goal accuracy of astrometry observations is 10 micro arcseconds. . Currently the construction of four stations was complete. And test observations are undergoing. We show the scientific goal and instrumental accuracy of VERA.

1.INTRODUCTION

The VLBI technique is one of radio interferometry, which combines signals from celestial objects by tape recorders not cables. Then it is possible to extend antenna separations over the earth. At 1997, it became around 30,000 km by using a spacecraft.(Hirabayashi, et al., 1999) For astrometry observations, VLBI technique supplies the most accurate data. By the mid-1990s, the VLBI technique has achieved the positional accuracy up to a few sub milli acrsecond (Ma, et al., 1998) . The group delay and delay rate at dual-frequency 2.3 and 8.4 GHz are determined for each celestial objects with each pairs of observing antennas. These data are compiled and positions of each celestial objects and antenna stations are solved. Recently phase referencing technique is used and has improved the accuracy of the astrometry observations. But current phase referencing technique is mainly used an antenna nodding method, which is that each antenna is switched between a calibrator and a target object with more than 30 second interval. This way is effective for lower than 8GHz observations. For higher frequency observations, nodding interval should be less than 30 seconds. It makes large loss for actual observing time because of large antenna slewing time. Then VERA; VLBI Exploration of Radio Astrometry, has adopted a two-beam system, which observe separated celestial objects simultaneously (Kobayashi, et al., 2001). It makes complete phase referencing VLBI observations possible. With 2,300 km maximu m baseline length, around 10-micro arc second accuracy will be achieved at astrometry observations. Main scientific targets for VERA are to determine the structure and kinematics of our galaxy (Honma, et al., 2000). By the measurements of the distance for the Galactic maser objects, three-dimensional distribution and proper motion will show the Galactic structure. VERA aims the 10-micro arc second accuracy to measure positions of maser objects, which is equivalent to the 10 % error at the Galactic center distance.

2.VERA system outlook

VERA has four VLBI stations in Japan with the 2,300 km maximum baseline length and the 1,200 km minimum baseline length. The station distribution map is shown at Figure 1. Two stations are in small islands, one is in Honshu island; main island of Japan, and the other is in Kyusyu island. The antenna of VERA has twenty-meter

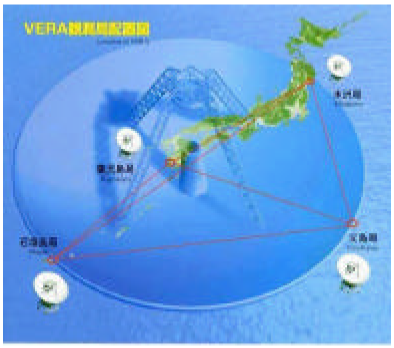

Fig. 1 Array configuration of VERA in Japan

Fig.2 VERA 20m diameter antenna

diameter shown at Figure 2. The receiver cabin is below the main surface to get more than 2 degrees width of the field of view. In this cabin, two-beam receiving system is installed, which is shown at Figure 3. Two-beam system is required that the maximum separation is 2.2 degree and the minimum separation is 0.4 degree. To realize it, movable receivers are used with the Stewart platform, which is consisted with six jacks. Six degree of freedom are restricted by

Fig. 3 Two beam receiver platform

Fig. 4 Coaxial spiral feed array for S and X bands

the six jack length. Highly strong jacks are used for accurate positioning. The receiver platform moves on the focus plane according to the separation angle. The tolerance of positioning is 0.3 mm for the phase calibration between two beams. Radiators on the antenna surface are used to calibrate the difference of effective ray path between two beams. Aperture efficiencies and system noise temperatures are shown at Table 1. The loss of signals by the dome on the receiver cabin is a penalty for the two-beam system. The 5% loss for 22 GHz and 8% for 43 GHz is expected from the laboratory test. And ray injection angle dependence is expected to be small. Observing frequencies are Q and K bands for celestial maser object observations and S and X bands for geodesy observations. 43 GHz and 22 GHz band receivers are used cooled HEMT amplifier. The expected system temperatures at good weather conditions are around 150 K and 250 K at K and Q band, respectively. And aperture efficiency of 22 GHz is around 50 % and degradation is small at 2-degree separation. But at 43 GHz, the aperture efficiency drops 10% at the 2-degree separation, because the

Table 1. Aperture efficiency and system noise temperature

	22GHz		43GHz	
separation	0 deg.	2 deg.	0 deg.	2 deg.
Antenna aperture eff.	50%*	48%	44%	34%
Tsys	150 K	150 K	250 K	250 K
Dome loss	5%	5%	8%	8%

aperture illumination loss become higher. For S and X band, a spiral array feed is used, which is shown at Figure 4. The coaxial feed is newly developed. Data acquisition system was newly developed. Observed signal is sampled with 2 channels, 1 Giga sample per second and 2-bit sampling mode. A digital filter processor filters these data. And the data recorder has a capability of 1 Giga bit per second recording and it is compatible with previous VSOP 256 Mbps recording system. A tape cart system is used and automatic 32 hours operation is possible. And Input and output interfaces are adapted to VSI; VLBI Standard Interface. The correlator used for the VSOP project is reused for VERA correlator. It is a 10-station VLBI correlator and has a capability of 256 Mega sample per second and 2-bit sampling for each station. It is used as a 5 station, 512Mega sample per second, 2-bit sampling correlator. Also the correlator input interface is modified for the VSI.

The total fringe sensitivity is shown in Table 2. Normally the reference object is selected a background compact radio galaxies and quasers, which are more than 100 times further than galactic objects. If the reference object has enough intensity, it is possible to integrate the observing maser object signal for long time. Then the sensitivity is lower than usual single beam VLBI arrays.

Table 2. Expected fringe sensitivity

	22GHz	22GHz	43GHz	43GHz
	Reference object	Maser object	Reference object	Maser object
Integration time	100 s	3600 s	100 s	3600 s
Fringe sensitivity	0.1 Jy	1.2 Jy	0.35 Jy	2.7Jy

Currently the system check is progressed. The repeatability of observations and accuracy of astrometry is under checking. The phase calibration error between two beams must be less than 3 degrees in total. And the accuracy of parallax measurements will be checked from 2003 to 2004. We plan to start usual observations from the beginning of 2004.

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