Proceedings of the 7th European VLBI Network Symposium
Bachiller, R. Colomer, F., Desmurs, J.F., de Vicente, P. (eds.)
October 12th-15th 2004, Toledo, Spain

VERA system

H. Kobayashi[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[1], H. Imai[2], S. Kuji[1], K. Horiai[1], S. Sakai[1], K. Sato[1], K. Iwadate1[1], Y. Kanya[1], T. Jike[1], T. Fujii[1], and T. Kasuga[3]

[1] National Astoronomical Observatory of Japan
[2] Department of Physics, Kagoshima University
[3] Department of Engineering, Hosei Unviersity

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 within Japan islands. To compensate phase fluctuations of interferometer visibilities, which are mainly caused by the atmosphere and local oscillators, VERA antenna has two receivers and observes two objects simultaneously. By the comparison the visibility phase between these two objects, 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 and phase fluctuations are ideally compensated between two objects. We show the scientific goal, instrumental accuracy and some results of VERA.

1. Introduction

The VLBI observation technique achieves the highest spatial resolution in astronomy observation techniques. Then it is the most powerful tool for astrometry observations. Currently the observed group delay is used for the astrometry observations, because phase of interferometry by VLBI has ambiguities caused by ambiguities of local oscillator phase, cable delay and atmospheric path delay. Then for mapping observations, closure phases and amplitudes are only observables and station gain and phase are fitted from observed fringe data. In order to overcome these situations, phase referencing observation techniques have been developed, whose concept is almost same as usual cable connected radio interferometer such as VLA. The point-like calibrator source and observing source are switched with a short time interval and relative phase and amplitude of observed visibilities are used as observables. For the VLBI observations, independent standard oscillator, such as a Hydrogen maser oscillator, is used as frequency reference. Then the coherent time is much shorter than cable connected interferometer. It requires the fast switching observations such as 3 minute interval or shorter. The ideal observation is simultaneous observations of calibrator and observing object. So VERA is the first observing system with 2 beams, which makes simultaneous observation of two objects within 2 degree separations. VERA has four stations in Japan, whose maximum baseline length is 2,300 km and minimum one is 1,000 km. Then the minimum fringe spacing is 1 mille-arc-second . Two of them are in Japanese main islands and the others are in isolated islands.

We aim the 10 micro-arc-second accuracy for the astrometry observations, which 100 times higher than the fringe spacing. VERA uses the water maser and SiO masers objects in the Galaxy. By the determinations of annual parallaxes and proper motions of these objects, we aims to build the three dimensional map of the Galaxy and reveal the motion field of the Galaxy.

2. Scientific Goal

VERA aims precise astrometry observations with 10 micro-arc-second accuracy. It makes possible to observe annual parallax with 10 % accuracy at the Galactic center distance and 20 % accuracy at the distance of opposite side from the Sun. Then it makes possible to measure the distance at whole of the Galaxy by annual parallax measurements. The Hipparcus satellite measures the annual parallax within 100 pc normally. Then VERA makes 100 times improvements from it. And by the radio-wavelength, it is possible to observe the whole galactic area because of less absorption than the optical-wavelength. And the main scientific goals of VERA project are below,

– Measurements of the annual parallax for more than 500 galactic maser objects and making 3 dimensional map of the Galaxy.
– Measurements of the proper motions of these maser objects and reveal the three dimensional velocity field of the Galaxy without assumption
– Measurements of the distances for Mira-variable star and establish the period-luminosity relation
– Measurements of the distances for water maser objects in nearby giant molecular clouds and reveal the three dimensional structure of them
– Measurements of the absolute positions of the components of AGN jets and reveal the stationary core component of them

And VERA is a powerful tool for phase referencing VLBI observations. But feasibility of imaging is very limited, because it has only four stations.

3. System Description

VERA has four stations in Japan. The distribution of them is shown in Figure 1. The maximum baseline length is 2,300 km

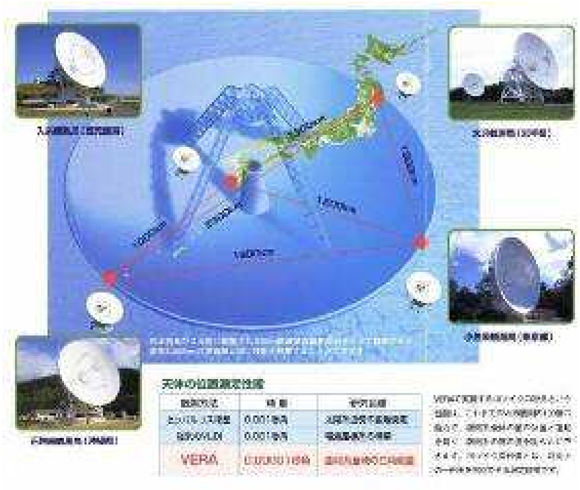

Fig. 1. Array configuration of VERA

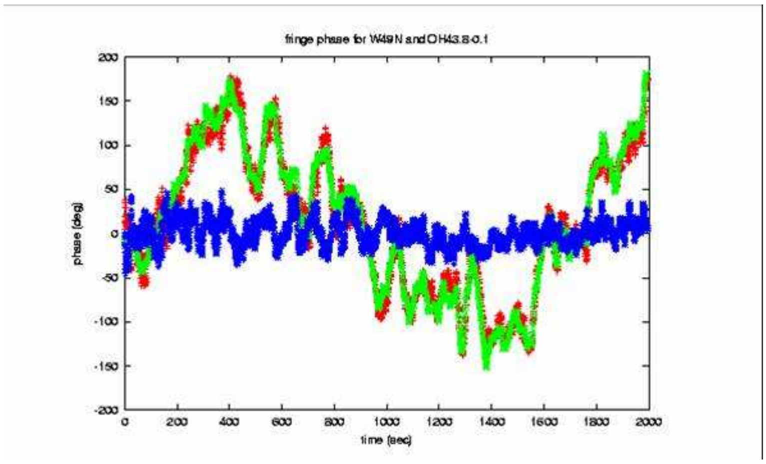

Fig. 3. phase variation of observing objects and difference

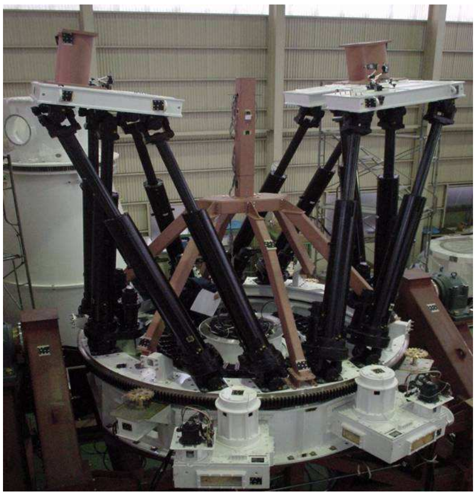

Fig. 2. 2 beam receiver platform

and the minimum is 1,000 km. The diameter of the antenna is 20-m and receiving bands are 2, 8, 22, 43 GHz bands. 2 GHz and 8 GHz are mainly used for the geodesy observations. 22 GHz band is used for water maser observations and 43GHz band is used for SiO maser observations, mainly. At 22 GHz and 43 GHz bands, it is possible to observe with 2 beams. 2 beam observing instrument is shown in Figure 2, which is a factory view. It is installed on the Cassegrain focus cabin and moves the receiving points according to the separations angle of observing targets. The minimum beam separation angle is 0.3-degree and the maximum is 2.2-degree.

The total roughness of the aperture and the sub-reflector is around 150 micron rms. The roughness of the aperture only is 100 micron rms. And it is almost same as four stations. The 22 GHz and 43GHz band receivers are used 20K cooled HEMT MMIC amplifiers. The recording rate of the VLBI terminal, which is newly developed for VERA based on the SONY tape recorder, is 1 Gbps. It is the highest recording rate of regularly operating VLBI arrays. The correlator for VSOP observations at Mitaka is modified and used for VERA. The Mitaka correlator has a capability of 10-station input with 512 Mbps per station. It is modified as 5-station input with 1 Gbps per station. And AIPS is used as data analysis software at moment. But we think it is needed to develop new software for 10 micro-arc-second accuracy analysis. Then it is started the development for accurate correction and analysis software. About the phase calibration between two beams, four noise sources are equipped on the dish surface symmetrically. The common signal is inputted to two beam receivers and relative phase between 2 beams is detected during observations. By using them, phase errors caused by antenna deformations, receiver LO phase variations and timing jitter of AD sampler are calibrated.

4. Current Status

VERA has started a construction from April of 2000. Three stations; Mizusawa, Iriki, and Ogasawara, were constructed at first. It was finished on the March of 2001. And the Ishigakijima station was started to construct from April of 2001 and finished on March of 2002. Currently system evaluation and test observation are going. The aperture efficiencies for 22 GHz band are 50

We have started some test observations. The pair of 3C345 and NRAO512, which is a famous AGN pair for phase referencing VLBI observations, have been observed for more than one year by VERA. The phase referencing observations itself

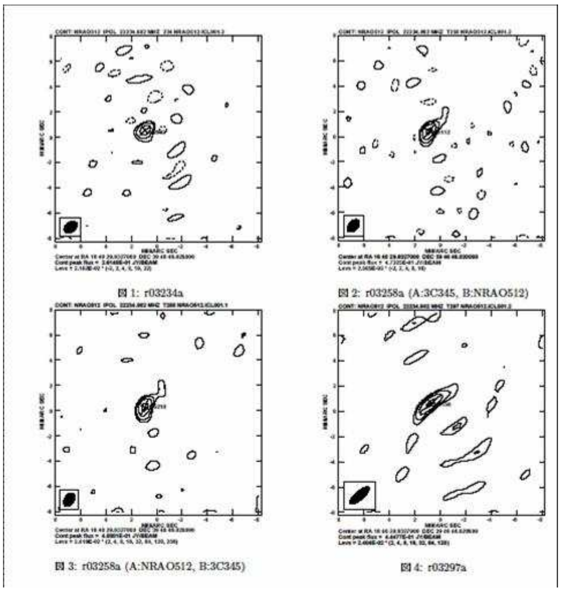

Fig. 4. Repeatability of the position of NRAO512 refered to 3C345

are succeeded and the repeatability of the measurements of relative position each other becomes 0.03 micro-arc-second r.m.s.. Figure 4 shows a image of 3C345 using phase referencing observations.

And we have selected strong water maser objects to observe proper motions and parallaxs at first. Some results are presented in this symposium.

5. Future Plan

We have not succeeded to detect proper motions yet, because the delay tracking model of the correlator is not enough for astrometric observations. Then the visibility from the correlator is needed corrections based on an accurate tracking models. So we have developped these software based on the Goddard CALC software. Then we aims to achieve 100 micro-arc-second accuracy in this year. And we would like to achieve 10 micro-arc-second accuracy until the end of 2006.