VLBI astrometry with dual-beam system of VERA

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abstract

We present the recent status and newest results of the VERA (VLBI Exploration of Radio Astrometry) project. First, we briefly introduce the VERA project, and then we would like to summarize the recent status of the project including the system development and system evaluation as well as the newest results such as fringe detections and initial astrometric observations with dual-beam system of VERA.

1 Introduction

VERA (VLBI Exploration of Radio Astrometry) is a new VLBI array which consists of four 20m antennas spread over Japan [1]-[4]. As the first VLBI array dedicated to differential VLBI, VERA has a dual-beam antenna system which enables us to observe a Galactic maser source and a nearby reference source simultaneously to remove the atmospheric fluctuation effectively, aiming at astrometry of Galactic maser sources relative to reference sources (QSOs and radio galaxies) with 10 microarcsec level accuracy. With that accuracy, VERA will be able to measure the trigonometric parallax and the proper motion of masers in the hole Galaxy. Hence, VERA will be one of the most powerful tools to study the structure and dynamics of the Galaxy as well as physical properties of Galactic masers. The major science targets of VERA will be the 3D structure of the Galaxy and the distribution of dark matter, outflows in star forming regions and stellar envelopes, maser physics in star forming regions and late type stars, precise calibration of the period-luminosity relation of Mira-type stars, and so on.

In this presentation, we would like to summarize the recent status of the project including the system development and system evaluation as well as the newest results of initial observations.

2 VERA System

2.1 overview

Figure 1 shows the map of the VERA array, which consists of four 20-mϕ antennas spread over Japan. VERA stations locate between 24° and 39° in North Latitude and between 120° and 140° in East Longitude, with the baseline length ranging from 1200 km to 2300 km. Three of the four stations have been constructed by April 2001, and the fourth station (Ishigaki-jima) has been finished in April 2002. VERA's antenna is designed for observational frequency from 2 GHz to 43 GHz with a possible extension to 86 GHz. For phase-referencing, each antenna is equipped with dual-beam system, in which two receivers are installed on the Steward-mount platform (see figure 2 for the view of the dual-beam platform). VERA's dual-beam system is fully steerable and can observe a pair of sources that are separated by as large as 2.2 degree, and as small as 0.3 degree.

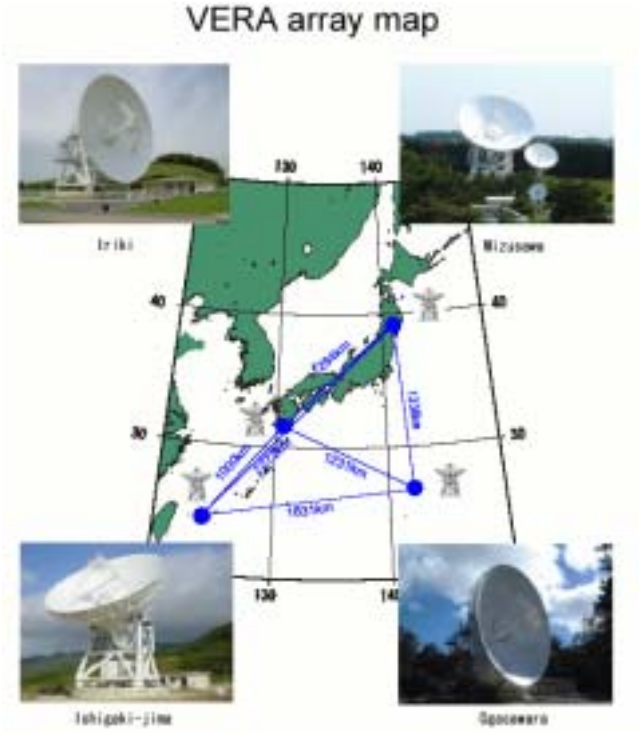

Figure 1: VERA array map. Site views are also shown.

VERA's Receiver system includes following four bands; S band (2 GHz), X Band (8 GHz), K band (22 GHz) and Q band (43 GHz). S and X band receivers are mainly for geodetic observation to determine baseline parameters, and the receivers for K and Q bands are for H_2O and SiO masers as well as continuum sources to be used as a phase reference. Receiver outputs are down-converted into the intermediate frequency (IF) of 5 to 7 GHz, and after the down-conversion again to the base-band, the signals are digitized and recorded on magnetic tapes at the maximum rate of 1 Gbps (Giga bit per second). This high rate provide us a total bandwidth of 256 MHz with 2-bit quantization. The magnetized data will be processed with the NAOJ-Mitaka FX correlator, which has been originally developed for VSOP (VLBI Space Observatory Program) and has been modified for VERA.

Since the radio waves from two sources (source and reference) go through completely different paths in the receiving system, there must be instrumental delay difference which causes an error in differential phase measurement. In order to correct for this instrumental delay, noise sources are mounted on the main reflector of antenna, and its emission is injected into dual-beam receivers after reflection by the sub-reflector. The correlation of this noise source (observed with dual-beam receivers) is being monitored on real-time to obtain the instrumental delay and its time-variation (see figure 3). With such a calibration system, one will be able to calibrate the instrumental delay within 0.1 mm.

2.2 Recent Status of System Evaluation

After the completion of three stations (Mizusawa, Iriki, Ogasawara) in April 2001, system evaluation as a single dish telescope has been started. We have already performed the first light observation as a single dish at Mizusawa, Iriki, and Ogasawara stations, and obtained good spectra of bright maser sources such as ORI-KL, W49N, W3OH and so on. Also, pointing performance check has been done by tracking several bright masers. The systematic error in pointing is found to be described well by the standard pointing model which includes parameters such as encoder offsets and non-orthogonality of azimuth and elevation axis, and so on. After the correction for these systematic effects, the residual pointing error is $\sim$10 arcsec in RMS, which is reasonably

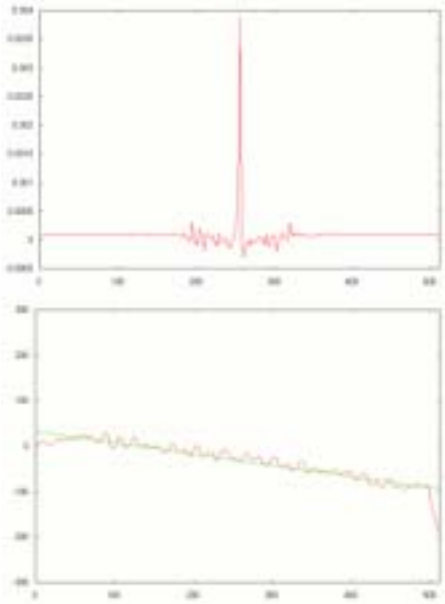

Figure 2: (left) Dual-beam platform system. Receivers are installed on the Steward-mount platform supported by six arms.

Figure 3: (right) Dual-beam fringe of noise source for phase-calibration. Top panel is in the lug domain (from -256 nsec to 256 nsec), and the bottom is the fringe phase in frequency domain (from 0 to 512 MHz)

small compared to the beam size of VERA antenna (2.5 arcmin at the K band and 1.3 arcmin at the Q band). The antenna efficiency is now under evaluation, and preliminary estimates show that the efficiency at K Band is around 50%.

In addition to the system performance check as a single dish, we have also started system evaluation as an interferometer. We have obtained the first fringe between Mizusawa and Iriki stations, which proved that VERA system works coherently as a radio interferometer (see figure 4). Also, we have started the evaluation of the dual-beam system. First, we have recently succeeded in simultaneous tracking of two sources using the dual-beam system. Also, we have detected the fringe of noise sources mounted on the main reflector for phase-calibration (an artificial fringe for monitoring the instrumental delay difference between beam A and beam B). Figure 3 shows examples of such a fringe obtained between dual-beam receiving systems. The top panel shows the correlation in lug domain, and the bottom panel shows the fringe phase in frequency domain. Using this phase-calibration system, we have already achieved the phase accuracy of $\sim$3 degree at K band, which is just the target accuracy of VERA's phase-calibration system ($\sim$0.1 mm in path length difference).

3 Initial Observations

While the system evaluation process is still on-going, we have also started test observations with VERA system. As mentioned in the previous section. we have made the first fringe detection between Mizusawa and Iriki stations. Figure 4 shows the first fringe of ORI-KL H_2O maser taken in February 2002 (in frequency-delay rate domain). After this successful detection of the first fringe, the VERA system has started working as a radio interferometer. We have also successfully obtained the fringe between Mizusawa 10m VLBI antenna and VERA Iriki stations, indicating that VERA array will be easily connected to existing VLBI network quite soon. Following the detection of the first fringe, now we have a plan to use VERA array to search for compact radio sources that can be used as the reference sources for VERA's phase-referencing observation. This is an extended version of radio source survey that has been conducted with J-Net (Japanese VLBI Network) [5],

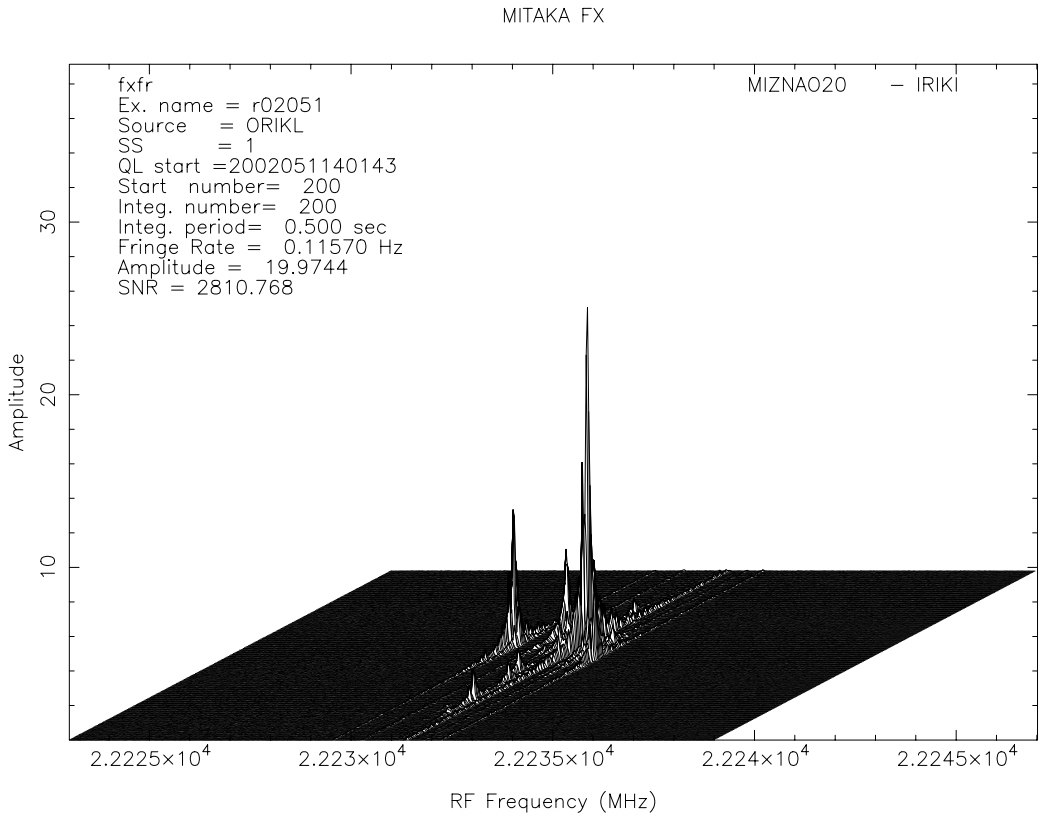

Figure 4: The first fringe obtained between Mizusawa and Iriki stations (ORI-KL H_2O maser).

and tentatively scheduled in June 2002. We also have a plan to perform dual-beam VLBI observations within a few months, which is the main observational mode of VERA array. Thus, at the conference in August 2002 we will be able to present the newest results of VERA including the radio source survey as well as the first VLBI observations with dual-beam system, and hopefully show some initial results of phase-referencing and astrometric observations.

References

[1] Sasao, T. 1996, in Proc. of 4th Asia-Pacific Telescope Workshop, ed. E. A. King, 94 (Sidney, Australia Telescope National Facility)
[2] Honma, M., et al., 2000, in Radio Telescope, ed. H. R. Buthcer, Proc. SPIE 4015, 624
[3] Kawaguchi, N., Sasao, T., & Manabe, S. 2000, in Radio Telescope, ed. H. R. Buthcer, Proc. SPIE 4015, 544
[4] Honma, M., 2001, in Proc. of IAU Sympo. 206, ed. V.Migenes, in press
[5] Honma, M., et al., 2000, PASJ, 52, 631