VLBI Facilities and Observations in China

X.Y. Hong[1], J. Zhang[2] & X. Z. Zhang[1]

(1 *Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai* 200030)
(2 *Urumqi Astronomical Observatory, NAO, CAS, Urumqi* 830011)

Abstract There are two radio telescopes working for VLBI observations in China. One is near Shanghai and the other is near Urumqi. Both are the members of the European VLBI Network (EVN), International VLBI Service for Geodesy and Astrometry (IVS), and Asia Pacific Telescope (APT). The new developments of the two VLBI stations and the joint international VLBI observations are described, and a new VLBI correlator in Shanghai is also introduced.

1 VLBI STATIONS

1.1 Sheshan VLBI Station

The Sheshan (also called Seshan) 25-meter radio telescope is an alt-az antenna run by Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences (CAS). The telescope is located about 30 km west of Shanghai.

The radio telescope started its operation in 1987. It is one of the five main astronomical facilities of Chinese National Astronomical Observatories. The VLBI station is a member of the EVN, IVS, and APT.

Antenna The station is located at the longitude of 121° 11' 59" E and the latitude of 31° 05' 57" N, with a height (ground) of 5 meters above sea level. Some parameters of the antenna are listed below.

Diameter : 25 meters
Antenna type: Kashegelun Beam wave-guide
Seat-rack type: Azimuth-pitching ring
Main surface precision: 0.65 mm (rms)
Point precision: 20" (rms)
Rolling range: Azimuth : -86° to 425° ; Elevation: 5° to 88°
Maximum rolling speed: Azimuth : 0.55° /sec; Elevation: 0.28° /sec

Receivers Five bands for VLBI observations are available at Sheshan VLBI station: L band (18 cm), C band (6 cm), K band (1.3 cm), and S/X band (13/3.6 cm). The parameters of the receivers are listed in Table 1. Column 1 gives the observation band. The frequency range is listed in column 2, followed by the efficiency of each band in column 3. The receiver type, polarization model, and system temperature are listed in columns 4, 5 and 6, respectively.

The L, C, and K bands are used for astrophysics and S/X double frequencies are used for geodesy. X band is also used for astrophysical observations sometimes.

The X-band receiver system has been upgraded to the wide-band system in Dec. 2000. Sheshan station participates in the wide-band experiments of geodynamics for IVS observation since 2001.

Table 1 Receivers of sheshan station

Band (cm) (1)	Bandwidth (MHz) (2)	Eff. (%) (3)	Type (4)	Polarization (5)	T_{system} (K) (6)
18 (L)	$1620-1680$	40	Room Temperature	LCP &RCP	~ 100
13 (S)	$2150-2350$	45	Room Temperature	RCP	~ 100
6 (C)	$4700-5100$	58	Cryogenic	LCP	$45-50$
3.6 (X)	$8200-9000$	48	Cryogenic	RCP	~ 50
1.3 (K)	$22100-22600$	$\sim$20	Cryogenic	RCP &LCP	$\sim$110

Recording system There are three recording systems (VLBA, MKIV and S2) at Sheshan VLBI station. Both thick and thin tapes are available for VLBA and MKIV recording system.

MKIV upgrade of Sheshan station was completed successfully in 2000. Sheshan station participated in the two-head recording test with 512 Mbit/s by EVN organization in Oct 2001. Fringes to Sheshan station of both head-stacks have been found successfully. The performance of the observing system of Shanghai station has been more advanced over the last few years.

Sheshan station is also equipped with Canadian S2 VLBI recording system. The system is being used for APT, VSOP, and other ad hoc VLBI observations.

Future plans Upgrade of frequency switching system at Sheshan station is going on. The work will be finished at the end of 2002. The frequency switch could be done in three minutes between two of C, K, and S/X bands. This will be very good for the multi-frequency observations.

A new Hydrogen Maser has been booked from Datum for Sheshan VLBI station. We will get the new hydrogen clock at the end of 2003.

New dual-polarization receivers for C and L bands are being made with cooperation of ASTRON (the Netherlands).

1.2 Nanshan VLBI station

Nanshan 25 m radio telescope is run by Urumqi Astronomical Observatory (UAO), NAOC, CAS. It is located at south 70 km from Urumqi city.

The radio telescope has been in operation since 1993. It is another one of the five main astronomical facilities of Chinese National Astronomical Observatories. Like Sheshan VLBI station, Nanshan VLBI station is also a member of the EVN, IVS, and APT.

Antenna The antenna is located at the longitude of 87° 11' E and the latitude of 43° 20' N, with a height above sea level of 2080 meters (ground). Some parameters of the antenna are listed below.

Diameter: 25 meters

Antenna type: Kashegelun Beam wave-guide

Seat-rack type: Azimuth-pitching ring

Point precision: 15"(rms)

Rolling range: Azimuth : -270° to 270° ; Elevation: 4° to 89°

Maximum rolling speed: Azimuth : 1.0° /sec; Elevation: 0.5° /sec

Receivers It has been outfitted with receivers for six wavelength bands centered near 92, 18, 13/3.6, 6 and 1.3 cm. Table 2 summarizes the relevant information. Columns are the same as those in Table 1.

A new receiver with double polarizations and Cryogenic system for L band has been made. It was installed in July, 2002. The new system is being tested.

Table 2 VLBI Receivers of Nanshan Station

Band (cm) (1)	Bandwidth (MHz) (2)	Eff. (%) (3)	Type (4)	Polarization (5)	T_{system} (K) (6)
92 (P)	314 − 340	30	Room Temp	LCP	150
18 (L)	1400 − 1720	52	Cryogenic	L/RCP	25
13 (S)	2150 − 2450	48	Room Temp	RCP	100
6 (C)	4750 − 5150	55	Cryogenic	LCP	38
3.6 (X)	8200 − 8600	50	Cryogenic	RCP	45
1.3 (K)	22200 − 24500	35	Cryogenic	LCP	180

Recording System There are four recording systems (MKII, MKIIIA, MKIV and K4) at Nanshan VLBI station. Both thick and thin tapes are available for MKIII and MKIV recording systems.

Nanshan station was first equipped with MKII recording system. The system is still available and is used for some ad hoc VLBI observations with Russian telescopes.

The MKIII recording system was upgraded to MKIV in 2000. Some problem occurred after the upgrade because of the un-normal MKIII system. The problem was solved in 2001. Nanshan station participated in the two-head recording test with 512Mbit/s by EVN organization in Oct 2001. Fringes to Urumqi station of both head-stacks have been found successfully.

Nanshan Station is also equipped with Japanese K4 VLBI recording system.

Future plans A new dual-polarization receiver for C band is being made with cooperation of MPIfR (Germany).

Nanshan station is planning to have a new Hydrogen Maser with stability of 10^{-15} or even higher.

2 SHANGHAI VLBI COORRELATOR

The Shanghai VLBI correlator is located in VLBI Laboratory of National Astronomical Observatories. The correlator is supported by Chinese VLBI Network (CVN), and also named CVN correlator. The project of CVN correlator started in 1995. The first fringes of astronomical observation data were obtained from the CVN correlator in 2000. During the development of the correlator, the NRAO experts give very successful helps for us. The CVN correlator is a two-station FX mode correlator. It uses two Penny & Giles reproducers for tape reproduction.

2.1 The main specification of the CVN correlator

Stations: 2 stations, 1 baseline.

Inputs: Each station support one Penny & Giles tape reproducer and one VLBA PBD with 8 IF channels.

Formats: VLBA formatted data, and Mark III Mode B unrestricted, Mark III Modes A & C, with some restrictions, and a subset of Mark IV.

Timing: Sampling rate 32, 16, 8, 4, 2 Msamp/sec.

FFT: 2 FFT engines, FFT sizes 64, 128, 256, 512, 1024 and 2048 points/channel, 2048 point FFT in 16 μs.

Quantization: Supports 2 bit 4 level, and 1 bit 2 level.

Archive: The results of CVN correlator should be written to disk files in FITS data format. The files can be transferred via FTP.

2.2 The results

After obtaining the first fringes, the CVN correlator processed more than 20 observations of astrophysics, geodetic, test purpose and spectral observations.

Figure 1 and 2 show the first fringes and results comparing between CVN and JIVE correrator.

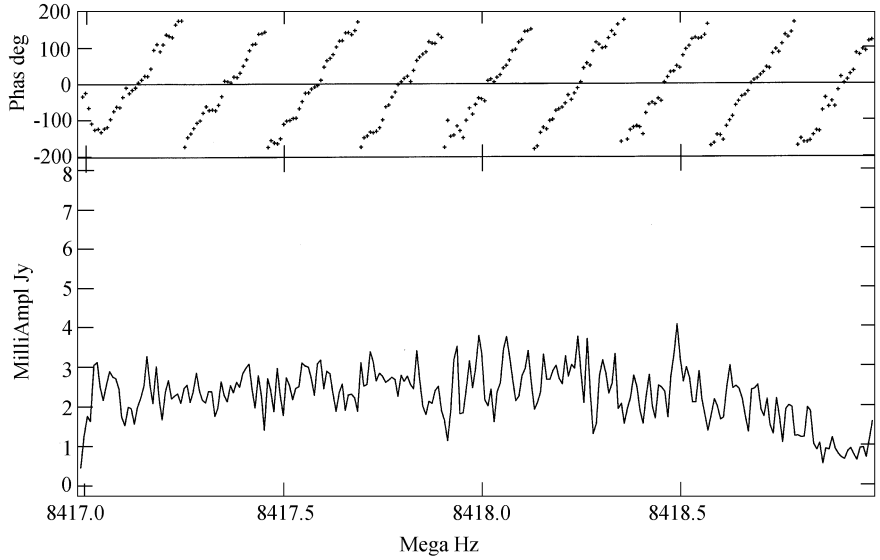

Fig. 1 First fringes on Shanghai correlator made available on Aug 8, 2000. It is the uncalibrated spectrum of DA193 for a single IF at X band on Sheshan-Urumqi baseline.

2.3 Future plans

A new playback system, based on hard disk array, is developing now for CVN Correlator. The Penny and Giles tape playback system will be replaced by a new system which is fully compatible with tape playback system, including data format, tracks, control commands and the status of playback system. CVN Correlator will use new playback system before the end of 2002.

Pre-design of 4-station correlator started. It should be beginning to develop in next year if the fund problem is solved. The 4-station correlator should use disk array and new FFT chips to reduce the size and power.

To use the present two stations correlator as test equipment, we plan to make real time VLBI experiments after the new playback system is established.

3 VLBI OBSERVATIONS

3.1 EVN

The EVN is a collaboration of the major Radio Astronomical Institutes in Europe & China, and performs high angular resolution observations of Cosmic radio sources. It is a large scale astronomical facility that is open to astronomers all over Europe and the rest of the world.

Sheshan and Nanshan VLBI stations have been the members of EVN since 1994. The resolution of EVN increases by three times in direction of the east-west by jointing Sheshan

and Nanshan VLBI stations. The two stations play an important role for the high angular resolution observations.

There are three or four sessions for EVN observations each year with about 20 experiments of each session. A lot of scientific results have been obtained. The publications of EVN can be found on the web of EVN (www.evlbi.org).

Hong et al. (2001) obtained a sub-sample of VLBI image of EGRET-detected AGNs. They observed 15 EGRET detected sources, which have not enough VLBI observations, with EVN at 5 GHz. The high angular resolution images of the sample have been gotten with joint observations of Sheshan and Nanshan stations. The images of 1229-021 and 1604+159 were shown in Figure 3 which showed core-jet structures.

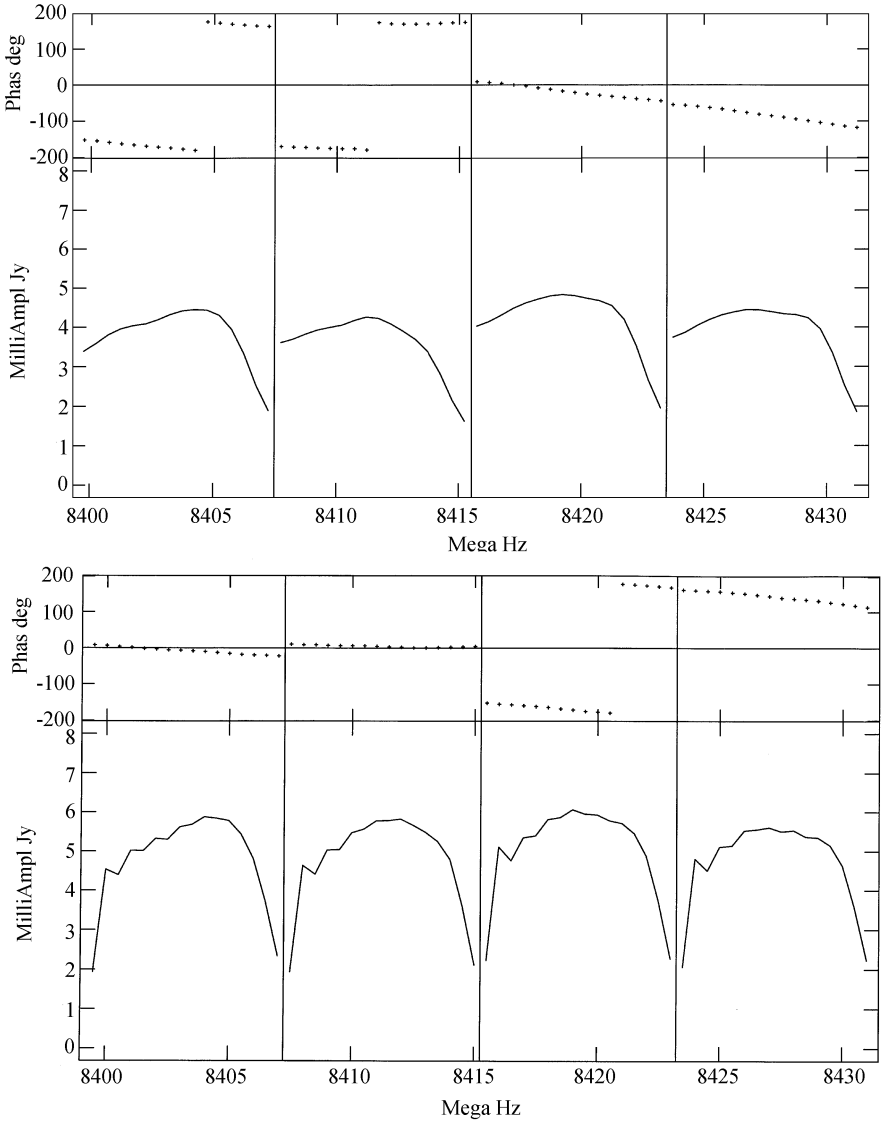

Fig. 2 Comparisons of correlator output. *(top):* Shanghai correlator; *(bottom):* JIVE correlator. It is the un-calibrated spectrum of DA193 for 4 IFs at X band on Medicina-Robledo baseline. The same data spanning 1 minute from N01X2 experiment was used.

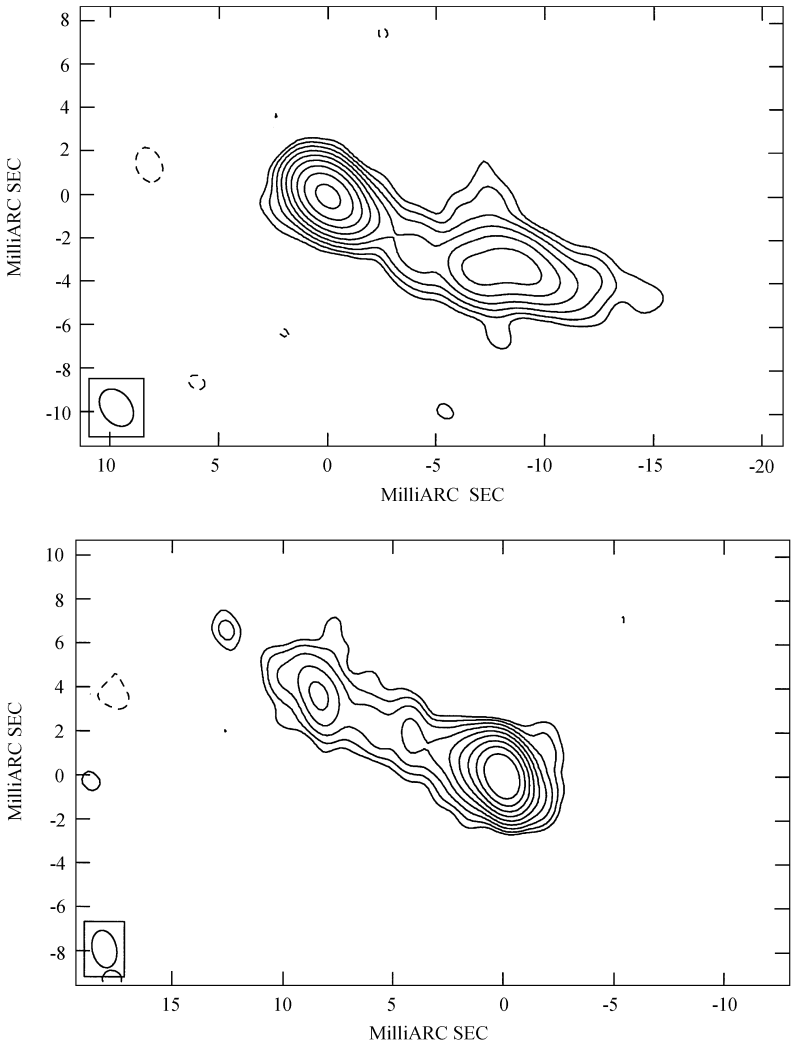

Fig. 3 (top): The VLBI image of 1229-021 at 5 GHz, Peak flux=0.30 Jy/beam, contour levels = $9.1 \times 10^4 \times$ (-1, 1, 2, 4, 8, 16, 32, 64, 128, 256) Jy/beam; (*right*) The VLBI image of 1604+159 at 5 GHz, Peak flux=0.18 Jy/beam, contour levels = $2.5 \times 10^4 \times$ (-1, 1, 2, 4, 8, 16, 32, 64, 128, 256) Jy/beam

3.2 IVS

IVS is an international collaboration of organizations which operate or support Very Long Baseline Interferometry (VLBI) components. IVS provides a service which supports geodetic and astrometric work on reference systems, Earth science research, and operational activities.

IVS provides data and products for the scientific community. Some of the products are a terrestrial reference frame (TRF), the international celestial reference frame (ICRF), and Earth orientation parameters (EOP). All IVS data and products are archived.

IVS products contribute to research in many areas, such as the solid Earth, tides, studies of the vertical, and VLBI technique improvement.

Sheshan and Nanshan VLBI stations joined IVS when it was established in early 1999.

Sheshan and Urumqi stations participate about 16 to 20 experiments each year (each experiment continuing 24 hours observations).

Before IVS was established, Sheshan and Nanshan joined the geodetic VLBI observations, e.g. CORE program which is organized by NASA.

3.3 APSG

The main object of the Asia-Pacific Space Geodynamics (APSG) Program is to unite all relevant activities in the region into a cooperative research project in plate tectonic, crustal motion and deformation, and sea level change in the area. This will provide a synergistic umbrella for scientists in the region to cooperate and to contribute to the better understanding of the processes involved and better prediction of major disastrous events. A major impetus for this program has been the emergence of space geodetic techniques with mm measurement capability.

All countries in Asia-Pacific area are urged to join in this project, while countries outside the area are warmly invited to participate. The project will promote international academic exchange and scientific cooperation, and will contribute to the scientific research level of the developing countries in this area.

Sheshan and Nanshan VLBI stations are the main stations of APSG for the VLBI technique and have participated in all APSG experiments.

3.4 VSOP

The Very Long Baseline Interferometry Space Observatory Programme (VSOP), which was launched in February 1997, stands for the VLBI Space Observatory Programme, a radio astronomy space mission led by the Institute of Space and Astronautical Science and the National Astronomical Observatory of Japan.

Shanghai Astronomical Observatory has been an important partner in VSOP observations, FOR both the peer-reviewed General Observing Time observations and the mission-led Survey Program.

The VSOP Survey Program is one of the major science endeavors of the mission. This program is systematically imaging the 264 brightest and most compact AGNs at 5 GHz, to form an unprecedented data base of the most energetic objects in the Universe. This will aid astronomers to understand the phenomena occurring in these AGNs, are most likely related to the super-massive black holes believed to exist at the centers of these objects, and will be very useful in planning future space VLBI missions such as VSOP-2.

The degree of international collaboration required for VSOP observations is illustrated by the fact that the first paper from the Survey Program (Hirabayashi et al. 1998, 2000) has 77 authors from 25 institutions in 12 countries. It is very pleasant to be able to record Shanghai Astronomical Observatory's role as one of the most active ground radio telescopes in the program.

The importance of the Sheshan VLBI station is underlined by the fact it provides a considerable improvement in the east—west extent of the European VLBI Network, and a similar improvement in the north–south extent of the southern hemisphere based S2 network. The fact that the Sheshan VLBI station has both an S2 and a VLBA recorder makes participation in almost all VSOP observations possible, without the time-consuming tape copying required for some other telescopes. According to our records, Shanghai Astronomical Observatory has participated in over 160 VSOP observations to date, which is a very significant, and highly valued contribution.

3.5 Ad-hoc VLBI observations

Radar VLBI The radar VLBI method represents potentially a powerful tool for investigating space objects without emitting. The combination of both techniques - radar for

good range and radial velocity resolution and VLBI for angle and angular rate information - results in three dimensional measurements. Possible applications cover the fields of research on near earth asteroids, investigation of short periodic variation of Earth group planets rotation and investigation of space debris (Tucarri et al. 2002).

Sheshan and Nanshan VLBI stations with other VLBI stations (Bear Lakes RT-64, Svetloe RT-32, Noto RT-32, Torun RT-32) have done some Radar VLBI experiments for the study of the Solar System allowed to discover the population of asteroids crossing the Earth orbit (NEA) and realize the problem named Asteroid Impact Hazard by using Evpatoria RT-70 to emitter radar signal.

LFVN Nanshan VLBI station joined Low Frequency VLBI Network (LFVN) project at wavelength of 92 cm. This activity allows to keep in operation the large radio telescopes of former Soviet Union countries, to accumulate the necessary VLBI experience for new generation of antennas staff and create the necessary prerequisites for its integrating with EVN.

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