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VLBI MEASUREMENT OF WEAK SOURCES WITH IMPROVED SENSITIVITY

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ABSTRACT

Compared with traditional analog system, the Chinese VLBI Data Acquisition System (CDAS) is a digital one with better bandpass and wider bandwidth which allow weaker sources to be detected and measured by VLBI techniques. After optimizing and verifying the performance of CDAS in wide bandwidth observing mode, we performed an experiment by observing 85 weak sources along the ecliptic with Chinese VLBI stations located at Shanghai, Kunming and Urumqi. The capability of CDAS has been demonstrated for the detection of weak sources with improved sensitivity.

Key words: astrometry - catalogues - techniques: interferometric

1. INTRODUCTION

The most accurate positions of radio sources with compact structures are measured and maintained by Very Long Baseline Interferometry (VLBI). These sources are used as reference or calibrating sources in differential astrometry, space geodesy and deep space navigation. The cumulative all-sky catalogue of calibrator sources[1] called rfc2014a has 6867 objects with X band information obtained from numerous VLBI surveys (Beasley et al., 2002; Petrov et al., 2008; Petrov et al., 2011).

In recent years, more and more VLBI stations have begun to install digital backends for data acquisition. Compared with the aged analog system, the new digital system has better bandpass and wider bandwidth, which allows weaker sources to be detected and measured by VLBI techniques with improved sensitivity. In order to evaluate the probability of finding more calibrator sources, we investigated the rfc2014a catalogue. Figure 1 shows the dependence of the logarithm of the number of sources in the whole sky N with a flux density greater than S, as a function of the logarithm of S determined by the correlated flux density at X band.

$$N(S) = 71 \cdot S^{-1.824} \tag{1}$$

From the above equation, we estimate that 9900 more calibrator sources can be found with flux density greater than 50 mJy.

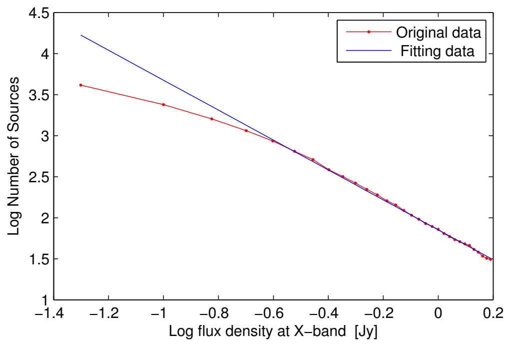

Figure 1. Dependence of the decimal logarithm of the number of compact sources versus the decimal logarithm of their minimum correlated flux density at X band.

2. STATUS OF VLBI DIGITAL BACKEND

The Chinese VLBI Data Acquisition System (CDAS) developed by the Shanghai Astronomical Observatory is a digital multi-channel Base-Band Converter (Zhang et al. 2010). As shown in Figure 2, CDAS was deployed at 4 Chinese stations in April 2010: the Shanghai 25-m radio telescope, Beijing 50-m radio telescope, Kunming 40-m radio telescope and Urumqi 25-m radio telescope. In October 2012, the new Shanghai 65-m radio telescope, the Tianma Radio Telescope, also installed the CDAS system. CDAS has the capability to output 16 channels in parallel and the maximum bandwidth of one channel is 32 MHz. Thus the total data rate is as high as 2 Gbps which can take full advantage of the Mark 5B recording system. Since 2010, it has been extensively used in Chinese domestic VLBI experiments. Due to its good phase-frequency response, it has been contributing to the improvement of measurement accuracies for single-channel differential VLBI observations of Chang'E lunar satellites.

The wide bandwidth mode of CDAS with 16 32-MHz

[1] Available at `http://astrogeo.org/rfc`.

Table 1
SUMMARY OF THE TEST OBSERVATIONS BY USING CDAS

Date (yyyy-mm-dd)	UT Range (hh:mm–hh:mm)	Stations	Frequency	Data rate (Mbps)	Channels	Sampling (bits)
2010-09-09	02:00–06:00	ShBjKmUr	S/X	1024	16	1
2011-01-14	02:00–04:00	ShBjKmUr	S/X	1024	16	1
2011-06-21	22:30–10:30	ShKmUr	X	2048	16	2
2011-07-07	06:00–08:00	ShKmUr	X	2048	16	2
2011-10-10	07:00–13:00	ShKmUr	X	2048	16	2
2012-01-12	04:00–06:00	ShKmUr	S/X	1024	16	1
2012-09-19	11:00–14:00	ShKmUr	S/X	1024	16	1
2013-06-20	06:00–06:00	ShKmUr	S/X	1024	16	1

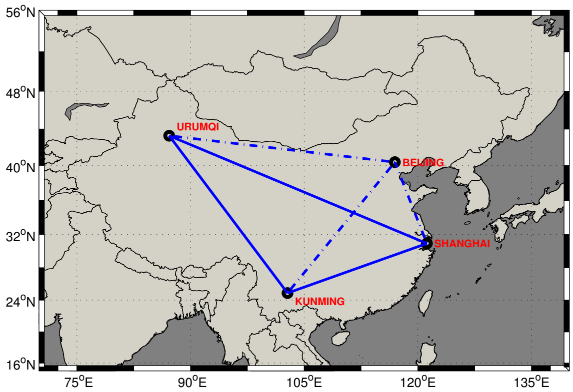

Figure 2. Distribution of the VLBI stations in China.

channels can obtain better baseline sensitivity, so we conducted a series of test observations as shown in Table 1. Unfortunately, during the first two test observations, we found the bandpass of some 32-MHz channels were not so good and the instrumental delays were not very stable. After optimization of the firmware in 2011, we conducted phase reference observations of MAXI J1836-194 at data rate of 2048 Mbps on 10 October 2011 (Yang et al., 2012). In order to solve the remaining irregular integer bits jumps when CDAS is working at 1Gbps or higher data rate, we upgraded the VSI interface cards of CDAS in 2012. A 3 hours fringe test on September 19 showed the delay residuals had become very stable on all baselines.

3. RESULTS OF WIDE BANDWIDTH EXPERIMENT

As shown in Table 1, we conducted a 24-hour wide bandwidth experiment by using CDAS on 20 June 2013 to demonstrate the improved sensitivity. 85 weak sources along the ecliptic plane were selected from a large pool of radio source catalogues. The total flux densities of those sources are at the level of 0.1 Jy, and of them, 29 sources were observed by VLBI for the first time. When making schedule files with SKED software, we added 15 strong geodetic sources. Figure 3 shows the distribution of all scheduled sources. After the experiment, the data recorded on the Mark5 modules were shipped to the Shanghai correlator for fringe search, data correlation and data reduction. Good fringes have been detected for most of the observed sources. There are 18 weak sources detected by VLBI for the first time. The positions of those sources were determined with a precision at the level of a few milli-arcseconds. Considering the limitation of baseline length and observed scans, the results are reasonable.

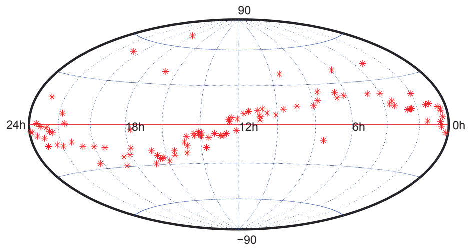

Figure 3. Distribution of scheduled radio sources. Most of them have a total flux density slightly greater than 0.1 Jy.

4. CONCLUSIONS

After a few test observations, finally we optimized and verified the performance of CDAS at a higher data rate than that of analog systems. In an experiment for detecting weak sources along ecliptic plane, we demonstrated the capability of CDAS to improve the baseline sensitivity at a data rate of 1 Gbps. Thus, it can be expected to be used for detection of more weak sources and densification of the celestial reference frame in the near future.

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