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e-VLBI Progress of the Chinese VLBI Network

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Abstract

At present the Chinese VLBI Network (CVN) contains two fixed stations, one mobile station and the 2-station Shanghai correlator. The PC-based VLBI data acquisition terminal and playback unit named CVN harddisk system was developed at Shanghai Astronomical Observatory recently. The CVN harddisk systems were installed at Sheshan station, Urumuqi station and Shanghai Observatory, and several e-VLBI test observations were completed in 2003. Now the Shanghai correlator is able to correlate the data from the tape or the harddisk. Based on the CVN harddisk system, research on the software correlator was also carried out. The prototype software correlator was successfully used in the station fringe check, satellite fringe search and data processing. When processing the satellite observation data, the hardware Shanghai correlator can produce the group delay & delay rate, guided by the software correlator. The CVN will be updated to a realtime VLBI network, including 4 stations and 2 realtime 5-station correlators (hardware & software), which will be applied to the Chinese Lunar satellite navigation, as well as the geodetic and astronomical observations in the future. Researches on the digital BBC and formatter have been carried out.

1. Introduction

Nowadays, the Chinese VLBI Network (CVN) contains three radio VLBI stations and one correlator. The Sheshan station is near Shanghai and the Nanshan is near Urumqi. The diameter of each antenna is 25 meter. They are also members of the European VLBI Network (EVN) and the International VLBI Service for Geodesy and Astrometry (IVS). The third one located in Kunming, southwest China, is a mobile VLBI station with a 3-meter antenna and a S-2 VLBI recorder [1]. The 2-station Shanghai correlator is placed at Shanghai Observatory. Since 2002, Shanghai Observatory has carried out the researches on the e-VLBI, and has achieved several results. The PC-based VLBI data acquisition terminal and playback unit named CVN harddisk system was developed and placed at the Nanshan, Sheshan station and the Shanghai Correlator last year. Besides, we have begun to develop some e-VLBI techniques like software correlator and digital Base Band Converter (DBBC), etc. Several observations based on the CVN harddisk system were successful. In addition, the software correlator processed the data, too. We will expand the CVN to a new 4-station realtime VLBI network with realtime correlators in 3 years, which will be used in the Chinese first lunar satellite navigation, as well as geodesy and astrometry.

2. CVN PC-Based VLBI Data Record and Playback Harddisk System

Since 2002, the VLBI Laboratory of Shanghai Astronomical Observatory has begun to develop the PC-based VLBI data record & playback system named CVN harddisk system. The main target of this system was that we needed a low cost and reliable harddisk system to replace the expensive and unreliable tape playback unit made by Penny & Giles Company. In order to make it, we decided to use, as far as possible, the ordinary industrial PCs with off-the-shelf Components. Another reason was that, although there were several harddisk systems like Mark 5, K5 and PCEVN, none of them was compatible with the Shanghai correlator (VLBA model). Thereby, we had to design the record interface and the playback interface compatible with the Mark IV formatter and the Shanghai correlator.

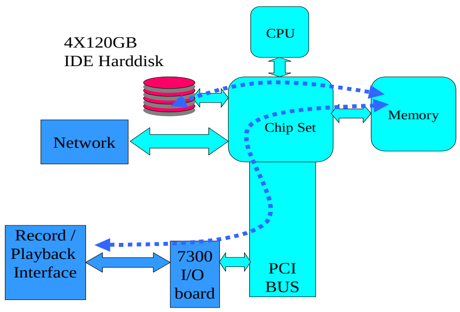

Figure 1. Structure of the CVN harddisk system.

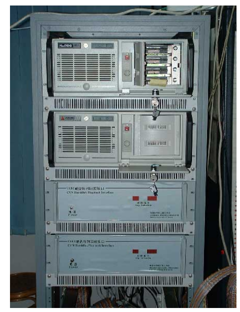

Figure 2. CVN harddisk system playback unit (upper) with plackback interface (lower).

Figure 1 shows the structure of the CVN harddisk system. The hardware platform is an ADLINK NuPRO-841 mainboard. We selected ADLINK PCI-7300B, an ultra-high speed digital IO board as the input and output interface. This board is a 32-channel, 40 MHz PCI data IO board, and the maximum IO speed reaches 80 MB/s. The operation system is Debin Linux. Data are stored in the normal Linux files. To increase the record and playback speed, four 120 GB harddisks are mounted on one CVN unit, and data are recorded in (or read from) the four harddisk simultaneously. The control software is self-developed.

Figure 3. CVN harddisk system (left) with the record interface.

With the record and playback interface, as shown in figure 2 and figure 3, the CVN system is compatible with both the Mark IV formatter and the Shanghai correlator. The total cost of one CVN harddisk unit is only $ 3000.

In the record mode, the data and the corresponding clock signals from the Mark IV VLBI formatter are changed from the ECL level to the TTL level by the record interface, and then received by the PCI-7300B IO board. The record interface is able to decode the Mark IV format and display the UTC, track information etc. The harddisk system can check the data quality by software before recording. The data are recorded only if there are no parity or frame errors.

The playback interface receives the control and monitor commands from the correlator through RS232 and MCB ports, and adjusts the output data speed accordingly. Therefore, from the view of the correlator, there is no difference between this harddisk playback system and a P&G tape playback unit.

The recording speed of one CVN harddisk unit is 288 Mbps (32 track@9 Mhz), and the maximum recording speed is up to 576 Mbps (32 track@9 Mhz). With four 120 GB disks, one unit can record 7 hours, when the data clock is 4.5 MHz, which is equivalent to the 80 ips tape speed. The playback rate is up to 288 Mbps (32 track@9 Mhz).

The milestones of CVN system are:

Mar 2003: Successful record testing at Sheshan station

Apr 2003: Disk-disk & disk-tape playback test

May 2003: First fringe demonstrated between Nanshan and Sheshan

May 2003: First successful e-VLBI fringe test between Nanshan and Sheshan (disk-internet-disk, FTP).

3. Software Correlator

Since the cost performance of the commercial computer increases wonderfully recently, it seems that there is a tendency of using software instead of hardware correlator in the VLBI data preprocessing. Because the CVN harddisk system stored data in the normal Linux files, we began to develop the software correlator prototype (Matlab version). At the beginning, this software was used to check fringe.

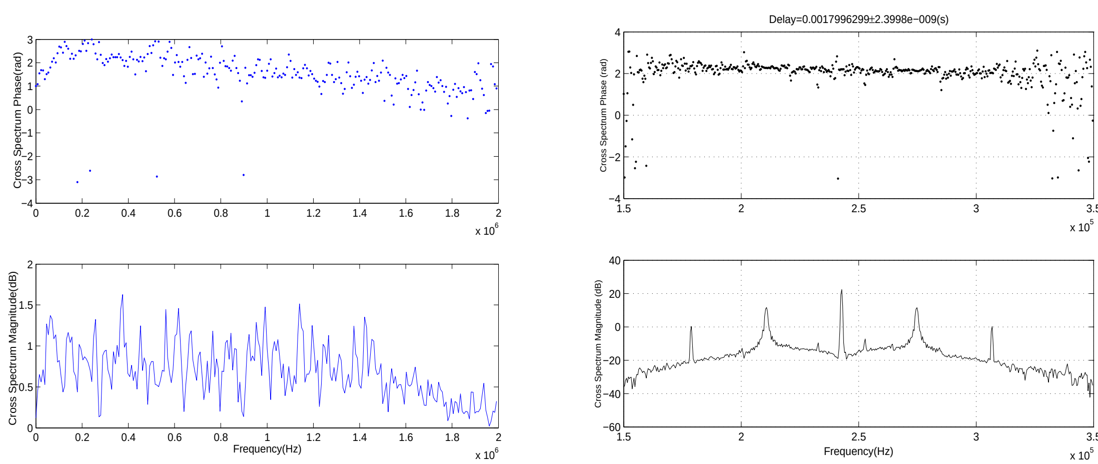

Figure 4. Fringe check by software correlator, phase (upper) and amplitude (lower) spectra, DA193 (left), satellite telemetry signal (right).

In fringe check observations, we chose two kinds of radio source. One was a strong extragalactic source, like DA193. Another source was the GEO satellite downlink telemetry signal. Due to the high SNR satellite signals, the software correlator was able to use 8 MByte VLBI data transmitted from each station through ftp to find legible fringe (Figure 4), and the corresponding observation time was as short as only 0.5 second. When observing DA193, the observing time was about 30 seconds, and the corresponding data was 500 MByte. Figure 4 shows the fringe of one track.

The software correlator was used to search fringe in the satellite observations. Last year we tried several satellite VLBI observations to study how to use VLBI to track the Chinese lunar satellite in the near future. We observed the downlink telemetry signals which most satellites had. Because the satellite orbit accuracy we got was bad, there were big error of the delay and delay rate model calculated from such orbit data. So there was not any fringe when we used the Shanghai (hardware) correlator to process the data. For this reason, we decided to apply the software correlator for fringe search firstly. The spectra of the satellite telemetry signals are quite different from those of the wideband extragalactic sources. The telemetry signal is a narrow band signal with a strong carrier wave in the center of the spectrum domain, as well as several tones (Figure 4). The software correlator calculated the frequency difference of the carrier wave received by two stations firstly, which was the Differential One-way Doppler (DOD) or the fringe rate. Then the DOD value was used to stop the fringe; finally, it correlated the signals and found out the group delay. According the group delay and the fringe rate found by the software correlator, the Shanghai correlator completed the correlation of satellite signals.

The precision of the DOD is only several mHz, while the group delay are less than 10 nanoseconds, when the integration time of the software correlator is 0.5 second. Considering the bandwidth of the telemetry signal is only 200 kHz, the software correlator's results are favorable, and therefore the software correlator is applied to calculate the delay & DOD individually. The software correlator also found the Nanshan station local oscillator frequency shift (about 100 Hz).

When observing the Geospace Double Star, which is a spin stabilization satellite with a 4-second spin period, the software correlator's results show the satellite spin effect on the fluctuation of the group delay and DOD (Figure 3). We will try to remove the effect which affects the precision of the delay and delay rate.

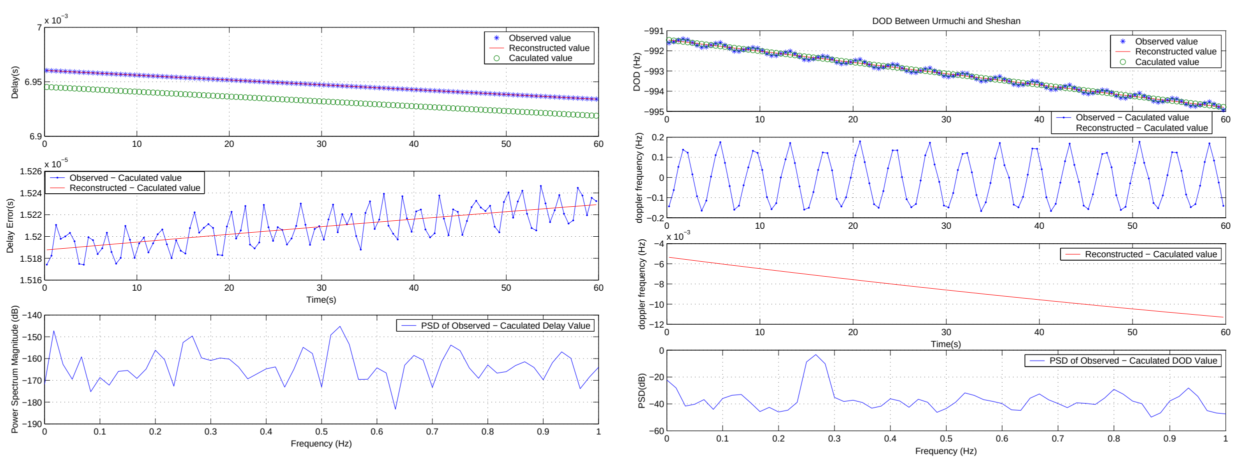

Figure 5. Satellite's spin effect on the delay (left) and DOD (right).

4. Observation and e-VLBI Data Transmission Experiment

Two CVN harddisk systems were placed at the Nanshan station and the Sheshan station last year. We have successfully made dozens of observations of wideband extragalactic source, satellite and maser by the harddisk system. Differential VLBI mode was tested in the satellite observation for preparation of the lunar satellite navigation.

Among these observations, we tried several e-VLBI data transmission experiments. After the observation, the Nanshan station transmitted the data from the local harddisks to the ones located at the Shanghai observatory through domestic ISDN or the Internet for the hardware and software correlator to correlate. At the same time, the disks at Sheshan were taken to Shanghai observatory by car.

Although the domestic network speed is only about 50 KB/s, these experiments still show the possibility of the e-VLBI of CVN, especially for the fringe check. It is inspiring that the network speed will increase a lot in the near future for the lunar project. e-VLBI or even realtime VLBI is doable at that time.

5. Realtime VLBI in the Chinese Lunar Project

China will launch its first lunar satellite in three years. Realtime VLBI will be used in the satellite navigation. For these reasons, two new big antennas will be built and added into the CVN in two years. One is a 50 m antenna which will be placed at Miyun, suburb of Beijing, another is a 40 m antenna, which will be placed at Kunming. The Shanghai observatory will build two 5-station realtime correlators, one is a hardware correlator, and another is software one. All these four stations and the correlators will be connected by high-speed optical fiber network. The software correlator will be the backup of the hardware correlator. Because in the lunar project the data speed is much lower compared with the astronomical observations, realtime, multiple station software correlator is doable.

The VLBI Laboratory of Shanghai observatory is developing the new equipment, which will be used in the realtime CVN, like formatter and DBBC. The prototypes of the formatter and DBBC have been finished and successful experiments were completed at the end of 2003.

The 3-station observation and e-VLBI test and data process will be completed.

6. Acknowledgements

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References

[1] Zhang, XZ,. Zheng, WM,. Shu, FC, Hang, ZY,. Xiang, Y., CVN Correlator and its Future, New Technologies in VLBI, Astronomical Society of the Pacific Conference Series Volumes, Vol. 306, 287–300, 2003.