Shanghai VLBI Correlator 2021–2022 Report

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Abstract This report summarizes the activities of the Shanghai VLBI Correlator during 2021 and 2022. Highlights include first operation for international VGOS data correlation as well as commissioning of the Shanghai and Urumqi VGOS stations.

1 Introduction

The Shanghai VLBI Correlator is hosted and operated by the Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences (CAS). It is located at the Sheshan campus, about 40 kilometers from the Xujiahui headquarters of SHAO. The Shanghai correlator has been used in the data processing of the Chinese VLBI Network (CVN) which consists of Seshan25, Tianma65, Kunming, Urumqi, and Miyun50 stations. The Shanghai correlator was accepted as an IVS correlator in March 2012. It became operational for the IVS data correlation in 2015.

2 Component Description

We are operating two types of correlators. The CVN correlator, developed by SHAO, is mainly used for spacecraft VLBI tracking and produces differential VLBI observables. The data latency is less than one minute in real-time mode, and the typical accuracy is better than 1 ns. The second correlator is the DiFX software correlator, which is dedicated to astronomical and geodetic data correlation.

The DiFX software was installed on a high performance hardware platform, with a 420 CPU core cluster system and total 1,400 TB storage space. Three Mark 6 units can be used to playback VDIF data. The suite version is Mark6_1.3c with dplane as 1.22 and cplane as 1.0.26. Features of the DiFX cluster system are listed as follows:

- DiFX 2.6.2 & 2.6.1, HOPS 3.22, nuSolve 0.7.3.
- Head nodes: DELL R820 (E5-4610 CPU, 2.4 GHz, 2*6 cores), 64 GB Memory, DELL R730 (E5-2623 CPU, 3.0 GHz, 2*4 cores), 64 GB Memory.
- Computing nodes: 20 DELL R630 nodes, two socket Intel E5-2660 CPU (2.6 GHz, ten cores), 64 GB Memory, 400 cores in total.
- I/O nodes: RAID6, 1,400 TB raw data storage capacity.
- Data playback units: three Mark 5B and three Mark 6.
- 56 G Infiniband for internal computing network connection.
- 1/10 G Ethernet for internal and external network connection.

DiFX 2.6.1 and HOPS 3.22 were patched in order to process VGOS raw data.

3 Staff

The people involved in the operation and development of the correlator as well as the VLBI digital backend are listed below.

1. Shanghai Astronomical Observatory, Chinese Academy of Sciences

Shanghai Correlator

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3.1 Operations Team

- Fengchun Shu: group head, scheduler, experiment oversight
- Zhong Chen: e-transfer support, cluster administration
- Xuan He: DiFX operation, software maintenance
- Tianyu Jiang: data playback, DiFX operation
- Yidan Huang: DiFX operation, post-correlation technique development
- Jiangying Gan: DiFX operation
- Wu Jiang: DiFX operation for astronomical data
- Zhanghu Chu: media library
- Shaoguang Guo: Mark 6 maintenance

Xuan He is the only person to work full-time on geodetic VLBI data correlation.

3.2 Technique Development Team

- Weimin Zheng: group head, software correlator and VLBI terminal development
- Juan Zhang: software correlator development and maintenance
- Lei Liu: software correlator development
- Ping Rui: visualization programming and operation for CVN correlator
- Fengxian Tong: VLBI scheduling and modeling
- Li Tong: VLBI raw data simulation
- Renjie Zhu: CDAS development
- Xiaochuan Qu: CDAS development

4 Summary of Activities

4.1 DiFX Correlation

The latest stable software versions of DiFX and HOPS were used for regular IVS data correlation. As for VGOS data, we used DiFX 2.6.1 for correlation, DiFX 2.6.2 for data conversion to Mark IV, and then HOPS 3.22 for post-processing. As mentioned in Section 2, DiFX 2.6.1 was patched to fix the extraction of the PCAL 10-MHz interval. The bug that caused the pc_phase of multiple data stream stations not to be calculated by the program was fixed in HOPS 3.22.

Our correlator has been operational for international VGOS data correlation since 2021. In addition to correlation reports and vgosDB files, we began to upload SWIN Level 1 data to the BKG Data Center[1] in 2022. We submitted SWIN files for five sessions observed in 2021. All SWIN files of the sessions correlated at SHAO in 2022 were uploaded. In some cases we produced FITS-IDI files, which can be downloaded on request by users.

We did not implement the function of Mark 6 native correlation. A software program similar to VMUX was developed and used to copy the data from modules to our disk array. A gathering rate at 10 Gbps and a dethreading rate at 9 Gbps can be reached.

4.2 e-VLBI

The network link to Seshan25 and Tianma65 is 10 Gbps. The network link to the Urumqi, Kunming, and Beijing stations is 200 Mbps for tracking spacecraft. In the Chang'e 5 lunar mission and Tianwen-1 Mars mission, we performed real-time data transfer at a 128 Mbps data rate for each station.

However, for regular geodetic observations, Urumqi and Kunming stations always ship modules to Shanghai. In 2022, we performed some Intensive UT1 experiments using Seshan13 and Urumqi13. After the end of observations, the raw data were e-transferred from Urumqi to Shanghai at a data rate of 100 Mbps.

In order to process IVS global sessions, we have established the network link to most of the IVS stations and correlators. The regular data rate is 2 Gbps. Two regular stations (MATERA and KOKEE) and three VGOS stations (GGAO12M, KOKEE12M, and MACGO12M), usually ship modules to Shanghai.

4.3 Experiments Correlated

We correlated 24 IVS sessions in 2021 and 23 sessions in 2022, including four VGOS sessions each year. Most of them are focused on VLBI absolute astrometry. There is no stringent requirement for data latency.

[1] `https://ivs.bkg.bund.de`

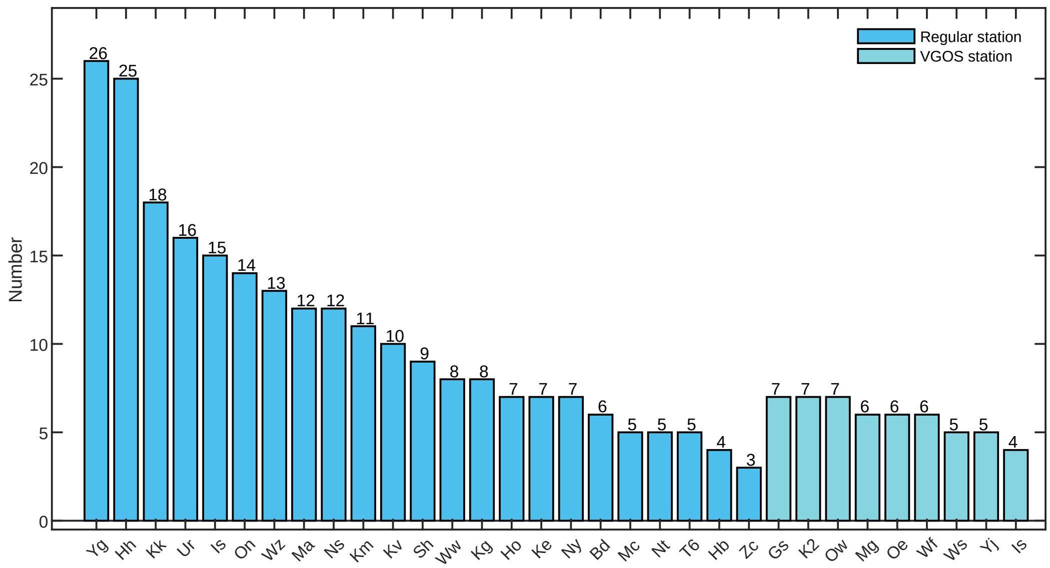

Fig. 1 Statistics of the total sessions for each station correlated at Shanghai from 2021 to 2022.

We aimed to deliver the correlation products in three months. More details can be found in Table 1.

Table 1 Statistics of experiments correlated.

Session Type	2021	2022
AOV	5	4
APSG	2	2
IVS-CRF	6	6
IVS-R&D	7	7
VGOS-OPS	4	4
Total	24	23

So far we have correlated 181 IVS sessions since 2015. The total cumulative data volume is approximately 7.7 PB. It is worth noting that the cumulative data volume from 2021 to 2022 is about 3.6 PB, collected from more than 260 station days. The top five stations with most observing days are YARRA12M, HARTRAO, KOKEE, URUMQI, and Ishioka. More details are shown in Figure 1.

All APSG sessions and some AOV sessions were scheduled by SHAO. The APSG observing sessions are dedicated to measure positions and velocities of stations in the Pacific Rim. The AOV sessions organized by SHAO were focused on astrometry of weak sources in the ecliptic plane and the southern hemisphere. Most recently, the AOV sessions are more focused on mixed-mode observations.

4.4 International VGOS Correlation

We have correlated eight VGOS-OPS experiments, with four sessions each year. The first session correlated at Shanghai was VO1047, observed on February 16, 2021. The raw data transmission status of VO1047 is shown in Figure 2.

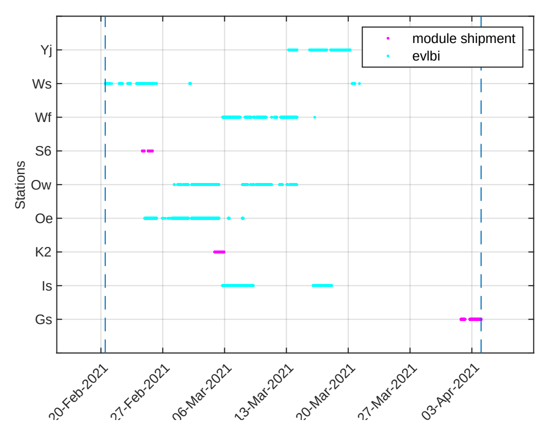

Fig. 2 Raw data transmission of VO1047.

Because we only have 2 Gbps bandwidth available for the international network link, the e-transfer of data is very time consuming. The data throughput rate is up to 18 Gbps during the correlation procedure.

In addition, we have performed nine mixed-mode AOV sessions, with the participation of two Australian VGOS stations.

4.5 Commissioning VGOS stations

During the commissioning phase, we have performed 14 experiments to test SESHAN13 and URUMQI13. Each experiment lasted for 24 hours. We first used a standard VGOS frequency sequence. In order to avoid a more serious RFI, the frequency sequence was modified. In addition to broadband observations, we also performed a few X/Ka dual band test observations.

The Chinese VGOS stations are equipped with the China Data Acquisition System (CDAS2) and Mark 6. The data produced by CDAS2 are real samples recorded in VDIF format, with eight threads and a length of 8,032 frames.

The PCAL of URUMQI13 is unstable, so we continously performed manual phase calibrations. The PCAL of SESHAN13 is relatively stable. However, the fringes in band A are relatively weak due to RFI caused by 5G base stations. The fringes in the high-frequency band D are sometimes weak. In addition, the proxy cable delays are very noisy; thus, they are not included in the database files.

4.6 Other Geodetic Related Correlations

Following the successful K-band fringe tests, there are regular K-band geodetic sessions conducted within the East Asian VLBI Network (EAVN). The first regular session has been correlated at Shanghai.

We correlated one LBA session aimed at astrometry of vela pulsar. We managed to handle the raw data of the DSS36 station. In this experiment, its S-band fringe was relatively weak.

5 Future Plans

We will continue IVS data correlation, with an emphasis on VGOS sessions and AOV mixed-mode sessions. Due to the change of the master file format, and the vgosDB name and correlation report format, we will update the associated softwares on the platform before the first observation data processed by SHAO in 2023. After maintenance of the Tianma VGOS antenna, we plan to perform more VGOS observations using three Chinese stations.

Acknowledgements

We acknowledge the support of National Natural Science Foundation of China (Grant No. 12073065).