Bonn Correlator Report

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Abstract We report on the status of the Bonn Correlation Center, focusing on geodesy for the years 2023 and 2024. Our duties as one of the IVS correlators and recent developments are summarized, as well as technical aspects of the compute cluster and its performance.

1 General Information

The Bonn correlator, located in Bonn, Germany, is operated jointly by the Max Planck Institute for Radio Astronomy (MPIfR) in Bonn and the Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie, BKG) in Frankfurt. The MPIfR hosts the correlator facility as well as the internet connectivity, shares with the BKG the costs of the cluster, and provides the astronomical and technical staff. The geodetic correlator personnel are employed by the BKG via a private contractor, the Reichert GmbH, and are supported by MPIfR colleagues in technical matters, hardware, and software.

2 Component Description

The Distributed FX (DiFX) software correlator (Deller et al. 2011) is used at the Bonn correlator in various versions. The correlator runs on a high-performance computing (HPC) cluster, which was renewed in 2015 to match both VGOS and mm-VLBI requirements. It consists of 68 nodes with 20 compute cores each, for a total of 1360 cores, three head nodes which allow execution of several correlations and post-processing in parallel, 2.8 PB disk space in RAID units and combined in a BeeGFS parallel cluster file system, 14 Mark 5 playback units, and 11 Mark 6 playback units each with four and some with six bays.

The raw data are recorded at the stations either on modules (Mark 5 or Mark 6) or on storage servers, commonly referred to as Flexbuffs. For geodetic experiments, the data are mostly e-transferred to the HPC cluster. The cluster is connected to the internet both through a commercial 10 Gbit/s line and a 1 Gbit/s line. The latter is part of the German Research Network (Deutsches Forschungsnetz, DFN). Currently, the most commonly used transfer protocol for geodetic internet transfers is the e-transfer server/client system (etc/etd) [1], where a client program runs server-to-server transfers. It supports the usage of remote wildcards superseding the login to a remote machine. The second transfer software in use is jive5ab/m5copy[2]. Developed as a VLBI data recorder software, it allows fast and flexible data transfers through high-speed internet connections.

The correlator output data (SWIN files) can be exported to FITS and HOPS (Mark IV) formats. For post-processing, the Haystack Observatory Postprocessing System (HOPS) is used, which is the standard tool for geodesy. The correlator data products and other auxiliary files (e.g., VEX and v2d files) are backed up daily on the HPC cluster. The final products are archived on

1. Reichert GmbH
2. Bundesamt für Kartographie und Geodäsie
3. Max-Planck-Institut für Radioastronomie

[1] https://github.com/jive-vlbi/etransfer

[2] https://github.com/jive-vlbi/jive5ab

the MPIfR archive server, where they are kept for at least ten years. The EXPAD and COMEDIA tools are used for the bookkeeping of the experiments and corresponding media correlated in Bonn. They are the front-ends to a local database which records all relevant information such as the observation date, participating stations, modules, and status of the experiment.

3 Staff

The geodesy group at the Bonn correlator has 1.6 FTEs.

S. Bernhart and Y. K. Choi coordinate the data logistics including e-transfer and module shipment, prepare and supervise correlation, perform post-processing, and deliver resulting observables to the IVS repository in the form of databases. In addition to these standard duties, they provide the stations with feedback on their performance and support tests of the VLBI systems, in particular for the Wettzell Observatory. Furthermore, the geodesy group maintains the e-transfer web page[3] (http://www3.mpifr-bonn.mpg.de/cgi-bin/showtransfers.cgi), which is used by the bulk of the IVS community to coordinate electronic data transfer, in particular with regard to bandwidth availability and port occupancy.

The MPIfR staff at the Bonn correlator is a subgroup of the VLBI Technical Department, headed by Helge Rottmann. Its members are Alan Roy, Jan Wagner, George Paraschos, Sven Dornbusch, and Gino Tuccari (guest). In addition to the scientific staff, there is one technician (Rolf Märtens) and two engineers (Michael Wunderlich, retired in 2024 but is still available as a consultant, and Asmita Gupta since July 2023).

The group is responsible for keeping the cluster software up-to-date and for hardware maintenance and repair, as well as for IT support and software correlator improvements. The group members are involved in several astronomical projects, which are focused on very high-resolution imaging, especially with the Event Horizon Telescope (EHT), and studies of active galaxies with the Global mm-VLBI Array (GMVA).

[3] Originally developed by Frederic Jaron

The Bonn correlator also serves as an inherent test bench for the DiFX and e-transfer software, so that all its personnel contribute to the debugging of these tools.

4 Current Status and Activities

4.1 IVS Correlation

Our duties include the correlation of two Intensive series (INT3 and VGOS-INT-M) and the R1 series, as well as the OHIG and T2 series for IVS S/X legacy sessions and VGOS 24-hour sessions.

In 2023, we processed 21 INT3 sessions (one hour, weekly on Mondays), 52 R1 sessions (24 hours, weekly), 11 T2 sessions (24 hours, bimonthly), eight OHIG sessions (24 hours, bimonthly), and eight VGOS sessions (24 hours).

In 2024, we correlated 49 R1 sessions, six T2 sessions, six OHIG sessions, and ten VGOS sessions. Since Ishioka became a fully operational VGOS station and due to the long downtime of the Sheshan telescope, only 13 INT3 sessions were observed. By suggestion of the Bonn correlator, the new VGOS-INT-M series was introduced in the same year, and 39 sessions could be processed.

For the legacy S/X correlation and post-processing we are currently using DiFX-2.6.3, which comes with HOPS v3.23. All legacy Rapid sessions have, in the meantime, turned into so-called mixed-mode sessions due to the participation of several (VGOS) stations that record dual linear polarization as opposed to the observing mode of the original legacy stations, which is right circular polarization (RCP). This requires the application of the "mixed_pol_yshift90 true" option in the fourfit control file which is only available in the latest release of HOPS v3.25 and adds a 90 degree phase shift to VGOS–VGOS baselines to get a coherent pseudo Stokes I combination and avoid de-correlation of the signal.

VGOS correlation and post-processing are performed by means of DiFX-2.5.5 (HOPS v3.22) together with HOPS v3.24/v3.25 for VGOS-OPS sessions and HOPS v3.24 for VGOS-INT-Ms.

4.2 Other IVS Duties

In mid-2024, Simone Bernhart became a member of the ESA GSET Working Group 3 (VLBI) as part of the ESA Genesis Mission[4]. The working group is tasked to advise and support ESA in the design of the Genesis VLBI transmitter and investigate and prepare for compatibility with normal IVS operations and IVS product generation.

4.3 EU-VGOS – Testing New Frequency Sequences

In recent years, VGOS operations have become much more standardized. Consequently, previous EU-VGOS activities have been reduced to a minimum. Nevertheless, after a VTC splinter meeting during the IVS General Meeting in Tsukuba in March 2024, it was decided to resume some of the work and start a series of test observations for new frequency sequences. These tests were carried out in April 2024 with the participation of six European VGOS stations (NYALE13N, ONSA13NE, ONSA13SW, RAEGSMAR, WETTZ13S, and RAEGYEB). A total of five different frequency setups were observed on five consecutive days, the first being the standard VGOS setup, which was followed by four new versions covering frequency ranges from 3 to 14 GHz. NYALE13N was only available on the first day due to an azimuth motor failure that occurred on the second day (and a planned maser maintenance on days 4 and 5). The test sessions were correlated in Bonn.

Because several problems arose during the observations, it was decided to repeat the tests in late November 2024, this time under the auspices of the IVS VGOS Technical Committee (VTC) and with the participation of additional non-European stations, including two sets of fringe test observations in order to fix possible issues, preferably before the proper observation. The correlation of these sessions was again assigned to the Bonn group.

[4] https://www.esa.int/Applications/Satellite_navigation/Genesis

4.4 Testing New DiFX Versions

In Spring 2023, Bonn started testing the (at the time latest) DiFX version 2.8.1 in order to be able to process future correlations for both legacy S/X and VGOS observations with preferably the same and up-to-date software version. Several issues were identified in the DiFX to HOPS interface and were reported to the HOPS developers. Further tests are pending until these issues are fixed.

5 Future Plans

The correlation cluster hardware was made VGOS-ready in 2015, but it has become susceptible to aging by now. Hence, a hardware upgrade is envisaged for the second half of 2025.

Moreover, the geodesy group will continue to test the latest DiFX version (currently DiFX-2.9) before applying it to operational geodetic analysis. After comparing the SWIN files as well as the resulting observables of the presently used DiFX versions (DiFX-2.5.5 and 2.6.3) and the upcoming release, we will switch to the latter one, should it turn out to be error-free.

References

1. A. T. Deller, W. F. Brisken, C. J. Phillips, J. Morgan, W. Alef, R. Cappallo, E. Middelberg, J. D. Romney, H. Rottmann, S. J. Tingay and R. Wayth, “DiFX-2: A More Flexible, Efficient, Robust, and Powerful Software Correlator”, PASP, 2011, 123, 275–287.