Bonn Correlator Report 2021–2022

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Abstract We report on the status of the Bonn Correlation Center focusing on geodesy for the year 2021 and 2022, as well as technical aspects of the cluster and its performance. We summarize our duties as one of the IVS correlators and recent progress.

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 and shares with the BKG the costs of the cluster, most of the staff and the Internet connectivity. Since January 2017 the personnel responsible for the correlation of geodetic sessions are employed by the BKG via a private contractor, the Reichert GmbH.

2 Component Description

The Distributed FX software correlator (Deller et al. 2011) in various versions is used at the Bonn correlator. For geodetic production we currently use DiFX-2.6.3 for legacy S/X sessions and DiFX-2.5.4 for VGOS observations.

The correlator is running on a high-performance computing (HPC) cluster, which was renewed in 2015 to match both VGOS and mm-VLBI requirements. It consists of (1) 68 nodes with 20 compute cores each, for a total of 1,360 cores, (2) three head nodes which allow execution of several correlations and postprocessing in parallel, (3) 3.0 PB disk space in RAID units and combined in a BeeGFS parallel cluster file system, (4) 14 Mark 5 playback units, and (5) 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, usually 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 line and a 1-Gbit line. The latter is part of the German Research Network (Deutsches Forschungsnetz, DFN). Various raw data formats have already been correlated in Bonn: Mark IV, Mk5, DVP, and various types of VDIF.

The correlator output data (SWIN files) can be exported to FITS and HOPS (Mark IV) formats. For postprocessing, the following software packages are available: AIPS, CASA, PIMA, and HOPS (Haystack Observatory Postprocessing System), the latter of which is the standard tool for geodesy. The correlator outputs and other important files (e.g., VEX and v2d files) are backed up daily on the HPC cluster. The final products are archived on the MPIfR archive server, where they will be kept for at least ten years. The EXPAD and COMEDIA tools are used for bookkeeping experiments and corresponding media correlated in Bonn. They are the frontends to a local database that records all relevant information such as the observation date,

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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 the correlation, carry out the post-processing, and deliver the resulting observ- ables to the IVS repository in the form of databases. Besides 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. Moreover, the geodesy group maintains the e-transfer web page (http://www3.mpifr-bonn.mpg.de/cgi-bin/showtransfers.cgi) that is used by the bulk of the IVS community in order to coordinate electronic data transfers, in particular regarding bandwidth availability and port occupancy.

The MPIfR staff at the Bonn correlator is a subgroup of the VLBI Technical Department, headed by H. Rottmann. Its members are A. Roy, J. Wagner, S. Dornbusch, and G. Tuccari (guest). In addition to the scientific staff, there is one technician (R. Märtens), and one engineer (M. Wunderlich). The group is responsible for keeping the cluster software up to date, 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).

H. Rottmann – head of the VLBI technical department, computer systems, and cluster administration, and is responsible for the beamforming/phasing software of ALMA, DiFX developer.

S. Dornbusch – soft- and firmware developer for the DBBC3 backend. Responsible for software maintenance, testing, verification, and station support for the DBBC2 and DBBC3. He is also an active soft- and firmware developer for the BRAND receiver system.

A. Roy – project manager for VLBI at the Atacama Pathfinder EXperiment (APEX), for DBBC3 commissioning, and head of the polarization conversion effort for Atacama Large Millimeter/submillimeter Array (ALMA) VLBI and the BRAND system.

G. Tuccari – guest scientist from INAF, leader of the Digital Base Band Converter project (DBBC) and the Fila10G development, as well as project engineer of the BRAND receiver.

J. Wagner – general support scientist work for mm-VLBI (EHT, GMVA, APEX setup and observing), correlation of EHT and partly GMVA experiments, technical assistance also for geodetic processing.

The Bonn correlator also serves as an inherent testbench 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 Intensive series (INT3), R1 series as well as OHIG and T2 series for IVS legacy S/X sessions and VGOS 24-hour sessions.

In 2021 we correlated 43 INT3 (one hour, weekly on Monday) sessions, 52 R1 (24 hours, weekly) sessions, seven T2 (24 hours, bi-monthly) sessions, six OHIG (24 hours, bi-monthly) sessions and eight VGOS (24 hours) sessions. In 2022, we processed 34 INT3 sessions, 52 R1 sessions, nine T2 sessions, six OHIG sessions, and eleven VGOS sessions.

4.2 Other IVS Duties

S. Bernhart has become a member of the IVS Committee on Education and Training (IVS CTE) that organizes IVS Training Schools on VLBI for Geodesy and Astrometry, the last one was held March 22–25, 2022 (virtual format) in conjunction with the 12th IVS General Meeting.

Moreover, she was part of the IVS Working Group on the implementation of a new vgosDB naming convention and master file format.

4.3 EU-VGOS

In March 2018, on the initiative of W. Alef of the Bonn Correlation Center, a collaboration with the three

European stations of Wettzell, Onsala, and Yebes, equipped with both standard S/X and VGOS systems, was launched to carry out a VGOS proof-of-concept study. The aim of the project is to verify the processing chain for VGOS experiments end-to-end, from the scheduling to the geodetic analysis of the derived observables.

Even though there were no observations scheduled in 2021 and only one in 2022, the various subgroups (WG Correlation, WG Analysis, WG Operations and WG e-transfer) as well as the EU-VGOS management team (F. Jaron, chair and S. Bernhart, secretary) were quite active performing a number of virtual meetings in order to discuss achieved results and future plans. In October 2021, the Second EU-VGOS Workshop was held as a hybrid meeting hosted by the TU Vienna.

At the (virtual) EU-VGOS General Meeting in April 2022, it was decided to install a proposal system for future observations.

4.4 DiFX-2.5.4 and 2.5.5

In addition to our EU-VGOS correlations, we started correlating 24-hour IVS VGOS sessions in 2021. Each correlator had their own local patches and different versions of DiFX and difx2mark4 to correlate and convert the data.

In August 2021, to regain a consistent DiFX-2.5 installation for VGOS correlation at all sites, J. Wagner gathered the accumulated patches and also backported certain features from mainline DiFX-2.6. Combined with Haystack-provided HOPS 3.22, these were released to the DiFX community as DiFX 2.5.4.

In October 2022, to fix an issue in correlation of multi-datastream Ishioka data that affects the handling of IF-specific LO and clock offsets (*loOffsets*, *freqClockOffs*), he released DiFX 2.5.5.

4.5 Multi-datastream Correlation

Recorded bands are spread across several files and previously these VGOS data should be vmux-ed to "merge" them for single-datastream correlation under DiFX-2.5.3. This occupied disk space doubly and needed extra time/work. In Bonn we carry out DiFX multi-datastream correlation, possible under DiFX-2.5.4/2.5.5 and 2.6.3 using multi-datastream configuration. Onsala Oe/Ow and Ishioka now observe using per-band recordings (multi-files) and e-transfer these recordings directly without prior "merging."

4.6 10-Gbps Upgrade

Previously, we used two 1-Gbps NREN (DFN) links (BONN, RZBONN Servers). In October 2021, we upgraded to a commercial 10-Gbps link (NetCologne) for e-VLBI and replaced the "BONN" server. "RZBONN" is still working. Transfer protocols that we use are JIVE jive5ab/m5copy, and JIVE e-transfer etc/etd[1]. After the upgrade, transfer speeds are much faster than before. For example, in the case of Onsala VGOS data (23 TB) transfer takes two days instead of two weeks.

5 Future Plans

In 2023 we are assigned to correlate 39 INT3 sessions, 52 R1 sessions, regularly planned for mixed-mode, seven T2, six OHIG, and ten VGOS sessions. The Australian stations are included in the network for the VGOS sessions from 2023.

Furthermore, the geodesy group will continue testing the latest DiFX version (currently DiFX-2.8) before applying it for normal operation. After comparing the SWIN files as well as the resulting observables of the presently used DifX version (2.6.3) and the upcoming release, we will switch to the latter one as soon as possible—its stability presupposed.

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 & R. Wayth, "DiFX-2: A More Flexible, Efficient, Robust, and Powerful Software Correlator", PASP, 2011, 123, 275–287.

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