

The Bonn Astro/Geo Correlator

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Abstract

The Bonn Distributed FX (DiFX) correlator is a software correlator operated jointly by the MPIfR and the IGG in Bonn and the BKG in Frankfurt.

1. Introduction

The Bonn correlator is hosted at the Max-Planck-Institut für Radioastronomie (MPIfR)¹ in Bonn, Germany. It is operated jointly by the MPIfR and the Bundesamt für Kartographie und Geodäsie (BKG)² in cooperation with the Institut für Geodäsie und Geoinformation der Universität Bonn (IGG)³. It is a major correlator for geodetic observations and astronomical projects, for instance those involving pulsar gating, millimeter wavelengths, and astrometry.

2. Present Correlator Capabilities

The Distributed FX correlator⁴ was developed at Swinburne University in Melbourne, Australia by Adam Deller (and collaborators) and adapted to the VLBA operational environment by Walter Brisken and NRAO staff. DiFX in Bonn is installed and running on a High Performance Compute Cluster (HPC cluster – see Figure 1).

Features of the software correlator cluster are:

- 60 nodes (8 compute cores each)
- 4 TFlops in the Linpack benchmark test
- 20 Gbps Infiniband interconnection
- 10 RAIDs (about 380 TBs storage capacity)
- one control node for correlation (*fxmanager*)
- two computers (called *frontend* and *frontend2*) for executing parallelized jobs on the cluster, e.g., post-correlation applications
- one control computer (*appliance*) for installing and monitoring the cluster
- closed loop rack cooling

The correlator cluster is connected via 2×1 Gb Ethernet to 14 Mark 5 units⁵ used for playing back the data. If more than 14 playback units are required, and in the case of e-VLBI, data are

¹<http://www.mpifr.de/div/vlbicor>

²<http://www.bkg.bund.de/>

³<http://www.gib.uni-bonn.de/>

⁴DiFX: A Software Correlator for Very Long Baseline Interferometry using Multiprocessor Computing Environments, 2007, PASP, 119, 318

⁵<http://www.haystack.mit.edu/tech/vlbi/mark5/>

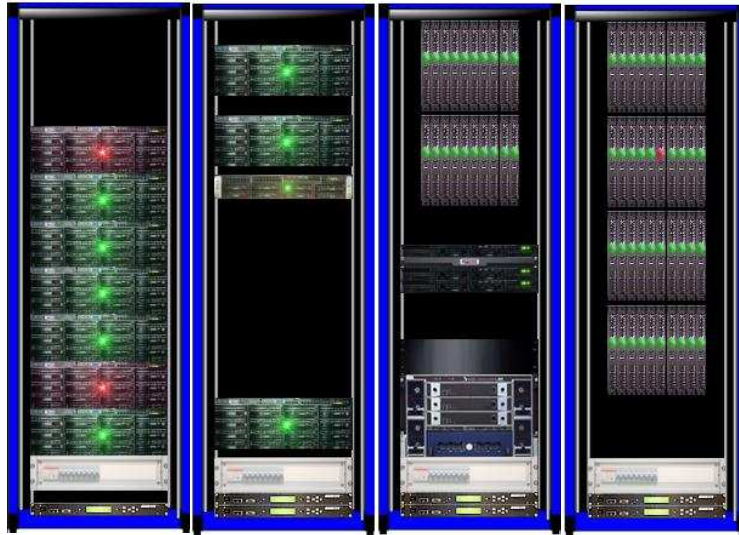


Figure 1. From the left: the first and second racks contain the storage RAIDs and *frontend2*; the third and fourth racks contain the cluster nodes, *fxmanager* and *frontend*.

copied to the raid systems prior to correlation. All Mark 5 can play back all types of Mark 5 data (A/B/C). The disk-modules in the Mark 5 are controlled via NRAO's mk5daemon program. The available functionality includes all necessary functions such as recording the directories of the modules, resetting and rebooting the units, and module conditioning.

A summary of the capabilities of the DiFX software correlator is presented in Table 1.

3. Staff

The people in the geodetic group at the Bonn correlator are

Arno Müskens - group leader, scheduling of T2, OHIG, EURO, INT3.

Simone Bernhart - e-VLBI supervision and operations, experiment setup and evaluation of correlated data, media shipping.

Alessandra Bertarini - experiment setup and evaluation of correlated data for both astronomy and geodesy, digital baseband converter (DBBC) testing (APEX fringe test). Friend of the correlator.

Laura La Porta - experiment setup and evaluation of correlated data, DBBC testing.

Frédéric Jaron - phasecal extraction for software correlator, software support, and Web page maintenance.

Two student operators for the night shifts and the weekends.

The people in the astronomical group at the Bonn correlator are

Walter Alef - head of the VLBI technical department, computer systems and cluster administration.

Alan Roy - deputy group leader, support scientist (water vapor radiometer, technical assistance, development of FPGA firmware for linear to circular polarization conversion, project manager for equipping APEX for millimeter VLBI).

Table 1. Correlator capabilities.

Playback Units	
Number available	14 Mark 5 (4 Mark 5A, 2 Mark 5B, 8 Mark 5C)
Playback speed	1.6 Gbps
Formats	Mark 5A, Mark 5B, LBA, VDIF
Sampling	1 bit, 2 bits
Fan-out (Mark 5A)	1:1, 1:2, 1:4
Nr channels	≤ 16 USB and/or LSB
Bandwidth/channel	(2, 4, 6, 8, 32) MHz
Signal	Single-, dual-frequency; all four Stokes parameters for circular and linear polarization
Correlation	
Geometric model	CALC 9
Phase cal	Phase-cal extraction of all tones in a sub-band simultaneously
Pre-average time	Milliseconds to seconds
Spectral channels	Max no. of FFT tested 2^{18}
Export	FITS export. Interface to MkIV data format which enables the use of geodetic analysis software and Haystack fringe fitting program.
Pulsar	Pulsar gating possible

Helge Rottmann - software engineer for correlator development and operation, cluster administration. DBBC and RDBE control software, Field System.

Heinz Fuchs - correlator operator, responsible for the correlator operator schedule, daily operations and media shipping.

Hermann Sturm - correlator operator, correlator support software, media shipping, and Web page development.

Rolf Märten - technician maintaining cluster hardware and Mark 5 playbacks.

Gino Tuccari - guest scientist from INAF, DBBC development, DBBC project leader.

Michael Wunderlich - engineer, development and testing of DBBC components.

Jan Wagner - PhD student, support scientist for APEX, DBBC development, DiFX developer.

David Graham - consultant (technical development, DBBC development and testing).

4. Status

Experiments: In 2011 the Bonn group correlated sixty-five R1, six EURO, seven T2, six OHIG, forty INT3, and about twenty astronomical experiments.

e-VLBI: e-transfers to Bonn are performed on a regular basis from Tsukuba, Ny-Ålesund, Onsala, Fortaleza, Hartebeesthoek, Metsähovi, Wettzell, Kashima (including data of the antarctic Syowa station), Aira, Chichijima, Japanese VERA stations Ishigakijima (all from Tsukuba) and Mizusawa (from Mitaka), Medicina, Yebes, Hobart and Warkworth. E-transfer reduces the time between observation and correlation since no shipment is required. The achieved data rates range from 100 Mb/s with Ny-Ålesund (limited by radio link) to 600 Mb/s with peaks up to 800 Mb/s

(with Metsähovi). The transfers are done using the UDP-based Tsunami protocol. The total disk space available for e-VLBI data storage at the correlator is currently about 70 TB. A webpage has been developed (<http://www.mpifr-bonn.mpg.de/cgi-bin/showtransfers.cgi>), which shows currently active (Tsunami) e-transfers and helps to coordinate transfer times and rates on a first come-first served base.

DiFX software correlator: A graphical user interface was installed on the DiFX control computer, which simplifies the use of the software correlator.

A new graphical user interface (comedia) has been implemented to replace the old tape library administration software. Comedia permits the operator to monitor the modules from the time they arrive at the correlator to the moment they are sent back to the stations. In particular, it allows one to trace whether a module can be released, a feature that was not present in the old tape library. All experiment and module related metadata are stored in a relational database.

The DiFX software correlator has been operated at Bonn since 2009 and has been continuously updated and improved. Thanks to the possibility of performing pulsar gating, the DiFX correlator in Bonn became a top center for the correlation of EVN pulsar experiments. Significant improvements have been made to adapt the DiFX correlator to the geodetic export path via Mark IV format and fourfit, although some issues are left that will probably soon be resolved. This requires at present some work-arounds sometimes causing delays in the submission of experiment databases.

A branch version of the DiFX software correlator for RFI mitigation is being developed as part of a PhD project.

DBBC: The Bonn group is involved in the development of the DBBC for the European VLBI Network (EVN) and geodesy. The DBBC is designed as a full replacement for the existing analog BBCs. The following stations have already bought one or more DBBCs: APEX, AuScope (Australia), Effelsberg, Onsala, Pico Veleta, Yebes, Wettzell, and Warkworth. The functionality of these DBBCs is currently being tested. The AuScope and Effelsberg stations already use the DBBC in their regular observations. A test at 2 Gbps was successfully performed using the Effelsberg and Onsala DBBCs in July 2011.

APEX: The Bonn VLBI group is equipping the APEX telescope for VLBI observations at 1 mm. The first fringe tests were performed in March 2011 (results pending).

5. Outlook for 2012

DiFX Correlator: Continue testing the DiFX software and ancilliary programs to match the geodetic needs.

e-VLBI: Tests of e-VLBI transfer with other antennas are planned or ongoing. In order to meet the requirements of the higher observing rate foreseen within VLBI2010, it is planned to upgrade the Internet connection from 1 Gbps to 2 Gbps. However, there are some issues concerning funding and technical implementation.

DBBC: Continue DBBC testing in the EVN stations that recently acquired DBBCs. Wide bandwidth modes are also under test. First observations at 2 Gbps are planned for 2012.

APEX Further fringe tests will take place at APEX in March 2012.

Phasing up ALMA The group is involved in an international project to add array phasing capability to ALMA. This will enable its use as an extremely sensitive station in 1 mm VLBI experiments.