The Bonn Astro/Geo Correlator

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Abstract The Bonn Distributed FX (DiFX) correlator is a software correlator operated jointly by the Max-Planck-Institut für Radioastronomie (MPIfR), the Institut für Geodäsie und Geoinformation der Universität Bonn (IGG), and the Bundesamt für Kartographie und Geodäsie (BKG) in Frankfurt, Germany.

1 Introduction

The Bonn correlator is hosted at the MPIfR[1] VLBI correlator center in Bonn, Germany. It is operated jointly by the MPIfR and the BKG[2] in cooperation with the IGG[3]. It is a major correlator for geodetic observations and astronomical projects such as VLBI at millimeter wavelengths, astrometry, RadioAstron[4] VLBI observations, and pulsar VLBI.

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[1] http://www.mpifr-bonn.mpg.de/
[2] http://www.bkg.bund.de/
[3] http://www.gib.uni-bonn.de/
[4] http://www.asc.rssi.ru/radioastron/

2 Present Correlator Capabilities

The DiFX correlator[5] was developed at Swinburne University in Melbourne by Adam Deller and other collaborators. It was adapted to the VLBA operational environment by Walter Brisken and the NRAO staff, and it is constantly updated by the worldwide DiFX developer group. In Bonn, the DiFX is running on a High Performance Compute Cluster (HPC cluster). Its technical specifications can be gathered from last year's annual report.

In preparation for the CONT14 correlation in spring/summer 2014, the Software Development Kit (SDK) of all 14 Mark 5 units was upgraded to version 9.3a.

Furthermore, in autumn the storage capacity was enlarged by an additional geodetc RAID to a total of about 610 TiB.

3 Staff

The people in the Geodesy VLBI group at the Bonn correlator are:

Arno Müskens - group leader and scheduler of T2, OHIG, EURO, and INT3 sessions.

Simone Bernhart - support scientist, e-transfer supervision and operations, experiment setup and evaluation of correlated data for geodesy, media shipping, and Web site maintenance.

Alessandra Bertarini - Friend of the correlator, experiment setup and evaluation of correlated data for

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

both astronomy (e.g. APEX) and geodesy, and digital baseband converter (DBBC) testing.
Laura La Porta - support scientist, e-transfer supervision and operations, geodetic experiment setup and evaluation of correlated data, and DBBC testing.

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 linear to circular polarization conversion software for phased ALMA, and project manager for equipping APEX for millimeter VLBI).
Gabriele Bruni - support scientist for RadioAstron, experiment setup and evaluation of correlated data, and e-transfer supervision and operations.
Armin Felke - FPGA programming for DBBC.
Heinz Fuchs - correlator operator, responsible for the correlator operator schedule, daily operations, and media shipping.
David Graham - consultant (technical development, DBBC development, and testing).
Rolf Märtens - technician maintaining cluster hardware and Mark 5 playbacks.
Helge Rottmann - software engineer for correlator development and operation, cluster administration, developer for the ALMA Phasing Project, and Field System.
Hermann Sturm - correlator operator, correlator support software, media shipping, and Web page development.
Gino Tuccari - guest scientist from INAF, DBBC development, and DBBC project leader.
Michael Wunderlich - engineer, development and testing of DBBC components.

4 Status

Experiments: In 2014 the Bonn group correlated 42 R1, six EURO, three T2, five OHIG, 47 INT3 experiments, and astronomical sessions (including 1 mm, 3 mm, RadioAstron and astrometric projects).

Moreover, the correlation of the 15 CONT14 observations was carried out in Bonn. The routine activities of the Bonn correlator were suspended for about two months to process the CONT14. All other data transfers to Bonn had been suspended during the CONT campaign to allow the nine e-VLBI stations to transfer their data without interruption. A total of 192.5 TB of data have been e-transferred to Bonn. Thanks to the cooperation of the astronomy cluster users and in collaboration with the institute's computer division, it was possible to obtain a temporary buffer of 230 TB additional storage space for emergency cases (e.g., playback problems with disk packs) for the duration of the processing.
e-VLBI: The total disk space available for geodetic e-transfer data storage at the correlator is about 170 TB.

On average $\geq$ 90 % of the stations do e-transfer. The average amount of e-transferred data per week is about 10 TB, considering only the regular INT3 and R1 experiments. Most transfers are done using the UDP-based Tsunami protocol, and the achieved data rates range from 100 Mb/s to 800 Mb/s. The upgrade of the 1 Gbps Internet connection to meet the requirements of VLBI2010 Global Observing System (VGOS) has not been realized yet — still due to funding issues and apparently buereaucratic obstacles.
DiFX software correlator: The DiFX software correlator has been operated in Bonn since 2009 and is updated regularly. The stable DiFX release 2.3 was installed in 2014. The Mark 5A/B/C control software "jive5ab", which was developed at the Joint Institute for VLBI in Europe (JIVE), was installed on the cluster and the Mark 5 units in preparation for future more automated e-transfers. Jive5ab can be used as a full replacement of MIT Haystack's control programs Mark 5A, DiMino, and drs. The installation on the Mark 5 units was tested initially by copying data from RAID onto modules in order to free up storage space in preparation for the CONT14.

Two other branch versions of the DiFX software correlator are available in Bonn: a DiFX version for RFI mitigation, developed by J. Wagner, now at KASI, and a DiFX version dedicated to RadioAstron, developed by J. Anderson, now at GFZ Potsdam.
DBBC: The Bonn group is involved in the development and testing of the DBBC VLBI backends and ancillary parts (ex. FILA10G) for the European VLBI Network (EVN) and geodesy. The DBBC2 is designed as a full replacement for the existing VLBI terminals and includes additional features. Stations such as for instance APEX, Pico Veleta, AuScope (Australia),

HartRAO (Africa), and a large part of EVN have ordered one or more DBBC2s. The FILA10G, VLBI to 10GE interfaces have also been exported to Haystack and Korean stations.

The next generation DBBC (DBBC3-L) is being developed, and two prototypes are being integrated and tested. The BBC3-L can handle a larger bandwidth of 4 GHz for each IF/polarization. A maximum of eight IFs can be processed by a single DBBC3-L, so a dedicated variant of the modular system can also be used as a complete VGOS backend at 32 or 64 Gbps, covering the full RF range up to 16 GHz.

APEX: The Bonn VLBI group has equipped the APEX telescope for VLBI observations at 1 mm. In 2013, APEX conducted its first scientific observations by taking part in the Event Horizon Telescope (EHT) campaign. Observations were carried out at 4 Gbps, lasted about 50 hours, and provided good detections for several sources including Sgr A* and M87.

In late 2014, upgrades were prepared and were installed in January 2015: two Mark 6 recorders, a temporary R2DBE on loan (2 GHz sampled bandwidth, 8 Gbps output), and a DBBC firmware upgrade for sampling 2x 1 GHz bandwidth (8 Gbps output) with 62.5 MHz-wide polyphase filter channels to match ALMA. APEX was the partner station for first-fringe tests with the phased ALMA and the South Pole Telescope in January 2015.

RadioAstron: Data from 13 global+RadioAstron experiments were transferred to Bonn until July 2014, the end of the AO-1 observing period. Since January 2015, two other experiments are being e-transferred to Bonn for the AO-2 observations. The correlation of the three key science projects based in Bonn is on-going, and six experiments were finalized in 2014. Raw data are routinely transferred to ASC (Moscow) via the Internet or HDD for backup purposes.

5 Outlook for 2015

DiFX Correlator: The present cluster used for correlation is now about seven years old. A proposal to the Max Planck Society for a new cluster was awarded for about 500 k€ and a new cluster with more than 1000 compute cores will be installed in the second quarter of 2015. Six full Mark 6 units (32 Gbps) have been procured for the correlator and will be mounted in racks after refurbishment of the present location of the Mark 5 units.

DiFX for RadioAstron: Merging of the RadioAstron DiFX branch version with the current trunk version of the DiFX is ongoing.

e-VLBI: Another 80 TB RAID will be purchased for geodetic e-transfers.

The jive5ab software will be tested for e-transfers, as we are planning to cooperate with JIVE in developing an automatic e-VLBI data transfer controlled by software at the correlator. In addition to enhanced computer security this will allow us to optimize the usage of our Internet connection. This is absolutely essential in cases where more than ten e-transfer stations take part in the weekly R1 experiments and when observations will be performed with higher data rates in the future.

DBBC: We will continue our support for the DBBC2 in the field. New wide bandwidth modes for the DBBC2 are under test. The development work on the DBBC3 will continue, and new wideband modes will be implemented.

Phasing up ALMA: The group is involved in an international project to add array phasing capability to ALMA. ALMA will record with a data rate of up to 64 Gbps, thus being an extremely sensitive station for participation in VLBI experiments at the 3 mm and 1 mm wavelengths. The correlation of 3 mm data will be done in Bonn. Correlation of 1 mm experiments will be handled in a shared effort between Bonn and the Haystack group.

The group made contributions in the phasing algorithm and in linear-to-circular polarization conversion. The first VLBI fringe test experiment was observed January 2015 on the baseline APEX-ALMA with up to 40 antennas phased.