

The Bonn Astro/Geo Mark IV Correlator

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Abstract

The Bonn Mark IV VLBI correlator is operated jointly by the MPIfR and the IGG in Bonn and the BKG in Frankfurt. Since 2007, e-VLBI transfers have become routine for geodetic experiments and, thanks to that, an Intensive series (INT3) was introduced and is correlated in Bonn. The hardware Mark IV processor system has not been changed since the last report except for the addition of another Mark 5B unit. In late December 2007, the first phase of a Linux cluster dedicated for the software correlator was installed. The cluster was extended in January 2009 after new infrastructure for sound insulation, electrical power, and cooling had been built in the correlator room. Astronomical correlation has been moved to the DiFX correlator.

1. Introduction

The Bonn Mark IV correlator is hosted at the Max-Planck-Institut für Radioastronomie (MPIfR)¹ 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 MPIfR's astronomical projects, for instance those involving millimeter wavelengths and astrometry. Production astronomical correlation has been moved to the DiFX software correlator in autumn 2009, while geodetic correlation is still ongoing on the Mark IV.

2. Present Correlator Capabilities

The Bonn correlator is one of the four Mark IV VLBI data processors in the world. It has been operational since 2000. It currently consists of a standard Mark IV correlator rack, 7 Mark 5A units, 4 Mark 5B units, and one additional unit dedicated to e-VLBI, which can also be used as a Mark 5A unit. All Mark 5s and a further Mark 5C unit are also connected to the software correlator. Capabilities of the Mark IV correlator can be found in Table 1. A Linux file server stores all files related to the correlation of the data. The correlator is controlled by a dedicated Linux workstation and an HP workstation, both connected to the Linux file server. Correlation setup, data inspection, fringe-fitting and data export are done on a second Linux machine connected to the Linux file sever. Data security is guaranteed by using a file system with redundancy (RAID level 5) and by daily back-up of the data on a PC disk.

Key parameters of the software correlator cluster are:

- 60 nodes with 8 compute cores each (480 cores total)
- 4 TFlops (floating point operations) in the Linpack benchmark test
- Infiniband 20 Gb interconnect
- two times 1 Gb Ethernet interconnect

¹<http://www.mpifr-bonn.mpg.de/div/vlbicor/>

²<http://www.bkg.bund.de/>

³<http://www.gib.uni-bonn.de/>

- two 20 GB raid systems
- FXmanager control computer which is the control node for the correlator
- Frontend control computer for users who use the cluster for other tasks than correlation
- Appliance control computer for installing and monitoring the cluster
- closed loop rack cooling

Table 1. Correlator Capabilities

PLAYBACK UNITS

Number available: 7 Mark 5A systems, 4 Mark 5B systems
 Playback speeds: real-time up to 1024 Mb/s
 (2024 Mb/s slowed down by a factor of 2)

SUPPORTED RECORDING

Record data-rates: any supported by Mark 5
 Formats: Mark III/Mark IV/VLBA (Mark IV/VLBA w/wo barrel roll, data demod.)
 Sampling: 1 or 2-bit (over-sampling not yet tested)
 Fan-out: 1:1 1:2 1:4 (fan-in not supported)
 No. of channels: ≤ 16 , USB and/or LSB
 Bandwidth/channel: ...,2, 4, 8, 16 MHz
 Signals: mono, dual frequency or dual polarization
 Modes: Mark III: B, C, BB, CC; A, AA (in 2 passes)
 128-16-1 128-16-2 128-8-1 128-8-2 128-4-1 128-4-2
 128-2-2 256-16-1 256-16-2 256-8-1 256-8-2 256-4-2
 512-16-2 512-8-2 1024-16-2 2048 Mb/s with Mark 5B+

CORRELATION

Geometric model: CALC 8
 Number of boards: 16 (DSP not yet implemented)
 Phasecal: dual tone extraction at selectable freqs (single tone analyzed)
 Pre-average times: 0.2 \rightarrow 5 s (default 2 s; 60/N s, N an integer; short
 integration times not with full correlator capacity)
 Lags per channel: 32 min. (\Rightarrow frequency resolution = BW/16), 1024 max.
 Maximum output: 8 stations: 28 baselines, 16 channels, 32 lags with ACF and
 full cross polarization
 10 stations tested with single polarization and ACF
 (requires mixture of Mark 5A and 5B)
 Multiple streams: Maximum of 4 independent correlations for
 simultaneous correlation of sub-nets, etc.
 Multiple passes: Depends on mixture of 5A and 5B.
 Up to 16 stations in 6 passes or less.
 Fringe-fit: Off-line FOURFIT run. (Dual frequency in single
 execution: dual/cross-polsn. in multiple executions)
 Export: Database, MK4IN to AIPS

VLBI data can be played into the cluster from 13 Mark 5 recorders via 1 Gb Ethernet. If more than 13 playbacks are required and in the case of e-VLBI, data is copied to the raid systems before correlation.

3. Staff

The people in the geodetic group at the Bonn correlator are:

Arno Müskens - group leader, scheduling of T2, OHIG, EURO, and INT3, and e-VLBI supervisor.

Alessandra Bertarini - experiment setup and evaluation of correlated data, software correlator development. Digital baseband converter (DBBC) testing. PhD student at IGG Bonn since early 2007, subject of the thesis: Effects on the geodetic VLBI measurables due to polarization leakage in the receivers.

Simone Bernhart - e-VLBI operations, experiment setup and evaluation of correlated data, media shipping. PhD student at the MPIfR since September 2003, subject of the thesis: Flux Density and Kinematic Measurements of the IDV Source 0917+624.

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

Bertalan Feher - setup and trial correlation of INT3 (until September 2009).

Rene Böckelmann - setup and trial correlation of INT3 (since October 2009).

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

Six student operators for the night shifts and the weekends.

The people in the astronomy group of MPIfR at the Bonn correlator who support IVS correlation are:

Walter Alef - head of the VLBI technical department, correlator software maintenance and upgrades, computer system and cluster administration. Friend of the correlator.

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

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

Helge Rottmann - software correlator development and operation. Cluster administration.

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.

Michael Wunderlich - engineer, technical VLBI developments, Mark IV correlator and Mark 5 maintenance.

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

Marcus Offermanns - DBBC production and testing.

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

4. Status

Experiments: In 2009 the Bonn group correlated 52 R1, five EURO, three T2, six OHIG, 49 INT3, and about 30 astronomical experiments.

e-VLBI: e-transfers are performed on a regular basis from Tsukuba, Ny-Ålesund, Onsala, Metsähovi, Wettzell, Kashima (including data of the Antarctic Syowa station), Aira, and Chichijima to Bonn. Data from Japanese VERA stations Mizusawa and Ishigakijima have successfully been transferred to Bonn (from Mitaka and Tsukuba, respectively) for the first time in 2009. e-transfer reduces the time between observation and correlation since no shipment is required. The data rates achieved range from 100 Mb/s with Ny-Ålesund (limited by radio link) to 600 Mb/s with peaks up to 800 Mb/s (with Kashima). 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 26.8 Tbyte.

INT3: The third Intensive series (INT3), which was introduced in late summer 2007, is scheduled and correlated in Bonn every Monday. Thanks to near-real-time e-VLBI transfer, the turnaround between observation and database submission to the analysis center is about seven hours.

Hardware Correlator: In 2009, the Mark 5A unit, which was previously used for e-VLBI, has been linked to the correlator as an additional Mark 5B unit. Instead, one of the Mark 5 units is now dedicated to e-VLBI. Hence, we currently have seven Mark 5A and four Mark 5B units available for correlation.

Software Correlator: In order to meet the requirements of the software correlator especially concerning cooling and noise reduction, the reconstruction of the correlator room was finished in early 2009.

DBBC: The Bonn group is involved in the development of a DBBC for the European VLBI Network (EVN) and geodesy. The DBBC is designed as a full replacement for the existing analog BBCs. The DBBC hardware is ready except for the 10 Gbit Ethernet board which is in the prototype stage. The DBBC firmware is 80 to 90% ready. The integration of the DBBC into the Field System is currently being developed in close collaboration with Himwich/NVI-GSFC and Neidhardt/Wettzell.

5. Outlook for 2010

Correlator: We are still expecting a gradual changeover to Mark 5B, which will further simplify the correlation process since the station units will no longer be needed.

Software Correlator: The implementation of the phasecal signal extraction into the DiFX correlator software is expected to be finished in the very near future. Geodetic verification will be completed in 2010, followed by the changeover of geodetic correlation to the software correlator.

e-VLBI: Stream correlation using e-VLBI transfer will continue, and e-VLBI tests with other antennas are planned/ongoing. An additional 20 TB data raid will be installed at the cluster at the end of February to increase the storage capacity for future e-transfers, especially with regard to the envisaged higher observing rate of 512 Mbps in the course of VLBI2010 and the changeover to the DiFX correlator. In order to meet the requirements of the higher observing rate, we are planning to upgrade our Internet connection from 1 Gbps to 2 Gbps. However, the funding and technical implementation prove to be difficult.

DBBC: The DBBC can be ordered from HAT-Lab and will be deployed in the field in 2010.