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, a new Intensive series (INT3) was introduced and is correlated in Bonn. Three Mark 5B units have been installed and are in regular use for stream correlation. In late December 2007, the first phase of a Linux cluster dedicated for the software correlator, which will become the long-term future replacement of the hardware correlator, was installed. Towards the end of 2008 the cluster was extended to 60 nodes with nearly 500 compute-cores and 40 TB of disk storage.

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.

2. Present Status and Capabilities

The Bonn correlator is one of the four Mark IV VLBI data processors in the world. It has been operational since 2000. It consists of a standard Mark IV correlator rack, eight Mark 5A systems and three Mark 5B systems, and one additional unit dedicated to e-VLBI, which can also be used as a Mark 5B unit. Two Mark 5B+ units for testing purposes and another two Mark 5C units, yet without C boards, are available in the labs. A summary of the Bonn correlator capabilities is 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 server. 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.

3. Staff

The people in the geodetic group at the Bonn correlator are
Arno Müskens - group leader, scheduling of T2, OHIG, EURO, INT3, and e-VLBI supervisor.
Simone Bernhart - experiment setup and evaluation of correlated data, media shipping, e-VLBI operations.
Alessandra Bertarini - experiment setup and evaluation of correlated data, software correlator development, e-VLBI commissioning tests, and media shipping. Digital baseband converter (DBBC) testing. Ph.D. student at IGGB since early 2007, subject of the thesis: Effects on the

[1] `http://www.mpifr-bonn.mpg.de/div/vlbicor/`
[2] `http://www.bkg.bund.de/`
[3] `http://igg.geod.uni-bonn.de/`

geodetic-VLBI measurables due to polarization leakage in the receivers.
Laura La Porta - (since Nov. 2008) experiment setup and evaluation of correlated data.
Stefan Klein - e-VLBI operations (successor of Christian Dulfer).
Bertalan Feher - setup and trial correlation of INT3.
Frédéric Jaron - e-VLBI support, software support, and Web page maintenance.
Four student operators for the night shifts and the weekends.

Table 1. Correlator Capabilities

PLAYBACK UNITS	
Number available:	8 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 rates 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:	$\leq$ 16, USB and/or LSB (multiple passes supported for >16 channels in MK4IN)
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)
Phase cal:	dual tone extraction at selectable freqs (single-tone analysed)
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 (higher output possible, but untested) 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:	Supported for >8 stations (up to 16 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

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 administration, and friend of the correlator.
David Graham - technical development, consultant, software correlator development, and DBBC development and testing.
Alan Roy - deputy group leader, water vapour radiometer (WVR), technical assistance, and development of FPGA firmware for linear to circular polarization conversion.
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 maintaining correlator, Mark 5, and development of the DBBC.
Rolf Märtens - technician maintaining correlator hardware and Mark 5 playbacks.
Marcus Offermanns - DBBC production, fixed-term contract for one year with INAF, Italy.
Gino Tuccari - guest scientist from INAF, DBBC development, DBBC project leader.

Figure 1. Left picture: sound and thermal insulation room for the software correlator still under construction, right panel: temporary correlator room with one Mark 5A rack (center - side view) standing in-room without cooling.

4. Status

Experiment Status: In 2008 the Bonn group correlated 45 R1, five EURO, two T2, 10 OHIG, 42 INT3, and about 30 astronomical experiments.
e-VLBI: Near-real-time e-VLBI transfers from Tsukuba, Ny-Ålesund, Onsala, Metsähovi, Wettzell, and Kashima have become regular at the correlator. Data from the Japanese Antarctic station Syowa, which frequently takes part in OHIG experiments, and data from Japanese stations Aira and Chichijima have successfully been transferred to Bonn (from Kashima) for the first time in 2008. e-VLBI transfer reduces the time between observation and correlation since no shipment is

required. The data rates achieved a range from 100 Mb/s with Ny-Ålesund (limited by radio link) to 400 Mb/s with peaks up to 800 Mb/s. 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 20 Tbytes. In addition to the standard geodetic experiments, we correlated two 8.3 GHz (X-Band) experiments within the framework of the Long Baseline Array (LBA) Calibrator Survey (LCS). Three of the four LBA stations that took part in the experiment were electronically transferred to the correlator.
INT3: The third Intensive series (INT3), which was introduced in late summer 2007, is scheduled and correlated at 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.
Correlator Status: The last tape drive was finally decomissioned, and no further experiments recorded on tapes can be correlated at Bonn. There are currently three Mark 5A units equipped with software development kit (SDK) 7.12.99. This SDK version allows the reading of Serial-ATA (SATA) Mark 5 modules. The first successful test using SATA modules was performed in October 2008. The SATA modules are used for the correlation of e-VLBI transferred data.
Software Correlator: In 2008, one astronomical multi-field (10 fields and 96 sources) VLBI experiment has been correlated and analyzed successfully. Furthermore, two geodetic INT3 experiments have been correlated but not yet analyzed. In order to meet the requirements of the software correlator, especially concerning cooling and noise reduction, the correlator room is being reconstructed since November 2008 (see Fig. 1).
DBBC: The Bonn group is involved in the DBBC development for the European VLBI Network (EVN). This unit is designed as a full replacement for the existing analog BBCs. The design of version 2 of the Analog-to-Digital Converter board (ADC2) was finished in 2008. A 2 x 10 Gbit Ethernet interface card is under development.

5. Outlook for 2009

Correlator: There will be 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 reconstruction work on the software correlator is expected to be finished by the beginning of February 2009. The changeover to the software correlator is expected for late 2009 or early 2010.
e-VLBI: Stream correlation using e-VLBI transfer will continue, and e-VLBI tests with other antennas are envisaged. Three stations that took part in a third experiment within the framework of the LCS project (observed in November 2008) will be electronically transferred to Bonn for correlation.
Personnel Changes: John Morgan, a Ph.D. student from Bologna, will be visiting the MPIfR until the end of April. One of his tasks might be the implementation of the phase calibration tones extraction into the software correlator. From March on, another MPIfR employee, Helge Rottmann, will dedicate 50 % of his time to the development of the software correlator.
DBBC: The production is soon to start, and the completion of the design of two prototype 10 Gbit boards is expected within the first quarter of 2009.