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Bonn Correlator Report for Astronomy and Geodesy

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Abstract

We report on the present status, capabilities and usage of the correlator, the processing efficiency for both astronomy and geodesy experiments, and on the planned upgrade to 12 stations. A short overview of the e-vlbi status and recent developments is given as well as a summary of the CONT05 sessions.

1. Introduction

The Bonn Mark IV correlator is hosted at the Max-Planck-Institut für Radioastronomie (MPIfR) Bonn, Germany. It is funded and operated by the MPIfR and by the (BKG) in co-operation with the Geodetic Institut of the Universität Bonn (GIUB)

The Mark IV processor system consists of the standard Mark IV 16-station-capable correlator unit installed by Haystack Observatory in December 1999. It is used for MPIfR-based astronomical observations with an emphasis on mm-wavelengths, astrometry and special VLBI experiments, and for geodetic observations under the auspices of the GIUB and in cooperation with the International VLBI Service (IVS).

For geodesy, VLBI can accurately measure the geodetic parameters associated with the shape of the Earth and its orientation in inertial space. This includes the positions and velocities of the sites occupied by VLBI antennas, UT1-UTC, polar motion and nutation.

The interaction of the astronomical and geodetic VLBI communities as realized at the Bonn correlator is a very good example in the world of VLBI for interdisciplinary synergies and cross-fertilisation of ideas, methods and efforts.

2. Present Status and Upgrades

2.1. Present Status

The Bonn correlator (Fig 1) is one of four Mark IV VLBI data processors worldwide and has been operational since 2000.

Nine of the 16 possible station inputs of the correlator are presently used. The station units handle the station-related operations and interface the nine tape playback units to the correlator. Eight Mark 5A disk playback units are operational and are connected to the station units in parallel with the tape drives. The operators can easily configure the correlator to accept Mark 5 disks or tapes. The total disk space for storing raw correlator data has grown in response to user demand to more than 1 TB.

Figure 1. Left: Part of the Mark IV data processor: correlator rack with two Mark 5 playback units and two station units as well as one playback tape drive. Right: one of the three new racks equipped with three Mark 5B units and space for the correlator interface boards (CIB).

Tape recordings with 32 tracks and Mark 5 recordings with 64 tracks can be correlated in one pass. This corresponds to maximum data-rates of 256 and 1024 Mbits/s respectively. Currently the correlator supports Mark IIIA, Mark IV, VLBA and Mark 5A formats, 1- or 2-bit sampling, with fanout up to 1:4.

The Mark IV correlator is intensively used. It has been possible to meet the increasing demand for correlation both from astronomy and geodesy by improving correlator software and firmware, the performance of the tape playback units, and by further streamlining operations. A leap in correlation efficiency has resulted from the use of Mark 5A disc-based systems, which offer substantially more robust recording characteristics, virtually error-free data, and random positioning within the recorded data. For Mark 5A-only experiments (e.g. IVS-R1) the correlator can run unattended for many hours.

2.2. Upgrading and Expansion

MPIfR and BKG decided in 2004 to upgrade the correlator to 12 Mark 5B disk playback systems. Similar projects are underway at MIT Haystack Observatory and USNO in Washington.

The expansion from 9 to 12 stations is only possible by using the Mark 5B system, as this system includes a newly designed station unit for the Mark IV correlator. As part of the Mark 5B development mostly done by MIT Haystack, MPIfR has developed and manufactured so-called high-speed serial links in sufficient numbers that also the Haystack and USNO correlators can be upgraded. MPIfR and MIT Haystack have further agreed on a joint project for upgrading the correlator software to allow the correlation of 12 stations simultaneously, on implementing the correlation of 2 Gbits/s recordings which will be correlated at a rate of 1 Gbits/s, and on replacing the present HP-UX based workstation with a more powerful and cheaper solution based on the Linux operating system.

At present three new cabinets have been built up each to be populated with four Mark 5s initially either of A and B-type as well as correlator interface boards required for Mark 5B units (Fig 1). Towards the end of 2006 we expect to be able to remove the remaining tape units.

3. e-VLBI

Media shipment is presently the most time-consuming operation. This will be changed by global high-speed networks. When the Mark 5 system was introduced for VLBI data recording, its potential for the direct transmission of data to the correlator via internet was realized. The development of e-VLBI capabilities has been undertaken in the USA, mostly by MIT Haystack Observatory, in Japan, and in Europe. The involvement of the MPIfR has been hindered considerably by the prohibitive costs of network connections and traffic in Germany as provided by the German academic research network (DFN) and the German Telekom.

Several futile attempts were made to find other ways to connect the Bonn Correlator to the internet at a bit rate of initially 1 Gbits/s, which seems to be the minimum rate to achieve at least VLBI data-rates of 512 Mbits/s. For the present maximum data-rate of the Mark IV data acquisition systems of 1024 Mbits/s, two 1 Gbit connections would be required.

As the planning now stands the MPIfR will install private fibres between MPIfRs 100m-antenna at Effelsberg and the institute at Bonn. A few fibres to connect the institute to the University of Bonn are already in the building. To connect e-VLBI from the University to the European academic network Géant the optical testbed VIOLA[1] might be used. The MPIfR has submitted a proposal to become an associated member of the VIOLA activities. Data transfer via VIOLA would be free of charge.

E-VLBI will use separate fibres to the normal Internet traffic to avoid problems with Internet security. It is planned to drive the e-VLBI fibres at 10 Gbits/s if possible. The VIOLA connection to Géant is limited to only 2.5 Gbits/s. Gbit connectivity to the correlator can be expected in summer 2006, and to the telescope at Effelsberg possibly in 2007.

4. Geodetic Correlation

4.1. Overview

The total correlation time from the beginning of January to the end of November 2005 was 7026 hours, of which about 40% were dedicated to astronomy experiments and 60% to geodesy experiments (Fig 2). Most of the time the correlation was performed by either one of the two day-time operators or one of the five students who cover night shifts and weekends. Unattended correlation was possible for the sessions that involved a maximum of eight Mark 5-equipped stations, no tapes and which needed only one module per station, like the geodetic IVS-R1 series. However in some cases a recorrelation was then needed due to Mark 5 software and station unit failures.

The processing factor (PF), defined as the ratio between the hours spent correlating to the hours spent recording the data, decreased with respect to 2004 as more stations upgraded to

[1] http://www.viola-testbed.de/

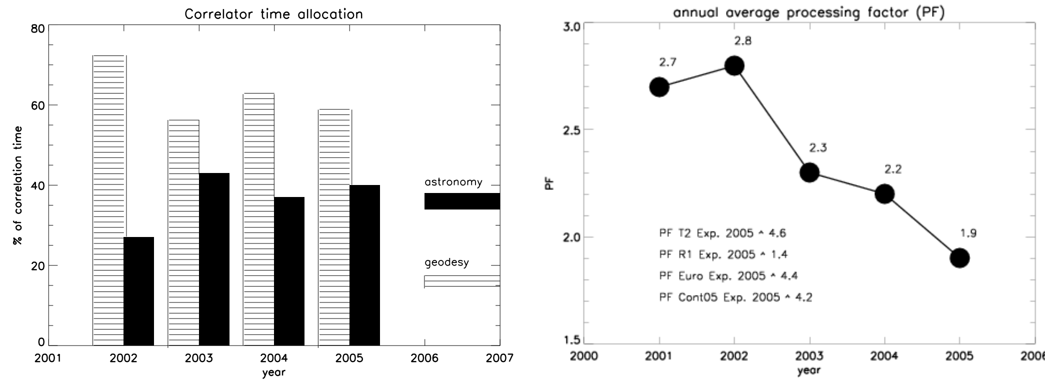

Figure 2. Left: Correlator time allocation for the last years in percentage. Right: Annual averaged processing factor (PF) plotted against the year.

Mark 5 recorders (Fig 2).

In 2005 the geodetic Bonn Correlator group correlated and released about 50 experiments, including IVS-R1, IVS-T2, EUROPE, five CONT05 sessions and one test with the Zelenchuckskaya station. IVS-Ohig 2004 experiments were correlated in December 2005 due to delays in transferring the Syowa data to Mark 5 modules.

Astronomers and geodesists have an agreement concerning correlator usage. The IVS-R1 series always have priority since they must be processed and analysed within 14 days of the observation. Other, non-urgent experiments are processed sequentially according to the requirements of the two groups.

Ftp-VLBI was successfully used to verify the operation of the Ohiggins station. A 60 second scan at a recording bitrate of 128 Mbits/s was transferred via ftp to Bonn in a few hours and fringes were found with the Mark IV correlator.

4.2. CONT2005

The involvement of the Bonn correlator in the CONT05 sessions started early in 2005, when IVS asked for the first time whether Bonn could support the correlation of part of the campaign. In late summer the three correlators involved (Haystack, Washington, Bonn) started to plan how to manage the CONT05 campaign. Based on correlator availability and an estimated processing factor (PF = obs. time / corr. time) it was decided how many sessions would be correlated where.

Bonn correlated the sessions C0501, C0507, C0508, C0514 and C0515. A processing factor of four could be achieved. The correlator control file preparation turned out to be a bit more elaborate than normal, partly due to the multiple passes required — three — and partly due to software problems caused by the unusually large observing logs and control files. Four out of five sessions ran smoothly. Unfortunately about 70% of the C0507 data needed recorrelation due to station-unit problems which led to an increased processing factor. During the campaign it became clear that the correlation and processing at the three correlators had to be standardised to minimise sytematic differences between the sessions of the CONT05 campaign. This successful approach will be retained for future experiments [2] .

5. Astronomy Correlation

The astronomical group correlated several projects observed in the European VLBI network, chiefly for local PIs but also for densification of position catalogues of compact sources and station position measurements of EVN antennas at 22 GHz. The Bonn correlator is used for analysis in the global 3 mm array, presently this uses 8 VLBA antennas and 5 antennas in Europe. All stations record with Mark 5A units at 512 Mbits/s in a 64-track mode. Subsections of the network also record at 1 Gbit/s. Multiple passes are necessary, particularly for spectral line correlation using 512 lags. Bonn technical and astronomical staff are also involved in optimising data acquisition at several stations and in water vapour radiometer (WVR) development.

6. Shipment and Logistic

The shipping time from the stations to the correlator was less then six days for almost all the stations, with some exceptional delays caused by the transport companies. In the case of Tsukuba the shipping lasted a couple of days longer than normal, since the data were transfered via e-VLBI from the station to Haystack. In Haystack the data were copied on a Mark 5 disk that was then shipped to Bonn. We are currently trying to improve the shipment from the correlator to the network stations by searching for better logistics providers.

7. Summary

All Mark IV data processors consist of a 16-station correlator, but they have been equipped with only seven to nine playback and station units. With the introduction of the lower-cost Mark 5B to replace both the MarkIV playback and station units, the correlators can be extended to up to 16 stations with moderate resources.

In the next step forward, MPIfR and BKG will upgrade the correlator to 12 stations by adding four Mark 5B units. This will include new Linux-based computers and a software upgrade to be developed in collaboration with Haystack observatory.

The reduced number of tape drives and station units will still be maintained until all IVS stations have upgraded to Mark 5.

In summer we expect to have Gbit/s connectivity from the correlator into Géant (European Academic Network) via dedicated fibres and shared lines of the 10 Gbit/s optically-switched test network VIOLA.

[2] for more details see http://ivscc.gsfc.nasa.gov/program/cont05/diary_bonn_corr.txt