Haystack Observatory VLBI Correlator

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Abstract This report summarizes the activities at the Haystack Correlator during 2013. Highlights include the transition from Mark IV to DiFX for full time production and the decommissioning of the Mark IV in July, enhancement of the DiFX cluster with additional disk space for increased flexibility, and processing of two 24-hour broadband delay experiments and new u-VLBI Galactic Center observations that included several new antennas. Non-real-time e-VLBI transfers and software support of other correlators continued.

1 Introduction

The Mark IV and DiFX VLBI correlators of the MIT Haystack Observatory, located in Westford, Massachusetts, are supported by the NASA Space Geodesy Program and the National Science Foundation. They are dedicated mainly to the pursuits of the IVS, with a smaller fraction of time allocated to processing radio astronomy observations for the Ultra High Sensitivity VLBI (u-VLBI) project. The Haystack correlators serve as development systems for testing new correlation modes, for hardware improvements such as the Mark 6 system, and in the case of the Mark IV, for diagnosing correlator problems encountered at Haystack and at the identical correlator at the U.S. Naval Observatory. This flexibility is made possible by the presence on-site of the team that designed the Mark IV correlator hardware and software. Some software support is provided to the Max Planck Institute for Radioastronomy in Bonn, Germany and to the general IVS community, for DiFX processing of IVS experiments.

MIT Haystack Observatory

2 Summary of Activities

2.1 DiFX Transition

The switch over to full-time DiFX production occurred in early July. The first IVS experiment fully processed on DiFX was RD1304, and all correlation is now done on the DiFX cluster. Because our cluster setup differs greatly from the other large installations on which our the DiFX software suite is based, various programs had to be modified from their default behaviors in order to work in the Haystack production environment. A particularly critical one was *genmachines*, which had to be modified to re-allocate core processors efficiently for us. *startdifx* also had to be adapted, and problems with corrupt module directories and Mark 5 playback unit readpos errors had to be resolved. These issues have been largely overcome, and production processing runs smoothly most of the time, but work remains to be done to improve the flexibility of the production environment to efficiently handle the inevitable problems that arise.

2.2 DiFX Cluster Developments

The amount of storage space was greatly increased over the last year with the addition of two new file

servers and more disks for the compute cores. The > 142 TB of additional space has made it possible to correlate more stations from files, to supplement the Mark 5 playback units. This, along with the increased number of stations sending their data via e-VLBI, allows experiments with a large number of stations to be correlated in one pass. Another file server and a new head node are due to be added to the cluster shortly.

2.3 DiFX Software Support

Support for the community continues for *difx2mark4*, *fourfit*, and HOPS. This support includes addition of features requested by users, other enhancements, and bug fixes.

2.4 USNO GUI Installation

John Spitzak of USNO visited Haystack in December to install the USNO GUI for setting up and running experiments. The GUI was demonstrated to work in our environment, which is the first time it had been installed outside of USNO.

2.5 DiFX-Mark IV Correlator Comparison of Experiment RD1208

RD1208 was processed in its entirety on DiFX in as nearly identical a way as possible to the Mark IV in order to use it for a comprehensive comparison. Analysis of this data is pending.

2.6 Broadband Delay

Major broadband delay experiments were conducted in January and May. In January the 24-hour "mixed mode" RD1301 session was observed, with the GGAO 12-m and Westford antennas recording broadband data and seven other IVS stations recording standard S/X data at frequencies partially in common with the broadband. But further development of "zoom mode" in DiFX is needed before the mixed wide/narrow band data can be processed. In May broadband data were recorded at GGAO and Westford over 24 hours primarily as a test of amplitude calibration. Processing of the amplitude data for the May session is complete, and work has begun to obtain geodetic results from the data.

2.7 DBE Testing

Various DBE testing projects were conducted during the year. Testing RDBE-H v1.4 vs. 1.5 firmware both in the lab and between GGAO-Wf is one example. Testing of RDBE v3.0 with complex mode format has begun.

2.8 Mark 6

A Mark 6 playback unit was added to the DiFX cluster late in the year. Zero-baseline data of various kinds have been obtained from the RDBEs to test Mark 6 recording, playback, and correlation. VDIF format fixes were initially needed in order to make correlation of this recording format work.

2.9 Galactic Center Observations

Further u-VLBI observations of the Galactic Center and other target sources, with dual polarization at most sites, were recorded and correlated in 2013. These included three stations in addition to those participating last year: APEX in Chile, Pico Veleta in Spain, and Plateau de Bure in France. In July, fringes were found to the LMT (Large MM Telescope), a new antenna in Mexico. This antenna will be added to Event Horizon Telescope (EHT) observations in the future.

2.10 2013 IVS TOW

For the IVS TOW meeting in May, the Haystack DiFX cluster was used for a "practical correlation" class. A

small computer lab was set up to give students practice in setting up an IVS experiment for correlation.

2.11 Support for Other Correlators

There were various projects to assist other correlators. The USNO Mark IV experienced a failure of crate two after some maintenance. This was diagnosed as a FIFO chip failure and repaired. Support was provided to Bonn for help with EHT co-processing of the March observations. Help was provided to the Seshan group so they could reproduce one of the DBE tests conducted in October 2012 at Haystack, in order for them to validate their DiFX installation. Similar support was given to the ASIAA group in Taiwan to assist them in getting started with EHT project correlation on DiFX.

2.12 e-VLBI

Non-real-time transfers have continued. Data from 17 sessions were transferred to Haystack this year from 20 stations (eight in Japan, four in Western Europe, four in Australia, two in South America, and two in South Africa): Kashima34, Kashima11, Koganei, Tsukuba, Chichijima, Ishigaki, Aira, Mizusawa, Onsala, Ny-Ålesund, Wetzell, Noto, Hobart, Yarragadee, Katherine, Warkworth, Fortaleza, Concepción (via Bonn), Hart15M and HartRAO. The number and speed of e-VLBI transfers increased significantly this year after an upgrade to Haystack's Internet connectivity in 2012 enabled data transfer rates up to 1.4 Gb/sec.

3 Experiments Correlated

In 2013, 31 geodetic VLBI sessions were processed, at least in part, consisting of 15 R&Ds, five T2s, and 11 tests of various types. The test sessions included the broadband sessions and fringe tests and an assortment of other projects, some of which were touched on in the summary above. As usual, smaller tests were not included in the above count because they were too small to warrant individual experiment numbers. Routine production (i.e., not test experiments) was performed full time on the Mark IV at the beginning of the year, then switched to the the DiFX correlator in July, as noted previously.

4 Current/Future Hardware and Capabilities

The Mark IV hardware correlator configuration described in last year's report has been powered down. The DiFX cluster currently consists of six PCs, each with dual hex core 2.66 GHz Intel Xeon processors. Two file storage servers, which can also act as DiFX compute nodes, provide 120 TB of file storage. These are all connected through a 40 Gb/sec infiniband network fabric using a Qlogic switch. Currently six Mark 5B playback units with DiFX fully installed are connected to the infiniband fabric. We have processed up to 19 stations in one pass with this setup through a combination of playback units and files.

In 2014 we plan to add more storage, more compute nodes, and a new head node, as currently one of the compute nodes serves in the latter role.

5 Staff

5.1 Software Development Team

- John Ball - Mark 5A/5B; e-VLBI, retired in August 2013
- Roger Cappallo - HOPS post-processing software; Mark 6 development; DiFX software development; correlation trouble-shooting
- Geoff Crew - DiFX correlator development, post-processing software; Mark 6
- Kevin Dudevoir - correlation; maintenance/support; Mark 5A/5B/5C; e-VLBI; Linux conversion; correlator software and build system development; computer system support/development; DiFX correlator development
- Jason SooHoo - e-VLBI; Mark 5A/5B/5C/6; computer system support
- Chester Ruszczyk - e-VLBI; Mark 5A/5B/5C/6
- Alan Whitney - system architecture; Mark 5A/5B/5C/6; e-VLBI

5.2 Operations Team

- Peter Bolis - correlator maintenance
- Alex Burns - playback drive maintenance; Mark 5 installation and maintenance; general technical support
- Brian Corey - experiment correlation oversight; station evaluation; technique development
- Glenn Millson - correlator operator
- Arthur Niell - technique development
- Don Sousa - correlator operator; experiment setup; tape library and shipping
- Mike Titus - correlator operations oversight; experiment setup; computer services; software and hardware testing
- Ken Wilson - correlator maintenance; playback drive maintenance; general technical support

6 Conclusion/Outlook

Operational correlation at Haystack has fully migrated to the DiFX software correlator. Enhancement of our modest cluster is expected to continue in 2014 with the addition of a dedicated head node and additional file servers. Efforts to improve the production environment will continue. Testing and full integration of Mark 6 recording systems and RDBE v3.0 into operations are underway. More broadband observations, including the addition of the Kokee 20-m antenna with a new broadband system, are anticipated.