Haystack Observatory Technology Development Center

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Abstract

Work at MIT Haystack Observatory is currently focusing on four areas:

1. Mark 5B/Mark 5B+ VLBI data systems
2. e-VLBI
3. Digital Backend
4. VLBI2010 Progress

We will describe each of these areas.

1. Mark 5B VLBI Data System

The Mark 5B VLBI data system is now being deployed to stations and correlators. The Mark 5B is based on the same physical platform, uses the same disk-modules, and supports the same maximum data rate of 1024 Mbps as the Mark 5A. However, the Mark 5B incorporates a VSI standard interface that can operate at an input-clock rate up to 64 MHz.

In order to use the Mark 5B system with an existing Mark IV or VLBA data-acquisition system, the installation of an adapter is required to create a VSI output. For an existing VLBA system, a Metsahovi-designed VSI-C board is used to create a standard VSI interface; the VLBA formatter is not used. For a Mark IV system, the existing Mark IV formatter is modified to create two VSI interfaces, allowing data from all 14 BBC's to be recorded to two Mark 5B's for a total aggregate data rate of 1792 Mbps. The Mark 5B also interfaces directly to the new Haystack digital backend (DBE, see below) and the European dBBC.

An FPGA-code upgrade has been designed for the Mark 5A playback system to allow disks recorded on the Mark 5B system to be replayed on a Mark 5A system and create output data in VLBA tape-track format. This upgrade, dubbed 'Mark 5A+', along with some modest correlator-software upgrades, will allow existing Mark IV correlators with Mark 5A+ playback systems to process data recorded on Mark 5B.

In addition, the Mark 5B supports all critical functionality of the Mark IV Station Unit, so that the Mark 5B may be directly connected to a Mark IV correlator through a simple interface without the use of a Mark IV Station Unit. This capability also allows existing Mark IV correlators to inexpensively expand the number of stations connected to the correlator. The Mark 5B system is fully integrated into the Mark IV correlator system at Haystack, and will be incorporated soon at the MPI and USNO Mark IV correlators.

A 2048 Mbps version of the Mark 5B, dubbed Mark 5B+, is now also available. The Mark 5B+ differs from the Mark 5B only by the substitution of a newer StreamStor disk-interface card from Conduant Corp.

2. E-VLBI Development

Haystack Observatory continues to develop the e-VLBI technique with a broad spectrum of efforts, including:

- VSI-E testing: Haystack Observatory is working with Kashima to test the prototype VSI-E implementation. This is a particularly good testbed as Kashima uses K5 data systems and Haystack uses Mark 5 data systems, thus providing an excellent test of VSI-E between heterogeneous data platforms. Once VSI-E is fully tested and functional, attention will be turned to tuning it for higher speeds, followed by broader deployment.
- Data transfer from Ny-Ålesund: A concerted effort over the last year has resulted in e-VLBI data transfers from Ny-Ålesund, one of the most remote sites in the geodetic-VLBI network. Through an agreement with NASA and the Norwegian Mapping Authority, and with the cooperation of local authorities to use a 100km on-island microwave link to the site at Ny-Ålesund, numerous e-VLBI data transfers have been successfully executed. Currently, transfer speed is limited to ~80 Mbps, but this speed may rise significantly with the proposed installation of an upgraded microwave link. The availability of e-VLBI data transfer from Ny-Ålesund greatly helps to ensure timely delivery of data since air connections are few and sometime unreliable due to inclement weather conditions.
- Regular e-VLBI data transfers: Routine use of e-VLBI at Haystack continues to grow. All data recorded on K5 systems at Tsukuba and Kashima are currently transferred via e-VLBI to Haystack Observatory, where it is transferred to Mark 5 disk modules and sent to target correlators at Haystack, USNO or MPI. Daily UT1 Intensive data from Wettzell are transferred via e-VLBI to a site near USNO in Washington, D.C., where it is picked up and taken to USNO for correlation.
- Automated data transfers: As routine e-VLBI becomes more prevalent, it is important that the data-transfer process be automated to the fullest extent possible. As part of an ongoing effort, work is continuing on the development of toolkits for helping to automate the transfer of VLBI data across Wide Area Networks. As a result, most e-VLBI data transfers are now mostly 'hands-off', including recovery from a variety of common problems. The software tools to enable automated data transfers is now also deployed to other sites, most particularly MPI, where they have a newly installed 1Gbps connection for e-VLBI transfer to the MPI correlator.

3. Digital Back Ends

Based on an NSF-funded astronomy VLBI project, and in collaboration with the Space Science Laboratory at UC Berkeley, Haystack Observatory has designed and tested an inexpensive Digital Backend (DBE) module which can be adapted to both geodetic and radio-astronomy VLBI applications.

DBEs have a number of distinct advantages, including absolute predictability and repeatability, sharp filter cutoffs, and low cost. The complete rack of 14 analog BBCs in a current geodetic VLBI system can be replaced with a DBE at a cost of less than $15,000, compared to at least $250,000 for the inferior and obsolete analog BBCs.

A pre-production FPGA-based DBE containing a single 'iBOB' DBE board is shown in Figure 1. The unit accepts two 500 MHz bandwidth IF signals, which are sampled at 1024 Msample/sec. The samplers are followed by a polyphase filter bank which divides each 500 MHz IF into fifteen 32 MHz bandwidth channels spanning the 500 MHz IF input (the 16th channel is not useful). With 2-bit sampling, the aggregate output data rate is 4096 Mbps to two VSI-H connectors. Using two

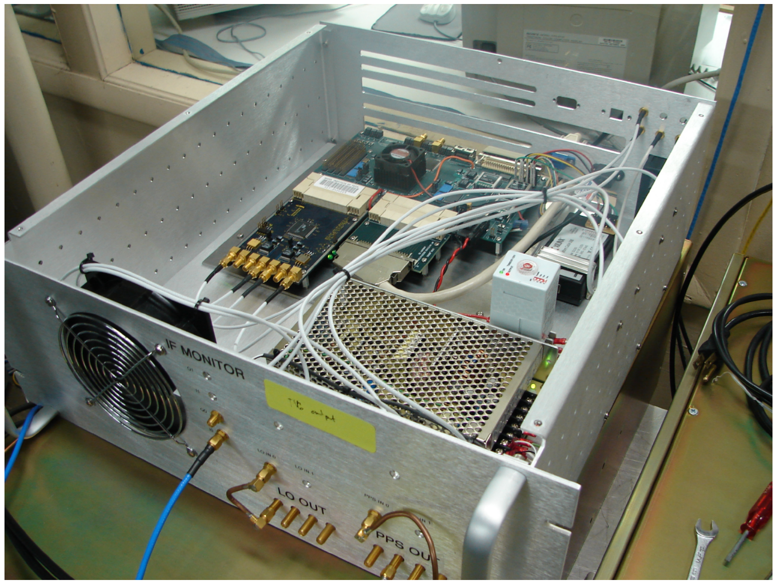

Figure 1. Pre-production DBE under test

Mark 5B+ recorders in parallel, the entire 4096 Mbps can be recorded.

The DBE chassis is designed to accommodate two 'iBOB' boards, which allows four 500 MHz IF inputs to be processed to four VSI-H output connectors for a total output data rate of 8192 Mbps, at a cost of less than $15,000.

In January 2007 a successful test experiment using DBEs was conducted using the Westford antenna and the GGAO antenna at NASA/GSFC. One DBE chassis (Figure 1) and two Mark 5B+ units were used at each site to record data at 4096 Mbps. Correlation was done on the Mark IV correlator at Haystack Observatory.

4. VLBI2010

A one-day technical brainstorming meeting (First VLBI2010 Working Meeting) was held at Haystack Observatory in September 2006 to hammer out the initial specifications for the proposed VLBI2010 geodetic-VLBI system. Among the major decisions made were:

- A 12m diameter antenna looks to be the most suitable compromise between sensitivity, slew speed and cost. The desired slew speed would allow the antenna to move between any two points in the sky within ~30 seconds.
- Reception of the entire ~2-15 GHz RF band looks both technically feasible and highly favorable to improved results, as well as being backwards compatible with current S/X equipment.
- A 'burst-mode' type observing strategy will make best use of the system. In the proposed scenario, an observation will capture data at 16-64 Gbps to high-speed RAM for ~5 seconds, then transfer the data to a slower-speed recording or data-transmission system while the antenna moves to the next source. This cycle would be repeated every ~30 seconds to gather several thousand observations per day at each antenna, far more than can be done

today.

Haystack Observatory is planning to outfit the Westford and GGAO antennas with broad-band feeds that cover ~2-15 GHz, along with DBEs that cover 2GHz of bandwidth, and conduct test observations in 2007 that will help to evaluate the new equipment and observing strategy. These tests will help to further guide the VLBI2010 development efforts.