Haystack Observatory Technology Development Center

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Abstract

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

1. Mark 5B VLBI data system
2. e-VLBI
3. Digital Backend

We will describe each of these areas.

1. Mark 5B VLBI Data System

The Mark 5B VLBI data system, developed at MIT Haystack Observatory, is nearing readiness for deployment. It is based on the same physical platform, uses the same disk-modules as the Mark 5A, and supports the same maximum data rate of 1024 Mbps. However, the Mark 5B incorporates a VSI standard interface.

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.

An engineering upgrade is being designed for the Mark 5A playback system to allow disks recorded on the Mark 5B system to be replayed on a Mark 5A system with the output in VLBA tape-track format; this upgrade to the Mark 5A is dubbed 'Mark 5A+' and will allow existing Mark IV correlators to process Mark 5B data on Mark 5A+ playback systems.

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 will allow existing Mark IV correlators to inexpensively expand the number of stations they support. We expect that the Mark 5B will be fully (hardware and software) interfaced to the Mark IV correlator system in early 2006.

Prototype Mark 5B systems are expected to be available in mid-2006. A 2Gbps version of the Mark 5B, operating at a maximum data-clock rate of 64MHz, is under development.

2. e-VLBI Development

In Spring 2005 Haystack Observatory hired Dr. Chester Ruszczyk, an expert in high-speed networking, to replace Dr. David Lapsley. We welcome Chet to our staff.

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

2.1. Super Computing 2005 e-VLBI Demonstration

In November 2005, Haystack worked in conjunction with the DRAGON project to set up dedicated light paths from three telescopes in the U.S. and Europe for a high-speed real-time e-VLBI demonstration at the SC05 meeting in Seattle, WA. Data from the Westford, GGAO and Onsala antennas were streamed to the Mark IV VLBI correlator at Haytsack Observatory at 512Mbps/station and correlated in real-time (no disk recording at either station or correlator). The data flows were successfully sustained for hours, showing that real-time e-VLBI is very viable provided good communication paths from the antennas to the correlators are available. The results of the correlation were streamed back to the Seattle conference floor in real-time (see Figure 1). We also attempted to bring Kashima, Jodrell and Westerbork into the experiment, but were hampered by various problems, indicating that high-speed real-time e-VLBI is still not quite ready for prime time!

Figure 1. Schematic diagram of real-time 512Mbps e-VLBI demo at SC05

2.2. 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, which is 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.

2.3. 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; approximately 100TB have been transferred over the last year, including all Tsukuba data from the CONT05 experiment. 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. Additionally, monthly UT1 Intensive data are transferred from Tsukuba to MPI for correlation.

Regular e-VLBI data transfers from Ny-Ålesund to Haystack are expected to begin in early 2006.

2.4. Automated Data Transfers

As routine e-VLBI becomes more prevalent, it is extremely 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.

2.5. DRAGON

Researchers at Haystack are participating in a project called "Dynamic Resource Allocation through GMPLS over Optical Networks" (DRAGON) in collaboration with the University of Maryland Mid-Atlantic Crossroads (MAX), Univ. of S. California Information Sciences Institute, George Mason Univ., NASA/GSFC and USNO, and industry partner Movaz Networks. This project has e-VLBI as one of its premier applications and provides advanced optical switching infrastructure for supporting e-VLBI experiments.

2.6. Measurement and Protocol Testing

Network performance characterization and protocol testing between various e-VLBI sites around the world continues. Tests within the United States, Japan, South America and Europe are ongoing. Recent results have demonstrated up to 900Mbps international data rates using advanced transfer protocols between servers located in Tokyo, Japan and at Haystack.

2.7. EGAE

Researchers at Haystack continue to work on the Experiment Guided Adaptive Endpoint(EGAE). EGAE provides the interface between a VSI data acquisition system and the network and implements the RTP-based VSI-E protocol. Current experiments include looking at the suitability of various transport protocols (e.g. TCP, High speed TCP, SABUL, TSUNAMI, etc.) for use within this framework and how best to integrate these protocols into the EGAE.

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 is designing and testing an inexpensive Digital Backend (DBE) module which will initially be used for radio astronomy, but which we plan to adapt for geodetic VLBI as well.

DBEs have a number of distinct advantages, including absolute predictability and repeatability, sharp filter cutoffs, and low cost. We estimate that the complete back of 14 analog BBCs in a current geodetic VLBI system can be replaced with a couple of DBEs at a cost <\$10,000, compared to at least \$250,000 for the inferior and obsolete analog BBCs.

A prototype FPGA-based DBE under test is shown in Figure 2. The DBE accepts a 500MHz bandwidth IF which is sampled at 1024Msamples/sec. The sampler is followed by a Polyphase

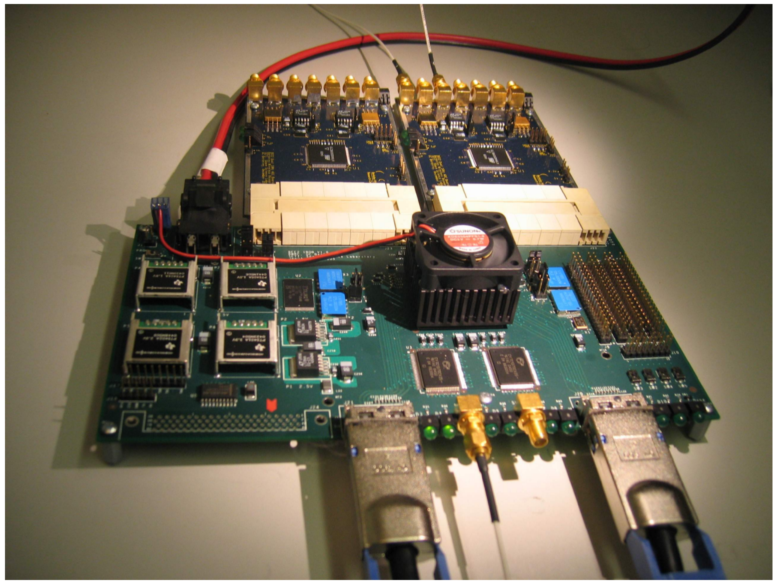

Figure 2. Prototype DBE under test

Filter Bank which divides the 500MHz IF into sixteen 32MHz bandwidth channels spanning the 500MHz IF input. With 2-bit sampling, the output data rate is 2048Mbps, which will interface to the next-generation Mark 5B data system.