Haystack Observatory Technology Development Center

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Abstract

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

1. Studies for a new geodetic-VLBI system based on small antennas and e-VLBI
2. Development of Mark 5 VLBI data system
3. Development of e-VLBI

We will describe each of these areas.

1. SAGE - Small Advanced Geodetic e-VLBI System Study

At the request of NASA, Haystack Observatory led a study to examine the possibility of replacing the current set of antennas used for geodetic VLBI with small, low-cost, high-efficiency wide-band systems using state-of-the-art technology. The study indicates that such systems are feasible and will be able to yield results which are as good or better than current systems can produce. Two candidate antenna systems were examined, one 6m diameter and one 12m diameter, with attendant first-order estimates for development and deployment costs, as well as a projected development schedule. Copies of the SAGE report are available on request.

2. Mark 5 Development

2.1. Mark 5 Upgrade to SATA Disk Compatibility

Haystack Observatory continues to work with Conduant Corp to develop a Mark 5 upgrade which will allow the Mark 5 to use the new serial-ATA (SATA) disks, as well as the existing parallel-ATA (PATA) disks and disk modules. The upgrade will require the replacement of the current Mark 5 chassis backplane with one which supports both PATA and SATA disk modules. A new disk module and module backplane will be required for SATA disks.

The biggest stumbling block has been finding a connector that is both compatible with SATA requirements (which must support multi-Gbps serial data through the connector – a very tough requirement!) and has sufficient durability for a large number of insertion/removal cycles. The current PATA connector is specified for 5000 insertion/removal cycles, but the best SATA connector is specified for only $\sim$ 500 insertion/removal cycles. The upgraded system will use this connector with the understanding that connector replacement, particularly at the correlators, may be necessary on a scheduled basis. The SATA upgrade is expected to be available mid-2005 and will apply to both Mark 5A and Mark 5B systems.

2.2. Mark 5B VLBI Data System

Development of the Mark 5B VLBI data system is nearing completion at MIT Haystack Observatory. 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 will incorporate a VSI standard interface and command set. The Mark 5B system may be used with a Mark IV or VLBA system with the use of simple interface electronics directly from the Mark IV or VLBA samplers, eliminating the need for an external formatter. For existing VLBA systems using VLBA formatters, the current recording limit is 512 Mbps due to formatter limitations; the use of a Mark 5B connected to the sampler outputs will allow the recording of 1024 Mbps. For existing Mark IV systems, the Mark 5B will allow connection of all 14 BBCs to two Mark 5B's for a total aggregate data rate of 1792 Mbps. In addition, the Mark 5B is being designed to support 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. Prototype Mark 5B systems are expected to be available in mid 2005.

3. e-VLBI Development

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

3.1. VSI-E Reference Implementation

David Lapsley has developed a reference implementation of the proposed VSI-E specification. This implementation is intended to act as a demonstration model for VSI-E and is available to all interested parties. The VSI-E framework provides signaling, control, framing and statistics support and is an extension to the Internet standard RFC3550. It also provides flexibility in that it allows users to choose the transport protocol that most suits their networking environment (e.g. UDP, TCP or other variants). Once the reference implementation is fully checked out and any needed changes made, attention can be turned to optimizing the code for high-speed operation.

3.2. Intensive UT1 Transfers from Kokee and Wettzell

After considerable delays in bringing up a satisfactory link to Kokee, success appears now to be in hand. Regular e-VLBI transfers of daily UT1 data from Kokee to ISI-E in Washington, D.C. are expected to begin in February 2005. Wettzell continues to be well connected with an E3 (34 Mbps) link to the University of Regensburg, then on to the German Federal Network (DFN) and the pan-European GEANT research network. Daily UT1 Intensive data will be transferred from Kokee and Wettzell to ISI-E in Washington, D.C.; the data will be hand carried on portable disks from ISI-E to the USNO correlator while USNO awaits a high-speed e-VLBI connection of its own.

3.3. 512 Mbps Real-time e-VLBI Demo at SuperComputing 2004

e-VLBI played a prominent role at this year's Super Computer Conference! This year's meeting, dubbed "SC2004" and held in Pittsburgh 7-12 Nov 2004, hosted live real-time demos for several hours each day during the week long show. E-VLBI shared exhibit space with the DRAGON project, in which MIT Haystack Observatory is a collaborator, and set up an exhibit where live results of real-time e-VLBI from the Haystack correlator were displayed. The demo was done in two modes for several hours during each day of the show:

1. Live real-time data were sent from the Westford (near Haystack in Massachusetts) and

NASA/GSFC (Maryland) antennas at 512 Mbps to the Haystack Mark IV VLBI correlator. The live correlation results were displayed in a 3-dimensional plot (see Figure 1 below) in Pittsburgh as the data were correlated, so the correlation signal could be seen building up and the noise declining as the integration period increased.

2. During periods when the antennas were not available, pre-recorded data were transferred to Haystack from Westford, GGAO, Onsala (Sweden), and Kashima (Japan), followed by immediate correlation, again showing results in Pittsburgh as the correlation proceeded. The transfer rates from all stations were several hundred Mbps.

Many visitors to the booth were interested in seeing a "real" science application of high-speed networking and learning about VLBI and e-VLBI. More information and photos are posted at *http://evlbi.haystack.mit.edu/sc2004.html*.

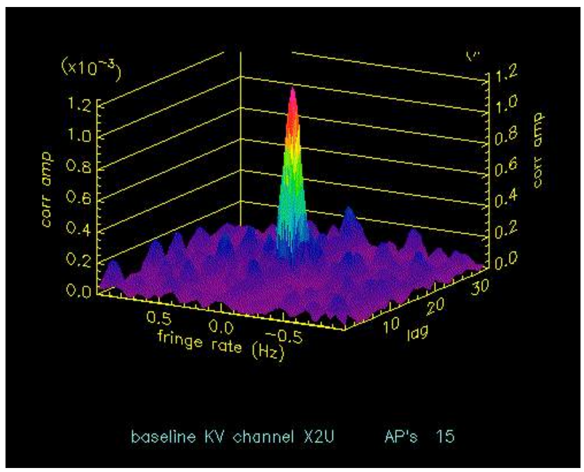

Figure 1. Real-time fringe display at SC2004 from Haystack correlator at SC2004 in Pittsburgh;

3.4. Production e-VLBI Facility Set-up at Haystack

Haystack Observatory has established a "Production e-VLBI Facility" which is dedicated to non-real-time e-VLBI transfers. Typically, about three 24-hr data sets per month from Kashima or Tsukuba are now transferred through this facility, with a typical volume of data around 300 GB/session; we expect usage to ramp up in the near future.

The equipment dedicated to the Production e-VLBI Facility includes:

- Two high speed servers for the transfer and conversion of data
  - Turtle (1.266 GHz Intel Pentium III Dell PowerEdge 2500)
  - Enterprise (a dual 2.4 GHz Xeon Dell PowerEdge 2600)
- Two 1.0 TB Lacie Bigger Extreme Firewire 800 external hard drives for the temporary storage of data
- A Mark 5 for the transfer of data from system disc to Mark 5 disc pack
- 3 Dell PowerConnect 5224 Managed Ethernet Switches

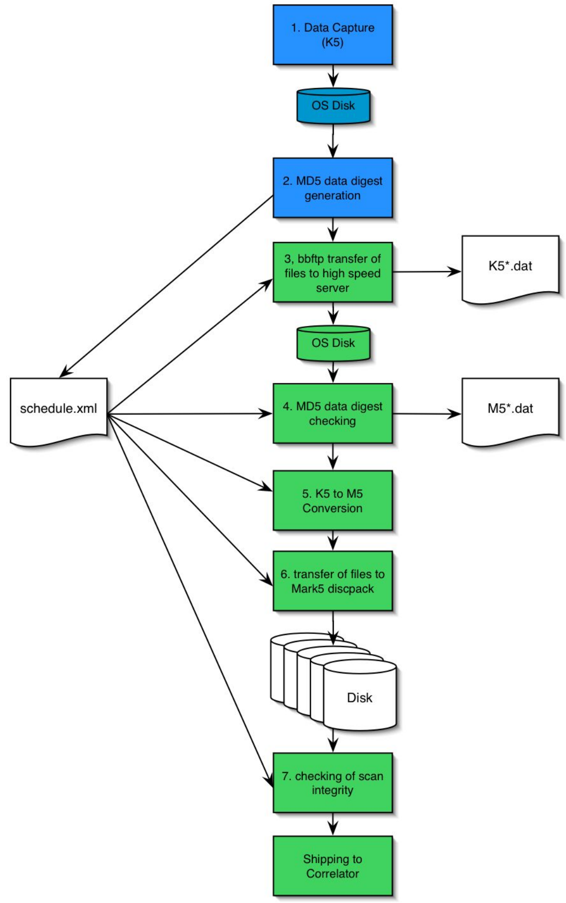

Figure 2. e-VLBI Production Facility (left); K5 to Mark 5A e-VLBI Production Process (right)

After data are collected at Kashima and Tsukuba (both in Japan) on K5 systems, automated procedures are executed to transfer, verify, convert to Mark 5 format, and transfer the data to Mark 5 disk modules. Figure 2 summarizes the steps involved in the process; e-VLBI memo #51, available at *ftp://web.haystack.edu/pub/e-vlbi/memoindex.html*, describes the process and XML control files in detail. The process has been structured in a very modular manner to easily accommodate transfers between both heterogeneous and homogeneous data systems. Currently, the system uses "bbftp" for data transfer, but in the near future this will be converted to VSI-E. .

3.5. DRAGON Project

Researchers at Haystack continue work on the Dynamic Resource Allocation through GMPLS over Optical Networks (DRAGON) program 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 its premier applications and will provide advanced optical switching infrastructure for supporting e-VLBI experiments.