Haystack Report – 8 Nov 2007

Mark 5

The Mark 5B (1 Gbps) and Mark 5B+ (2 Gbps) systems are now operational and are both used in routine field operations. The Haystack correlator has been upgraded to support Mark 5B playback systems and operation has proven to be quite reliable. Because the Mark 5B replaces the troublesome Mark 4 Station Units, the reproducibility of results has proven to be exceptional and has allowed a new level of testing and verification of the correlator system which was never before possible. Work is now proceeding to support the Mark 5B for real-time e-VLBI on the Mark 4 correlator.

A new Mark 5 module that supports SATA disks is now available from Conduant. The SATA disk modules are fully interchangeable with the current PATA modules and will allow the use of the SATA disks, which are beginning to become dominant in the marketplace, particularly in the larger-capacity disks. Users should be aware that upgraded firmware and software are needed to support the SATA disks.

A 'Mark 5C' system is being developed in cooperation with Conduant to support 4Gbps sustained recording across 16 disks (two Mark 5 disk modules). The data interface for the Mark5C will be a direct 10 Gigabit Ethernet connection into the disk system compatible with digital-back-end (DBE) systems which are now being developed in Europe and the U.S. We expect that both of the enhancements will be available some time in 2008. Specification documents for the Mark 5C and the supported Mark 5C data formats have been distributed to the community for comment.

DBE

The DBE system developed jointly by Haystack and UC Berkeley, based on a polyphase filter concept, has now been successfully used in a number of experiments over the past year. Each DBE contains two Berkeley-designed 'iBob' boards that have had their Xilinx FPGA chips programmed to process two 500MHz BW IF signals into contiguous 16MHz or 32MHz channels for a total output of 4Gbps from each of the iBobs, or 8Gbps from a full-up DBE. The DBE has been used with Mark 5B and Mark 5B+ systems to record experiments with both 2Gbps and 4Gbps; an experiment at 8Gbps/station is planned for late summer 2008 using a new experimental 2-15GHz broadband system being developed for geodetic VLBI.

Discussions between Haystack and NRAO have led to an agreement to develop the next generation of DBE. This development effort will be based on a next-generation 'iBob2' board currently being developed jointly by UC Berkeley, NRAO and South Africa. Haystack will develop the FPGA code for a 'DBE2' personality that accepts 2 IFs at 1GHz bandwidth each and processes them with two polyphase filter banks for a maximum aggregate output rate of 8Gbps over two 10 Gigabit Ethernet connections. NRAO will develop the FPGA code on the same hardware platform to implement multiple dBBCs on each iBob2 board with full backwards compatible with the current analog system. The first prototype units from both Haystack and NRAO are projected for early 2008. The cost of a DBE2, including sampler board, is expected to be <$5K (perhaps as low as about $2K).

Haystack has developed a flexible IF/LO system which accepts any IF signal in the range ~0.1-12GHz and mixes down any 500MHz or 1000MHz part of the IF band to a desired Nyquist zone for input to a digital backend system. Such a flexible LO/IF system is valuable for connection of VLBI backend systems to first-time VLBI telescopes (such as some mm telescopes), and will also provide needed flexibility for the broadband 2-15GHz geodetic system

UVLBI

In April 2007 a large 230GHz Ultra-wide-bandwidth VLBI (UVLBI) experiment, led by Shep Doeleman, was conducted using SMTO in Arizona, CARMA in California, JCMT in Hawaii and Pico Veleta in Spain, concentrating on the galactic center. This was a challenging experiment since neither CARMA nor JCMT has ever been used for VLBI before. Two Mark 5B+ recorders were used to record 4Gbps at SMTO, CARMA and JCMT; a Mark 5A was used to record 1Gbps at Pico Veleta. Fringes were obtained between SMTO, CARMA and JCMT, but not to Pico Veleta. Of primary interest are the two long-baseline observations on SgrA*, the massive black hole candidate in the Galactic Center. Fringes obtained on these baselines place a firm upper limit on the size of the compact SgrA* emission of <40 micro-arcseconds, or 4 Schwarzschild Radii for the 4 million-solar-mass black hole.

Burst-mode VLBI

Haystack has received a grant to develop a burst-mode VLBI system that will capture VLBI data at 16Gbps from two DBE2 systems to high-speed electronic memory for ~30 seconds, then dribble the data to recorders at ~4Gbps for a couple of minutes; the cycle will then repeat. This type of system is valuable in situations where one needs to collect as much data as possible over a short period of time. One obvious application is mm-VLBI where the coherence of the atmosphere usually limits coherent observations to about 30 seconds, and the best SNR is achieved by collecting as much data as possible over a ~30 second period. Another application is geodetic VLBI where there is a need to move around the sky as quickly as possible from one observation to the next; in this case, a possible strategy is to record 5-10 seconds of on-source data in a burst mode, then dribble the data to recorders while the antenna spends the next 30 seconds moving to the next source. The burst-mode system will also be designed to support pulsar systems by gating the data stream and recording data only during the active part of the pulse period.

Frequency standards for mm/sub-mm VLBI

As VLBI moves to higher frequencies, the stability of frequency references required to maintain phase coherence between VLBI sites becomes critical. Though the troposphere limits high frequency VLBI coherence times, high altitude sites often experience very good weather conditions. At the ALMA site in Chile, the measured coherence time of the atmosphere is > 10 seconds 60% of the time at 230GHz and 45% of the time at 345GHz (Holdaway 1997). To match this excellent 'seeing', a VLBI frequency standard has to have a fractional stability (Allan Standard Deviation) of $\sigma_y(10s)<2x10^{-14}$ for 10 second integrations. Only the very best Hydrogen masers can achieve this, but other frequency references, notably Cryogenic Sapphire Oscillators (CSO), have stabilities at least an order of magnitude better than Hydrogen masers over 1-200 second time scales. Haystack is collaborating with the Frequency and Metrology Group at the University of Western Australia to explore adaptation of CSOs produced by that group for VLBI use. Through this NSF-funded work, we expect that one CSO with a GPS-conditioned, phase locked 10MHz reference output will be available for high frequency VLBI work in ~2009.

e-VLBI

Haystack continues to develop and test the VSI-E application software and is currently working with the VLBI community to extend the VSI-E specification to include support for GigE and 10GigE data streams.

On 21 May 2007 real-time e-VLBI fringes were obtained between a VLA antenna in New Mexico and Westford in Massachusetts. These were the first real-time e-VLBI observations to the VLA site and are a precursor for potential further development of e-VLBI with the VLA and VLBA.

In October 2007 a 10 Gbps dedicated fiber link was established between Haystack Observatory and Washington, D.C., with connection into the Internet2 backbone at 10 Gbps. This link will be used for high-data rate e-VLBI development and transfers.

Alan Whitney