Haystack Report – 22 Sep 2008

Mark 5

The Mark 5B (1 Gbps) and Mark 5B+ (2 Gbps) systems are now operational and are both used in routine field operations and at the Haystack correlator. Data recorded at 2Gbps on the Mark 5B+ are correlated at half-speed (1Gbps) on the Haystack correlator. Because the Mark 5B/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 near completion to support the Mark 5B for real-time e-VLBI on the Mark 4 correlator.

All Mark 5 types now support SATA disks housed in SATA-compatibles disk modules from Conduant. The SATA disk modules are fully interchangeable with the current PATA modules. SATA disks are becoming dominant in the marketplace, particularly in the larger-capacity disks. Users should be aware that upgraded Mark 5 and Conduant firmware and software are needed to support the SATA disks.

The Mark 5C system continues to be 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. Conduant is now testing the 10GigE daughterboard (for the Amazon StreamStor card) that is necessary for the Mark 5C. The Mark 5C will be compatible with the almost-complete VDIF data-format specification. A prototype Mark 5C system is expected to be operational in late 2008.

Digital BackEnd

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, including a highly successful 1-mm experiment on SgrA*. 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 fall 2008 using a new experimental 2-15GHz broadband system being developed at Haystack for geodetic VLBI.

Haystack and NRAO continue to work under a cooperative agreement to develop the next generation of DBE. This effort is based on a next-generation ‘iBob2’ board (dubbed ‘ROACH’) currently being developed jointly by UC Berkeley, NRAO and South Africa. Haystack is developing FPGA code for a ‘DBE2’ personality that will accept 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 is developing FPGA code on the same hardware platform to implement multiple dBBCs on each ROACH board with full backwards compatibility with the current analog

BBCs. The first prototype units from both Haystack and NRAO are projected for early 2009. The cost of a DBE2, including sampler board, is expected to be <$5K.

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 of Haystack, was conducted using SMTO in Arizona, CARMA in California, and JCMT in Hawaii, 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 at each site to record 4Gbps. Of primary interest were observations on SgrA*, the massive black hole candidate in the Galactic Center. The results from this experiment 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. The results were published in the 4 Sep 2008 issue of Nature. A follow-up experiment with all Mauna Kea mm-wavelength apertures (JCMT, SMA, CSO) "phased-up" is planned for Spring 2009.

Burst-mode VLBI

Haystack is working 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 maintains a 10GigE link between Haystack and GGAO (Maryland) for support of new broadband geodetic systems, with a 2.5Gbps link to the outside world. We are investigating the possibility of a 10Gbps connection from Australia to Haystack as part of an Internet2 initiative, but costs are currently unknown.

Alan Whitney