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IVS Technology Coordinator Report

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Abstract

This report of the Technology Coordinator includes the following: 1) continued work to implement the new VLBI2010 system, 2) the 1st International VLBI Technology Workshop, 3) a VLBI Digital-Backend Intercomparison Workshop, 4) DiFX software correlator development for geodetic VLBI, 5) a review of progress towards global VLBI standards, and 6) a welcome to new IVS Technology Coordinator Bill Petrachenko.

1. VLBI2010 Progress

Progress continues towards the goal of a next-generation VLBI2010 system. Much more detailed information about VLBI2010 development is presented elsewhere in this volume; here we briefly report some of the highlights.

1.1. Development of the VLBI2010 Broadband System

The VLBI2010 system continues to be developed at several locations:

1. The VLBI2010 13-m 'twin-telescopes' installed at Wettzell will be formally inaugurated in April 2013. RMS surface accuracy is better than 60 micrometers, and the antenna and the subreflector are aligned. A tri-band feed will be installed soon, followed by measurements of G/T and pointing tests. A new broadband "Eleven" feed and accompanying receiver and recording systems are currently being installed.
2. The broadband 'QRFH' 2-14 GHz broadband feed from Caltech has been successfully tested on the VLBI2010 prototype antenna at NASA/GGAO and will soon also be installed on the Westford antenna. Experimental results for beam patterns and efficiencies closely match theoretical predictions. The QRFH feed can be easily re-designed to accommodate a wide variety of antenna geometries.
3. Digital-backend development continues in China, Europe, Japan, Russia, and the United States. A VLBI Digital-Backend Intercomparison Workshop was conducted at Haystack Observatory in October 2012 to test inter-compatibility between independently developed DBE units.
4. Mark 6 VLBI data system: The Mark 6 system is entering service at 8 Gbps. Several successful experiments have already been conducted, and the system continues to be made more robust. Routine service at 8 Gbps is expected in the first half of 2013, with expansion to 16 Gbps by the end of 2013.
5. A number of VLBI2010 data-taking sessions between Westford and NASA/GSFC were conducted during 2012, including several operating at 8 Gbps/station. Many were recorded onto four Mark 5C units at each station using RDBE backend units as data sources, at an aggregate data rate of 8 Gbps/station, but a single Mark 6 is now able to replace the four Mark 5C units. More of the processing of VLBI2010 data continues to be moved from the

Mark IV correlator to the DiFX correlator at Haystack Observatory as the DiFX correlator becomes more capable of processing VLBI2010 data.

6. DiFX correlators at MPI, Haystack Observatory, and U.S. Naval Observatory continue to be developed and used for processing geodetic VLBI data.

2. 1^{St} International VLBI Technology Workshop at Haystack Observatory

The annual international e-VLBI workshop, the 10th of which was convened in 2011 in South Africa, was expanded in 2012 to include a broader scope of technical VLBI developments and was renamed *1st International VLBI Technology Workshop*. It was held at Haystack Observatory 22-24 October 2012 and attended by 68 participants from 17 countries.

Prior to the meeting, an intrepid group of ∼20 attendees braved cold and wind to climb ∼1000m-high Mt. Monadnock in nearby New Hampshire, which offered spectacular views of the New England fall foliage display.

The three-day workshop included sessions on antennas, receivers, digital backends, phase-calibration, recording, and e-VLBI, as well as some recent VLBI science achievements, and it was judged to be highly successful by all. The program and presentations from the workshop are available on-line at *http://www.haystack.mit.edu/workshop/ivtw/program.html*.

The 2nd International VLBI Technology Workshop will be held in fall 2013 in South Korea.

Figure 1. Attendees of 1st International VLBI Technology Workshop held at MIT Haystack Observatory.

3. VLBI Digital-Backend Intercomparison Workshop

The 2nd International VLBI Digital-Backend Intercomparison Workshop was held at Haystack Observatory immediately following the VLBI technical workshop reported above. (The first was held in 2009.) Participants from China, Europe, Japan, and the U.S. spent two very busy days preparing equipment, recording wide-bandwidth correlated noise, and processing through the Haystack DiFX correlator to test the proper operation and intercompatibility of all the units under test. A full report of this workshop is contained elsewhere in this IVS annual report.

4. DiFX Software Correlator for Geodetic VLBI

The so-called DiFX software correlator was originally developed at Swinburne University in Australia by Adam Deller, primarily for astronomical VLBI use. The development of an economical and powerful software correlator, a dream less than a decade ago, has been made possible by the relentless march of Moore's Law to provide powerful inexpensive clustered PCs with high-speed data interconnections that can distribute and correlate VLBI data in an efficient manner. Several institutions that support geodetic VLBI correlation processing now have DiFX correlators (MPIfR, USNO, and Haystack Observatory) and have been working to augment the core DiFX software to meet the needs of geodetic VLBI. This includes the integration of much of the Mark IV post-correlation software involving data-management, output data formats, fringe finding and delay estimates, and editing/quality-assurance software. In addition, a substantial amount of work has been done to support the VDIF data-input format and to support correlation of mismatched sample rates and recording bandwidths.

5. Review of Global VLBI Standards

One of the goals of the IVS Technology Coordinator over the past 15 years has been to promote development and implementation of global standards for VLBI. During this time, the following VLBI-related standards represent some of the progress that has been made.

5.1. VEX/VEX2

VEX (VLBI EXperiment), created in the late 1990s and updated in the early 2000s, is a pseudo-language that describes the detailed configuration of each station in an experiment, as well as the schedule of observations. The scheduling process creates a VEX observation file for each experiment that describes that configuration and schedule for each station, as well as a corresponding station-specific SNAP file (Standardized Notation for Antenna Procedures, created in the 1980s) that is created to drive the Field System at each station. During an experiment, a VEX-format log file is created that aids in post-experiment correlation and post-correlation processing. VEX is now used to support a majority of geodetic VLBI observations and is also becoming quite prevalent for astronomical VLBI as well.

Over the past few years, evolving VLBI technologies and capabilities have prompted the creation of a VEX2 Task Force to update and modernize VEX to accommodate these new capabilities, particularly digital backends and VDIF data formats, in a natural way. The VEX2 specification is nearing completion and is projected to be released in early spring 2013.

5.2. VSI

The original VSI (VLBI Standard Interface) specification was created in 1999 to specify a standardized electrical data interface (dubbed VSI-H for 'VSI-Hardware') and software control interface (dubbed VSI-S for 'VSI-Software'). As a result, many of the VLBI data-recording/playback systems developed in the 2000s (Mark 5B, PC/EVN, K5, and LBA) support the VSI interface specification. In recent years, the VSI-H specification has been superseded by the industry-standard 10-Gigabit Ethernet interface that is now being widely adopted in new VLBI data systems (Mark 5C and Mark 6).

5.3. VDIF Data Format

The VLBI Data Interchange Format (VDIF) format was developed by the VDIF Task Force and subsequently ratified by the VLBI community in 2009. Designed to be fully compatible with 10Gigabit Ethernet, as well as being very flexible in terms of channelization, sample depth, sample rate, etc., it is being implemented in virtually all new VLBI data equipment. In addition, software has been implemented on several software correlators to support at least some basic VDIF modes. As more complex VDIF modes are put into use at stations, correlator software will need to develop in parallel to support them.

A VDIF2 data format, including the accommodation of arbitrary sample rates (including those that do not have an integral number of samples in a single second) is nearing completion but is not quite ready for ratification; such 'non-standard' sample rates are being designed into some of the new SKA-related systems that would like to participate in global VLBI over the next few years. The new VDIF2 standard will also relax the constraint of an integral number of filled data packets per second and will allow much more flexibility in the choice of packet lengths. Progress towards completion and ratification of VDIF2 is expected in 2013.

5.4. VTP

VLBI Transport Prototype (VTP) has been developed to specify how VDIF data frames should be streamed over standard networks such as Ethernet, and it is gaining acceptance for e-VLBI data transport and transfers. One of the primary purposes of VTP is to allow the easy identification of dropped and/or duplicated packets that might occur during the data-transmission process over high-speed networks.

5.5. VLBI Standards Website

The Web site *www.vlbi.org* has been created to act as a common source for definitions and information on VLBI standards, as well as a directory to VLBI on-line technical information located at numerous VLBI institutions around the globe. These include VEX, VSI-H, VSI-S, VDIF, VTP, and standardized VLBI file-naming conventions, as well as a VLBI technical resources page. As new standards and technical VLBI resources emerge, they will be included at this Web site.

6. Welcome to New IVS Technology Coordinator

The author will be stepping down as IVS Technology Coordinator at the end of 2012, coincident with retirement from MIT after 45 years of involvement with VLBI (although I plan to continue

part-time for at least a while). It has been my great privilege to serve in this capacity and to work in this endeavor with so many wonderful and talented people over all the globe; without this great community support, my job would have been made much harder and the results less satisfactory. Thanks to you all.

Bill Petrachenko of Natural Resources Canada (NRCan) has been selected as the new IVS Technology Coordinator, beginning in 2013, and will be serving in a permanent position on the IVS Directing Board. Bill has long and deep experience in the theory and practice of VLBI and will be a great addition to the IVS team. Many of you are already familiar with the key role that Bill has played, and continues to play, in the development of VLBI2010. I have no doubt that his vision, expertise, and steadfastness will be a major force in helping to successfully steer VLBI technology development over the coming years.