IVS Technology Coordinator Report

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Abstract

The efforts of the Technology Coordinator in 2006 were primarily in the following areas: 1) beginning coordination work to implement a new geodetic VLBI system as outlined in the IVS Working Group 3 'VLBI2010' study, 2) continued development and deployment of e-VLBI, and 3) support of the 5th annual e-VLBI Workshop held at MIT Haystack Observatory. We will briefly describe each of these activities.

1. VLBI2010 Progress

A VLBI2010 workshop was held at MIT Haystack Observatory on 15 September 2006. The purpose of the workshop was to build on the conclusions of the September 2005 IVS Working Group 3 report and set the stage to begin actual development of a new geodetic VLBI system. A number of broad conclusions and decisions were reached during the meeting, including:

1. A goal of 4 psec precision for the group-delay observable for each baseline-observation appears to be a good match to the 1 mm geodetic measurement accuracy goal of VLBI2010.
2. A 12 m diameter antenna with Tsys ~50K with ~60% efficiency and the ability to move between any two locations in the sky within ~ 30 sec appears to be a reasonable choice.
3. The system should cover a continuous ~2-15 GHz band; this choice has several clear advantages:
   - Maintains backwards compatibility with current S/X system
   - Extends the current spanned bandwidth by almost a factor of two.
   - Allows for growth for observing up to ~13 GHz of bandwidth when the data transmission and correlation technology allows, though the new broadband system may require the use of dual-linear polarization.
4. A 'burst mode' type of operation appears to be highly desirable, which would have roughly the following characteristics:
   - Capture on-source data into high-speed RAM for ~5 sec at a data rate of perhaps 32 Gbps, covering 4 dual-polarization bands of 1 GHz each across the 2-15 GHz receiver bandwidth.
   - Transfer data to a recording system or data-transmission system for ~20 sec at a rate of ~8 Gbps while the antennas move to the next source.
   - Repeat this cycle continuously over 24 hours to collect ~2800 observations, many more than are collected today. Besides rapid sky coverage, this mode of operation will quickly sample the atmosphere in all directions to allow better determination of changing atmospheric parameters.
5. Hydrogen-maser technology is almost certainly sufficient for the requirements of VLBI2010 – uncertainties in atmosphere are expected to dominate H-maser uncertainties most of the time.

6. A study needs to be made of the benefits and problems associated with placing multiple antennas at a single site. A preliminary study indicates that placing multiple smaller, faster antennas at a single site is better than a single larger antenna, even if the single large antenna is fast. The best use of multiple antennas is to have them pointing at different areas of the sky since the effect of clock errors can be minimized or eliminated. However, with a single very fast antenna, the need for multiple antennas at a site is greatly diminished.

There are many challenges to implementing the proposed system, including:

1. cost of a fast-moving 12 m antenna
2. feed technology to cover the 2-15 GHz RF band
3. system calibration – a system of injection of short 10-30 ps pulses into the feed has been suggested
4. recording and/or data-transmission technology to absorb the vast amount of data generated by such a system (~60 TB/day at each station!)
5. how to correlate this large amount of data

Progress is being made towards implementing a system suitable to meet VLBI2010 goals, including:

1. identification of potential antenna vendors, though costs for motions at the desired speeds are not yet known.
2. identification of a couple of candidate dual-linear-polarization feeds to approximately span the 2-15 GHz broadband goal.
3. demonstration of broadband digital back-end technology in Japan, Europe and the U.S. that will form the basis of back-end channelization for VLBI2010 systems.
4. demonstration VLBI experiments with 4 Gbps recording capability conducted in Japan and U.S.

A VLBI demonstration of the convergence of these technologies is planned for summer 2007 which will outfit two existing antennas (Westford and GSFC/GGAO) with broadband systems recording at 8 Gbps. Not only will such a system demonstrate a large step toward the required technology, it should substantially increase observation SNRs to uncover systematic error sources which have heretofore been masked.

2. E-VLBI Development

e-VLBI development is continuing on a number of fronts, which we will briefly describe here:

2.1. Ny-Ålesund Connected

During the last year a number of e-VLBI tests and experiments have been conducted with the Ny-Ålesund station, one of the most remote stations in the VLBI network. Courtesy of arrangements between NASA and Norway, which jointly own an undersea fiber-optic cable from Svalbard to the mainland, these tests have allowed a significant amount of data to be transferred from Ny-Ålesund to Haystack Observatory, where they are recorded on Mark 5 disk modules and shipped to the target correlator. The current speed of the connection is limited to less than 100

Mbps, but plans are being discussed to increase the speed to ~300 Mbps, which would be suitable to transferring essentially all data from Ny-Ålesund via e-VLBI. Since Ny-Ålesund media have traditionally been among the most difficult to transport rapidly and reliably, the new e-VLBI connection promises a real step forward.

2.2. MPI Correlator Connected

The Mark IV VLBI correlator at MPI Bonn has recently been connected at 1 Gbps. This connection will allow data to be transferred directly from remote stations to the MPI correlator. Tests of this new link are currently underway and production use of the connection is expected in early 2007.

2.3. Continuing Expansion and Development of Routine e-VLBI Data Transfers

Routine use of e-VLBI 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. Syowa (Antarctica) data are now being transferred to Haystack from Japan, after the Syowa K5 disk media have been physically shipped to Japan. 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 are expected to begin within the next few months. The biggest impediment to rapid e-VLBI expansion continues to be station connectivity to high-speed networks, but the situation is improving. Tsukuba, Kashima, Onsala, Westford, Onsala, and Medicina are now connected with 1 Gbps links, though some issues remain in actually using some of the links at full speed. Wettzell is connected at ~30 Mbps, with plans to upgrade to ~600 Mbps in Spring 2007. TIGO is in the process of upgrading its connection to ~30 Mbps. Projects are underway to connect Hobart, Fortaleza, and Svetloe in 2007.

2.4. VSI-E Beta Testing

VSI-E beta testing continues, though progress has been somewhat slower than desired. A reference implementation of the proposed VSI-E specification has been developed and is undergoing testing. The primary purpose of VSI-E is to provide a standardized specification for e-VLBI data formats and protocols that is compatible between both homogeneous and heterogeneous VLBI data systems. The VSI-E framework provides signaling, control, framing, and statistics support and is an extension to the Internet standard RFC3550. It also provides flexibility for users to choose the transport protocol that best suits their networking environment (e.g. UDP, TCP, or other variants). The first live testing of VSI-E is currently ongoing using Kashima, Ny-Ålesund, and Haystack. The Kashima site is a unique testbed since data are collected on the K5 at Kashima, while Haystack uses Mark 5A systems, enabling testing on heterogeneous systems. Once the reference implementation is fully checked out, attention can be turned to optimizing the code for high-speed operation, followed by broader deployment.

3. 5th International e-VLBI Workshop Held at MIT Haystack Observatory

The 5th International e-VLBI Workshop was held 17-20 September 2006 at MIT Haystack Observatory in Westford, MA. The return of the workshop to Haystack, where the first e-VLBI workshop was held in 2002, followed the cycle of these annual workshops from U.S. to Europe to Japan to Australia and back again to Haystack. The workshop was attended by more than 60 participants from 15 countries. The workshop was expanded to four days (from the usual two) by the addition of two days of tutorial lectures and demonstrations before the main body of the workshop itself. These tutorial sessions were designed to help attendees deepen their knowledge about some of the various complex aspects of networking and e-VLBI, including detailed discussion of transmission protocols, the problems and pitfalls of tuning a network for optimum speed, a primer on network security for e-VLBI, and an in-depth look at VSI-E. The workshop presented an opportunity to share the experiences of progress and developments in e-VLBI around the world and to explore possibilities for coordination and cooperation. The standard of presentations was again very high, and many new results and plans were presented. e-VLBI is set for rapid progress around the world in the next few years. All presentations from the workshop are available online at *http://www.haystack.edu/geo/vlbi_td/abstract.html*. The workshop series will continue its rotation around the world with the next e-VLBI workshop to be hosted in Europe at MPI. We all look forward to another stimulating and valuable meeting.