Canadian VLBI Technology Development Center

Wayne Cannon, Calvin Klatt

Abstract

The Canadian VLBI Technology Development Center has been active in a number of areas during the 22 month reporting period.

The S2 Geodetic VLBI program continues to make significant advances on many fronts, including development of the frequency switched S2 VLBI data acquisition system, enhancement of the S2 correlator capabilities to process frequency switched VLBI observations, utilization of a transportable antenna and the expansion of capabilities for scheduling, data processing and analysis. A number of experiments have been conducted using the Algonquin, Yellowknife and the Canadian Transportable VLBI Antenna (CTVA).

The next-generation, S3, VLBI system continues to be under active development at the Space Geodynamics Laboratory. It is capable of 1 Gbit/sec recording with unattended record times as long as 160 hours (depending on system configuration) using robotic tape changers.

1. Introduction

The Canadian VLBI Technology Development Center is a collaborative effort of the Space Geodynamics Laboratory of the Center for Research in Earth and Space Technology, (SGL/CRESTech), the Geodetic Survey Division of Natural Resources Canada (GSD/NRCan) and the Dominion Radio Astrophysical Observatory (DRAO) of the Herzberg Institute for Astrophysics of the National Research Council of Canada, (DRAO/HIA/NRC).

2. S2 VLBI Geodesy

Introduction

The Canadian S2 geodetic VLBI program is developing a complete "end-to-end" geodetic VLBI system and operational capability. This effort involves a wide range of activities including development of the frequency switched S2 VLBI data acquisition system, enhancement of the S2 correlator capabilities to process frequency switched VLBI observations, utilization of a transportable antenna and the expansion of capabilities for scheduling, data processing and analysis.

S2 VLBI Data Acquisition System (S2-DAS)

The S2 VLBI data acquisition system is being jointly developed by SGL and the GSD. The S2-DAS is designed to accomodate up to four VLBA/MkIV-type single sideband baseband converters (BBCs), each with a local oscillator (LO) independently frequency switchable under computer control. The objective of the development of the S2-DAS is to enable high sensitivity group delay measurements without appealing to a more costly parallel IF/baseband sub-system.

There are currently four S2 DASs in use. An additional three are in production: two for GSD and one for BKG. These should be available for operational testing within the first half of 2001.

The DAS Operating System (DASOS) has seen extensive development in the past 22 months. Much effort has gone into frequency switching with automatic gain control (1999) and automated self tests (2000). The official release of DASOS is planned to occur in April 2001.

DAS-PCFS communication requirements are being established. Development of a station wavefront clock model is also underway.

S2 VLBI Correlator

The Canadian S2 Correlator is a six station correlator using S2 playback terminals and is designed to handle S2 frequency switched bandwidth synthesis data. Recent activity has focussed on the development of post processing software to enhance system performance monitoring.

Canadian Transportable VLBI Antenna (CTVA)

The CTVA is a 3.6m radio telescope acquired to facilitate densification of the terrestrial reference frame in remote regions. The antenna will be colocated with GPS elements of the Canadian Active Control System (CACS) to provide fiducial station positions. The GSD is responsible for CTVA system development.

Since 1997 the antenna has been located at DRAO near Penticton, B.C. Recent work focusses on antenna sensitivity and system stability and reliability. Extensive testing through CGLBI (S2) experiments has occurred. We anticipate that the antenna will be moved to a new site in 2001.

S2 Geodetic Experiment Scheduling, Operations and Analysis

The Canadian Geodetic VLBI program involves all aspects of Geodetic VLBI operations, from experiment design through analysis. Anthony Searle has recently joined the GSD VLBI group. He has taken on many scheduling and analysis tasks and has assisted with experiment operations.

The CGLBI experiment scheduling was improved as a result of the introduction of S2 support in the SKED software. The CGLBI scheduling (and drudging) process is approaching full automation through use of scripts. The analysis software was updated to f-SOLVE and we have both CALC 8.2 and 9.1 available. Minor software changes to SOLVE remain necessary for CGLBI data to be analyzed. Software to create Mk3-type databases from (S2) frequency-switched experiments (CGLBIDB) was written and has been used on a regular basis.

A number of S2 VLBI experiments have taken place in the reporting period (see below). A significant amount of simulation work (using SKED and SOLVE) has taken place to investigate the system performance and possible future directions (S2 CORE?) for S2-based geodesy. An investigation into multi-beam VLBI (several small antennas co-observing with large ones) is underway.

The GSD has produced a CGLBI website which is regularly updated to reflect experiment activity (www.vlbi.ca). An analysis web site was created as a contribution to the IVS. This website documents SOLVE: f-SOLVE is documented elsewhere.

Interferometric Experiments

In the reporting period 23 developmental experiments (CG006/June 1999 through CG028/ December 2000) have been performed using the S2 VLBI system, ALGOPARK and the CTVA. Of these, 17 were 24-hour geodetic experiments and the remainder were system tests. Yellowknife participated in 10 of these experiments, 6 being 24-hour geodetic.

Fringes have been obtained in each S2 interferometric experiment. The measured baseline length between ALGOPARK and PENTICTN using the S2 system has been repeatable within 1 cm.

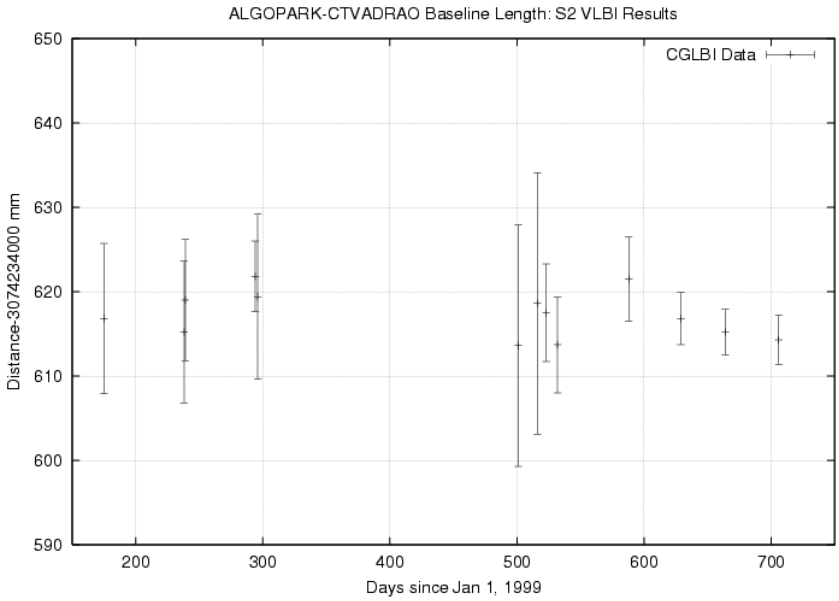

Figure 1. Penticton - Algonquin S2 Baseline Length Measurements

3. S3 Wide Bandwidth VLBI Data Record/Playback System Development

VLBI applications to geodesy and astrophysics can benefit from higher signal to noise ratio observations. The most attractive means of achieving large factor improvements in SNR in geodetic VLBI observations is by developing wide bandwidth VLBI data record/playback/correlation systems.

The Space Geodynamics Laboratory (SGL) located on the campus of York University in Toronto, Canada is developing a family of wide bandwidth VLBI data record/playback systems designated "S3", as a next generation follow-on to the "S2".

The S2 VLBI data record/playback system is a 128 Mbit/sec, Mostly-Off-The-Shelf (MOTS) VLBI data record/playback system based on an array of eight video tape transports together with custom designed signal channel cards and a single board control computer housed in a standard VME enclosure. The S2 is specified to operate without error correction coding at a Bit Error Rate (BER) of the order of 10^{-4}; however typical BER performance in the S2 is of the order of 10^{-5}. The extensive use of MOTS hardware in the S2 design resulted in a low cost, high performance, VLBI data record/playback system of which more than 50 have been fabricated at SGL and are now in use in a variety of radio astronomy and VLBI applications in more than a dozen countries around the world.

The S3 VLBI data record/playback system is the next generation MOTS VLBI system. It has inherited a significant amount of its architecture from the S2 although the VME backplane has been replaced with a wide bandwidth Compact PCI backplane. In addition the interface for the S3 will be compatible with the VLBI Standard Interface (VSI) specification. The S3 is constructed as an array of eight JVC "Digital-S" (now designated "D9") digital video tape transports, each of which is able to record/playback VLBI data at a rate of 150 Mbit/sec, of which 128 Mbit/sec is "user data", for an overall user data rate of 1024 Mbit/sec (1 Gbit/sec). Recent S3 system tests

at SGL in which pseudorandom digital data was written to and read from the S3 tape transport indicate that the signal to noise ratio on the S3 eye pattern is comparable to that of the S2. The S3 is expected to provide a BER performance that is comparable to the S2.

The tape change interval for the S3 tape array is 2.5 hours at a data rate of 1024 Mbit/sec (1 Gbit/sec) with longer tape change intervals being possible when operating the S3 at reduced data rates. The cost of recording media for the S3 is expected to be $150 (US) per hour at a data rate of 1024 Mbit/sec (1 Gbit/sec).

The S3 VLBI data record/playback system is designed for system upgrades based on the recently introduced JVC High Definition TV "D9-HD" tape transport, which in the S3 context will record/playback VLBI data at a rate of 300 Mbit/sec. The D9-HD will enable the fabrication of the "Compact" version of the S3 system, the "S3-C", which will record/playback VLBI data at a rate of 1024 Mbit/sec (1 Gbit/sec) on a compact array of only four tape transports.

The D9-HD will also enable the fabrication of the "Extended" version of the S3 system, the "S3-E", which will record/playback VLBI data at a rate of 2048 Mbit/sec (2 Gbit/sec) on an array of eight tape transports. Dual operation of the S3-E will provide for VLBI data record/playback at data rates as high as 4096 Mbit/sec (4 Gbit/sec).

SGL has implemented a TiltRac robotic tape changer for the S3 family of VLBI data record/playback systems. The tape changer is a true Commercial-Off-The-Shelf (COTS) system developed especially for use with the JVC D9 and D9-HD tape transports. The robotic tape changer is available in single-bay, dual-bay, and triple-bay configurations. SGL has implemented a dual-bay configuration in its development system. The robotic tape changer provides the option of long unattended operation intervals with the S3 family of VLBI data record/playback systems.

System Config	Data Rate (Mbps)	Tape Duration (Hrs)	Unattended Operation (Hrs) Single Bay Robot	Double Bay Robot	Triple Bay Robot
S3	1024	2.5	-	65	130
	512	5	-	130	260
	256	10	-	260	520
	128	20	-	520	1040
S3-C	1024	1.25	32.5	97.5	162.5
	512	2.5	65	195	325
	256	5	130	390	650
S3-E	2048	1.25	-	32.5	65
	1024	2.5	-	65	130
	512	5	-	130	260
	256	10	-	260	520
Dual	4096	1.25	-	32.5	65
S3-E	2048	2.5	-	65	130
	1024	5	-	130	260
	512	10	-	260	520

Table 1. S3 Tape Durations and Unattended Operating Times with Robotic Tape Changer