Canadian VLBI Technology Development Center

Wayne Cannon, Calvin Klatt

Abstract

The S2 VLBI data record and playback systems, developed at CRESTech's Space Geodynamics Laboratory on the campus of York University, are now in use around the world for a variety of radio astronomy, VLBI, and space VLBI applications in over a dozen countries.

The S2 VLBI correlator, developed jointly by the the Canadian Space Agency, the Geodetic Survey Division of NRCan, the Herzberg Institute for Astrophysics, and the Space Geodynamics Laboratory has been operational in a six station configuration for more than two years at the Dominion Radio Astrophysical Observatory (DRAO) in Penticton BC, Canada mainly in support of space VLBI observations. The "end-to-end" completion of the S2 VLBI system will be achieved with the final deployment of the frequency switched, S2 VLBI data acquisition system. The frequency switched S2 VLBI data acquisition system is intended to enable geodetic VLBI measurements with sensitivities comparable to the Mark IIIA using only two base band converters. The Canadian geodetic VLBI program using the S2 system also involves the development of the Canadian Transportable VLBI Antenna (CTVA) to be used to establish quasar referenced geodetic control points over the Canadian landmass.

The next-generation, S3, VLBI system capable of 1 Gbit/sec recording with unattended record times as long as 60 hours using robotic tape changers, is also under active development at the Space Geodynamics Laboratory.

1. Introduction

The Canadian VLBI Technical 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

2.1. Introduction

The Canadian S2 geodetic VLBI program involves development of 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 analytical capabilities for scheduling and analysis.

2.2. S2 VLBI Data Acquisition System (S2-DAS)

The S2 VLBI data acquistion system is being jointly developed by SGL and the GSD. The S2-DAS is designed to accept up to four IF inputs between 100 MHz and 1000 MHz and to accomodate up to four VLBA/Mark IV-type single sideband baseband converters (BBCs). Each BBC in the S2-DAS is provided with a local oscillator (LO) that is independently frequency switchable under computer control over the entire 900 MHz IF range. LO frequency switching in the S2-DAS is

phase coherent and requires less than 1 ms to settle to within 1 degree of its final phase. Resolution of the LO is 1 Hz, limited only by software. The objective of the development of the S2-DAS is to enable high sensitivity, bandwidth synthesis, group delay measurements for geodetic VLBI without appealing to a more costly parallel IF/baseband sub-system.

The "end-to-end" S2 geodetic VLBI system including the transportable antenna, the frequency switched S2-DAS, and the "frequency switched" S2 correlator are currently undergoing a program of shakedown field testing. This field testing program is designed to progressively test and debug all aspects of the system, culminating in the demonstration of a high precision geodetic capability.

2.3. S2 VLBI Correlator

The Canadian S2 VLBI Correlator development has been supported by the Canadian Space Agency (CSA) as a contribution to the international space VLBI missions (RadioAstron, VSOP) and has been in a "production" operational mode for space VLBI for more than two years.

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 reduce the UVFITS standard output of the correlator to a format usable in the CALC/SOLVE analysis software package.

2.4. Canadian Transportable VLBI Antenna (CTVA)

The CTVA is a 3.6-m 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.

In 1997 the antenna was moved from the Ottawa area to a site at the Dominion Radio Astrophysical Observatory (DRAO) near Penticton, B.C. In the past year several site-related tasks have been completed. Recent work focusses on antenna sensitivity and system stability and reliability.

2.5. CTVA Specifications

- Reflector : 3.6 m diameter
- Receiver : S and X (uncooled)
- Azimuth speed : 150 degrees per minute
- Elevation speed : 60 degrees per minute
- PCFS version : 9.3.17
- VLBI equipment : S2 VLBI data acquisition system and S2 VLBI data record system
- Time standard : CH-75 Transportable Hydrogen Maser

2.6. S2 Geodetic Experiment Scheduling, Operations and Analysis

The Canadian Geodetic VLBI program involves all aspects of Geodetic VLBI operations, from experiment design through analysis. Considerable effort in the past year has been made to establish experiment design, optimal scheduling and analysis capabilities. Scheduling is currently performed

Figure 1. Canadian Transportable VLBI Antenna (CTVA)

using SKED, SCHED and DRUDG. The current version of SKED is not S2-tape friendly, requiring the use of SCHED for final schedule production.

The simulation capabilities of SKED have been used for optimization of geodetic S2 schedules. These simulations require the SOLVE software, which was installed at GSD in 1997-1998. The GSD installation of CALC/SOLVE and associated software approximately matches that at the USNO. Local changes to the software in the past year have been made to account for the anticipated differences between S2 and Mark III/Mark IV databases.

The GSD has successfully proposed to support the IVS by providing a VLBI Analysis web site which is expected to be available in "Beta" form in the coming year.

2.7. Interferometric Experiments in 1998

The developmental experiments listed in 1 have been performed using the S2 VLBI system and the CTVA. Fringes have been obtained in each S2 interferometric experiment.

Table 1. Canadian S2 Development Experiments: 1998

Experiment	Date	Stations	Principal Objective
CG002	July 10, 1998	CTVA-ARO	Interferometer Sensitivity
CG003	July 30, 1998	CTVA-ARO	Frequency-Switching Functionality
CG004	August 20, 1998	CTVA-ARO	Automatic Gain Control
CG005	October 19, 1998	CTVA-ARO	Overall System Performance

2.8. Staff Responsibilities

Table 2 lists staff responsibilities for the S2 development.

Table 2. S2 Geodetic VLBI System Development Team Members

Team Member	Principal Interest/Activity
Mario Bérubé	CTVA, Operations
Marc Bujold	S2 DAS Software
Georg Feil	S2 DAS Software
Calvin Klatt	Scheduling, Analysis
Alexander Novikov	S2 DAS Hardware
Bill Petrachenko	Overall Project Leadership, Correlator, CTVA, DAS
Josef Popelar	Scientific Leadership

3. The S3 and S3-E VLBI Data Record and Playback Systems

3.1. Introduction

The Space Geodynamics Laboratory has begun work on the development of the S3 VLBI data record and playback system, which will resemble the S2 in that it will consist of an array of eight digital videotape transports. A brief description of the S3 and progress to date on its development is presented below.

The S3 is designed as a VLBI data record/playback system based on an array of eight digital video tape transports with a modular architecture similar to the S2 consisting of two rack mountable or "desk top" S3 Tape Transport Array Modules (S3-TAMs) and one rack mountable or "desk top" S3 Data, Signal, and Control Module (S3-DSCM). Each tape transport in the S3 array will record/playback VLBI data at a rate of 128 Mbit/sec for an overall data rate of 1024 Mbit/sec. The unattended data record/playback time at a data rate of 1024 Mbit/sec for the S3 will be 2.5 hours with longer unattended record/playback times available in the S3 when used at lower bandwidths using a subset of tape transports. For example:

DATA RATE	UNATTENDED OPERATION TIME
1024 Mbit/sec	2.5 hours
512 Mbit/sec	5 hours
256 Mbit/sec	10 hours
128 Mbit/sec	20 hours

The S3-Extended (S3-E) VLBI data record and playback system would be a dual, 16 tape transport, version of the S3 which could record/playback VLBI data at a rate of 2048 Mbit/sec with an unattended record/playback time of 2.5 hours.

The S3 and S3-E would both be available with an optional robotic tape changer. The S3 robotic tape changer would permit operation of the S3 at data rates of 1024 Mbit/sec for as long as 60 hours without operator intervention. The cost of recording media for the S3 is expected to be $140 (US) per hour at a data rate of 1024 Mbit/sec and for the S3-E $280 (US) per hour at a data rate of 2048 Mbit/sec.

3.2. Staff Responsibilities

Table 3 lists staff responsibilities for S3 development.

Table 3. S3 VLBI Data Record and playback System Development Team Members

Team Member	Principal Interest/Activity
Wayne Cannon	Project Management, Scientific Objectives
Georg Feil	S3 Software, Software Management
Bryan Feir	S3 Software, Transport Control
Paul Newby	Signal Channel Electronics, Engineering Management
Alexander Novikov	S3 Software and Hardware