VLBI DATA Acquisition Terminal modernization at the Deep Space Network

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Summary

- VLBI at Deep Space Network
- DSN VLBI Processor –DVP- Overview
- Required DVP functionality: customers support
- Automated VLBI Operations with the DVP
DVP effort working group

- **JPL group**: Robert Navarro, Steven Rogstad, Eric Clark, Chuck Naudet, Chris Jacobs, Chuck Goodhart, Les White, Joseph Trinh, Melissa Soriano, Doug Wang, Elliot Sigman

- **DSN operations** (ITT Exelis Systems Division): John Luvalle, George Martinez

- **Canberra DSCC station**: Shinji Horiuchi, Phil Pope

- **Goldstone DSCC station**: Larry Snedeker

- **Madrid DSCC station**: Cristina Garcia-Miro, Ioana Sotuela, Juan Lobo
VLBI at the DSN

**Internal customers:**

- JPL Reference Frame Calibration project:
  - Earth Orientation Parameters determination: JPL TEMPO experiments, once every two weeks
  - Maintenance of inertial celestial reference frame for JPL navigation: S/X and X/Ka bands (The Celestial Reference Frame at X/Ka-band talk)
- JPL Delta Differential One-way Ranging (DDOR): support JPL navigation group
- Proof-of-concept of VLBI applications for navigation: phase referencing, same beam interferometry, etc.

**External customers:**

- EVN + global observations: DSN is an associate member of the EVN
- IVS Geodesy and Astrometry observations
- Australian VLBI observations: Australian Long Baseline Array –LBA-

**Other non-VLBI customers:**

- GBRA Host Country groups: single dish spectroscopy
- GBRA Guest Observe Programs: pulsars, DSN transient observatory, etc.
Aim of the DVP

• Replace aging VLBI Data Acquisition Terminal hardware (MarkIV DAT) with modern Digital Backend system based on JPL Wideband VLBI Science Receiver (WVSR).

• Replace PCFS computer by Dell PowerEdge R210 server as Data Processor and Controller (DPC) computer (debian linux). Replace Field System application by driver, command, modeling and monitor and control WVSR based s/w.

• Upgrade to Mark5C recorder for data recording.

• Make incremental improvements to JPL VLBI Software Correlator to support Mark5C hardware and data formats.

• Maintain compatibility with other VLBI centers for DSN support of international VLBI and Host Country activities.
DVP overview

- IF SWITCH
  - IF_IN1
  - IF_IN12
- JPL IF Digitizer
  - IF1
  - IF2
  - (1280 MHz sample clock)
- ROACH TRANSITION MODULE
  - Fiber to copper
- ROACH
  - (CHANNELIZE AND FORMAT)
- CC&S
- LVDS
- DVP Control Computer
  - (DVP M/C)
  - (Vex I/F)
- DSN VLBI Processor (DVP)
- 1PPS
- 100MHz
- Fiber Optic
- 10GigE
- MARK5-C RECORDER
- Data Disk pak
- DSN Station Network Monitor/Control
- Freq & Timing
  - IF_IN1
  - IF_IN12
  - 1PPS
  - 100MHz
- JPL IF Digitizer
- ROACH TRANSITION MODULE
- ROACH
- (CHANNELIZE AND FORMAT)
- DVP Control Computer
  - (DVP M/C)
  - (Vex I/F)
- DSN Station Network Monitor/Control

(CLP)
DVP overview

- IF switch up to 12 IF inputs from DSN antennas (at least 3 antennas at each complex support VLBI).
- Two IF inputs, each covering up to 500 MHz of bandwidth.
- Accepts DSN IF input band of 100-600 MHz. Good for L band (1.4-1.9 GHz), S band (2.3 GHz), X band (8.4 GHz), K band (18-26 GHz), Ka band (31.2 GHz) and Q band (38-50GHz).
- Uses JPL IF sampler module and CASPER ROACH board for Digital Processing and Channelization.
- Interfaces to JPL Deep Space Network monitor & control infrastructure.
- Records up to 32 upper/lower or 16 complex channels (in-phase and quadrature-phase). Channel max BW is 16 MHz (or 32 MHz for complex channels). Supported bits per channel = 8, 4, 2 or 1 bits.
- Phase calibration signal real time detection.
- Mark5C recorder used for data recording. Data stored on Mark5 modules in VDIF format.
- VEX 2.0 files used for input.
- Compatible with other digital developments (DBBC, RDBE, etc.)
DVP overview

- **Freq & Timing**
  - IF_IN1
  - IF_IN12

- **IF SWITCH**
  - IF1
  - IF2

- **JPL IF Digitizer**
  - (1280 MHz sample clock)

- **ROACH TRANSITION MODULE**
  - Fiber Optic
  - Fiber to copper

- **ROACH**
  - (CHANNELIZE AND FORMAT)

- **DVP Control Computer**
  - (DVP M/C)
  - (Vex I/F)

- **MARK5-C RECORDER**
  - Data
  - Disk pak

- **DSN Station Network Monitor/Control**

- **DSN VLBI Processor (DVP)**

- **DVP Control Computer**
  - 1PPS
  - 100MHz

- **DSN Station**

- **Network Monitor/Control**
DVP: JPL IF digitizer module

- Already in operational use at the DSN.
- A/D samples 8 bits at 1280 MHz.
- Digitally controlled built-in attenuator.
- Optically isolated from digital processing back ends:
  - Spurious signals attenuated 97 dB below A/D saturation level: S/C tracking
  - Enables use for spectral line work.
- Generates 1280 MHz sampling clock from 100 MHz reference.
- Uses interface module to connect to ROACH Board.
DVP channelization and sub-band filtering

- JPL VLBI DAT Digital Backend Channelization broken up into two stages:

  - First stage:
    - polyphase filterbank breaks input signal up into 7 fixed bands of data, each 160 MHz (complex).
    - Channels centered at 80, 160, 240, 320, 400, 480 and 560 MHz.

  - Second stage:
    - selects one of seven first stage wideband inputs.
    - applies digital mixer for precise channel location selection.
    - Cascade of downconverting filters (CIC & FIR) provides variable output bandwidth per channel.
    - A total of 16 complex sub-channels can be formed (32 MHz to 1 KHz).
    - Changed to upper/lower representation using Hilbert transforms. Processing organization means upper/lower channels always occur in contiguous pairs.
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Sub-band filter performance

- Aim is to get 0.1 db ripple in passband and at least 40 db attenuation in stopband.
SubChannel output

- Actual data from tone buried in noise shown below. Sub-channel is 16 MHz upper / 16 MHz lower.
- Cutoffs of Upper and Lower bands apparent at edges.
DVP overview

- First prototypes to be installed during Spring 2012 at Ro & Go
- DVP piggyback recording for some time
- Recording tests @ 2 Gbps without dropout during 8 hours
DVP overview
DVP GUI

DVP1 Configuration

**Site:** 11  
**Time:** 12/048 00:28:20

### Main Status
- **Status:** Operational
- **DSS ID:** 0
- **Ant Status:** None
- **Source ID:** None
- **Source RA:** 0.0 deg
- **Source DEC:** 0.0 deg

### IF Input A
- **Input Power:** 0.0 dBm
- **ADC Amp:** -18.84 dBm
- **ADC RMS:** 10.26
- **ADC Peak:** 16 dB
- **Attenuator Setting:** 3 dB
- **IF Source:** Not Set
- **RF to IF LO:** 8100 MHz
- **RF Freq:** 842000000.00 Hz

### IF Input B
- **Input Power:** 0.0 dBm
- **ADC Amp:** -41.78 dBm
- **ADC RMS:** 0.73 dB
- **ADC Peak:** 2 dB
- **Attenuator Setting:** 15 dB
- **IF Source:** Not Set
- **RF to IF LO:** 8100 MHz
- **RF Freq:** 842000000.00 Hz

### Mark5 Status
- **State:** IDLE
- **Bank A State:** Empty
- **Bank B State:** Empty
- **Bank A Free:** N/A
- **Bank B Free:** N/A
- **Cfg Bitrate:** 0000.0 Mb/s

### Command
- **Select Script...**
- **IF Switch...**
- **Attenuator...**
- **RF FREQ...**
- **Mark5 Record...**

### Channel Status

<table>
<thead>
<tr>
<th>Chan ID</th>
<th>Status</th>
<th>Input ID</th>
<th>PCal Tone</th>
<th>PCal Drift (deg/min)</th>
<th>PCal Resid (deg)</th>
<th>PCal Avg Mag</th>
<th>Power (dBm)</th>
<th>Offset (Hz)</th>
<th>BW</th>
<th>Bits</th>
<th>FGAIN Multi</th>
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<td>0.0</td>
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<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

### Selected Channel Commands
- [Configure Channel...](#)
- [Frequency Offset...](#)
- [Filter Gain...](#)
- [Data Histogram Plot...](#)
- [FFT Spectrum Plot...](#)
Required DVP functionality

- VEX 2.0 files used for input, should contain appropriate $blocks for DVP configuration and precess coordinates for observing date.

- Antenna calibration performed using custom built DSN tools (ACME): gain curve, DPFU and noise diode versus frequency measurements substitute onoff / gnplt / rxgfiles.

- DVP log XLATOR to Field System type log:
  
  - System temperature calibration: total power on each channel calculated at digital stage, IF total power measured using power meters. Output in ANTAB format.
  
  - Phase calibration signal: real time tone extraction, in /pcald/ notation.
  
  - Antenna status: provide /onsource/ and /flagr/ status.
  
  - Weather: provide /wx/ notation.

- Mark5C monitor data.

- Equivalent gps-fmout: DVP digitizer does not provide 1pps output from internal clock.

- Automatic delivery of logs to users (IVS servers, vlbeer, etc).
Automated VLBI operations with the DVP

- DVP Interfaces to JPL Deep Space Network monitor & control infrastructure (NMC).
- NMC interfaces with all DSN subsystems (microwaves control, noise diode control, etc.): directives, responses and monitor data.
- NMC automation scheme: Connection Blocks and TDNs in Automation Language for Managing Operations (ALMO), superset of Tcl/Tk.
- Ability for simultaneous subsystems configuration, using closed loop control (directive/response), reducing manual input and critical operator errors.
- Pre-pass, during pass and post-pass tasks performed using connection blocks.
Automated VLBI operations with the DVP: example

- Example of a pre-pass VLBI experiment supported with DVP and NMC automation:

  - **pre_VLBI_XS_65**: checks station time delay, checks necessary equipment in the link, executes DVP script building software to produce a DVP command script and a DSN antenna pointing file from VEX file.
  
  - **starting_DVP_VLBI_XS_SGP_65**: start DVP application.
  
  - **conf_micro_VLBI_XS_SGP_65**: configures microwaves to sky.
  
  - **ZenCal65_VLBI_XS_SGP**: configures noise diode and executes Zenith calibration.
  
  - **conf_PCGM_65**: configures and turn on phase calibration signal.
  
  - **schedule_start_65**: starts DVP schedule, sends READY email.
  
  - **move_DSS65forRFC**: configures and moves DSS65 antenna to sources, checks antenna status and fires noise diode at appropriate times, checks Mark5 status, sends START email.
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Many thanks!

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