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

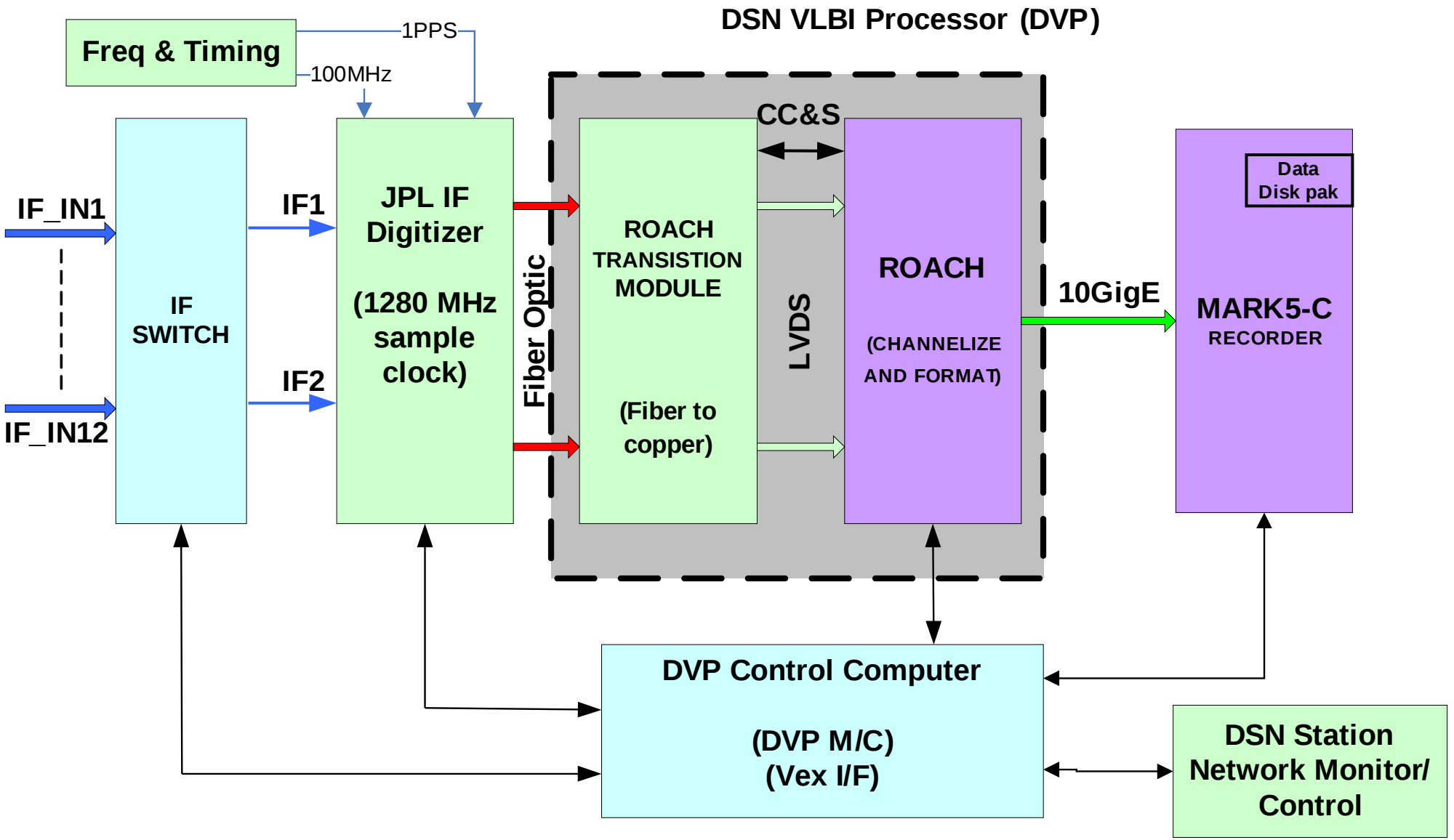
VLBI at the DSN

- **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.

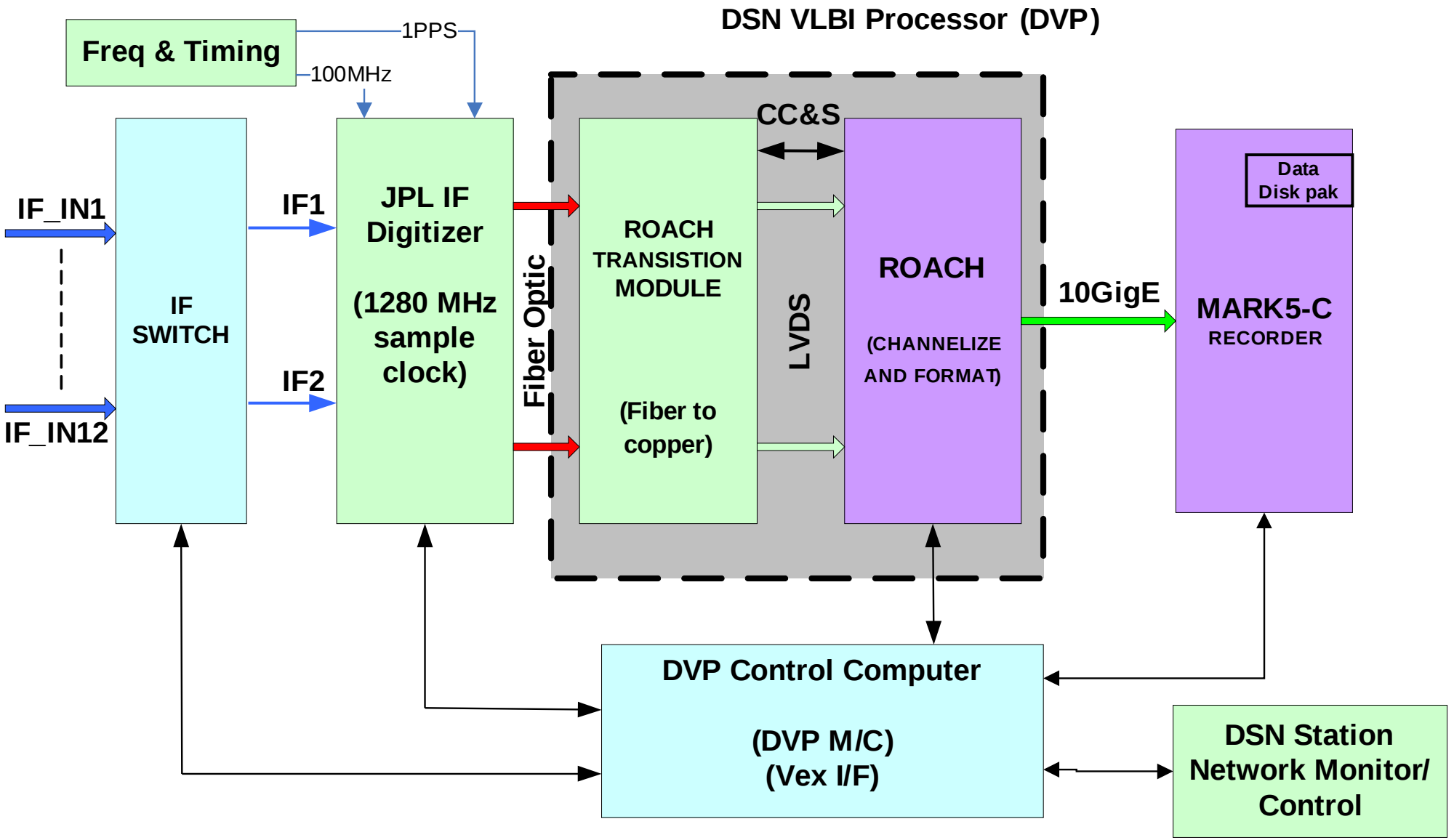
DVP overview



DVP overview

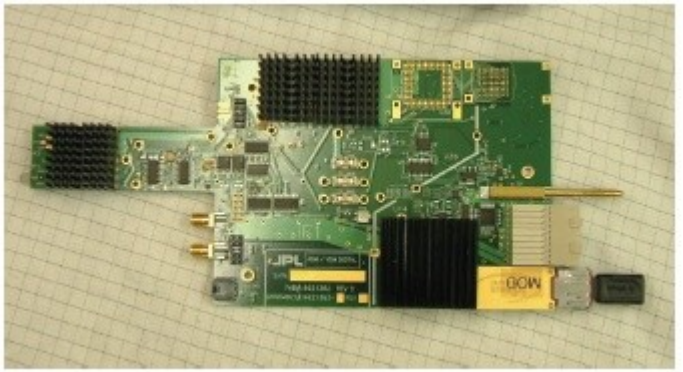
- IF switch up to 12 IF inputs from DSN antennas (at least 3 antennas at each complex support VLBI)
- Two IF inputs, each covering up to 500 MHz of bandwidth.
- Accepts DSN IF input band of 100-600 MHz. Good for L band (1.4-1.9 GHz), S band (2.3 GHz), X band (8.4 GHz), K band (18-26 GHz), Ka band (31.2 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



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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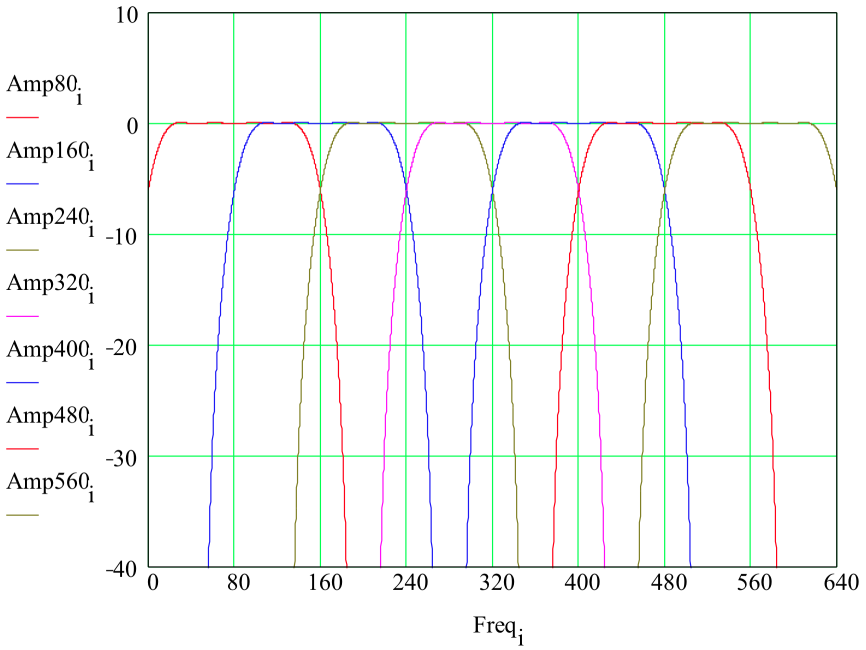

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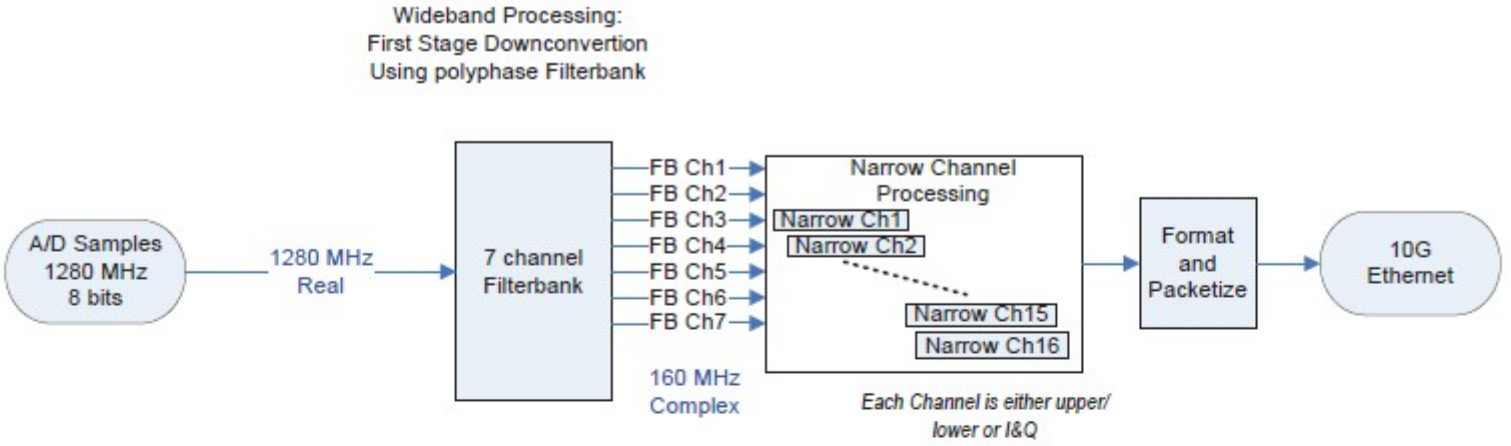
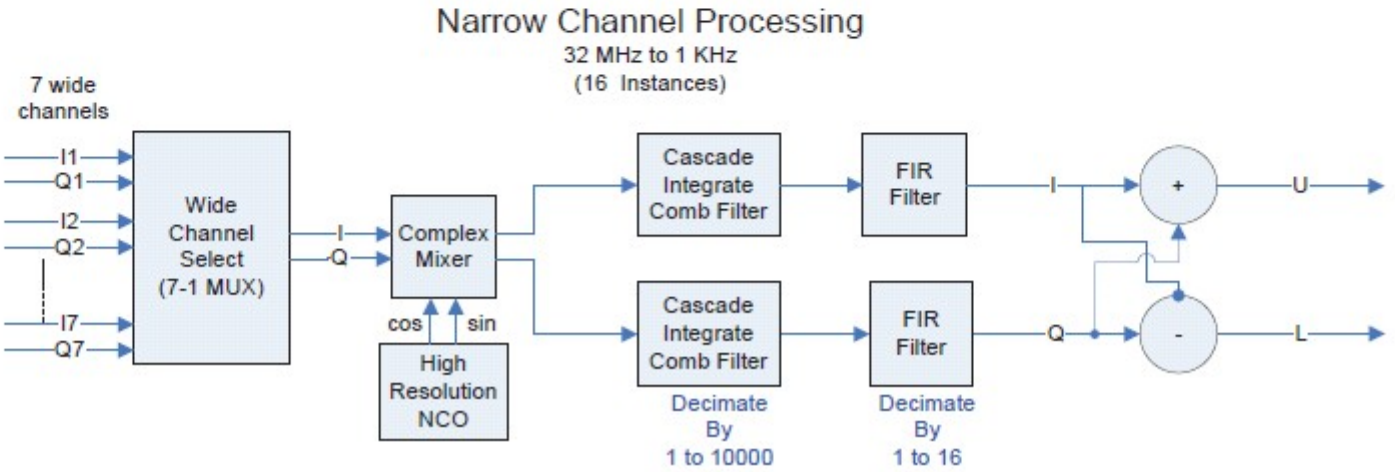
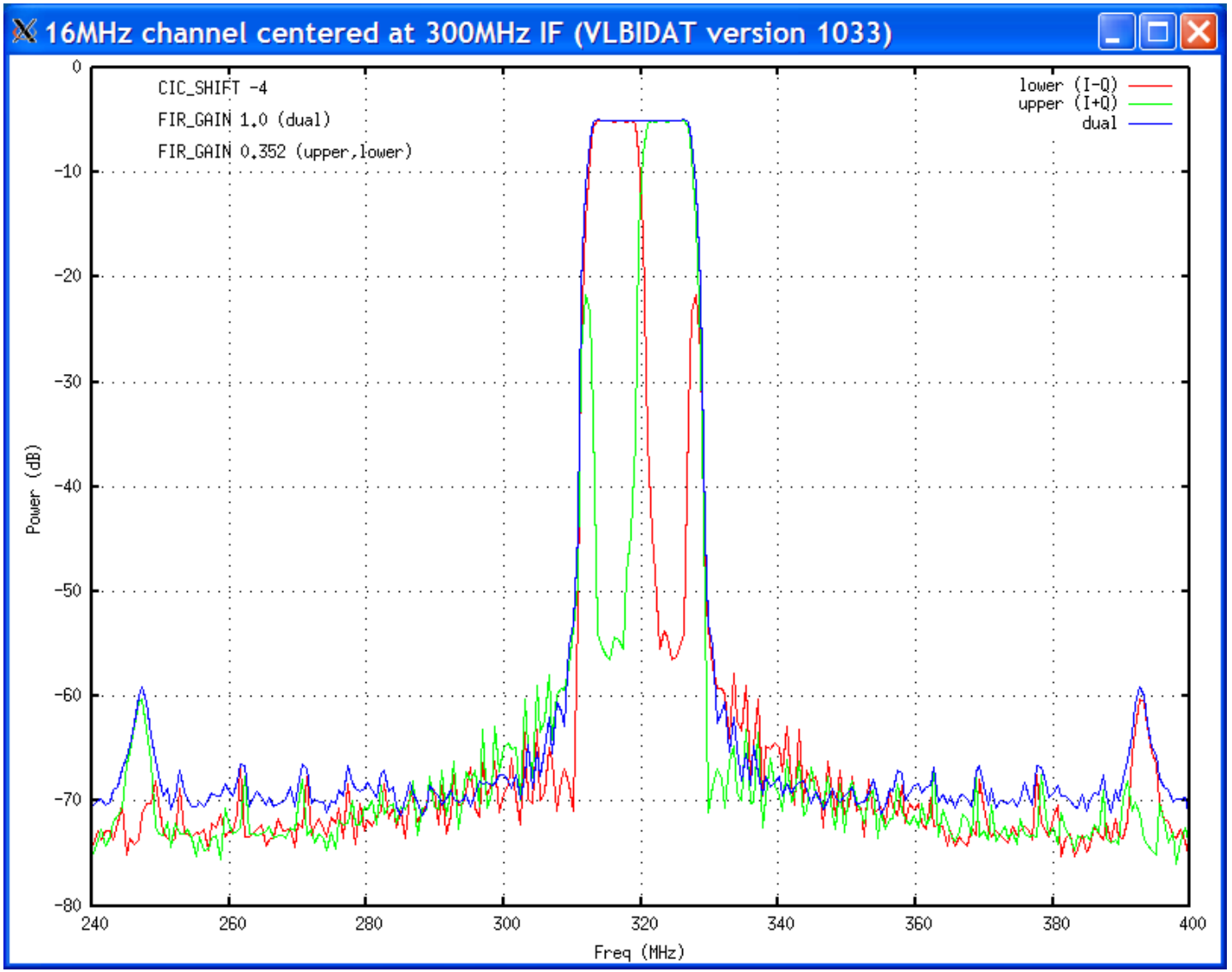
Sub-band filtering stages





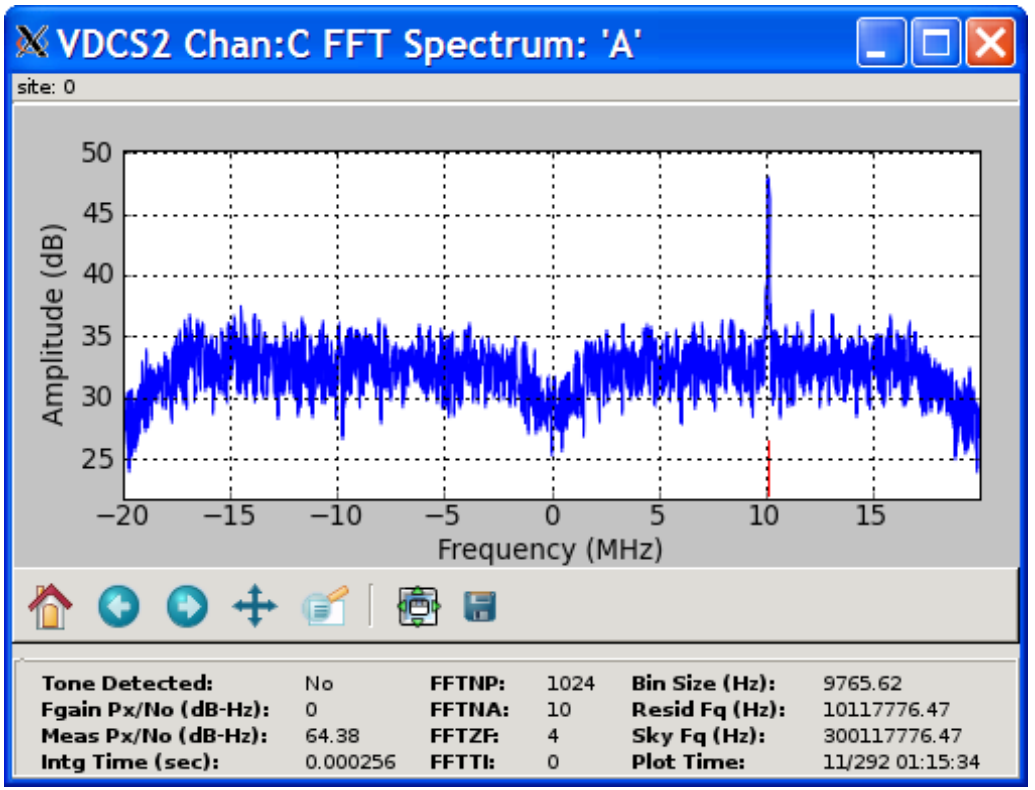
Sub-band filter performance

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



SubChannel output

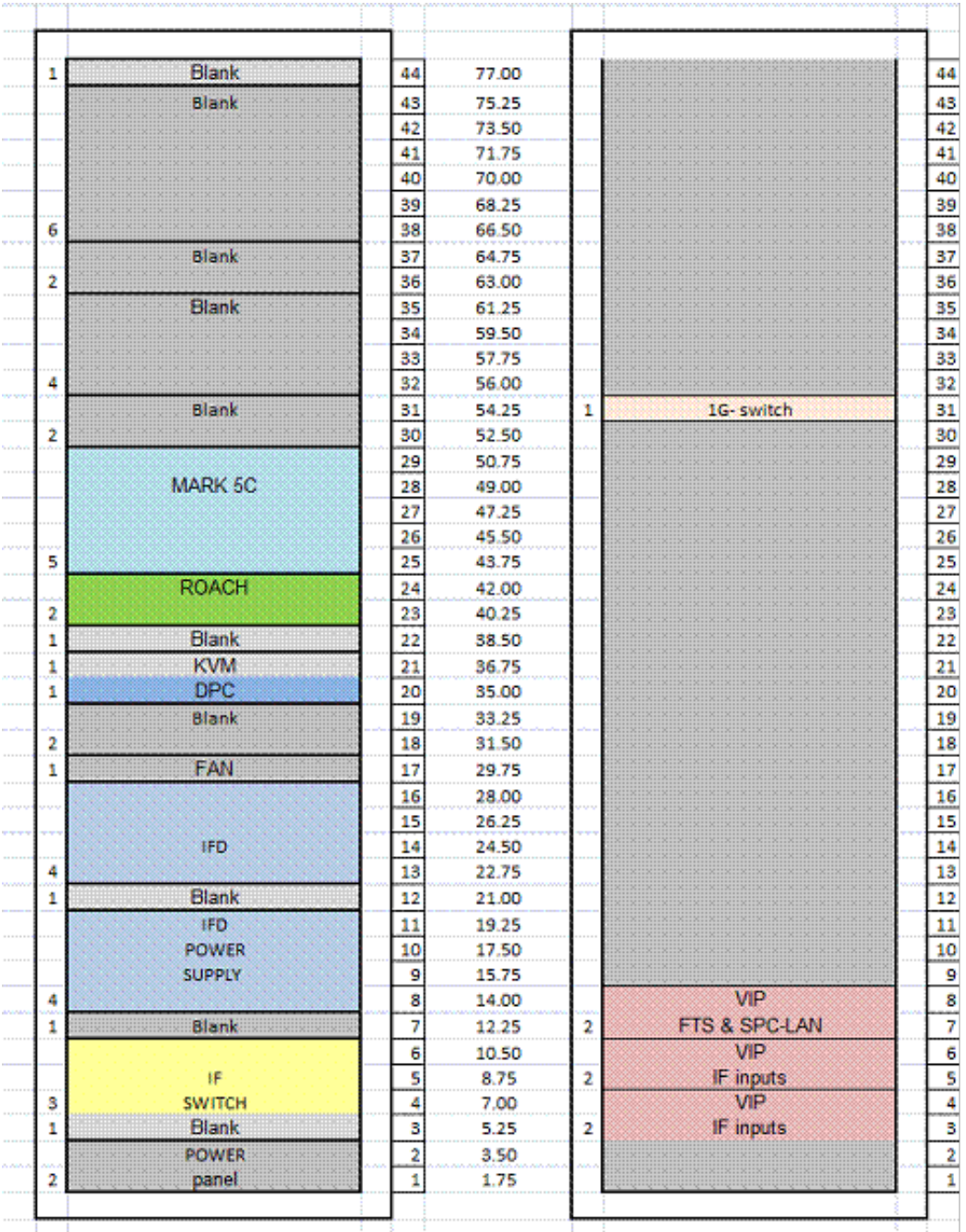
- Actual data from tone buried in noise shown below. Sub-channel is 16 MHz upper / 16 MHz lower.
- Cutoffs of Upper and Lower bands apparent at edges.



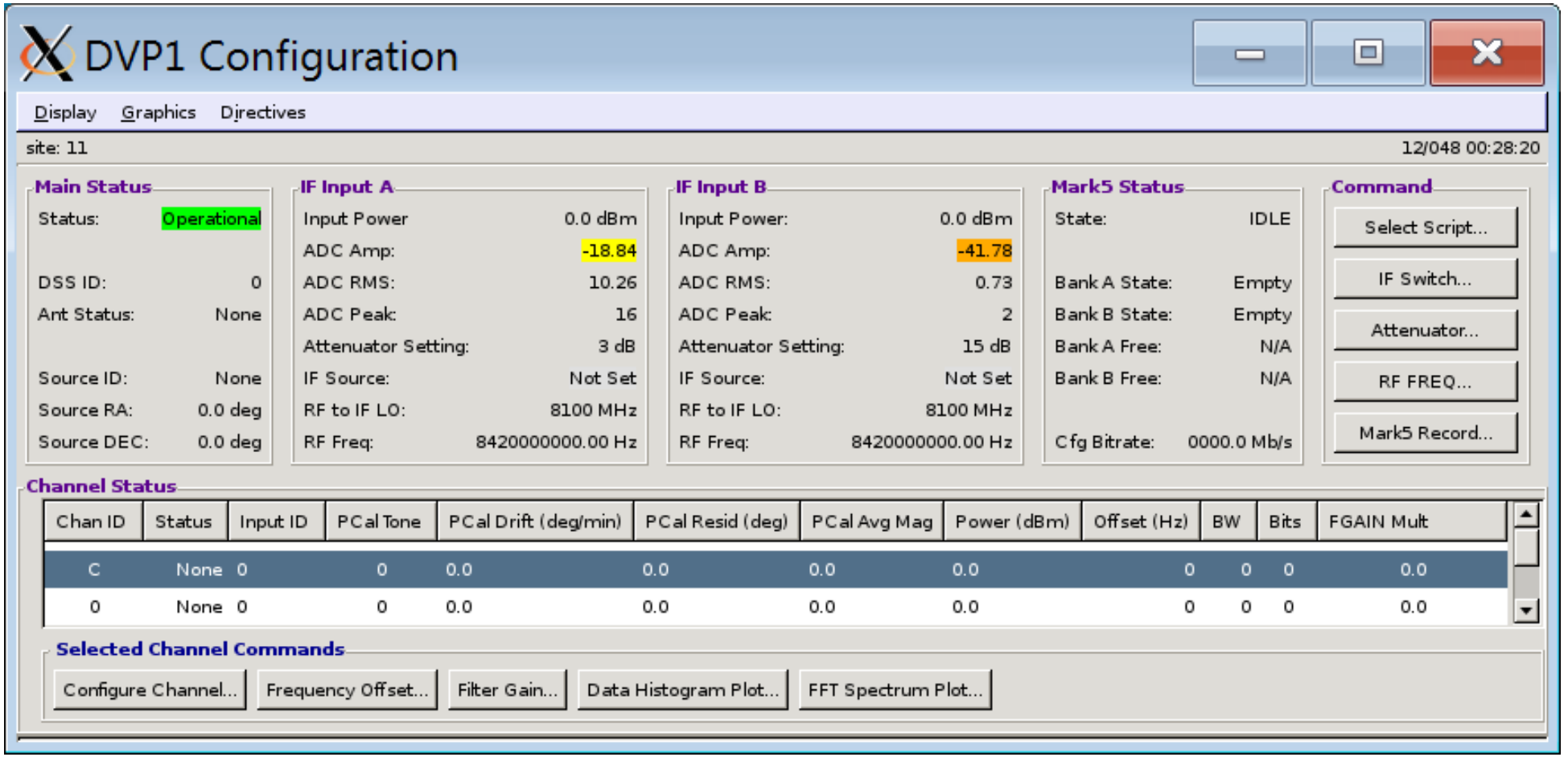
DVP overview

- 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

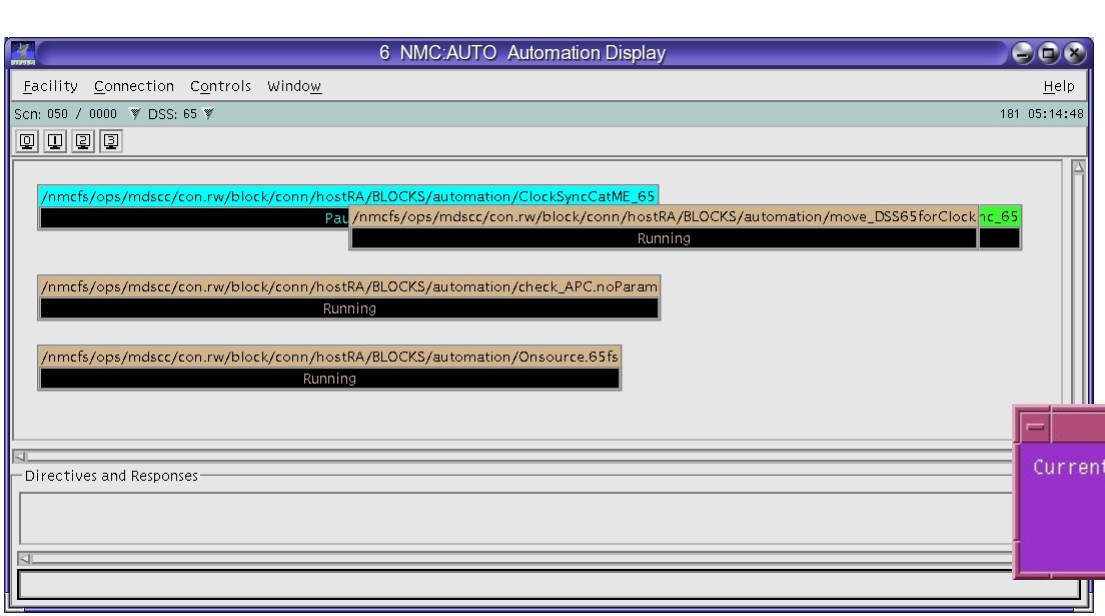

DVP1 Configuration
Display
Graphics
Directives
site: 11
12/048 00:28:20
Main Status
Status: Operational
DSS ID: 0
Ant Status: None
Source ID: None
Source RA: 0.0 deg
Source DEC: 0.0 deg
IF Input A
Input Power 0.0 dBm
ADC Amp: -18.84
ADC RMS: 10.26
ADC Peak: 16
Attenuator Setting: 3 dB
IF Source: Not Set
RF to IF LO: 8100 MHz
RF Freq: 8420000000.00 Hz
IF Input B
Input Power: 0.0 dBm
ADC Amp: -41.78
ADC RMS: 0.73
ADC Peak: 2
Attenuator Setting: 15 dB
IF Source: Not Set
RF to IF LO: 8100 MHz
RF Freq: 8420000000.00 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
Chan ID Status Input ID PCal Tone PCal Drift (deg/min) PCal Resid (deg) PCal Avg Mag Power (dBm) Offset (Hz) BW Bits FGAIN Mult
C None 0 0 0.0 0.0 0.0 0.0 0 0 0 0.0
0 None 0 0 0.0 0.0 0.0 0.0 0 0 0 0.0
Selected Channel Commands
Configure Channel...
Frequency Offset...
Filter Gain...
Data Histogram Plot...
FFT Spectrum Plot...

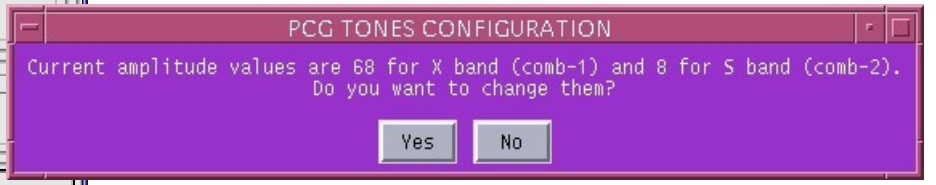
Required DVP functionality

- 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

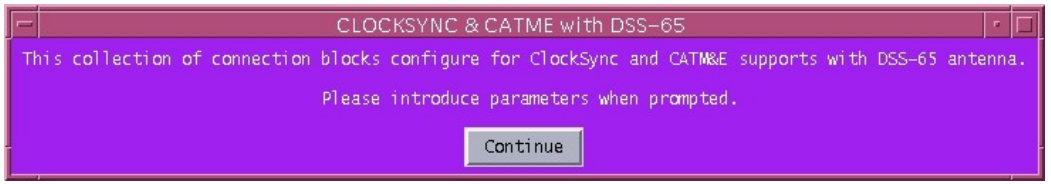
- DVP Interfaces to JPL Deep Space Network monitor & control infrastructure (NMC).
- NMC interfaces with all DSN subsystems (microwaves control, noise diode control, etc.): directives, responses and monitor data.
- NMC automation scheme: Connection Blocks and TDNs in Automation Language for Managing 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.

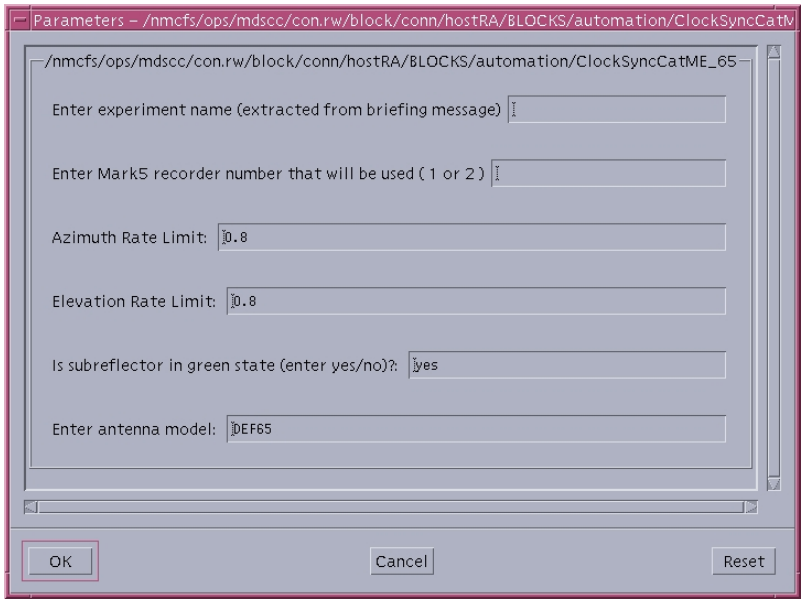


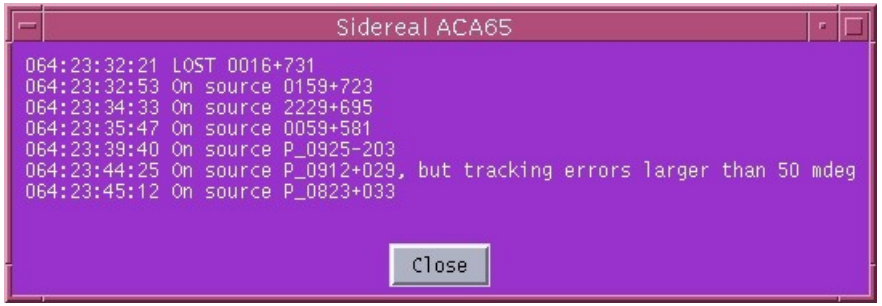


Automated VLBI operations with the DVP: example

- 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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