Implementation Issues and Choices for VLBI data Acquisition System in DSN

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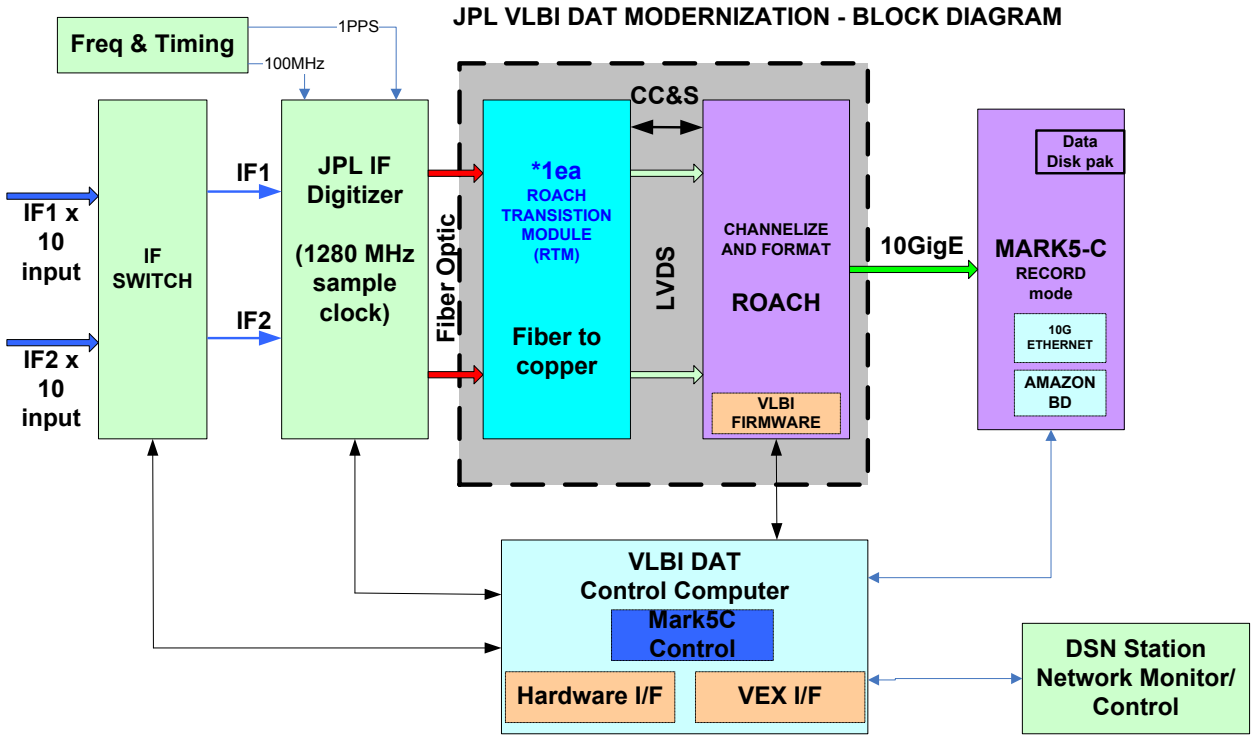
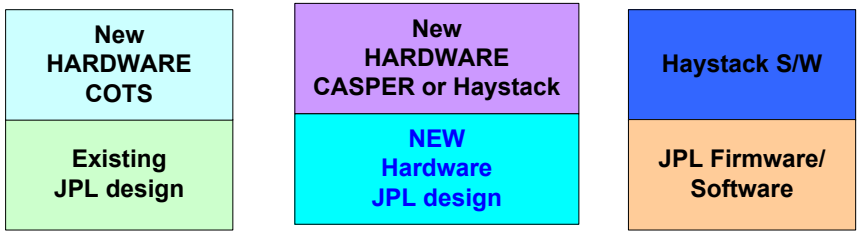
Key features of new DSN VLBI Processing System

- An IF Switch will handle up to 10 IF inputs from DSN antennas.
- Two IF inputs, each covering up to 500 GHz of bandwidth.
- Accepts DSN IF input band of 100-600 MHz. Good for S band (2.3 GHz), X band (8.4 GHz) and Ka band (31.2 GHz)
- Uses JPL IF sampler module, CASPER ROACH board for Digital Processing and Channelization.
- Mark5C disk packs used for data storage
- Interfaces to JPL Deep Space Network monitor & control infrastructure.
- VEX files used for input
- Data stored on disk in VDIF format
- Records up to 32 upper/lower or 16 complex channels. Channel max BW is 32 MHz.

Block Diagram of VLBI recording system for DSN





* ROACH = Reconfigurable Open Architecture for Computing Hardware

VEX files on the DVP

- **VEX files are delivered to the DVP manually or through a DSN process**
- **Script building software**
  - A Python script on the DVP
  - Automatically started by delivered VEX files
  - Parses VEX files by searching for relevant blocks
  - Produces a DVP command script and a DSN antenna pointing file
- **VEX file blocks used**
  - $EXPER – Getting the experiment name
  - $STATION – Configure which IF switch antenna input to use
  - $SOURCE – Antenna pointing and scan labeling
  - $FREQ – Configuring the channel frequency, bandwidth and bits
  - $IF – Determining the RF to IF downconversion oscillator value
  - $PHASE_CAL_DETECT – to determine whether phase-cal should be present
  - $SCHED – for determining when to start and stop scan recordings and when/where to point the antenna

Script Builder Products

- **DVP Script File**
  - A set of commands, including some time stamps
  - Executed on the DVP using the SCRPT command
  - Each command is a separate script or executable that runs in a BASH shell and performs a specific function (ie: CHAN for channel config.)

- **Antenna Pointing File**
  - Sent to the NMC through a shared file system and run by a Temporal Dependency Network (TDN)
  - Points the antenna to RA, DEC of a source at the specified time
  - Format of each line:

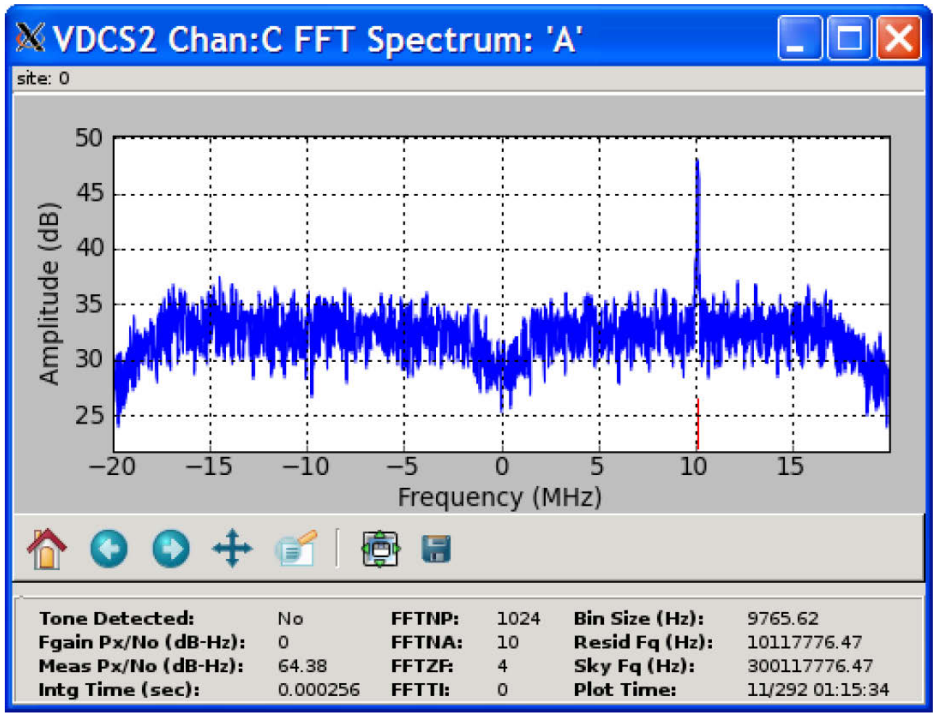
    <ascii_time_stamp> <RA (hr)> <DEC (hr)> <RA (deg)> <DEC (deg)> <source name>

Sub-band filtering

- Wideband 1280 MHz real to seven channel 160 MHz wide channel filterbank completed. Channels centered at 80, 160, 240, 320, 400, 480 and 560 MHz.
- 32 upper/lower or 16 complex sub-channels can be formed
  - Max real channel BW= 16 MHz; Minimum BW = 500 Hz
  - Max complex channel BW = 32 MHz; Minimum BW = 1000 Hz
- Sub-band filtering used two stage filtering.
  - 1st stage is CIC filter that decimates from 2 to 10,000
  - 2nd stage is Fir filter that decimates from 1 to 16
  - Fir filter has 16n taps, where n = decimation factor.
  - Sub-band channels are complex. Changed to upper/lower representation using Hilbert transforms
- Processing organization means upper/lower channels always occur in contiguous pairs.

Sub-band Filter performance

- Filter performance mainly affected by FIR filter coefficients in second stage filtering. But for FIR decimation of 1, CIC effects are noticable.
- Aim is to get 0.1 db ripple in passband and at least 40 db attenuation in stopband.
- Actual data from tone buried in noise shown below. Sub-channel is 16 MHz upper / 16 MHz lower.



VDIF usage

- Would like to use VDIF, not Mark5B emulation mode as main mode for DSN VLBI recorders.
- Would like to support both upper/lower and complex channels.
- Single Channel Data Threads are more flexible, but more difficult to implement in firmware. Buffer space one key issue.
- Multi-Channel Data Threads easier to implement and take less FPGA memory, but limit all channels to same data rate, bit representation.
- If single channel data threads used, then a hybrid data thread with an upper/lower channel would be more convenient . It would allow packet size to be same as complex channel without requiring twice the memory.
- What Payload Frame size? Some where between 2000 and 5000 bytes?

More VDIF Usage
Frame Rates

Possible Frame sizes and rates for 16 complex or 32 upper/lower channels

Complex BW	Bits/sample	Samples/Frame	Frame Size	Data Frames/Sec
32 MHz	1	1250	5000 Bytes	25600
32 MHz	2	625	5000 Bytes	51200
8 MHz	1	1250	5000 Bytes	6400
8 MHz	2	625	5000 Bytes	12800
2 MHz	1	1250	5000 Bytes	1600
1 MHz	2	625	5000 Bytes	3200

Possible Frame sizes and rates for 1 single channel or 1 upper & 1lower channel

Complex Bandwidth	Bits/sample	Data Format	Samples/Frame	Frame Size	Data Frames/Sec
32 MHz	1	Real	16000	2000 Bytes	2000
32 MHz	2	Real	8000	2000 Bytes	4000
32 MHz	1	Complex	8000	2000 Bytes	4000
32 MHz	2	Complex	4000	2000 Bytes	8000
2 MHz	1	Real	16000	2000 Bytes	125
2 MHz	2	Real	8000	2000 Bytes	250
2 MHz	1	Complex	8000	2000 Bytes	250
2 MHz	2	Complex	4000	2000 Bytes	500