DP Capabilities

LWA Current and Future Users Meeting

R. Navarro
M. Soriano, D. Wang, E. Sigman, L. D'Addario

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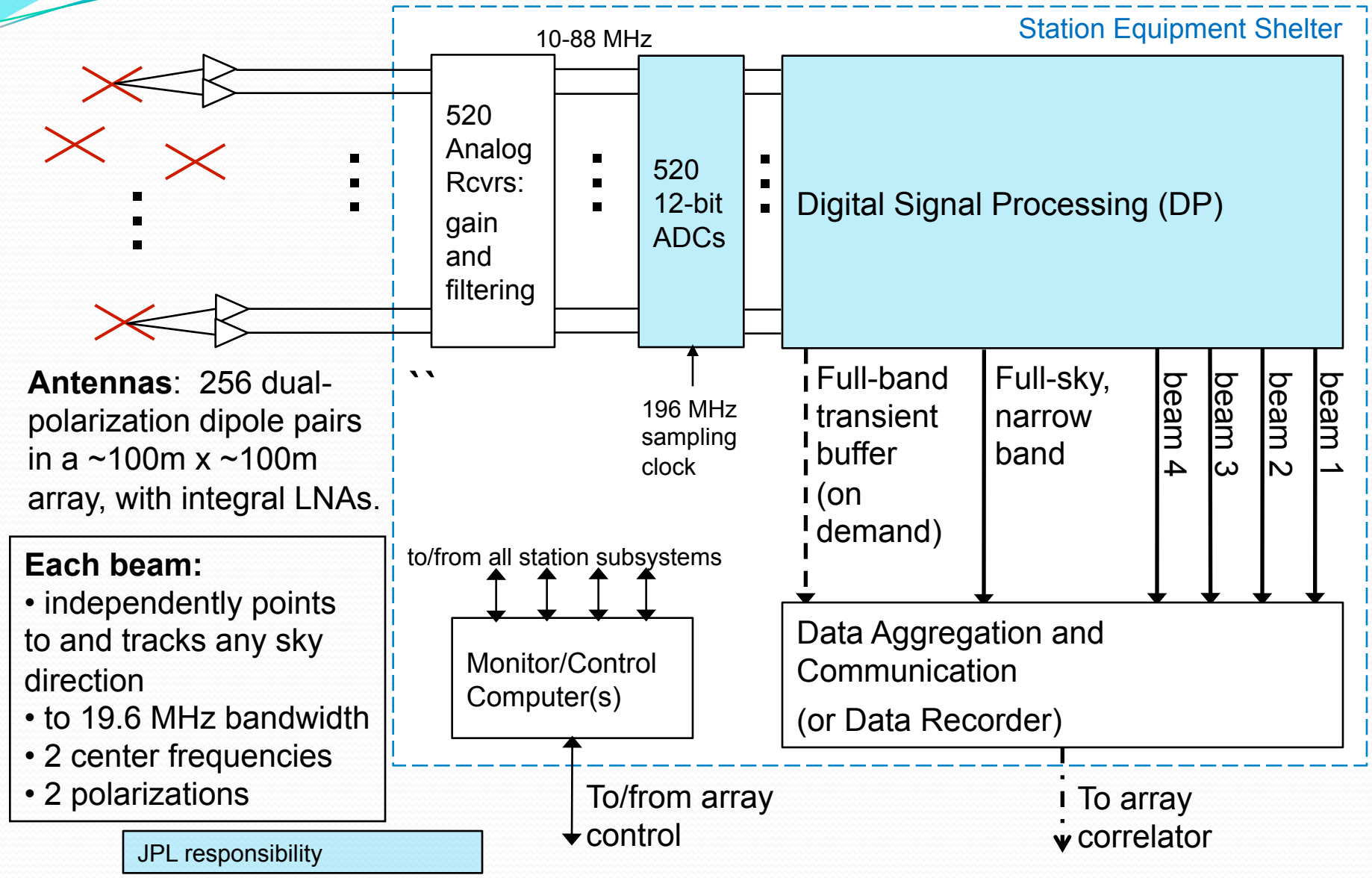
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology, Pasadena, California

LWA Station: Simplified Block Diagram

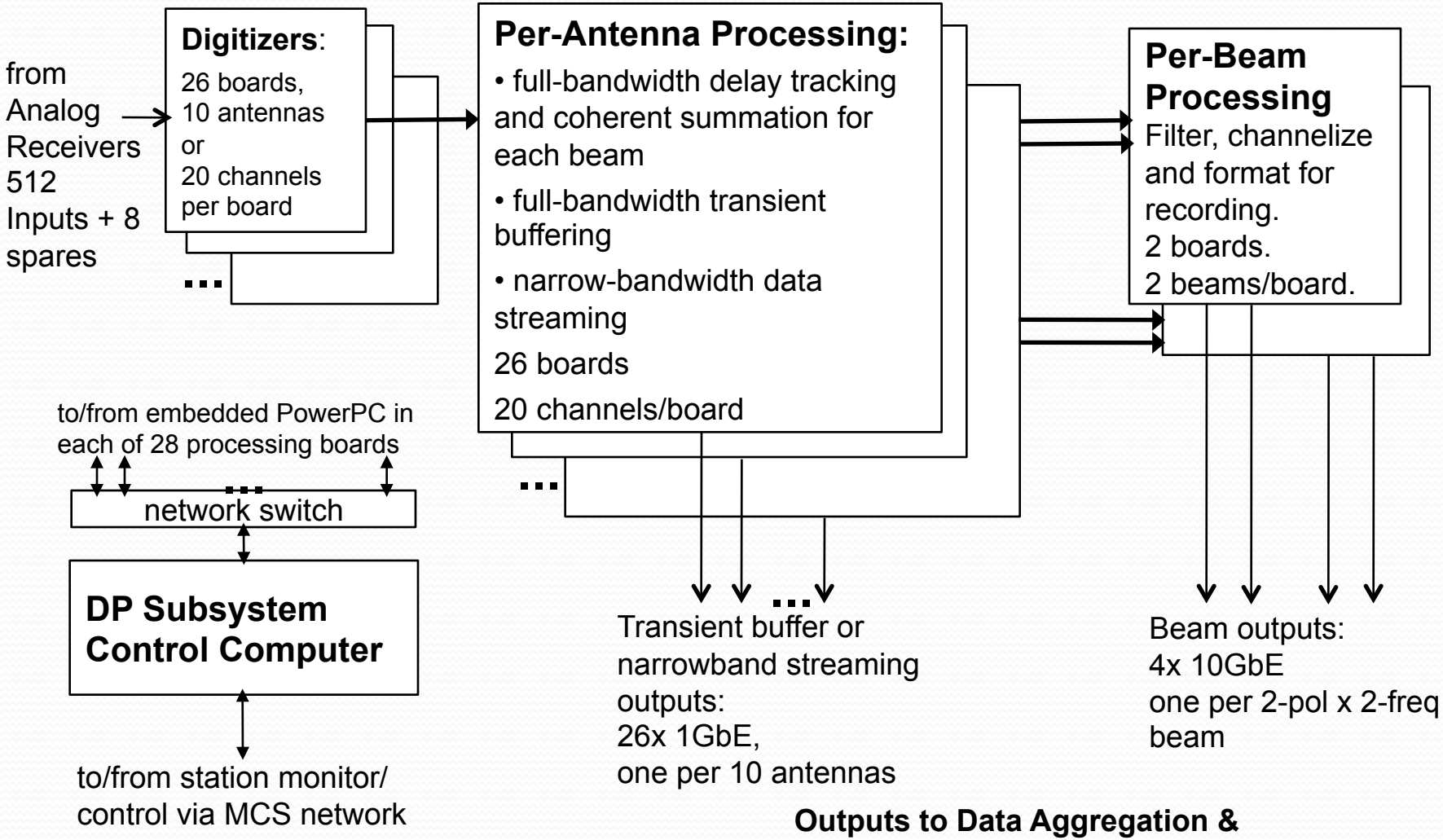


Antennas: 256 dual-polarization dipole pairs in a ~100m x ~100m array, with integral LNAs.

Each beam:
- independently points to and tracks any sky direction
- to 19.6 MHz bandwidth
- 2 center frequencies
- 2 polarizations

JPL responsibility

Digital Signal Processing (DP) Subsystem



DP Capabilities Highlights

- Inputs – from Analog Signal Processing subsystem
  - 260 x 2 signals from Analog Receivers (ARXs), as polarization pairs from antenna stands
  - Nominal band: 10 to 88 MHz
- Processing
  - Digitizes each signal by sampling at 196 MHz and quantizing to 12 bits.
  - **TBW: Wideband Transient Buffer** - Provides a buffer that captures 57 msec of samples from 520 digitizers, beginning at an externally supplied trigger pulse
  - **TBN: NarrowBand Transient Buffer** - Provide a tunable digital downconverter for each of 520 sample streams with a bandwidth up to 100kHz, and a signal path allowing continuous output of 520 narrow bandwidth sample streams.
  - **BFUs: Beamformer Units** - Form 4 independently steerable beams, each with signals for two polarizations, as the delayed and weighted sums of the input signals. Delays and weights must be updated often enough to cause the beam to track any sidereal rate source.
  - **DRXs: Digital Receivers/Tuners** - For each dual-polarization beam (8 signals), provide two tunable digital downconverters with output bandwidths up to 19.6 MHz.
- Outputs – to Data Aggregation and Communication subsystem
  - 16 beamformer signals (4 beams, 2 polarizations, 2 tunings) at up to 19.6 MHz bandwidth each
  - TBW: captured samples from all digitizers, full bandwidth, limited duty cycle
  - TBN: narrow-bandwidth sample streams

Commanding DP through MCS

- MCS subsystem provides means to control and monitor DP through commands and responses in UDP packets
- DP can accept up to 80 commands per second from MCS.
- DP Commands for general system configuration
  - INI – Initialize DP subsystem. Read config files, load firmware, run processes, calibrate or re-calibrate system.
  - SHT – Kill all DP processes. Low Power state
- DP Commands for control of transient buffers and beamformer functionality.
  - TBW – Configure/Trigger Transient wide band buffers
  - TBN – Configure Transient Narrow Band Buffers
  - BAM – Configure Beams
  - DRX – Configure Recording of Digital Receiver Tuning Outputs
  - FST – Load new FIR filter coefficient tables

DP Monitor Responses

- Using the RPT command, DP Monitor Responses are sent to MCS.
- Monitor (RPT) Responses
  - TBW_STATUS (idle, busy)
  - BEAM_FIR_COEFFS (value is 28)
  - FIR1 to FIR4 – read out coefficient values
  - TNOM1 to TNOM4 – pipeline delay through beamfomer daisy chain.
  - ANTx_RMS, ANTx_OFFSET, ANTx_PEAK – input data statistics. Updated every 5 seconds.
  - BOARDx_STAT – hardware status info (voltage, temperature, beam calibration, etc)

Timing Concepts

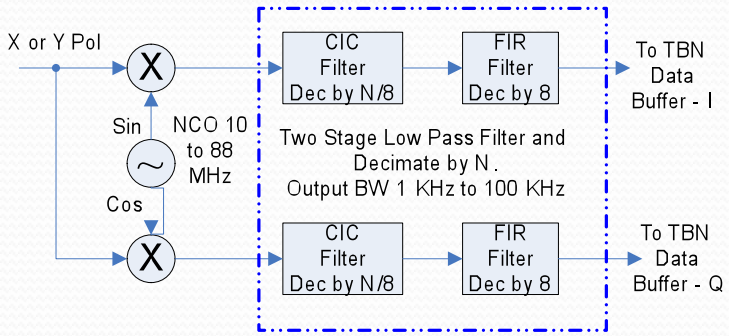
- Time on DP Partitioned in to SLOTS of length 1 second.
- Control commands intended for slot N must be received and accepted in slot N-2
- Slots are synchronized with system 1PPS.
- For TBN and BAM commands, time is divided into 100 subslots. (10 millisecond duration)
- Subslots mainly used for rapidly changing beam pointing.

TBW Capabilities

- **TBW** Command: This command sets up configuration of all Wideband Transient Buffers (TBW).
- Amount of data captured is settable. Maximum is about 57 ms of data.
- Time to read data back is about 4 minutes for full data capture on all 260 stands.
- Key Parameters:
  - TBW_BITS (4 or 12 bits, only 12 bits currently functional)
  - TBW_TRIG_TIME (Number of samples from start of SLOT)
  - TBW_SAMPLES – (1 to 12,000,000 samples)

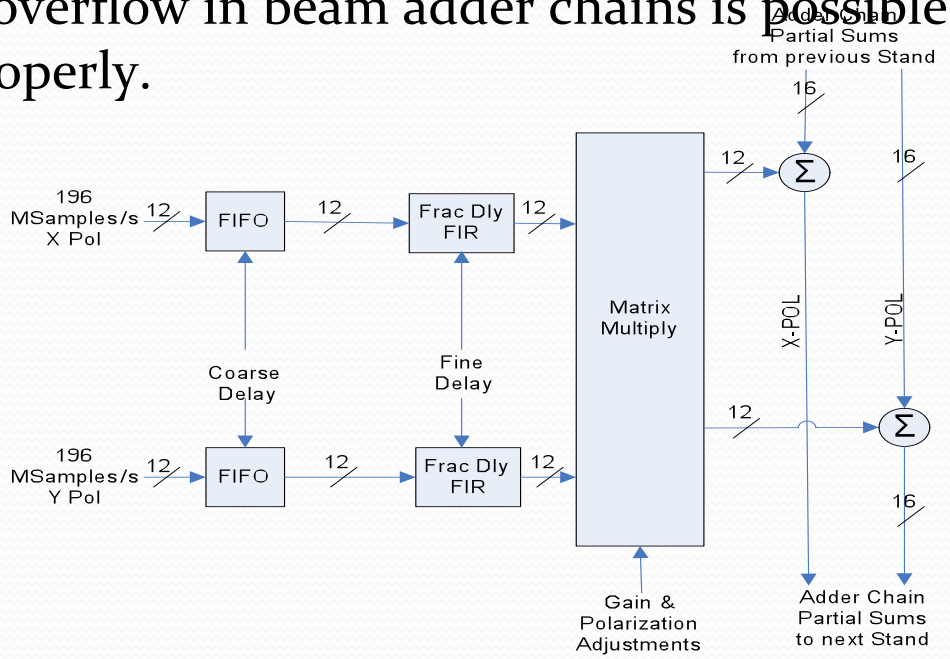
TBN Capabilities

- **TBN** command - This command sets up configuration of the Narrowband Transient Buffers (TBN). The TBNs are set up to run continuously.
  - TBN_FREQ – Center frequency of TBN in Hz (resolution to 0.046 Hz)
  - TBN_BW – Filter number 1-7 (covers BW 100KHz to 1 KHz)
  - TBN_GAIN – divides output by 2^x where x varies from 0 to 30.
- TBN output is continuous after issuing a TBN command.
- TBN output will stop when a TBW command is sent.
- TBN output is 8 bits In-Phase and 8 bits Quadrature



Beamformer Capabilities

- 4 independent beams
- Beams formed by adding 260 stands: Vary delay and gain to form beams
- Delay resolution is 0.319 ns (5.1 ns sample period; 1/16 fractional dly)
- Max delay is 5.22 microsecs. (1023 sample clock periods)
- Beam adder chains are 16 bits. Allows for up to 4 bits of data growth.
- Adder chain pipeline delays calibrated with INI command.
- Numerical overflow in beam adder chains is possible. Gains must be adjusted properly.



More Beamformer Capabilities

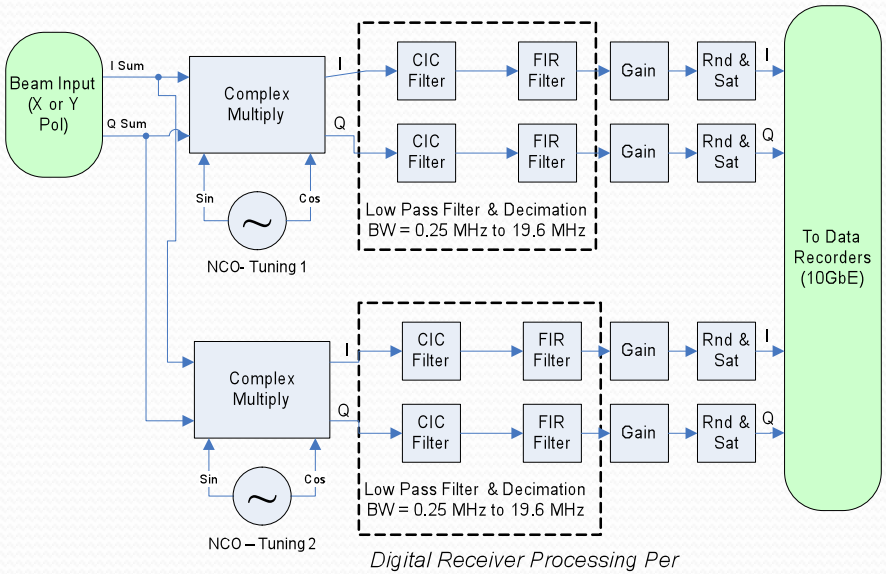
- **BAM** - This command sets up configuration of a beam.
  - BEAM_ID (1 to 4)
  - BEAM_DELAY[520] – 16 bit fixed point number that specifies coarse (12 bits) and fine delay (4 bits) for all 520 antenna inputs. Fine delay is actually index into 16 sets of 28 coefficients for FIR Filter
  - BEAM_GAIN[260][2][2] – specifies 2x2 matrix multiplications for gain and polarization adjustments for all 260 stands.
  - Sub_slot – A number from 0 to 99 specifying which subslot for gain/delay settings to take effect.
- **FST** – Load new fine delay filter coefficients

Recording – TBW & TBN

- TBN & TBW share a MCS_DR unit.
- Both data sets formatted into Ethernet Packets. (Mark5C)
- TBW
  - Data Frame contains 400 samples for 12 bit data for both polarizations of a stand.
  - Header contains
    - TBW_ID – Stand and polarization ID
    - Time tag – First sample in # samples since 1970 Jan 1 00:00 UTC
- TBN
  - Data Frame is 520 samples (I & Q)
  - Header Info:
    - TBN_ID – stand and polarization ID
    - Time Tag – Like TBW time tags

Beamformer Output Processing

- Each of 4 Beams has 2 Tunings and 2 Polarization outputs
- Each of 4 beam has a dedicated MCS_DR unit – over 10GbE I/F
- Digital Receiver functionality forms tunings and formats data for output.
- Output BW is {19.6, 9.8, 4.9, 2.0, 1.0, 0.5 and 0.25 MHz}
- Output data is quantized to 4 bits. Gain adjustment allows choice of bits to record. Rounding and Saturation logic prevent DC offset and overflow.



Digital Receiver Processing Per Beam, Per Polarization

Recording – Beamformer Outputs

- DRX data frame is 4096 bytes per 1 tuning & 1 polarization.
- Data is 4 bits I, 4 bits Q.
- DRX_ID in header.(denotes, beam, tuning and pol.)
- Time tag in data header – time of 1st sample since 1970 Jan 1 00:00 UTC..

- **DRX** Command.
  - DRX_BEAM (1 to 4)
  - DRX_TUNING (1 to 2)
  - DRX_FREQ (10 to 88 MHz, 0.046 Hz resolution)
  - DRX_BW (250 KHz to 19.6 MHz)
  - DRX_GAIN (Divide by 2^0 to 2^{15})