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**

**Digitizers:**
- 26 boards
- 10 antennas or 20 channels per board

**Per-Antenna Processing:**
- full-bandwidth delay tracking and coherent summation for each beam
- full-bandwidth transient buffering
- narrow-bandwidth data streaming
- 26 boards
- 20 channels/board

**Per-Beam Processing**
- Filter, channelize and format for recording.
- 2 boards.
- 2 beams/board.

**Beam outputs:**
- 4x 10GbE
- one per 2-pol x 2-freq beam

**Outputs to Data Aggregation & Communication Subsystem**

**DP Subsystem Control Computer**
- to/from station monitor/control via MCS network
- to/from embedded PowerPC in each of 28 processing boards
- network switch

**from Analog Receivers 512 chan.**
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
  • Signal level: +/- 0.71 Volts

• Processing
  • Digitizes each signal by sampling at 196 MHz and quantizing to 12 bits.
  • TBW: Provides a buffer that captures 57 msec of samples from 520 digitizers, beginning at an externally supplied trigger pulse
  • TBN: 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 reduced-rate sample streams.
  • BFUs: 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: 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
TBW Capabilities

• TBW Command: This command sets up configuration of all Wideband Transient Buffers (TBW).

• Key Parameters:
  • TBWBITS (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
- TBN output is 8 bits In-Phase and 8 bits Quadrature
Beamformer Capabilities

- Two types of delay – Coarse and Fine
- Default set of coeffs implement fractional delay.
- Coarse delay in sample clocks from 0 to 1024.
- Beam daisy chain is 20 bits. Allows for up to 4 bits of data growth.
- Beam data not saturated in daisy chain. 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). Fine delay is actually index into 16 coeff sets of FIR Filter
  - BEAM_GAIN[260][2][2] – specifies 2x2 matrix multiplications for gain and polarization adjustments
  - Sub_slot – A number from 0 to 99 specifying which subslot for gain/delay settings to take effect.
Timing Concepts

- Time on DP Partitioned into 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.
System Commands & Responses

- **Commands**
  - FST, – Setup FIR coefficient table
  - INI – Initialize or re-Initialize system
  - SHT – Shutdown system

- **Monitor (RPT) Responses**
  - TBN_STATUS
  - BEAM_FIR_COEFFS (value is 28)
  - TNOM1 to TNOM4 – pipeline delay through beamfomer daisy chain.
  - ANTx_RMS, ANTx_OFFSET, ANTx_SAT – input data statistics. Updated every 5 seconds.
  - BOARDx_STAT – hardware status info (voltage, temperature, etc)
Recording – TBW & TBN

- TBN & TBW share a MCS_DR unit.
- Both data sets formatted into Ethernet Packets. (Mark5C)
- TBN
  - Data Frame contains 400 samples for 12 bit data for both polarizations of a stand.
  - Header contains
    - ID field of stand
    - 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
    - Time Tag – Like TBW time tags
Recording - DRX

• Each beam has a dedicated MCS_DR unit
• DRX data sent in 10GbE data payloads of size 4096 samples for one tuning & one polarization.
• Decimation factor in data header
• Time tag in data header – time of 1st sample since 1970 Jan 1 00:00 UTC. – Samples units depend on decimation.