Scientific Impact

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It's still WIDAR

- 32 stations, scaleable in 8-station increments; up to 256 allowed
- 8 x 2 GHz "basebands", each comprised of 16 tunable sub-bands
- 16,384 channels per baseline @ max. BW
- 4 million channels per baseline, w/ recirculation
- High spectral dynamic range
- 1, 2, 3, 4, or 8-bit initial quantization; 4- or 7-bit after sub-band filter
- RFI excision
- Flexibility

Conceptually much simpler

- "Baseband" quadrants, each handling one BB pair
  - ➢ vs. previous sub-band correlators
- Each sub-band pair is independent of all others
- Full recirculation for *all* sub-bands
  - ➢ Full flexibility in bandwidth and channelization
- Much easier to understand
- Much easier to explain -- huge benefit for a national facility!
- Exception: autocorrelations

Conceptually much simpler

- Incremental buildup of correlator makes more sense
  - Could either add a few antennas with full BW, or more antennas with lesser BW (might depend on board availability)

Added capabilities

- R2: recirculation on *every* sub-band
  - Old scheme: only half
- Phase up entire (16 GHz) bandwidth
  - Old scheme: only 1 GHz
  - 1-2 subarrays per sub-band (!)
- Sub-band beams and pulsar modes
  - Each sub-band could have different phase bins (except STB DUMPTRIG limitations) -- could simultaneously track up to 128 different pulsars!
  - Can mix phase binning in some sub-bands with "normal" observations in others
  - Each sub-band can have a different phase center

Equivalent capabilities

- All previous cross-correlation modes still work (see Memo #28): even wide-bandwidth
- 32 stations at full bandwidth
- Expansion in 8-station increments
  - Can expand with 1, 2, 3, 4 quadrants, depending on bandwidth per station (4 GHz chunks)
  - Separate VLBA correlator makes more sense

Lost capabilities & restrictions

- Can't trade bandwidth for stations (since one cannot cross-correlate baseband pairs)
  - ➢ Can't use the same correlator for VLBA+EVLA
- Subarrays come in groups of 4 antennas
  - – Not seen as a major problem
- Don't get all autocorrelations, and figuring out which you *can* get is complex

Subarrays

Restrictions

- Antennas within a four-antenna group defined by the Baseline Board must use synchronized real-time dump timing
  - This is because one dump control signal is selected and used for each chip -- this is set by the chip design.
    - Each Correlator Chip Cell (CCC) can use different integration times, but those integration times for all CCCs in a given Correlator Chip must be harmonically related. So, if sub-bands correlated by the same Correlator Chip belong to multiple subarrays, those subarrays must have the same minimum hardware integration time.
- In practice this means that antennas within a four-antenna group must either not use recirculation, or use the identical recirculation setup
  - One also cannot mix pulsar phase binning and non-pulsar modes within the same four-antenna group, but this seems less important

Restrictions

- The two re-timing FPGAs on each BLB have cross-bar switches and are wired together, to allow grouping any set of 4 antennas within the full 32.
  - With 32-27= 5 "extra" stations, one can make the system even more flexible
- This provides complete flexibility in defining up to 8 completely independent subarrays.
  - 8 is a magic number because the Correlator Chips on a BLB are arranged in an 8x8 square; all chips in the same row or column receive the same data streams. The cross-bar + wiring described above gives complete freedom in determining which antennas go to which data streams.
- NOTE: the number of truly independent subarrays is also limited by the number of independent DUMPTRIGs provided by the STBs.

DUMPTRIGs

- Number of independent DUMPTRIGs limits:
  (1) Number of independent pulsar phase bin parameters (one per DUMPTRIG)
  (2) Number of truly independent subarrays -- those relying on the same DUMPTRIG have to use dumptimes which are harmonically related.
  -- Likely ok, but messy…
- Currently: 2 independent DUMPTRIGs per STB
  - Using a bigger chip would push this waaaay up

Autocorrelations

The Issue

- Wideband autocorrelations unchanged
  - Time multiplexed
  - No sub-band boundaries
- More efficient use of BLBs means diagonal corr. chips obtain cross- as well as auto-correlations
  - In many cases one only gets half the sub-band autocorrelations (e.g., 5R x 5R & 6L x 6L)
  - These restrictions result from limitations in the correlator chip wiring -- only the primary inputs can go to all corr.chip quads.

Specific restrictions (both 4- and 7-bit)

- 4-pol'n product modes (RR, LL, RL, LR)
  - can obtain only ONE pol'n A/C product per antenna
  - can't get the SAME pol'n A/C product for paired antennas
  - CAN get cross-pol'n A/C products (e.g., 5R x 5L)
  - examples:

    1R x 1R + 2L x 2L OK
    1R x 1L + 2R x 2L OK
    1R x 1L + 2R x 2R no good
    1R x 1R + 2R x 2R no good

    - CAN get ONE pol'n for all antennas, at all times
    - Another option: obtain ALL auto-corr'n pol'n products, but only for half the antennas
      - E.g., 1R x 1R, 1L x 1L, 1R x 1L; 3R x 3R, 3L x 3L, 3R x 3L; etc., but without any autocorr'ns for antennas 2, 4, 6, …

Specific restrictions (both 4- and 7-bit)

- 2-pol'n product modes (RR, LL)
  - same as 4-pol'n product modes, above
- 1-pol'n produce modes (e.g., RR)
  - can get ALL auto-correlations

Complications

- Correlator setup
  - Painful to explain, painful to implement
- Correlator output data format (Binary Data Format & Science Data Model)
  - Auto- and cross-corr'n products have different dimensions, and are not necessarily from related chips

Examples (memo 29/next talk)

- 32 stations, 4-bits: half A/C products
  - all pol'n products for 2 of every 4 stations,
  - OR, one pol'n product for each station (2 in RCP, 2 in LCP)
- 32 stations, 7-bits: all A/C products
- 28 stations, 4-bits: all PP for 22 stations
- 26 stations, 4-bits: all A/C products
- Multiple subarrays: messy…

Why we care

- General diagnostic
  - time multiplexing probably OK
- RFI identification & excision
  - not fully worked out yet…
  - pol'n info likely not critical
  - most RFI NOT time variable on timescale available at BLB (msec)
  - RFI likely concentrated in a few sub-bands -- could devote extra correlator resources to those sub-bands

Why we care

- Gain calibration (scale to template spectrum -- ACFIT)
  - not clear this is needed for (or possible with) EVLA
- Bandpass calibration (amplitude only)
  - seldom useful in practice, due to single-dish woes
- Polarization delay calibration, based on (e.g.) 5R x 5L
  - Seldom used, often discussed
  - Currently used at the VLA, but only occasionally (~each re-configuration)
  - Need only one antenna, to provide one point to tie the electric vector position angle (EVPA)
  - Easy to do with occasional special calibration observation, at worse one scan at beginning of each run

Why we care

- Tsys(frequency)
- Divide cross- by auto-corr'ns on a channel-by-channel basis?
  - might want this for Tsys weights & Van Vleck corr'ns, but that is far from obvious

Possible fixes

- Don't worry about it
  - No compelling reason we must have all sub-band auto-corr'ns at all times
  - Non-RFI uses have low duty cycle
  - We still have the wideband auto-corr'ns (though those are time-multiplexed)
- Time multiplexing
  - Switching auto-corr'n modes requires stopping the correlation (including the cross-corr'ns done in the same chip) for two interrupts (20 msec)
  - Fine for cross-pol'n calibration

Possible fixes

- Use an extra quad or two for the auto-corr'ns
  - Main use is likely for RFI, where we have limited bandwidths
  - Could allocate half the correlator for auto-corr'n (costs spectral res'n)
- Use an additional (or unused) Baseline Board, in auto-corr'n mode
  - Works in 4-bit mode, or can just toss lower 3 bits of 7-bit datum
  - each BLB gives 64 auto-corr'ns (2048 channels covering 128 MHz), dumping every 10 msec
    - Limited by GigE connection to the CBE
    - Faster dumps possible with fewer channel

Missing zero lags

The Issue

- Zero lags are required to normalize the cross-correlations
- Previously these were obtained from sub-band auto-corr'ns

Fixes

- Use zero lags from Station Boards
  - 10msec time resolution currently
  - Doesn't *exactly* correspond to cross-correlation spectra (time res'n, recirculation, blanking, …)
  - Must get this to the CBE within two LTA dumps (not a problem)
- Use re-timing/cross-bar FPGAs or recirculation chips
  - Just need 64 lag-0 accumulators