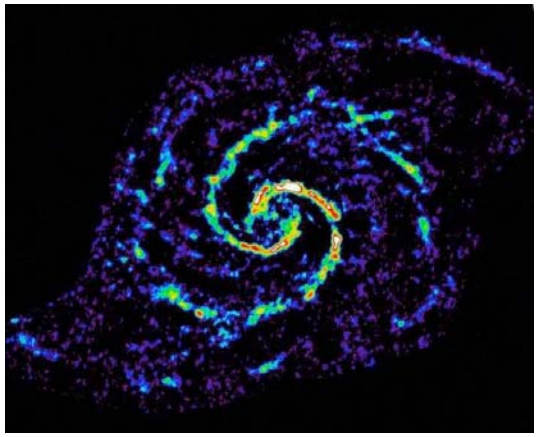
The CARMA Correlator System

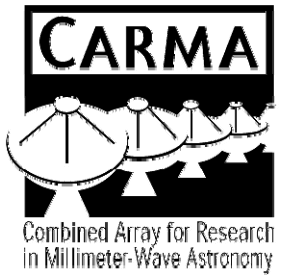


David Hawkins, David Woody, Ira Snyder
(Caltech)

Kevin Rauch, Marc Pound
(U. Maryland)

David MacMahon
(UC. Berkeley)

Overview

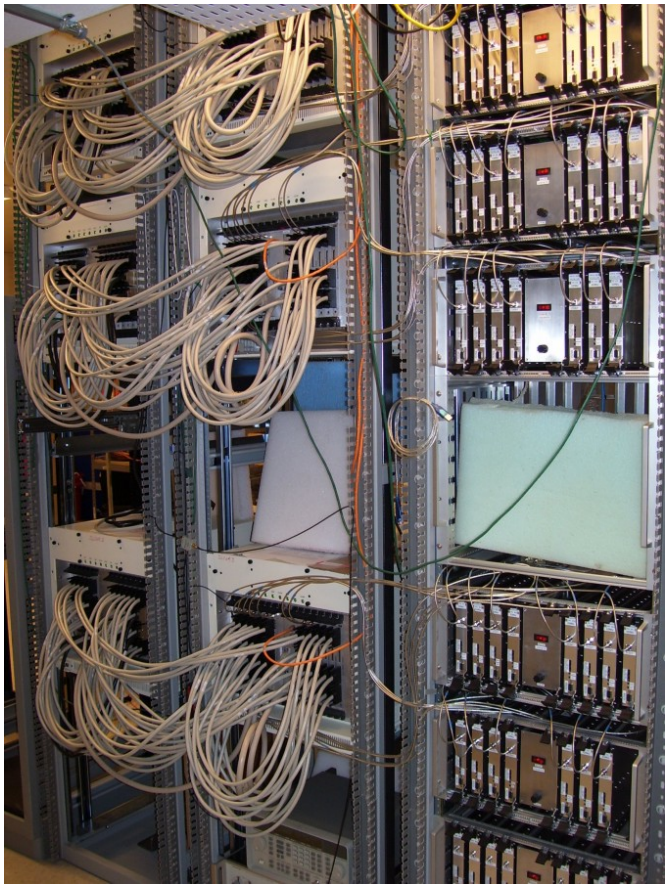


- CARMA telescopes and correlators
- CARMA Digitizer/Correlator Board
- CARMA Board Correlator Systems
- Future Development

CARMA Telescopes

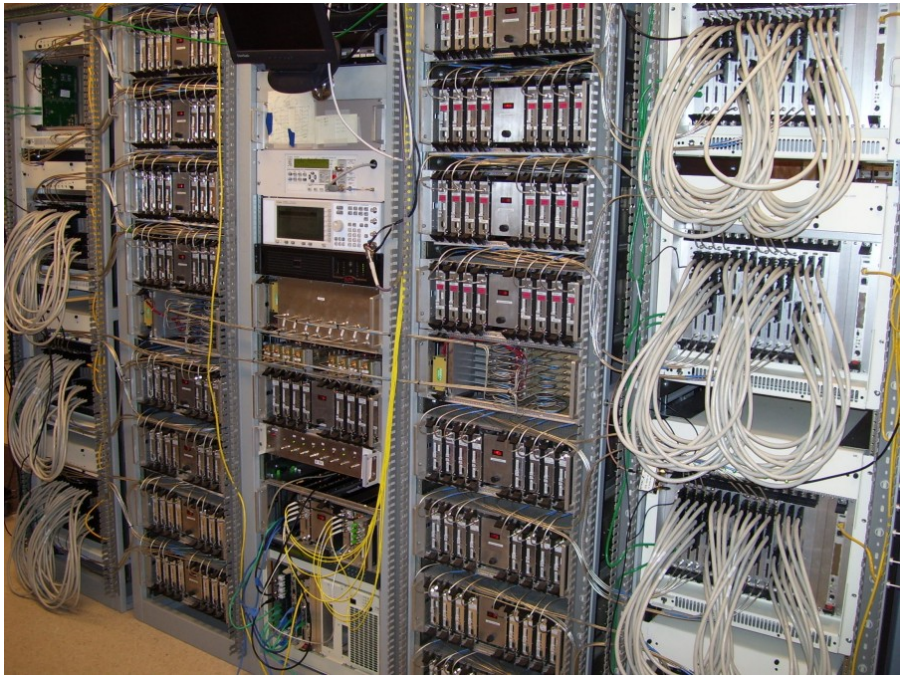
6 x 10m (OVRO) + 9 x 6.5m BIMA) + 8 x 3.5m SZA

The COBRA Correlator Systems

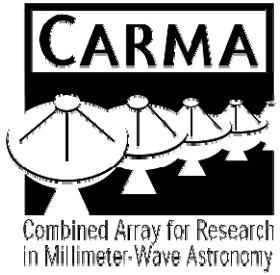


CARMA 'First Light' Correlator
3 bands x 15-telescopes x adjustable LO x
500MHz down to 2MHz bandwidth

SZA Correlator
16 bands x 8-telescopes x fixed
500MHz bandwidth



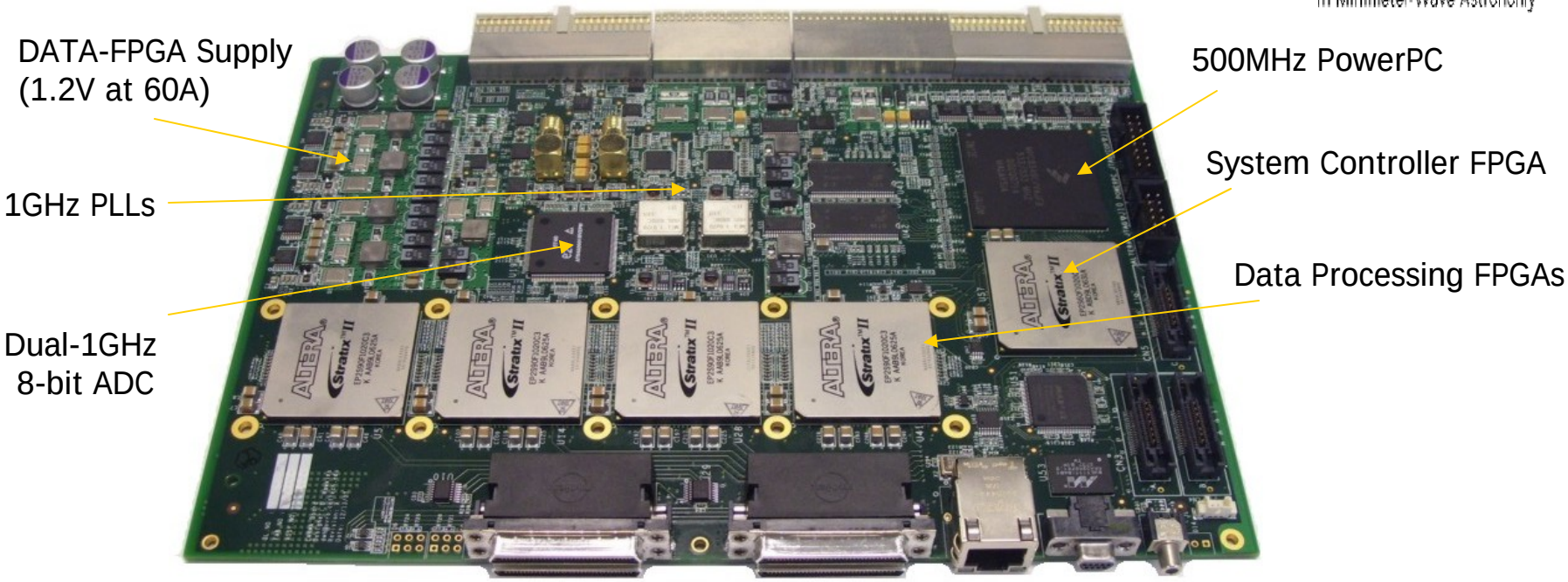
CARMA Board Data Processing



- Digitizer Board;
  - Samples 2-antennas x 500MHz bands @ 1GHz to 8-bits
  - 180-degree phase-switch demodulation
  - Delay (slope) and offset (lobe-rotation) correction
  - Digital filtering for spectral modes
  - Calculates auto-correlations and a single cross-correlation
  - Transmits 2-antennas x (up to) 4-bits x 500MHz on each of four front-panel cables to the correlator boards

- Correlator Board;
  - Receives up to 8-antennas (28-possible baselines)
  - Calculates 16 single-polarization baselines (4 correlations per FPGA)
  - Calculates 2 polarization components per baseline in dual-polarization mode (8 correlations per FPGA)
  - 90-degree phase-switch demodulation

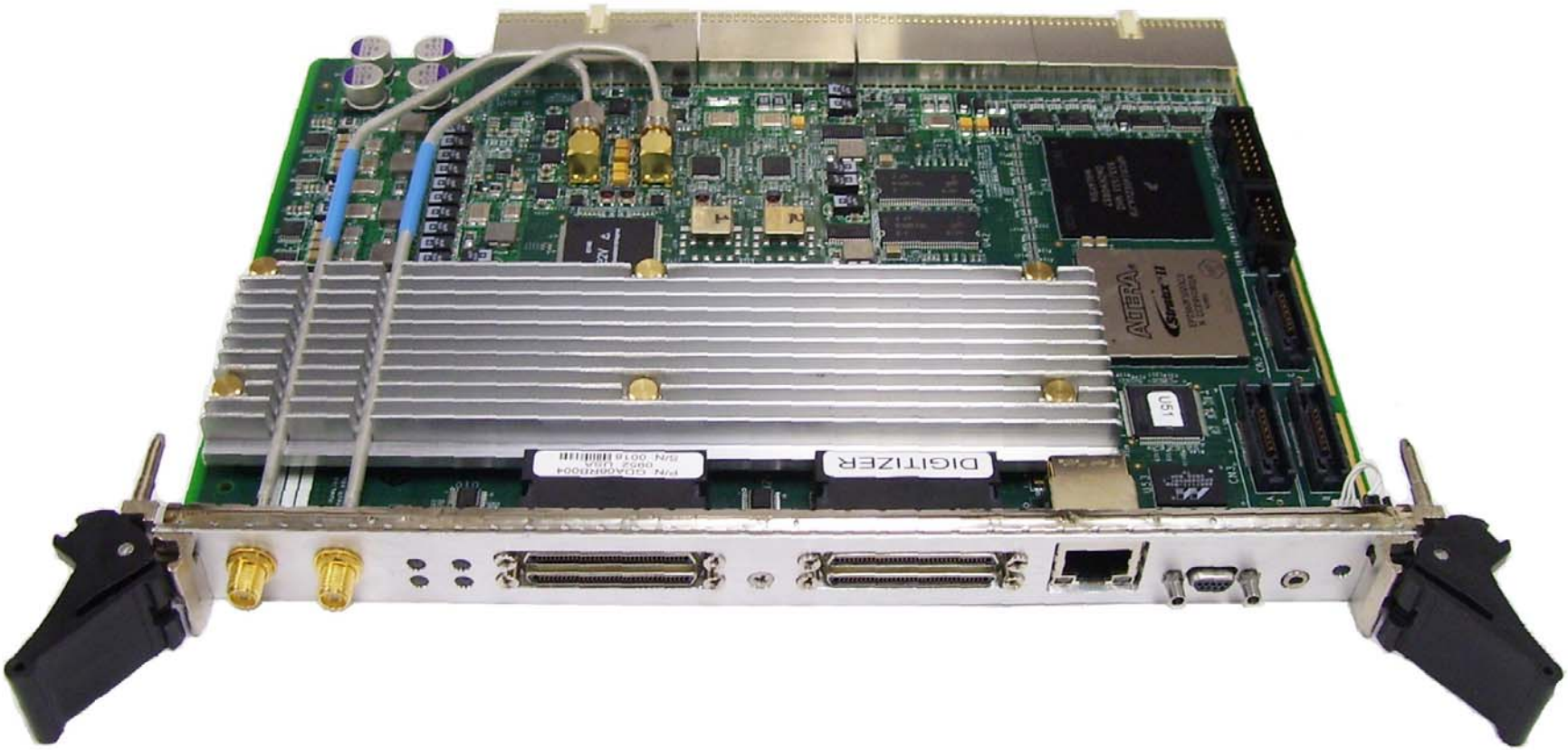
CARMA Digitizer/Correlator Board



- 2-antennas input
- 500MHz bandwidth each input
- FIR filtering
- Digital Downconversion
- Digital Delay
- Auto/Cross Correlation

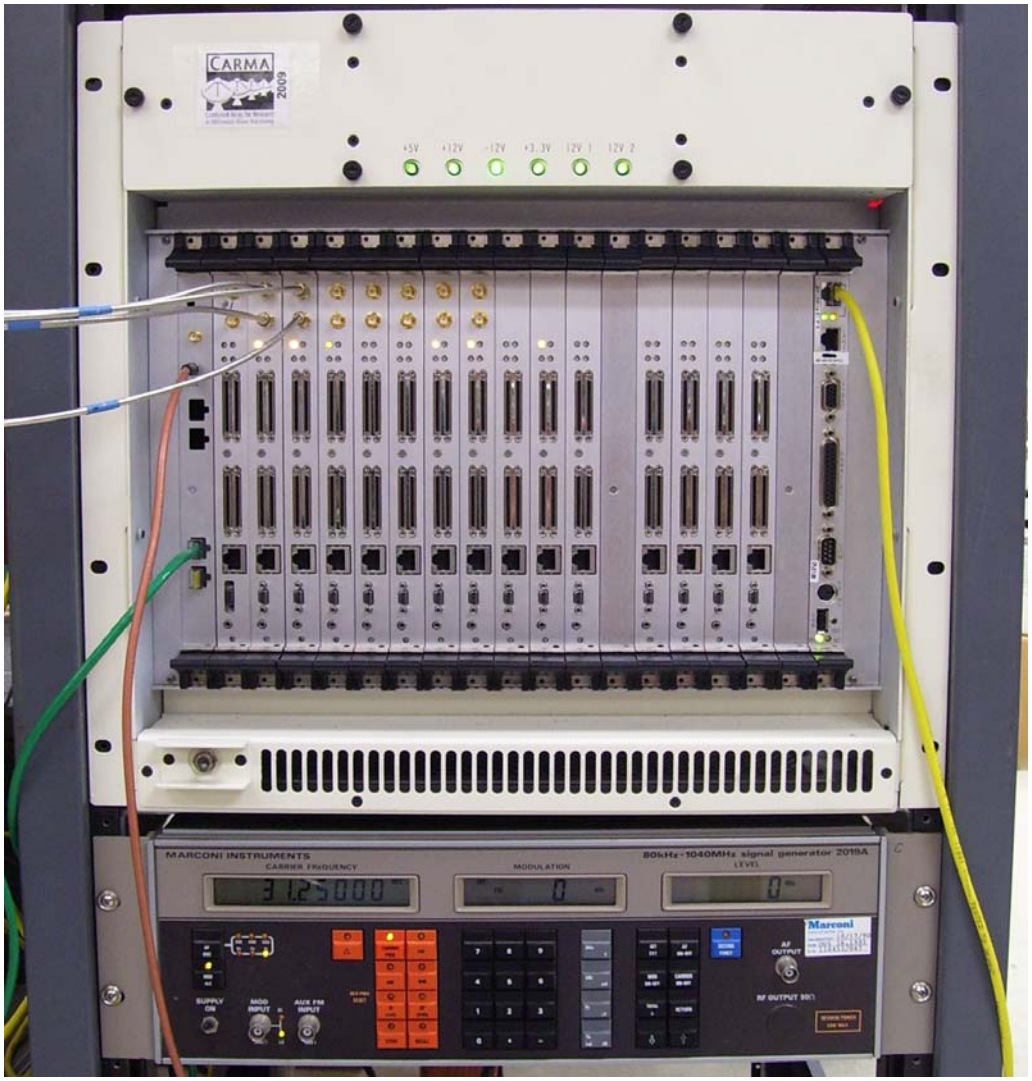
- DATA-FPGAs average correlation data
- SYS-FPGA coordinates real-time DMA of averaged data to PowerPC memory
- PowerPC runs Linux, performs lower-rate data processing and monitoring

CARMA Digitizer/Correlator Board



Fully assembled CARMA Digitizer Board

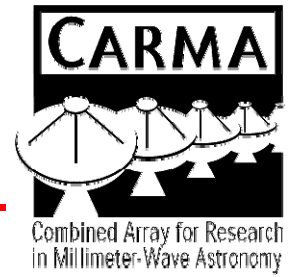
CARMA Board-based Band



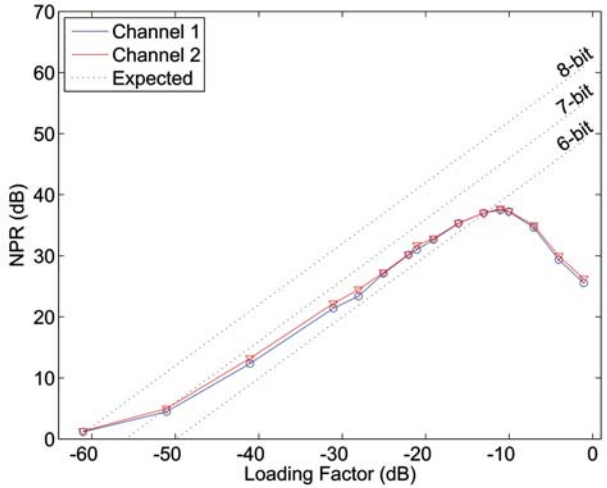
15-antenna setup
- 8 digitizers
- 7 correlators

- 500MHz band per crate
- Digitizer-to-Correlator data (LVDS) cables are not connected

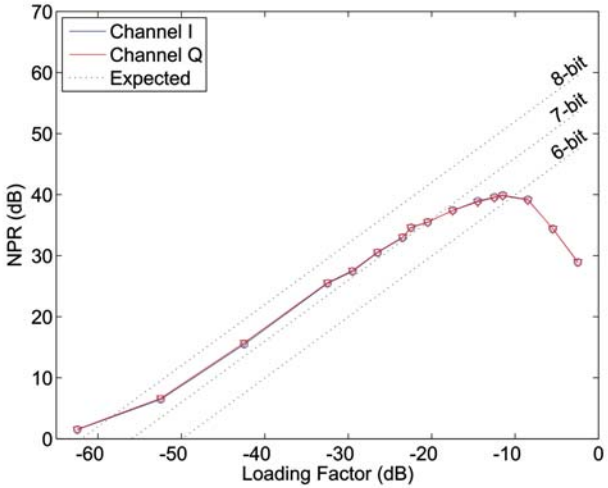
Digitizer testing; Noise Power Ratio

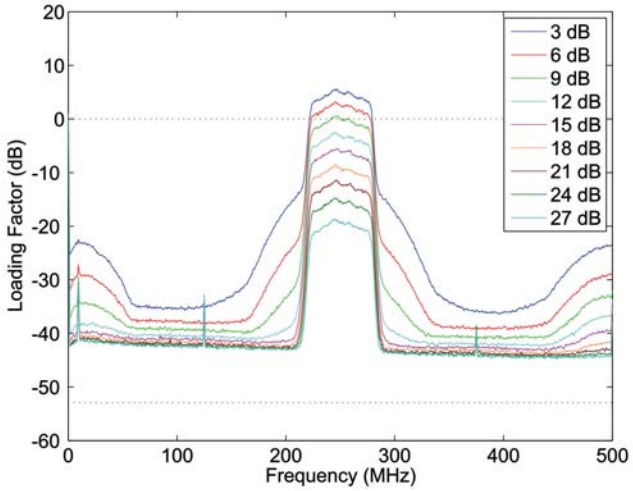


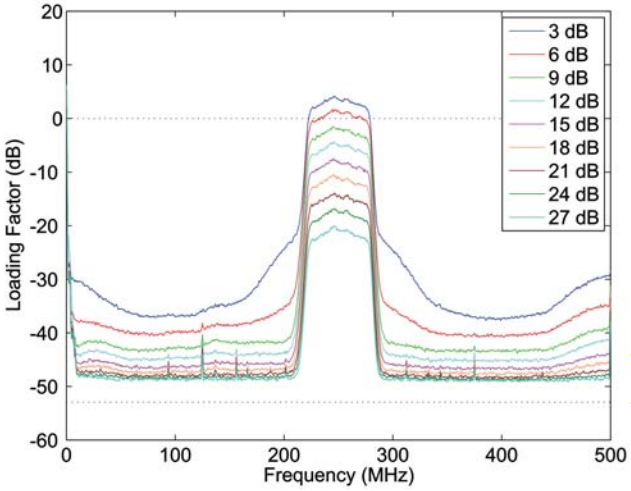
LeCroy Scope



CARMA Board





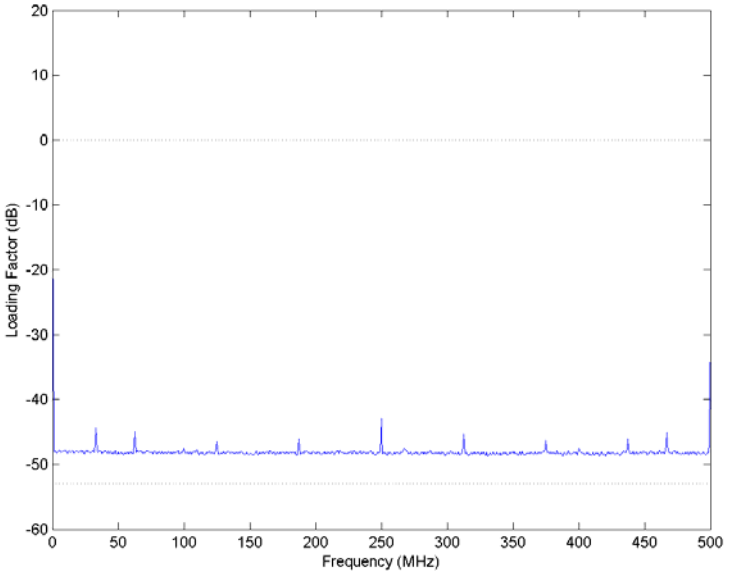


NPR (dB) =
6.02B + 4.77

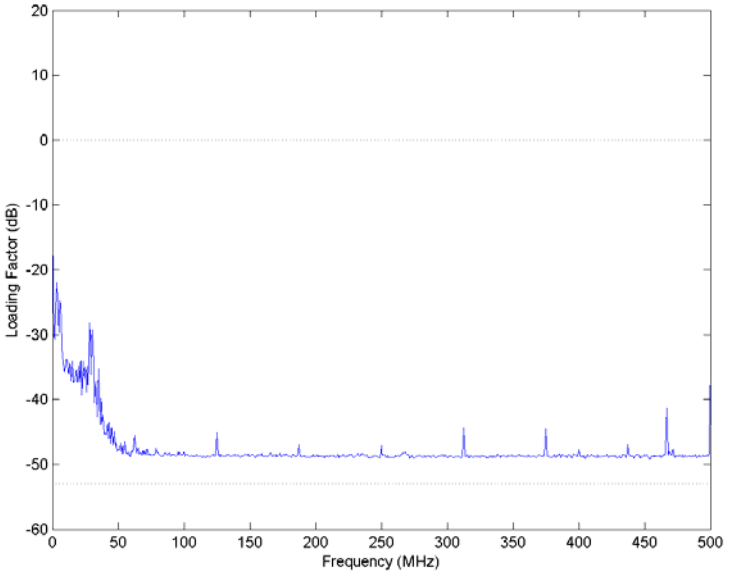
46dB for 6.8-bits

53dB for 8-bits

Digitizer testing; Switching noise



No RF cables



With RF cables passing over a switching power supply

Spectral Resolution

Bandwidth	Number of frequency channels			
	COBRA	CARMA		
	2-bit (87%)	2-bit (87%)	3-bit (96%)	4-bit (99%)
500MHz	17	129	81	33
250MHz		193	129	49
125MHz		289	225	97
62MHz	61	385	321	161
31MHz	65	385	321	161
8MHz	65	385	321	161
2MHz	65	385	321	161

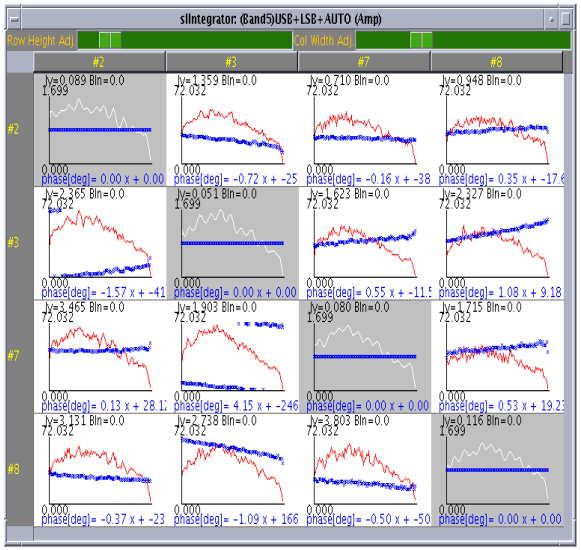
~ 6x increase

CARMA board-based bands support 2-, 3-, and 4-bit correlation

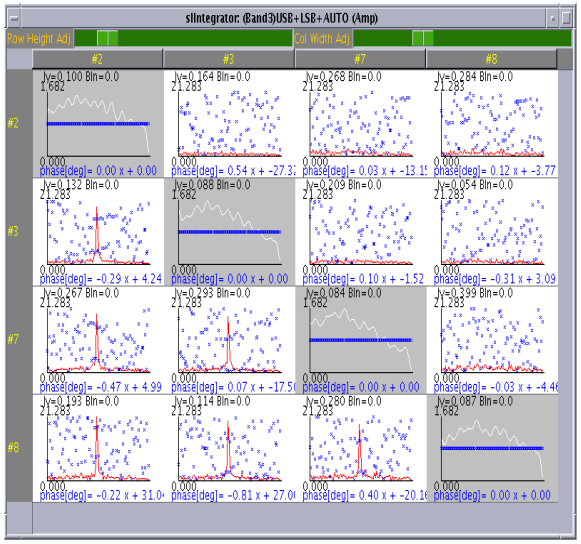
Astronomical Spectra

Combined Array for Research in Millimeter-Wave Astronomy

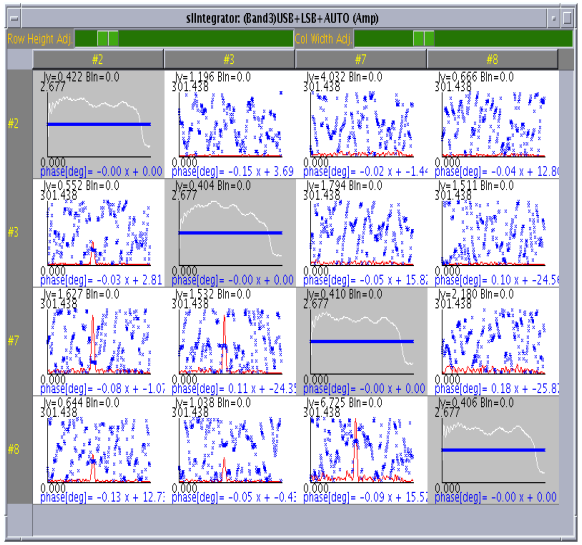
Data taken: 11/24/2009



500MHz continuum
(3C454)

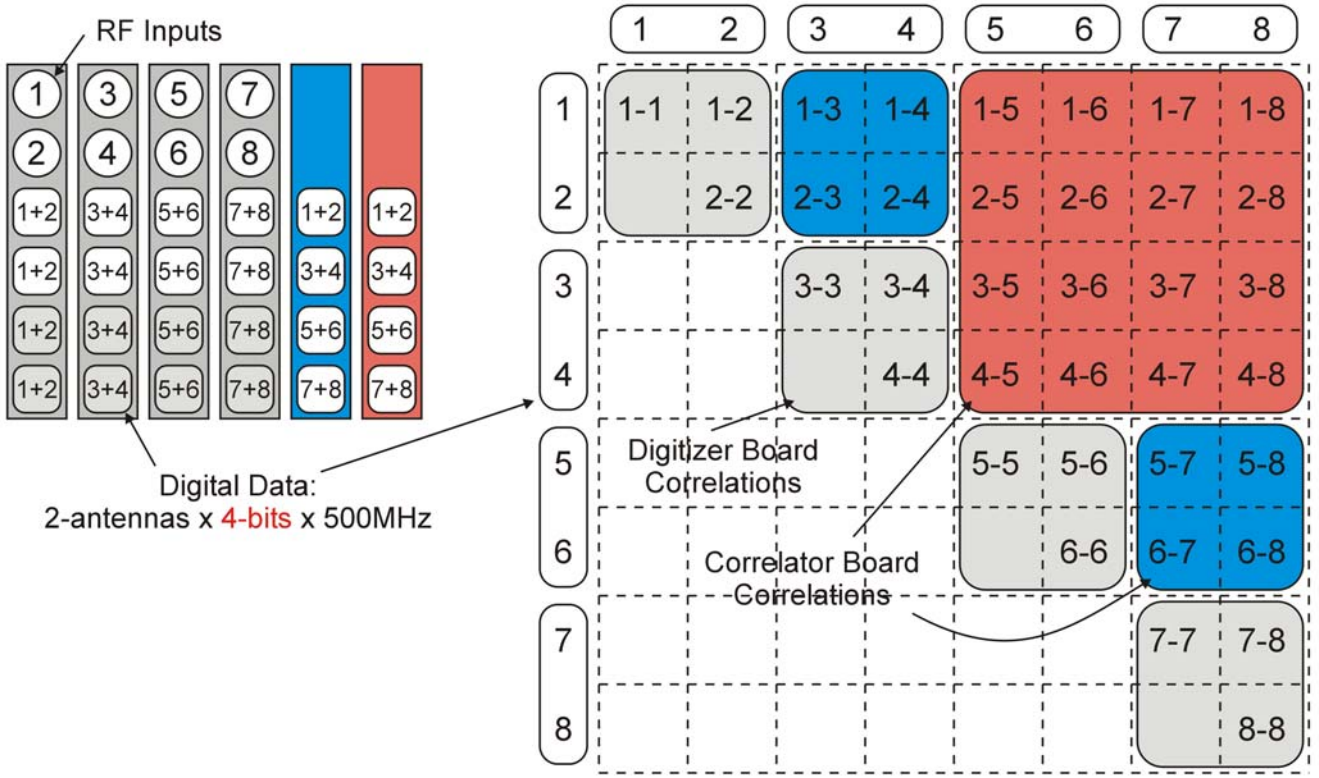


500MHz line
(Upsilon Herculis
SiO maser)



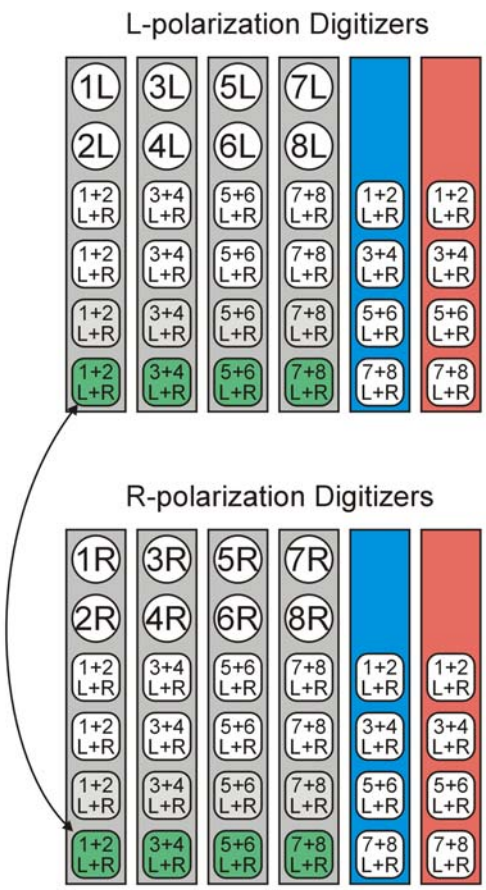
62MHz line

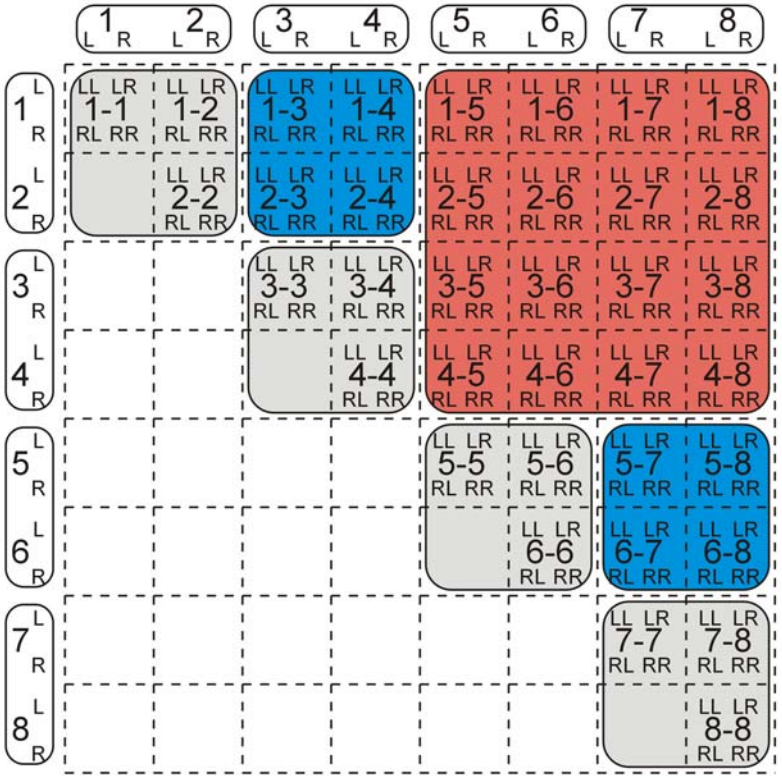
Single-polarization mode



(8-antenna hypothetical system)

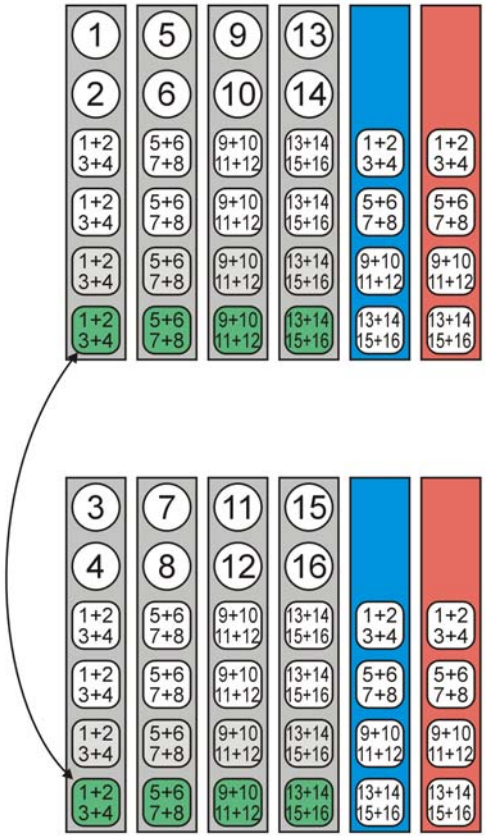
Dual-polarization mode

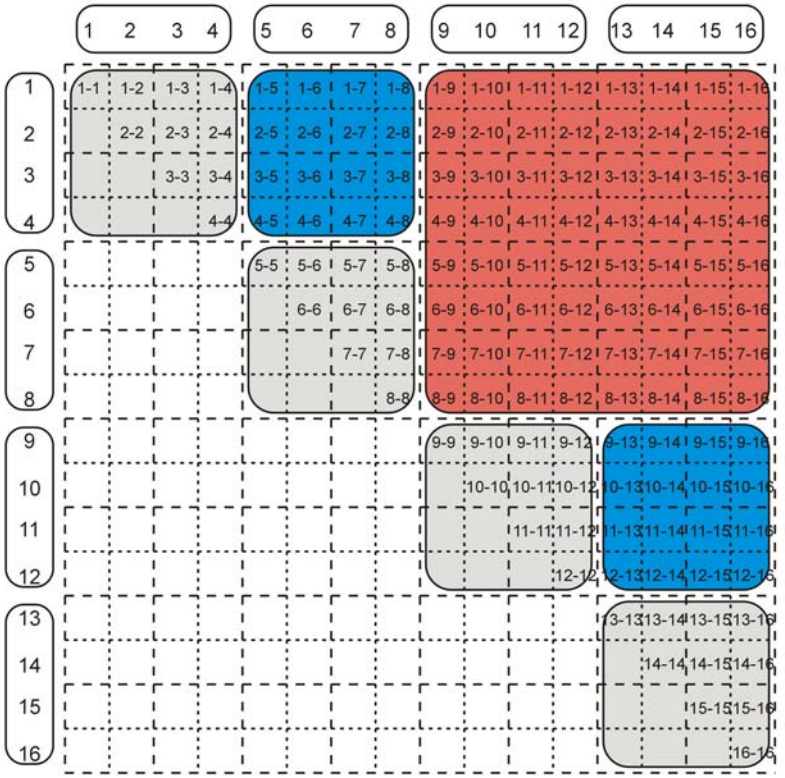




Digital Data:
2-antennas x 2-polarizations x 2-bits x 500MHz

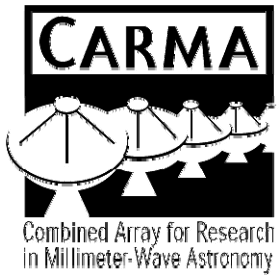
Single-polarization dual-band mode





Digital Data:
4-antennas x 2-bits x 500MHz

Summary + Future Development



- Status;
  - Now:
    - 8 antenna x 8GHz COBRA (SZA)
    - 15 antenna x 1.5GHz COBRA
  - Next month:
    - 15 antenna x 4GHz CARMA
  - Near future:
    - Switch-yard enabling;
    - 15 antenna x 2-pol x 2GHz
    - 23 antenna x 2GHz
- Next steps;
  - 20GHz ADCs
    - Eliminates downconverters
  - Re-cycle the CARMA digitizers as correlators
    - Doubles the number of bands and processed bandwidth