SWARM: A Compact High Resolution CASPER Correlator and Wideband VLBI Phased Array

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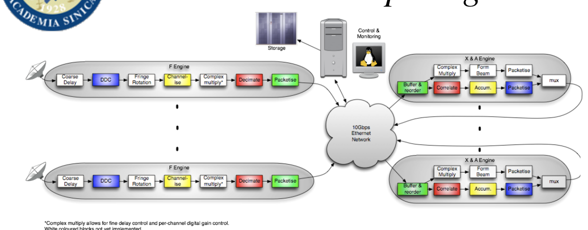
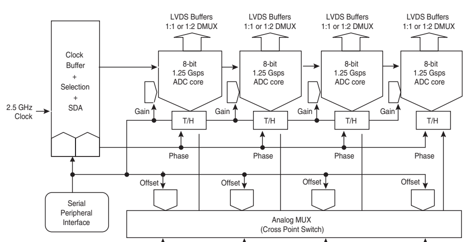
https://www.cfa.harvard.edu/twiki5/view/SMAwideband

Smithsonian

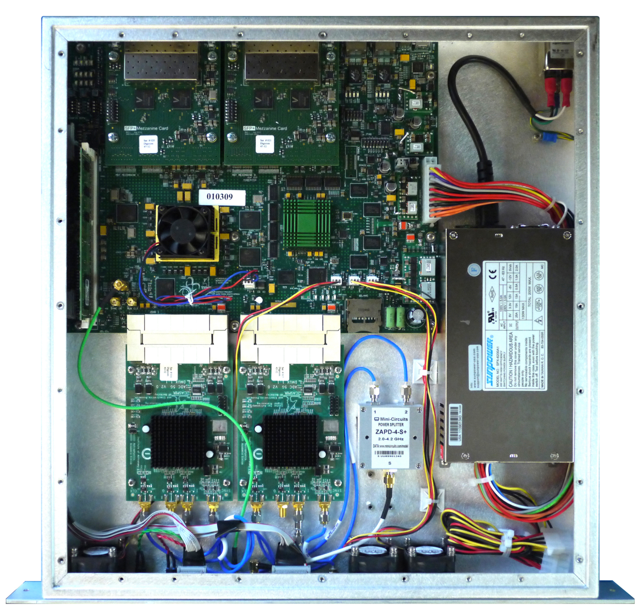
The *SMA Wideband Astronomical ROACH2 Machine* (SWARM) processes 4 GHz usable in single polarization mode, flexibly reconfigurable as full Stokes dual polarization. It uses open source technology from the *Collaboration for Astronomy Signal Processing and Electronics Research* (CASPER). A 4.6 GSa/s analog-to-digital converter board uses a commercial chip from e2v on a PCB designed by ASIAA. The DSP platform is the second generation *Reconfigurable Open Architecture Computing Hardware* (ROACH2). Each of two channels per ROACH2 sample a 2.3 GHz Nyquist band from a custom block downconverter.



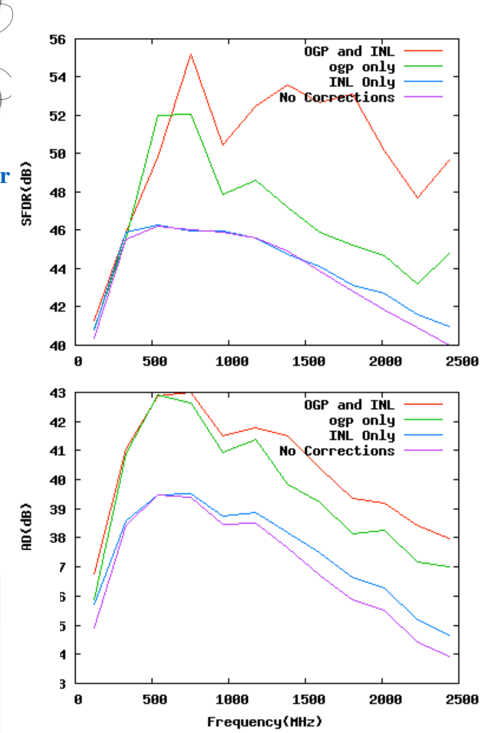
CASPER Packetized FX Correlator and Beamformer (https://casper.berkeley.edu/)

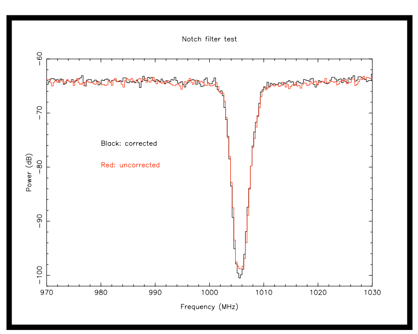


Quad core interleaved e2v ADC EV8AQ160



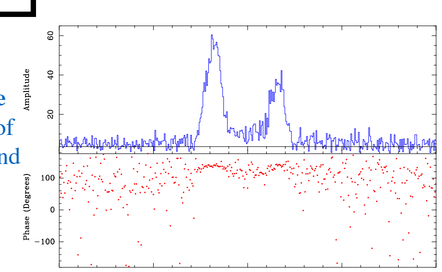
SWARM ROACH2 assembly with two ADCs installed, and dual SFP+ networking mezzanine cards.



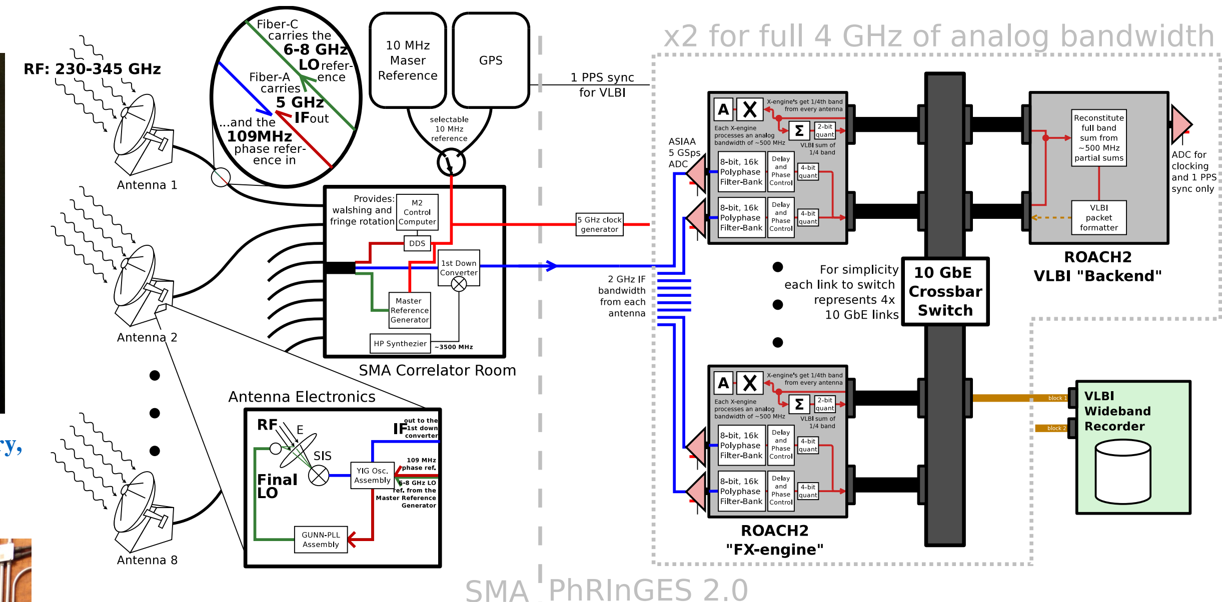


Spurious Free Dynamic Range (SFDR), Signal to Noise and Distortion Ratio (SINAD) and Noise Power Ratio (NPR), and the impact of of quad core alignment (offset, gain and phase, OGP, and Integral Non-Linearity, INL) (Patel et al., JAI, 3, 1)

SWARM installation in laboratory, fed by sophisticated phase agile antenna simulator (J. Test poster)

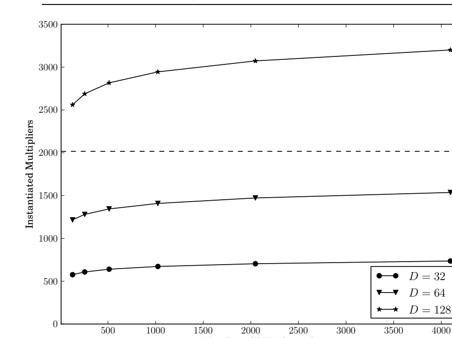


SWARM on Mauna Kea, and **first light fringe** on maser source MWC349.



SWARM block diagram (above) and **specifications** (below).

Feature	Specification	Remarks
Number of antennas	8	2 receivers each.
Bandwidth per receiver	2 GHz	Dual polarization in each side band.
Number of sidebands	2	90-270 Walsh splits SBs, Rx are DSB
Simultaneous receivers	2	Dual frequency or dual polarization 230 & 345 GHz
Baselines	56	28 per Rx, full Stokes, 112 total
Spectral resolution	140 kHz	2.3 GHz Nyquist / 16384 channels
Fastest dump rate	0.65 s	Single full Walsh cycle
Phased array bandwidth	4 GHz	2 GHz ×dual pol.



$$M_{\mathrm{PFB}} = \underbrace{D \log_2 ND}_{\mathrm{FFT}} + \underbrace{TD}_{\mathrm{FIR}} - \underbrace{2D}_{\mathrm{optimization}}$$

$$A_{\mathrm{PFB}} = \underbrace{\frac{3}{2} D \log_2 ND}_{\mathrm{FFT}} + \underbrace{D(T-1)}_{FIR} + \underbrace{D}_{\mathrm{reorder}}$$

FPGA DSP Utilization: Before committing to the ROACH2 we needed to understand that the bit code would fit the Virtex 6 SX475T FPGA. Utilization is dominated by the PFB, (an FFT with improved channel isolation). A hard reality is that the FPGA cannot run nearly as fast as the ADC. So D (demultiplex factor) of parallel streams are processed. D is also the ratio of ADC to FPGA clock rate. Bandwidth (~D) is much more expensive than spectral resolution (~1/N). See https://www.cfa.harvard.edu/twpub/SMAwideband/MemoSeries/sma_wideband_utilization_1.pdf

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