Advanced ATNF Correlators

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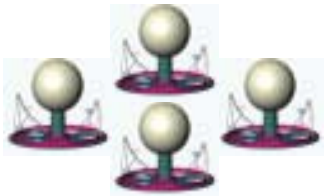
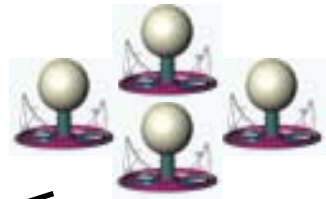
Topics

- New signal path, including new technology correlator
- Increased RF Bandwidth
- Increased Dynamic Range

A Wideband Upgrade for the Australia Telescope Compact Array

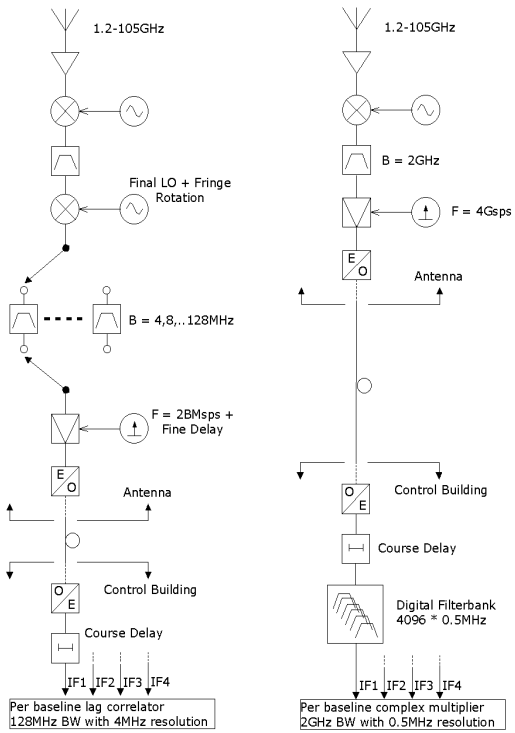




Luneburg Lens Phased Array

6 * 22m antenna AT Compact Array

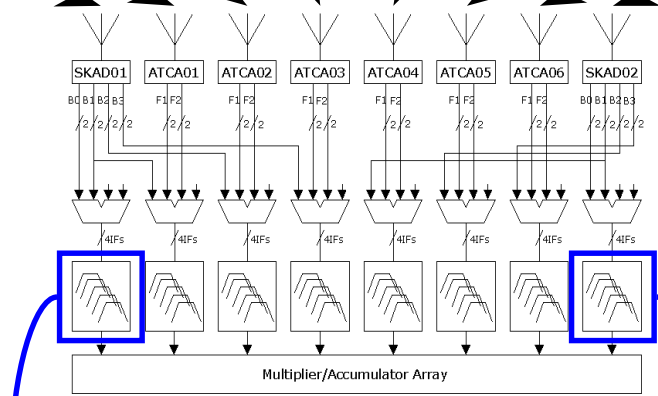
Luneburg Lens Phased Array



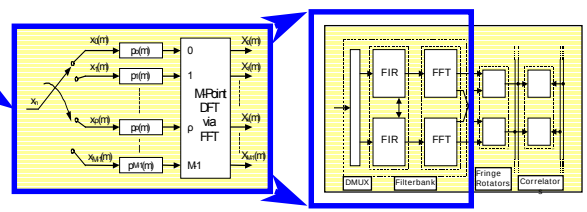
Current System

New System

RF, IF and Baseband Signal Path



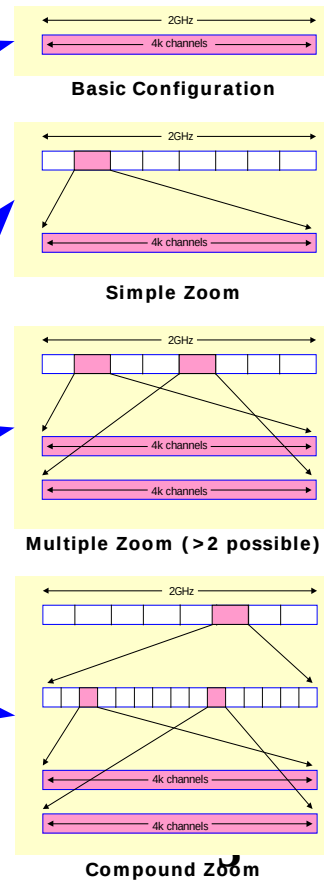
Extended Interferometer Structure



A 2GHz bandwidth polyphase digital filterbank with 4096 channels ... ... will fit into four XC2V6000 FPGAs

Filterbank Architecture

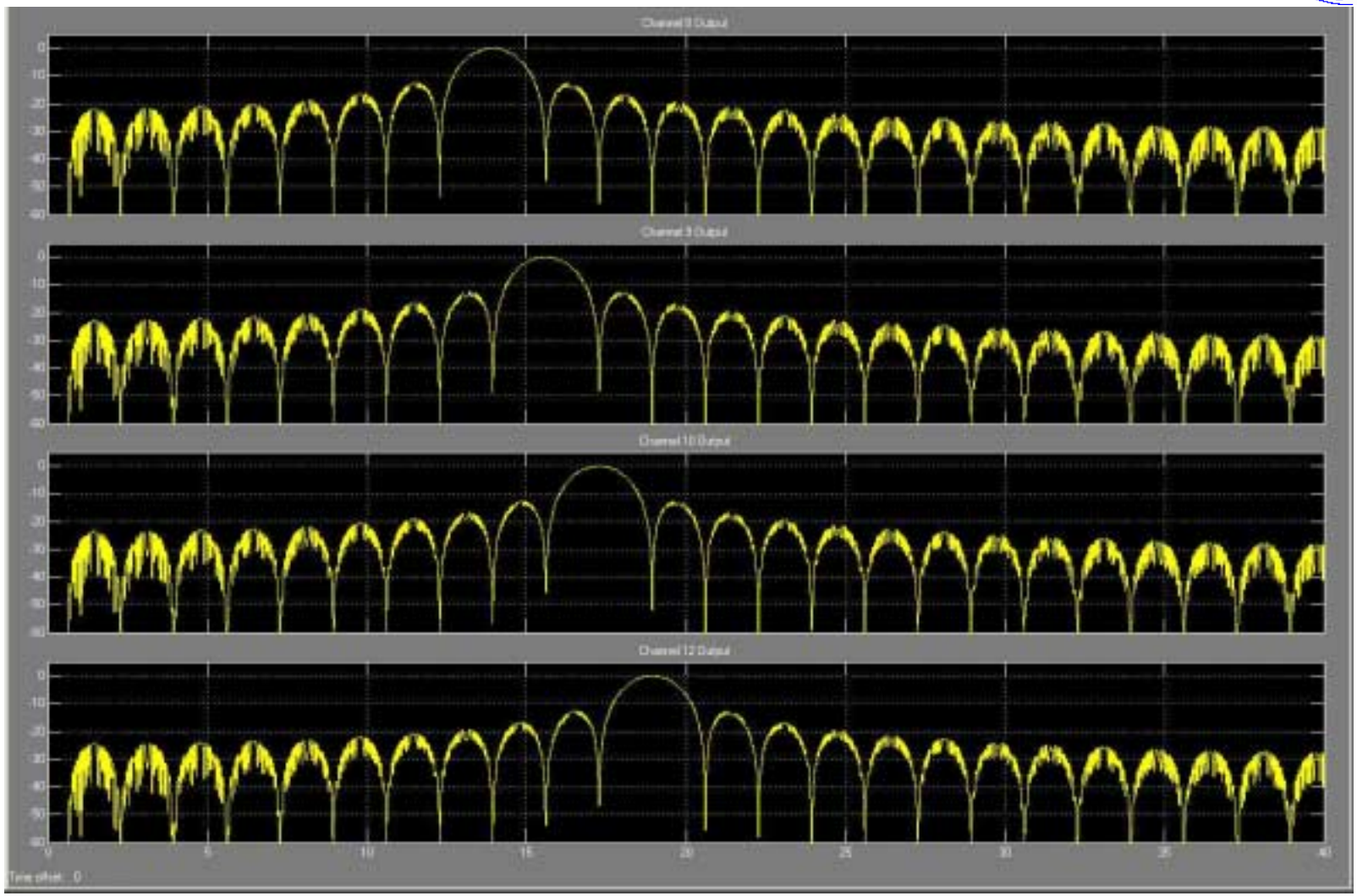
FPGA hardware may be completely reprogrammed to produce many different filterbank configurations, as different observations may require.



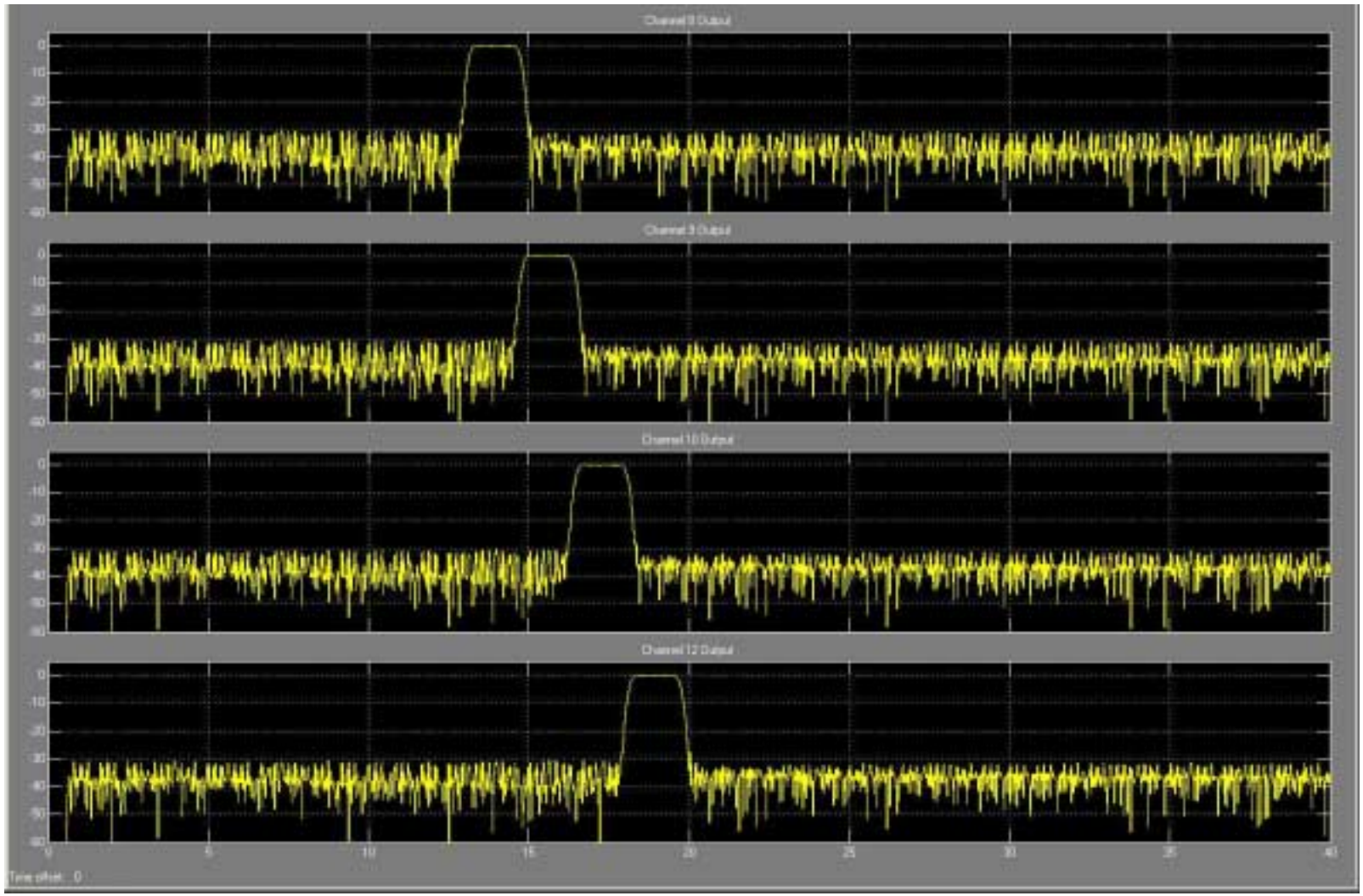
Increased RF Bandwidth

- Now : 128MHz 2-bit data (32)..(128) channels
  Future: 2048MHz 2..8-bit data 2048 channels
- Continuum
  - Sensitivity $\propto \sqrt{B\tau}$; $\sqrt{B2/B1} = 4$
  - Quantising Noise: 2-bit$\rightarrow$Tsys*1.14, 8-bit$\rightarrow$Tsys*1.001
    - » Net gain $\approx$ 4.5, equivalent to 20* telescope speed.
- Spectral Line
  - Multiple simultaneous lines
  - Features $\propto f_0$, 4MHz+4096chans $\rightarrow$ 128MHz+4096chans
  - Density $\propto f_0^2$ (lines $\rightarrow$ forests), 4MHz $\rightarrow$ 4GHz
- Imaging
  - (u,v) $\leftrightarrow \bar{s} \bullet \frac{\bar{d}}{\lambda} = \bar{s} \bullet \bar{d} \frac{f}{c}$. Smearing $\leftrightarrow \frac{\delta f}{f} \leq \frac{D}{d}, \Rightarrow \frac{B}{\delta f}$ chans
  - 2GHz $\rightarrow$ baselines (u-v tracks) *60 at X-band
  - MFS or BWS (Bob Sault tomorrow).

Conventional Channelisation



Increased Dynamic Range-DFB



Increased RF Dynamic Range

- "Samplers" both sample and digitise the waveform
  - → fold spectrum and shift it to baseband
  - → add noise and create distortion
- Astronomy: 2 bit digitisers, only 4 (3) states.
  CD audio: 16 bit digitisers, → 64000 states.
- 2-bit ↔ RF random process, P(coherent) << P(noise).
  Correlation ⇒ many lo-res I/Ps → few hi-res O/Ps,
  and requires P(fringe) << P(total) & constant
  P(total).
- "Interference" (LEOS, TV) doesn't obey the rules!
  Modest in-band signals removed by post processing
  (intmit), but strong signals → saturation, gain
  modulation, spectrum corruption. Need more bits!

New Samplers/Digitisers

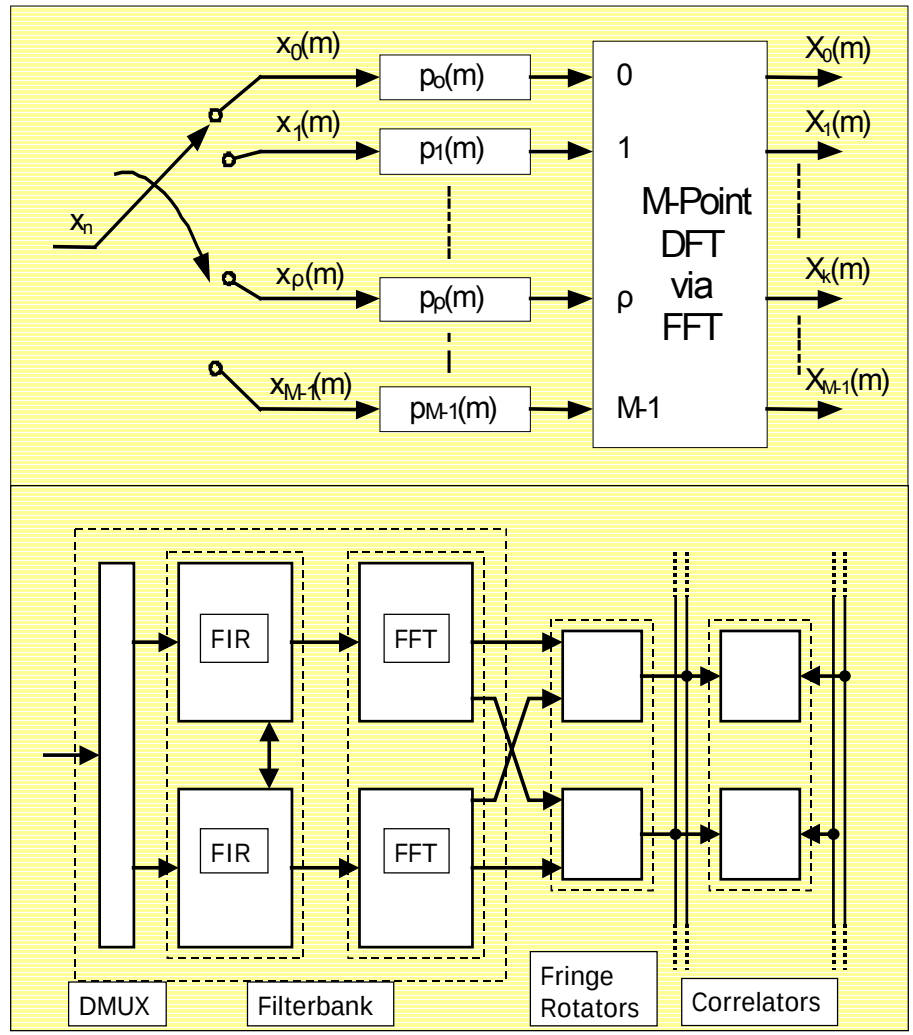
- 128MHz(BW) @ 8-bit ADC o.k. but 2GHz @ 8-bit cost ~M$! Wait a few years, ADC development << Moore's Law
- ATEG → InP 2-bit digitiser @ 8Gsps
  4GHz(BW) @ 2-bit → DSP → 2GHz @ 3-bit
  Extra 6dB is worth it
- Photonic samplers using soliton carriers
  - Physically separates sampling and digitising
  - Combines photonic bandwidths (huge) with available electronics
  - Ideal for SKA?, possibly developed on ATCA
- New backends built with 8-bit inputs to allow digitisers to catch up.

New 2GHz Correlator

- Novel “FX” architecture based on digital filterbanks implimented in COTS FPGAs.
  - 2GHz IF → 2k 1.0MHz complex channels → correlation.
  - Delay function and fringe rotation incorporated.
- “FX” ⇔ array of elementary narrowband correlators.
  - Key process is splitting input spectrum, ie filterbank.
  - Ideal channel shape
    - » Flat top → efficient correlation
    - » Steep sides, nonoverlapping → independent data streams
    - » Deep stopbands → avoid aliased noise and interference.
  - Technology choices
    - » Analog: passive filters impractical, BBCs too expensive
    - » Naked FFT: crude, fails on all criteria
    - » DSP: good match to objectives, proven at lower bandwidths

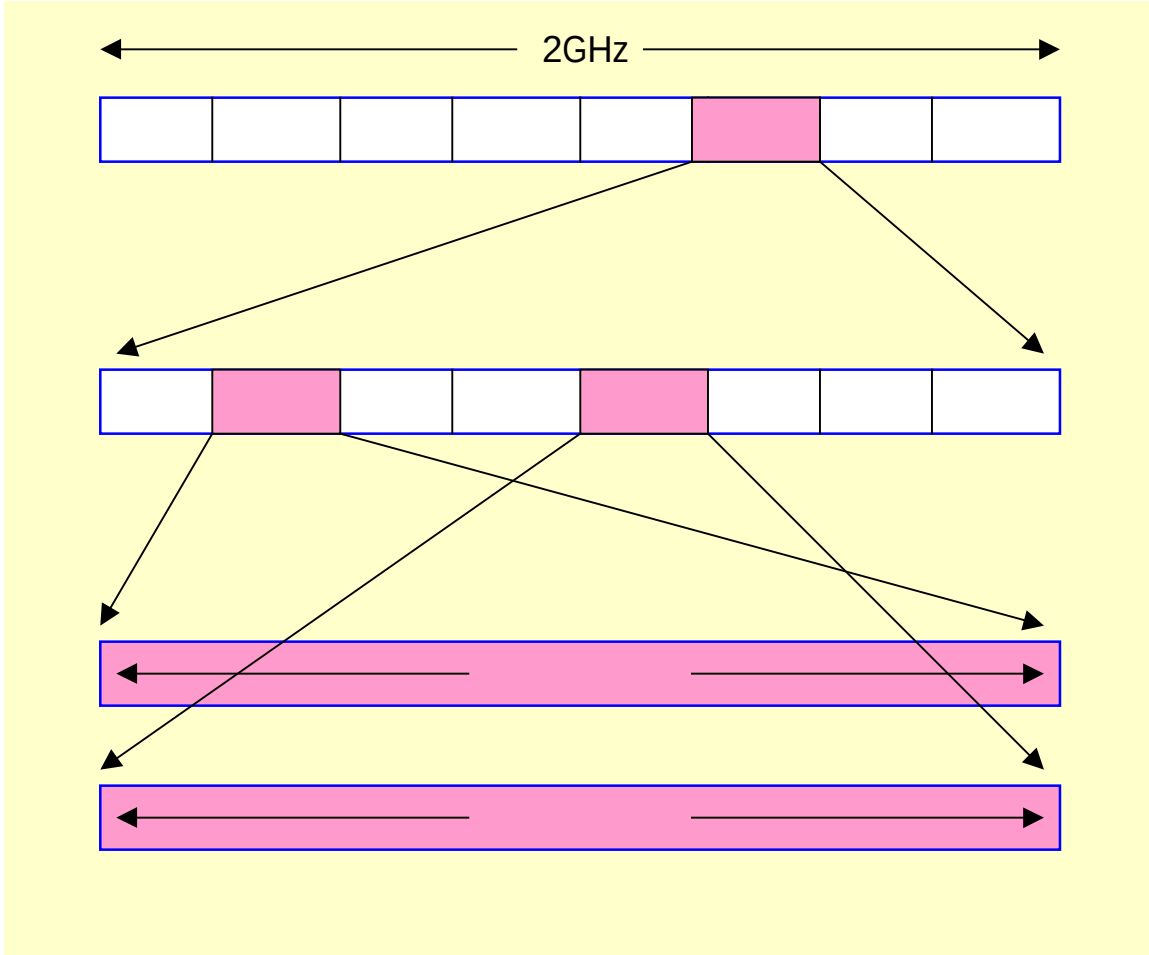
Correlator Architecture

- Polyphase Dig Filterbank
  - Equivalent to 2k BBCs
    - » Two filters per BBC
    - » 32k taps per filter
    - » Clocked at 4GHz
  - Only one filter as 4k*8
    - » Oscillator matrix = DFT
    - » Clocked at 1.0MHz * 256
    - » Fractional sample delay
- COTS FPGAs
  - Massive grunt per $
  - Design circuit, not chip
    - » More chans, BW, d-range
  - Endlessly reconfigurable



Zoom!

- Standard
- Zoom
- n*Zoom
- n*Zoom^n



More Info

- http://www.atnf.csiro.au/research/electronics.html

InP Sampler/Digitiser

- Operation up to 8 Giga-Samples/s
- Contains no demux
- 119 transistors, 57 resistors and 3 capacitors
- 350 mW on a 1.6mm x 1.2mm die