ATNF Synthesis Imaging Workshop

Correlators

(Backend System)

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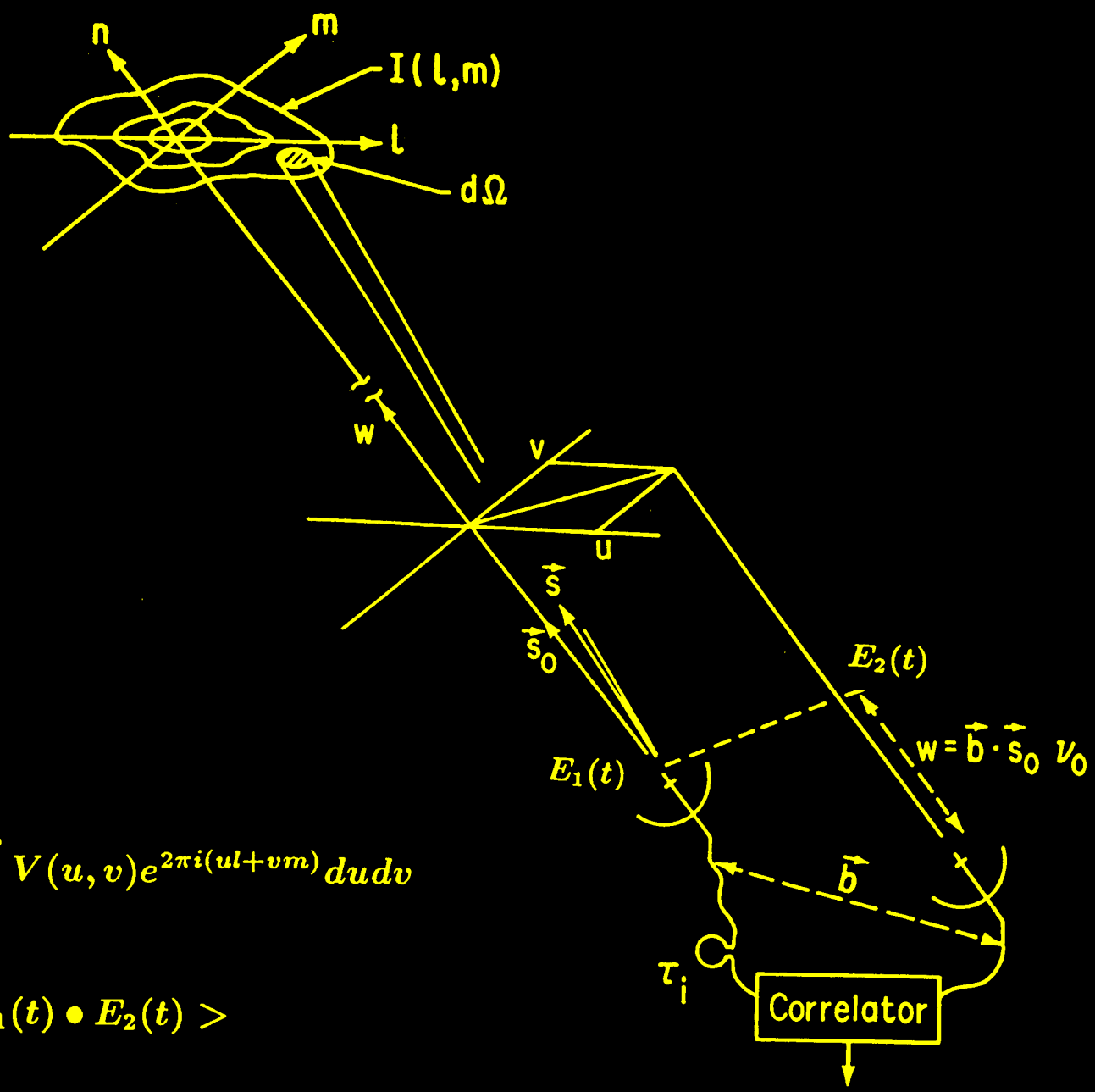
An Aperture Synthesis Array Radiotelescope

- A collection of simple interferometers
- An array of N antennas
- Processed in pairs
  - N(N-1)/2 pairs or *baselines*

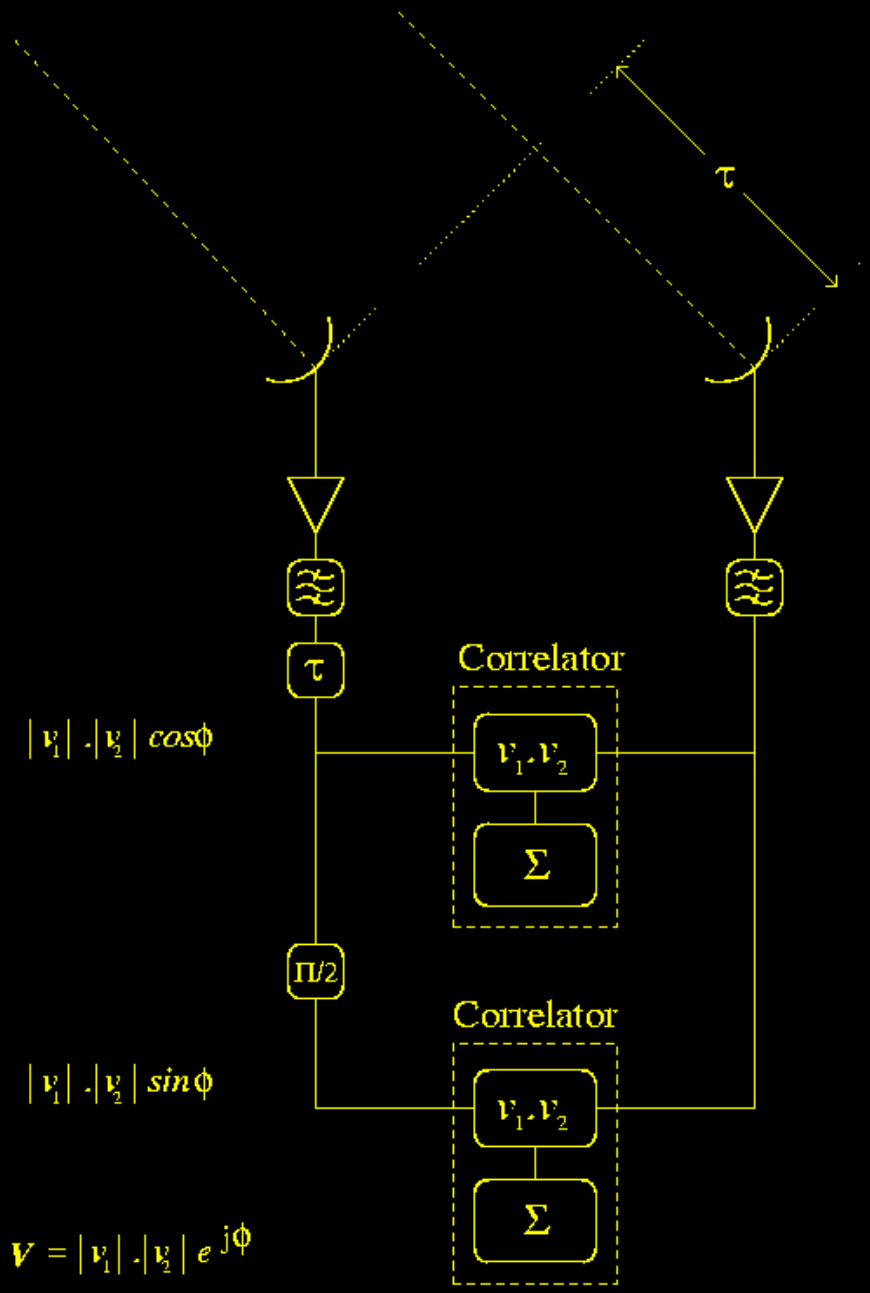


$$A(l,m)I(l,m) = \int_{\infty}^{\infty}\int_{\infty}^{\infty} V(u,v)e^{2\pi i(ul+vm)}dudv$$

$$V(u,v) = < E_1(t) \bullet E_2(t) >$$

- u,v in wavelengths

Complex Correlator



Measures visibility or cross power (complex)

Band limiting filter

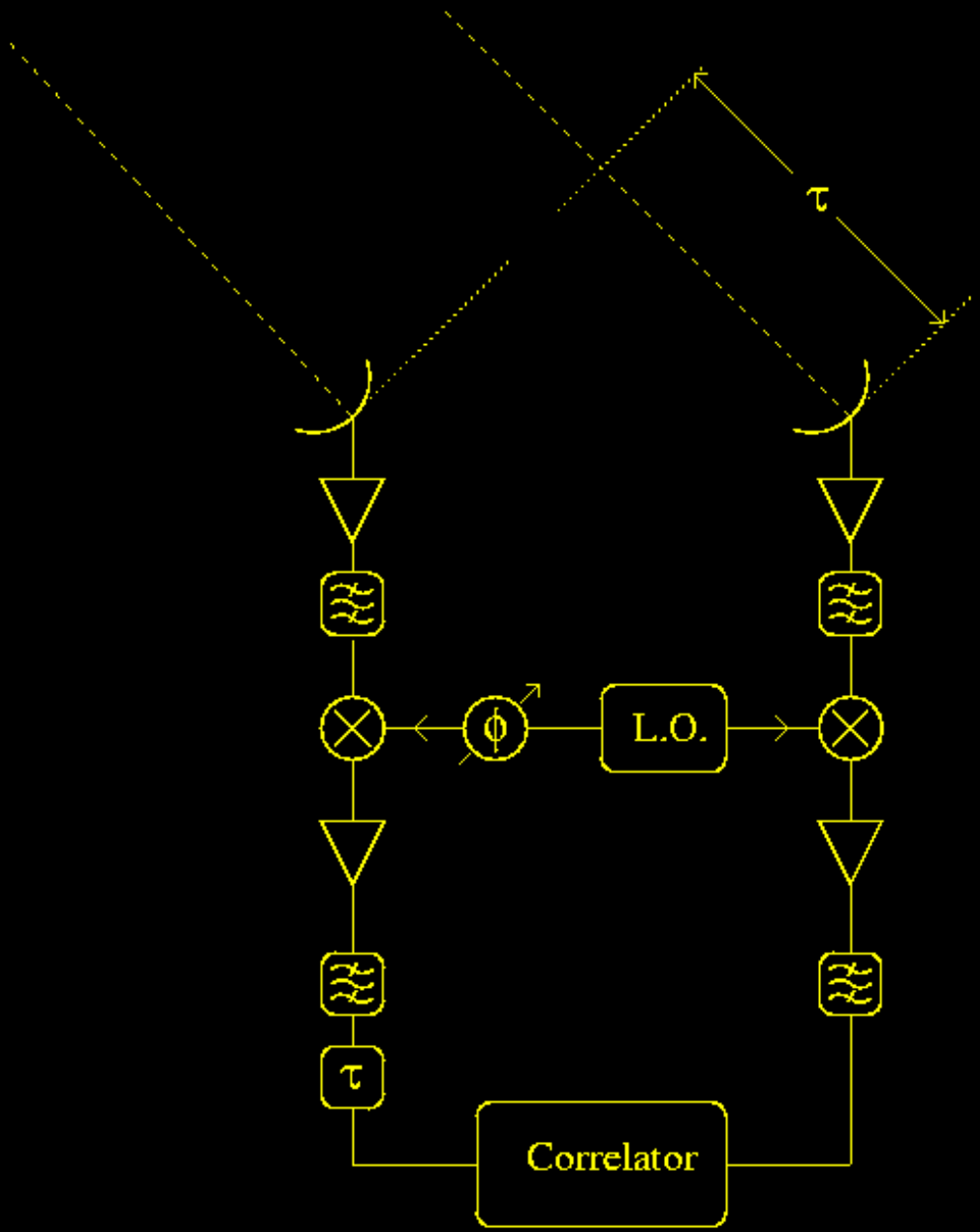
Cosine correlator

90 degree phase shift

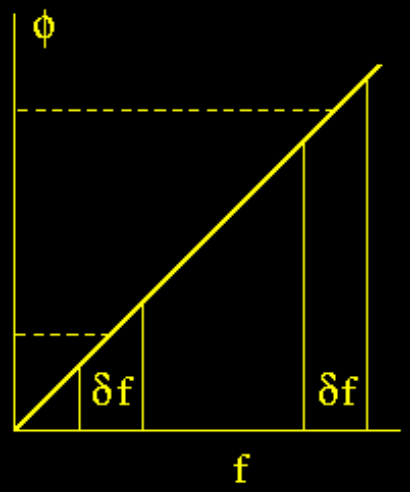
Sine correlator

Base-band Correlator

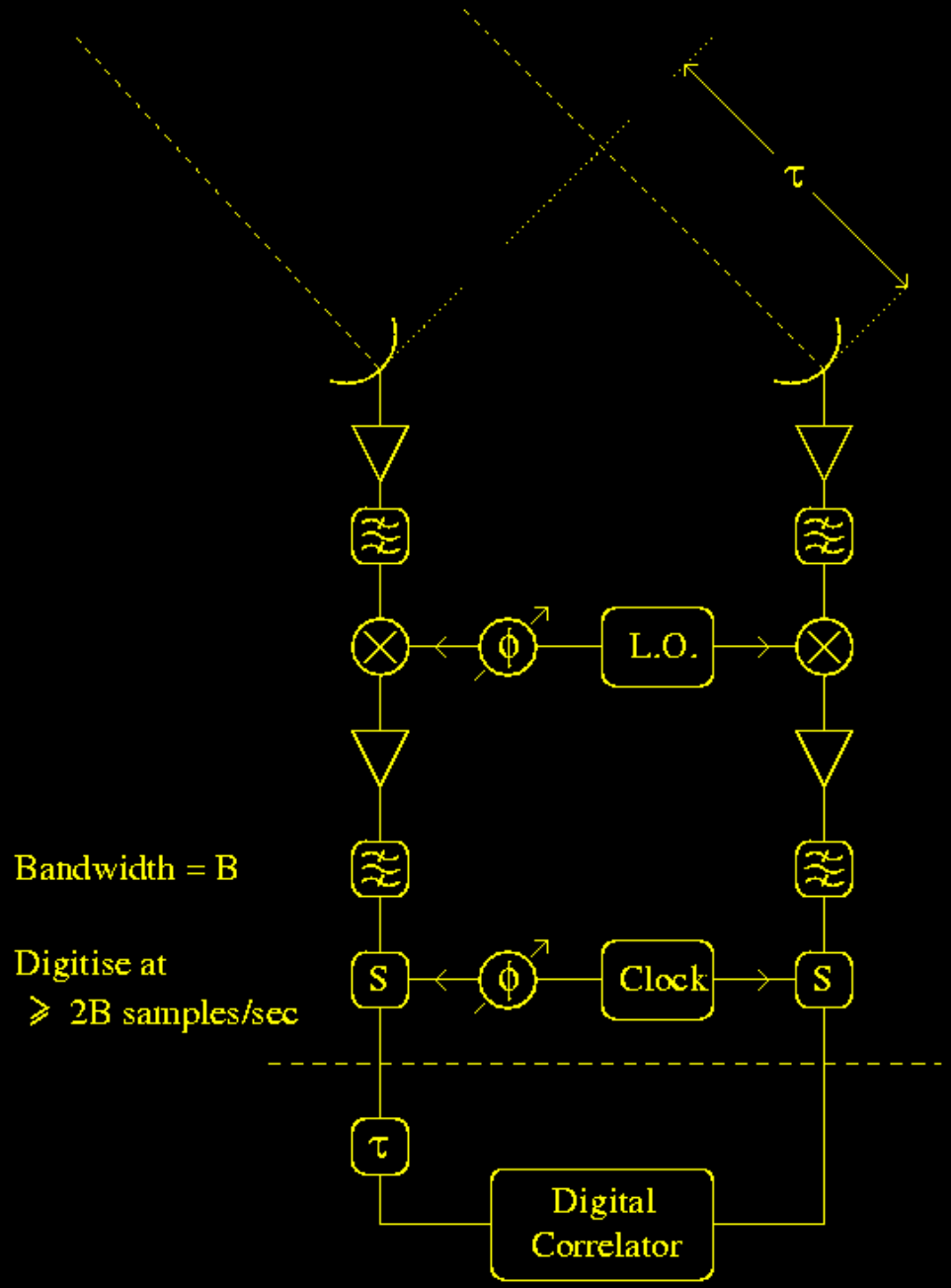
- with fringe rotation



Common Local Oscillator



Digital Correlator

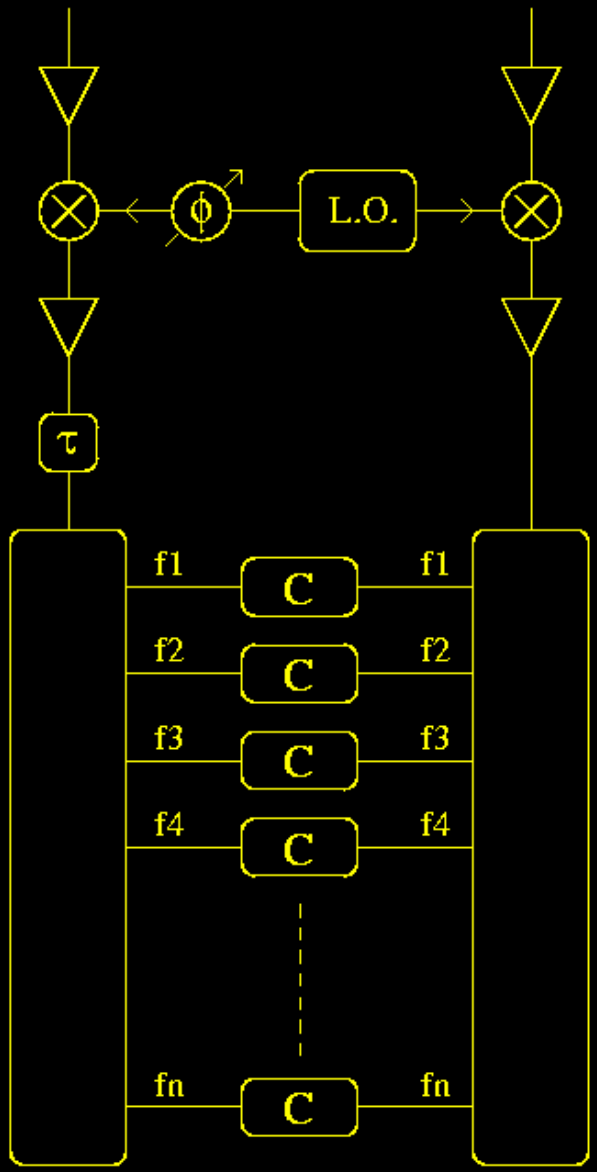


Sampler/digitiser
- with fine delay control

Advantages of measuring the Cross Power Spectrum

- Reduces the effects of frequency smearing and provides more independent measurements on the u,v plane. (MFS)
- Allows measurement of any frequency dependence in the source, e.g. spectral lines.
- Provides an easy method of delay calibration.
- Provides means of removing interference.

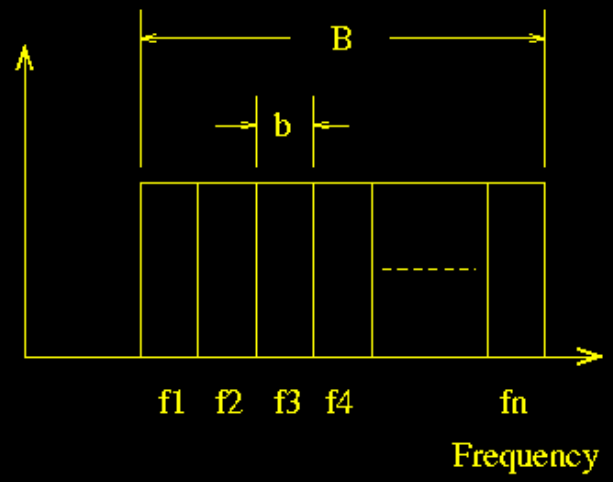
Spectro-Correlator



Correlators

B = Total bandwidth

b = Channel bandwidth



Filter Banks

Visibility / Cross Power

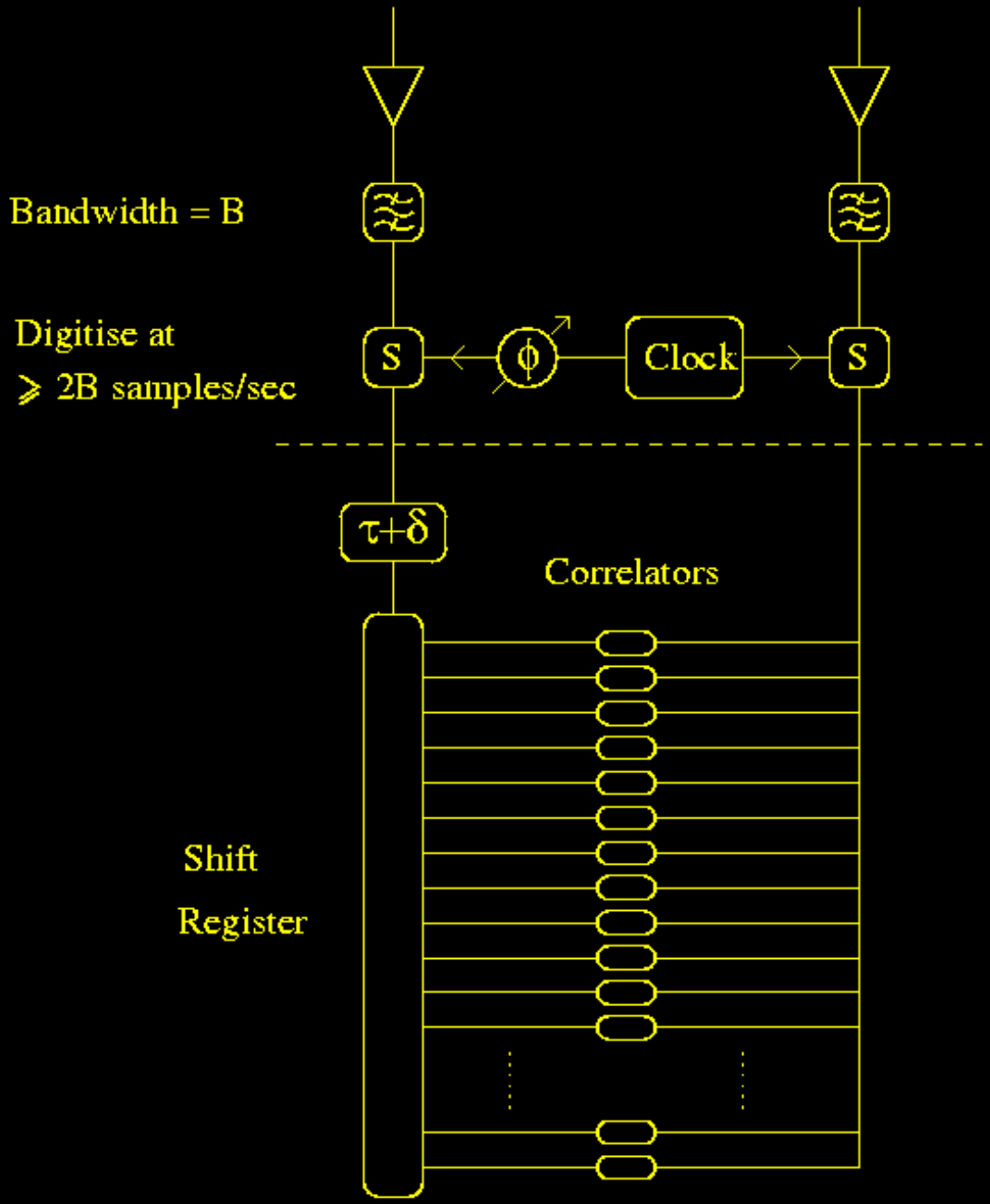
$$V(u,v) = \langle E_1(t) \bullet E_2(t) \rangle$$

Cross Power Spectrum -- Cross Correlation Function

$$V(f) \Leftrightarrow C(\tau)$$

$$C(\tau) = \langle E_1(t) \bullet E_2(t+\tau) \rangle$$

Cross-correlation Spectro-Correlator



Digital Cross-correlator

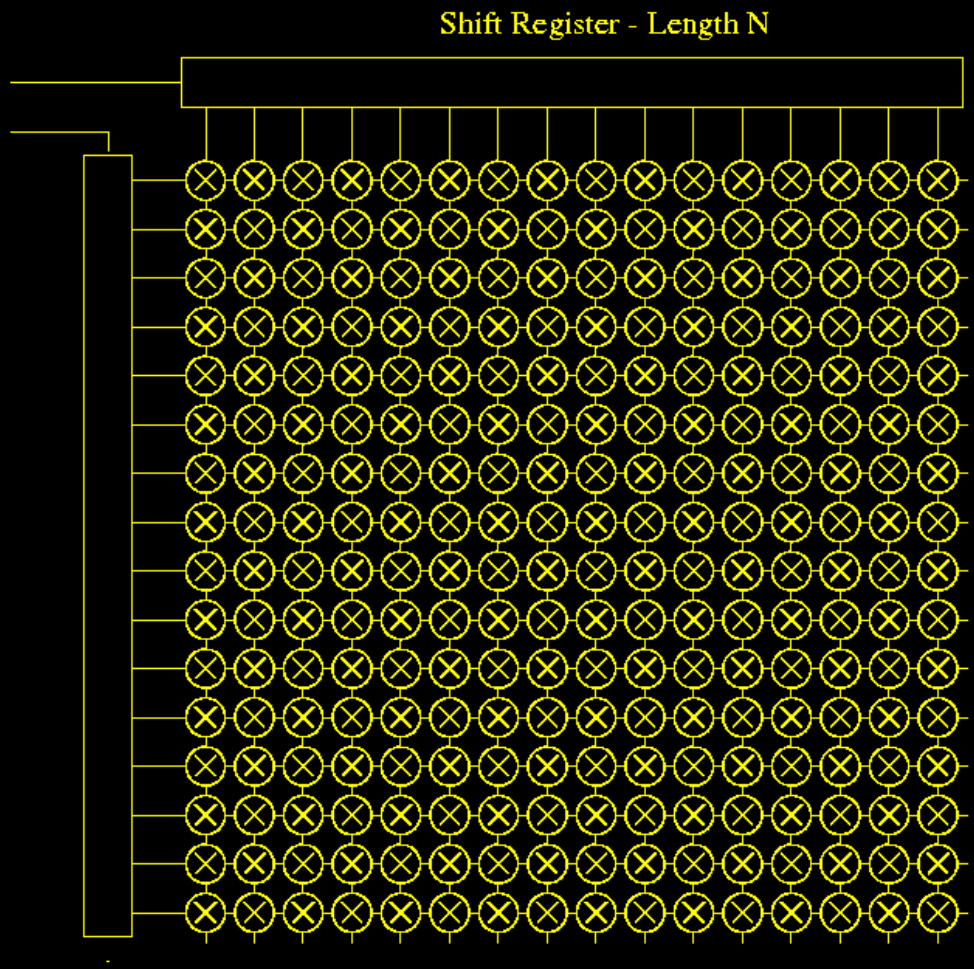
$$C(\tau) = \langle E_1(t) \bullet E_2(t+\tau) \rangle$$

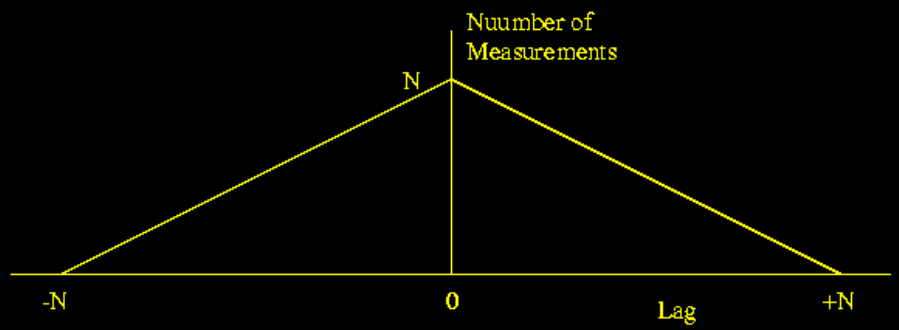
Measure over a range of (positive and negative) delays

The ATCA Correlator

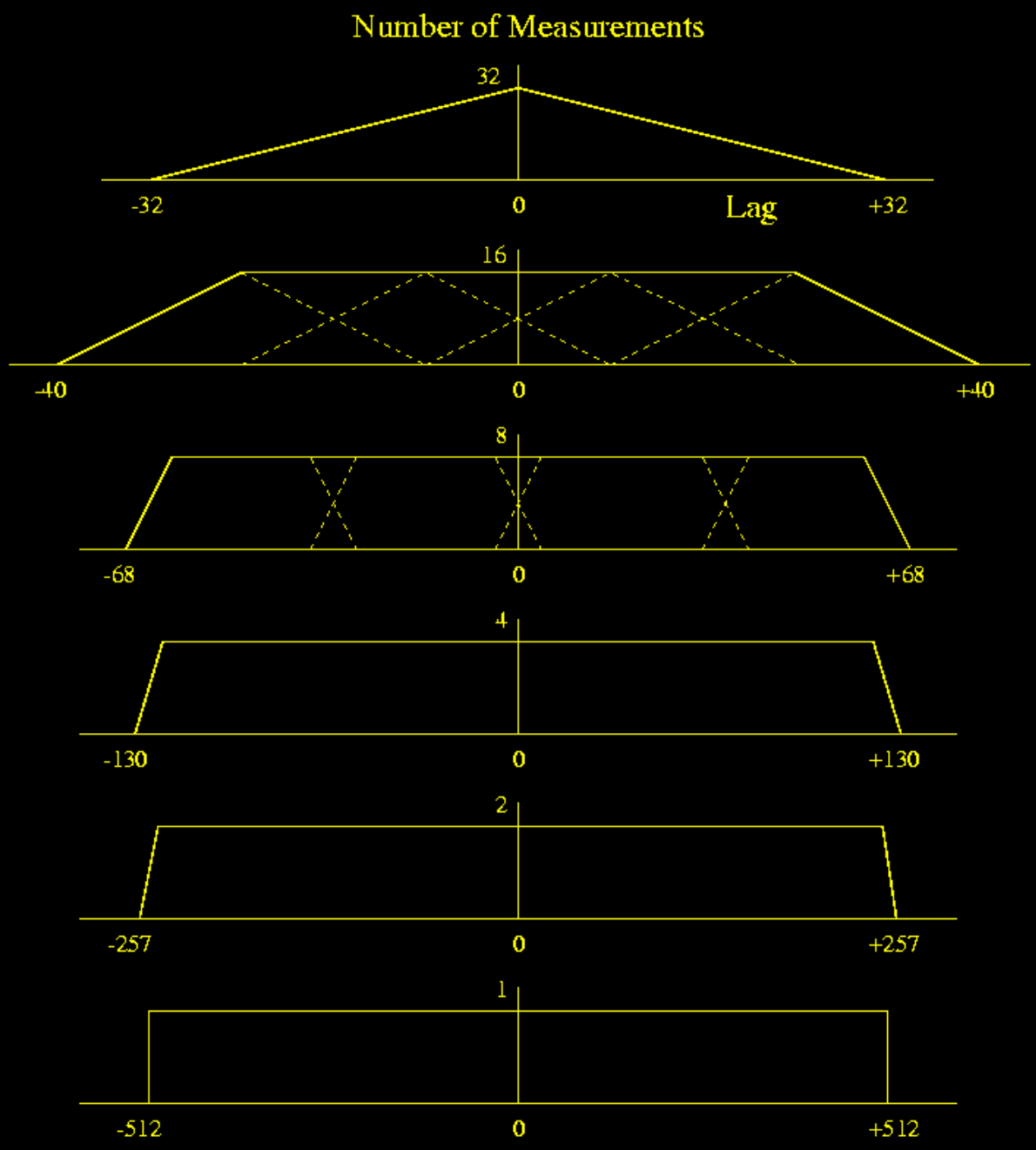
- A digital cross-correlator
- Bandwidths - 128 MHz to 4MHz
- Maximum sample rate - 256 Msamples/sec
- Processing elements - 8 Msamples/sec
- Parallel processing
- Large number of simple processing elements
- 2 bit quantisation

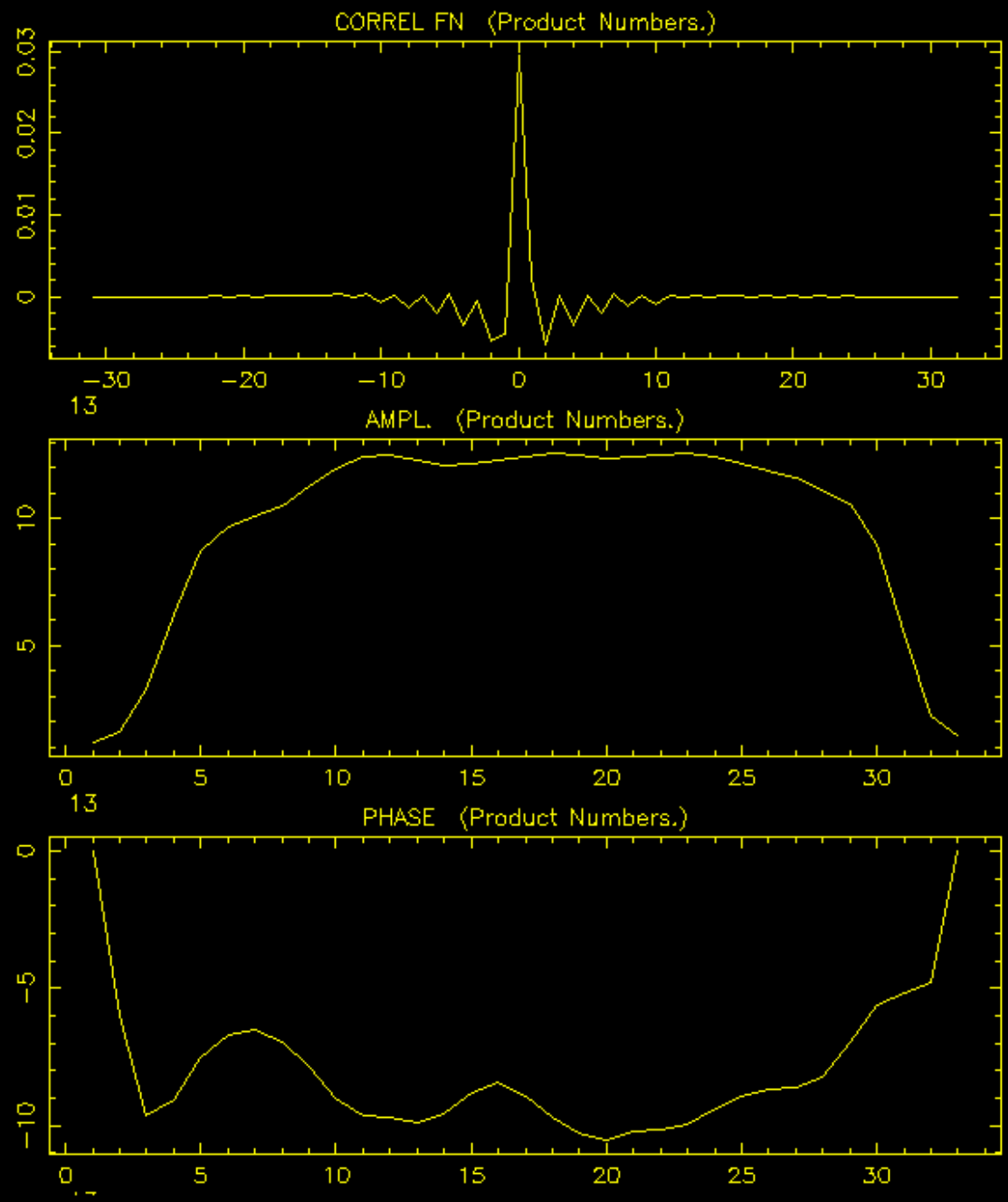
Parallel Processing in the ATCA Correlator

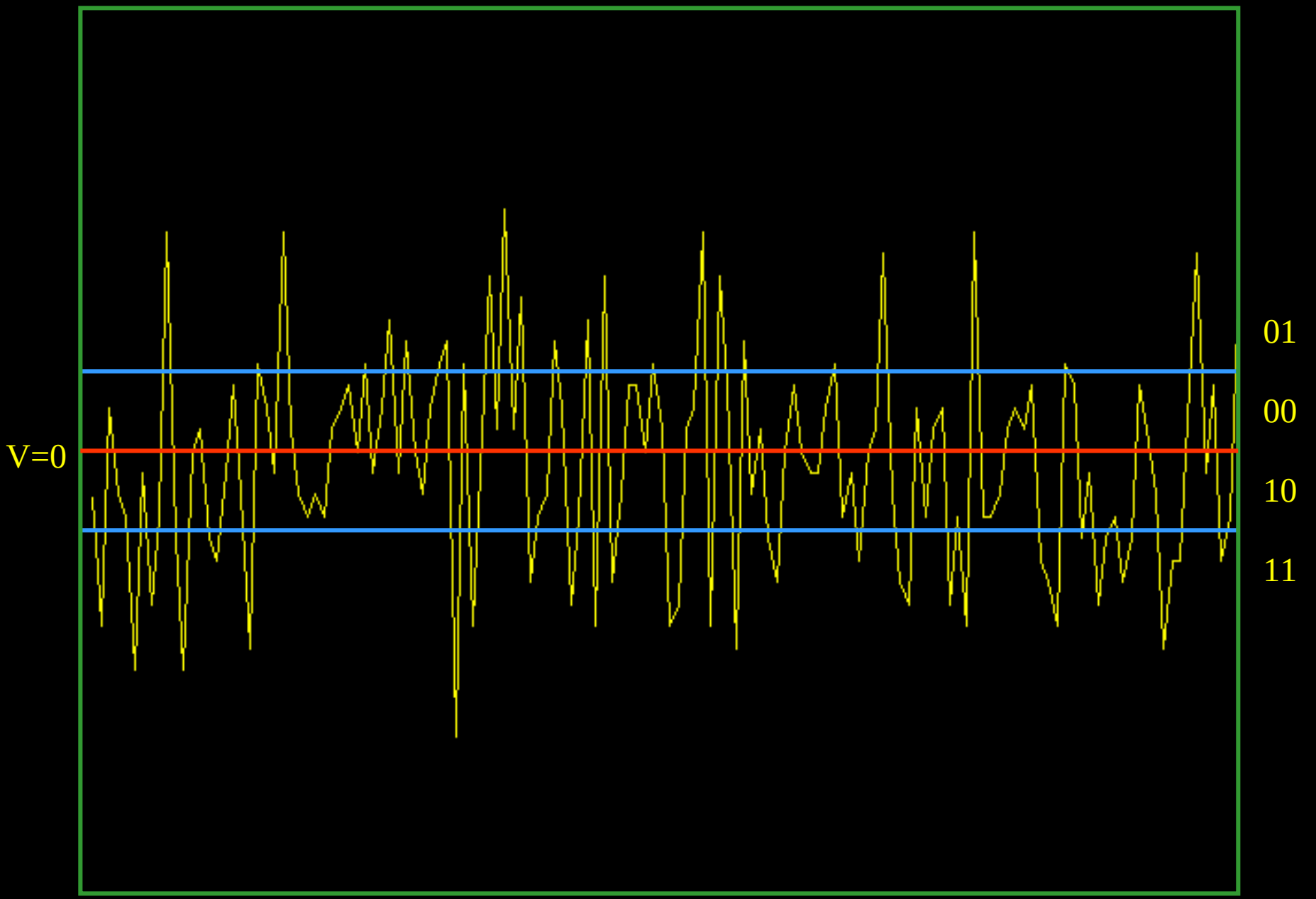




Correlation function window in the lag domain - for maximum bandwidth


Number of Measurements
Bandwidth
32
-32
0
Lag
+32
128MHz
16
-40
0
+40
64MHz
8
-68
0
+68
32MHz
4
-130
0
+130
16MHz
2
-257
0
+257
8MHz
1
-512
0
+512
4MHz


CORREL FN (Product Numbers.)
0.03
0.02
0.01
0
−30
−20
−10
0
10
20
30
13
AMPL. (Product Numbers.)
10
5
0
5
10
15
20
25
30
13
PHASE (Product Numbers.)
0
−5
−10
0
5
10
15
20
25
30


V=0
01
00
10
11

Samplers with coarse quantisation

Bits	Levels	Efficiency
1	2	0.64
2	4	0.88