Adaptive Filters Revisited : RFI Mitigation in Pulsar Observations

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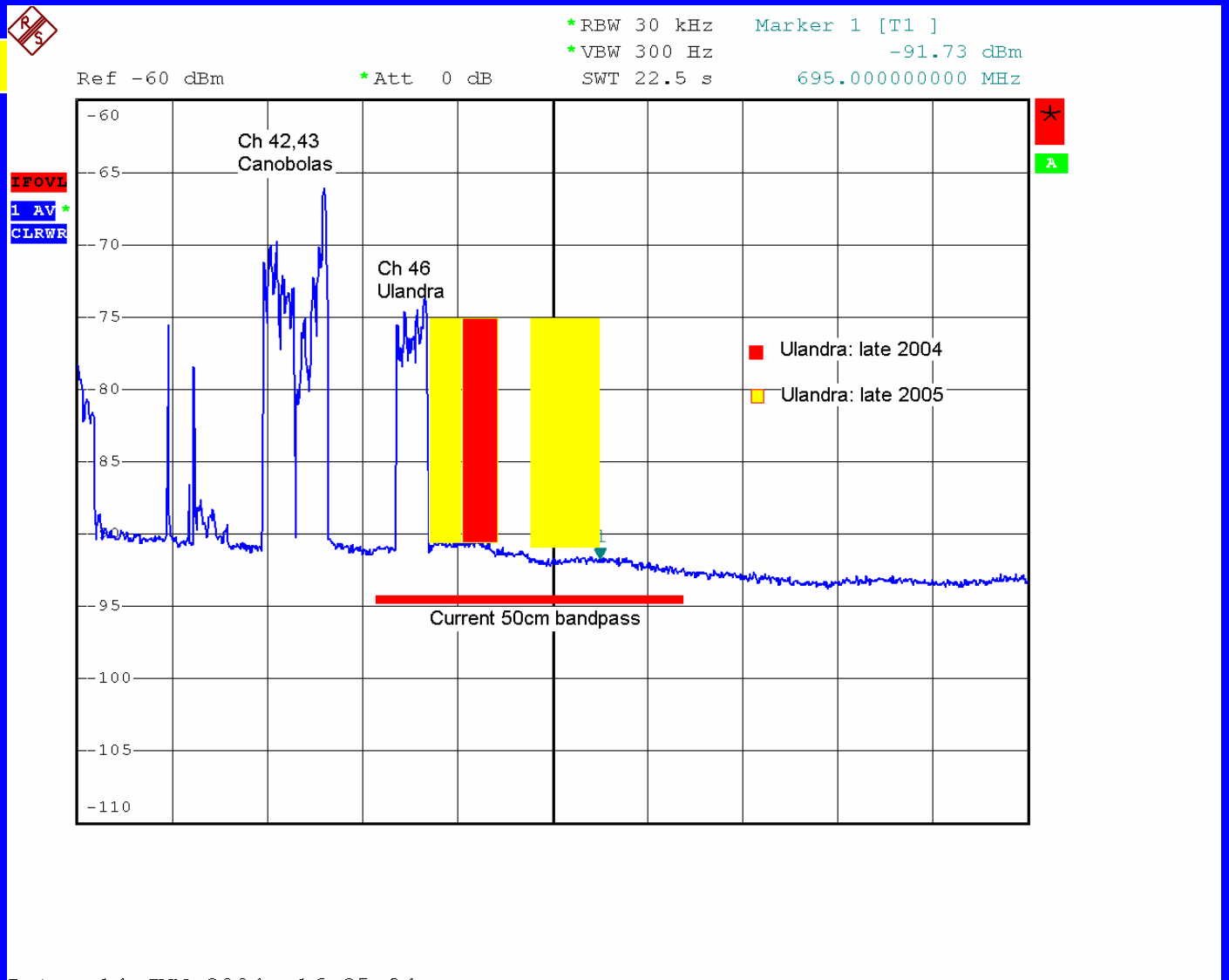
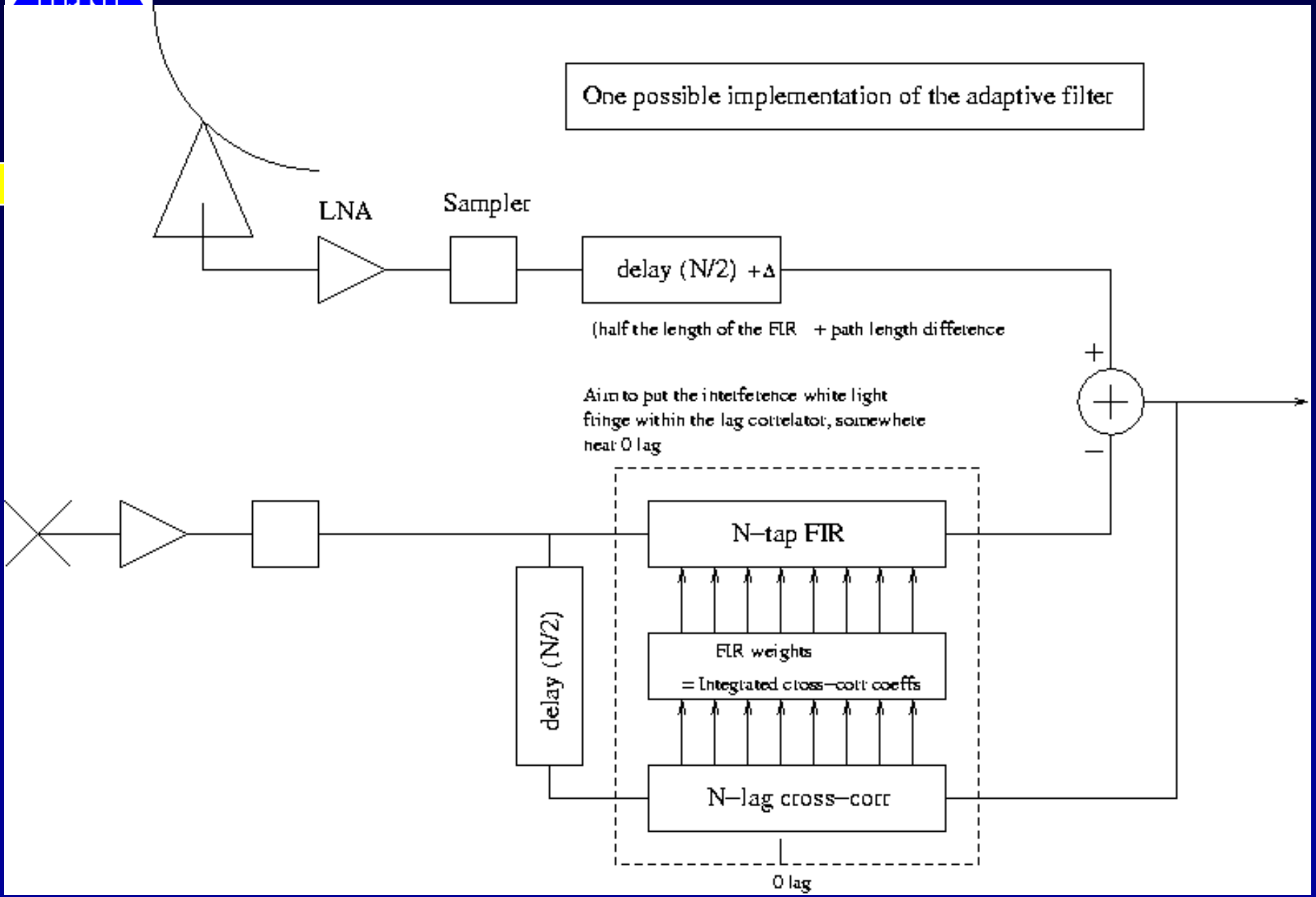
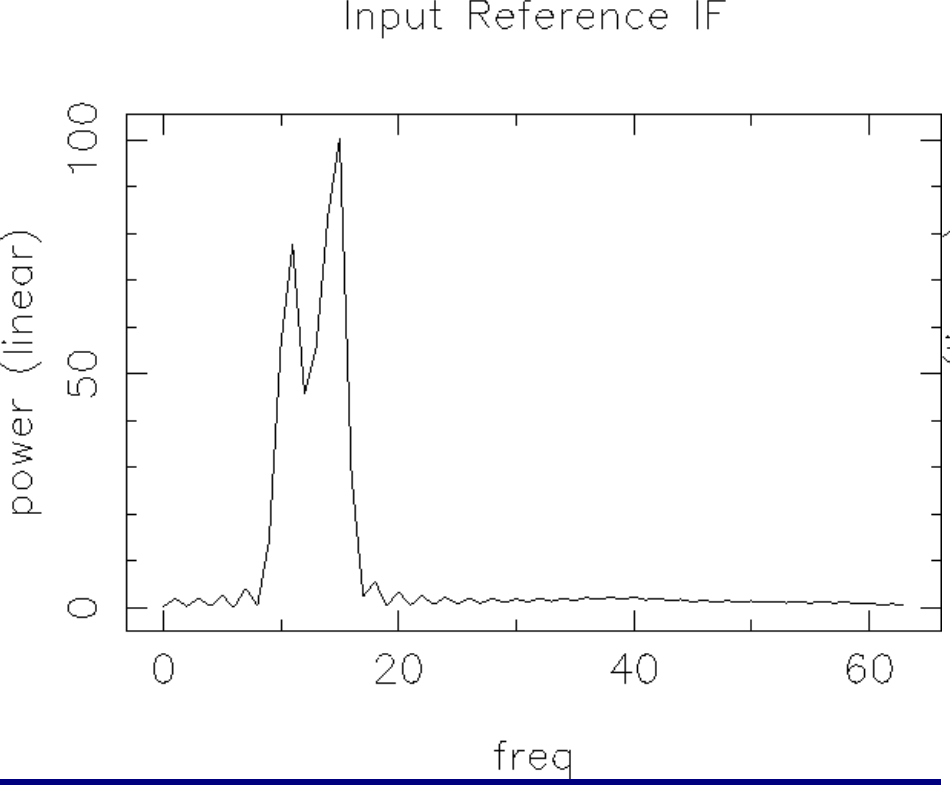
The Motivation : Parkes 50cm Observing Band

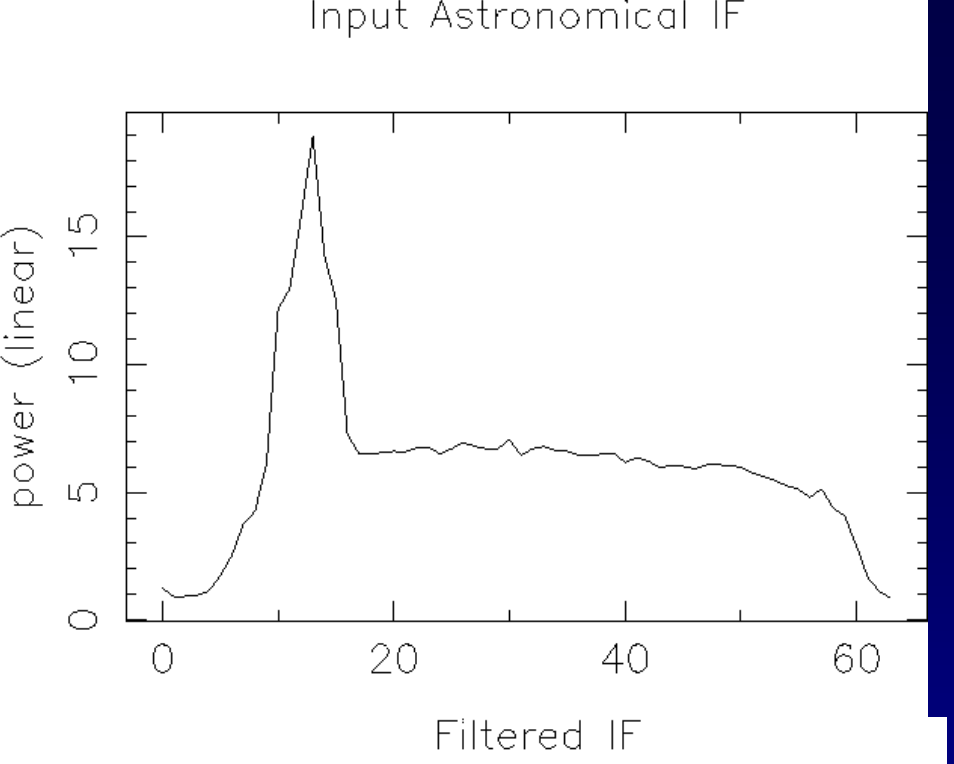


The adaptive filter is well suited to this problem

- It filters the IF – compatible with the downstream processing.
- We know the location of the RFI – a good reference copy is available.
- The RFI is strong.
- Can be implemented in real-time (on-line) hardware.
- The post-correlation alternative is very expensive.

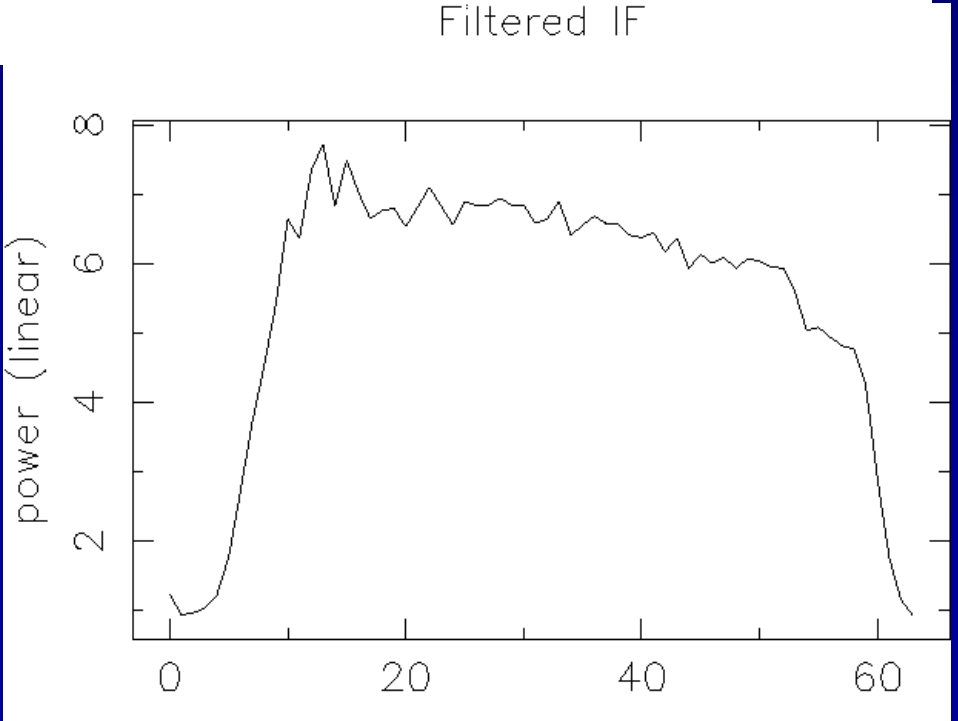

One possible implementation of the adaptive filter
LNA
Sampler
delay (N/2) +Δ
(half the length of the FIR + path length diffetence
Aim to put the intetfetence white light
ftinge within the lag cottelatot, somewhete
neat 0 lag
+
−
N–tap FIR
delay (N/2)
FIR weights
= Integtated cross–cott coeffs
N–lag cross–corr
0 lag





Power spectra

Top: input IF
Bottom : filtered IF



Filter attributes

INR = Interference/RXnoise ratio (reference IF)

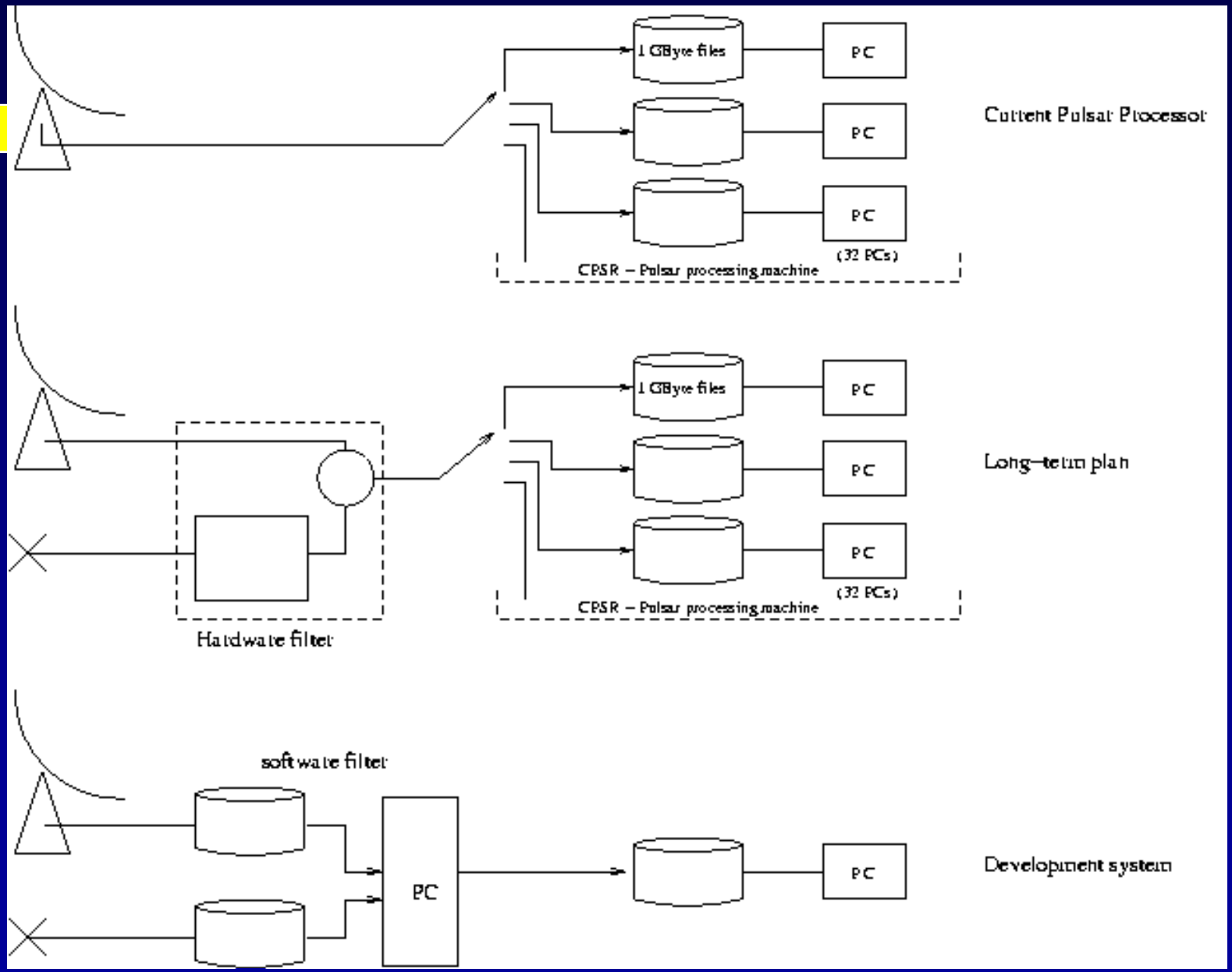
In the signal IF, RFI power is replaced by :

RXnoise, magnitude = RFI power / (1 + INR)

RFI power reduced to RFI power / $(1 + INR)^2$

Filter attributes (2)

- The filter will adapt automatically if the conditions change – to delay/phase/amplitude changes between signal and reference channels.
- Filter fairly neutral to fluctuations in RFI power if common to both signal and reference. (If the RFI transmitter modulates the power level). True for large INR; sampling bits.
- The filter cuts out if there is no RFI common to signal and reference.


1 GByte files
PC
PC
PC
(32 PCs)
CPSR – Pulsar processing machine
Current Pulsar Processor
1 GByte files
PC
PC
PC
(32 PCs)
CPSR – Pulsar processing machine
Hardware filter
Long–term plan
software filter
PC
PC
Development system

Current status

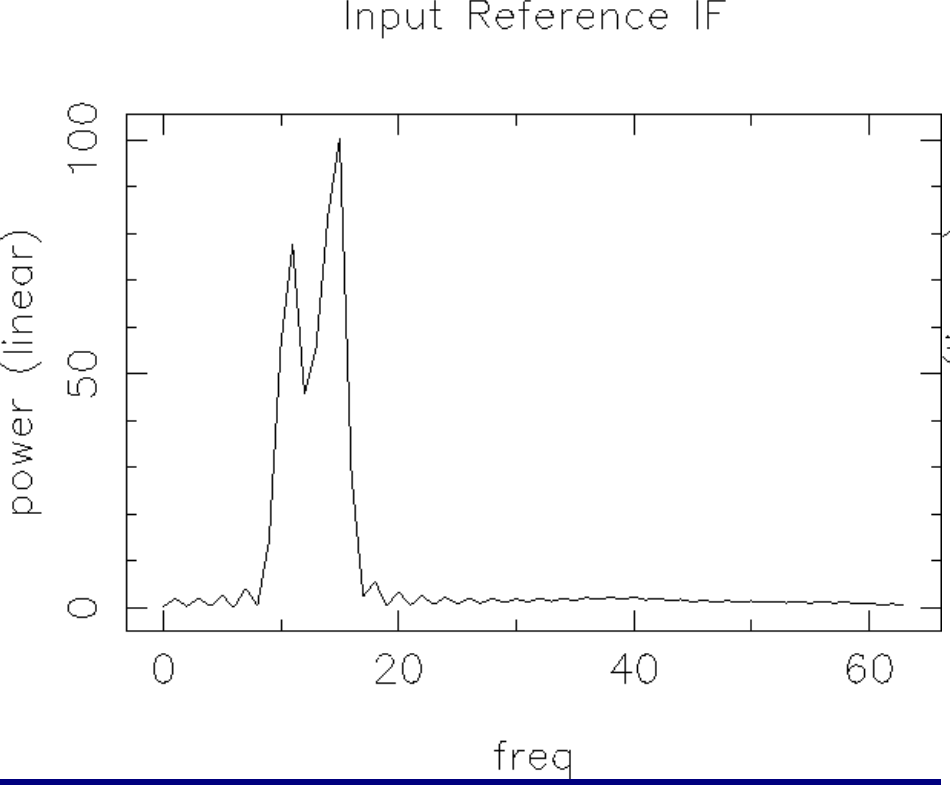
- Software implementation of the filter.
- Baseband data (CPSR2) (1 Gbyte files)

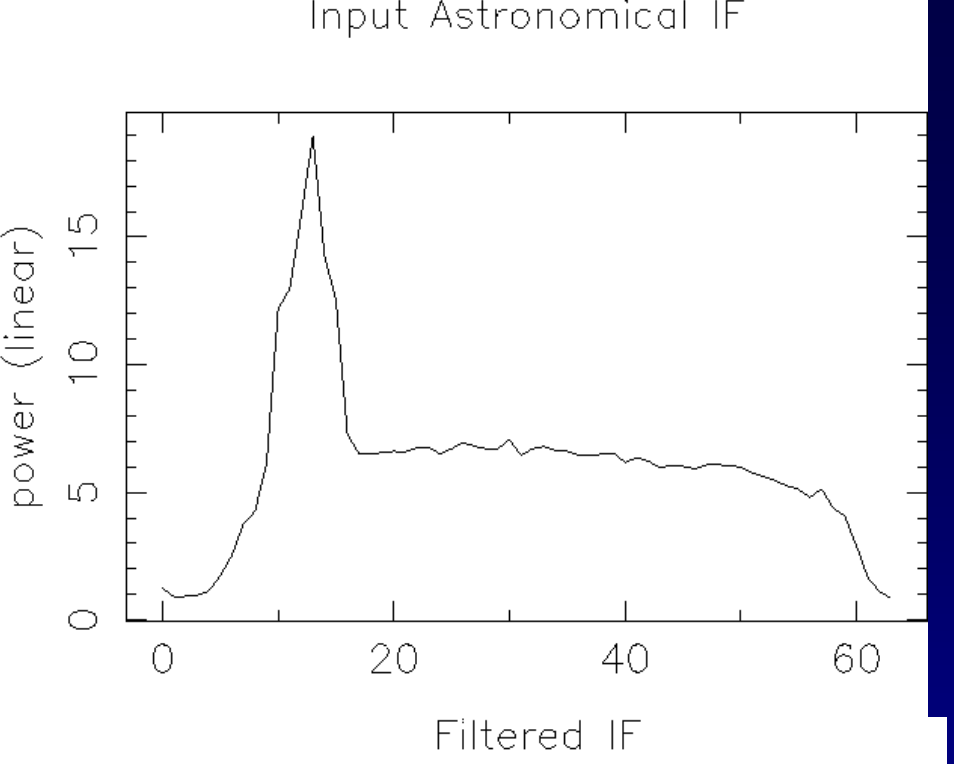
  + Software filter to produce a new CPSR2 data file for de-dispersing/folding.
- We have started to quantify the RFI impact on the pulsar observations and timing.
- We continue to investigate the practical (observational) problems with RFI mitigation.

Field Trials

- 64 MHz bandwidth centred on 675 MHz
- Dual polarisation
- 2-bit sampling
- Pulsar J0437-4715 (5.7 msec period)

- Filter works as predicted – RFI reduced by expected amount
- Filter is linear – the pulse characteristics unaffected





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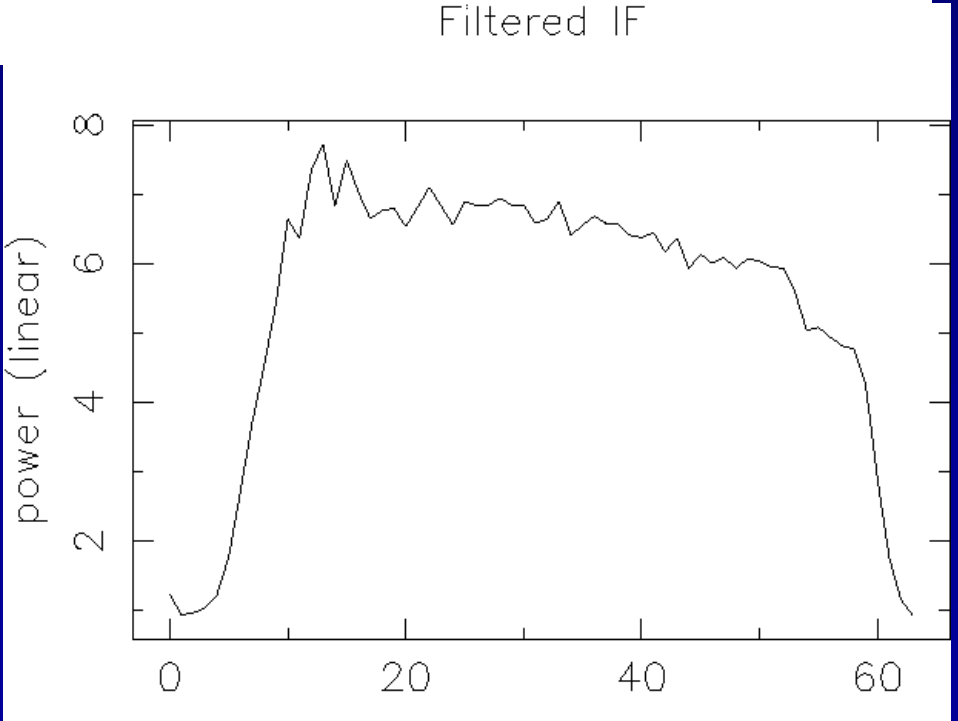
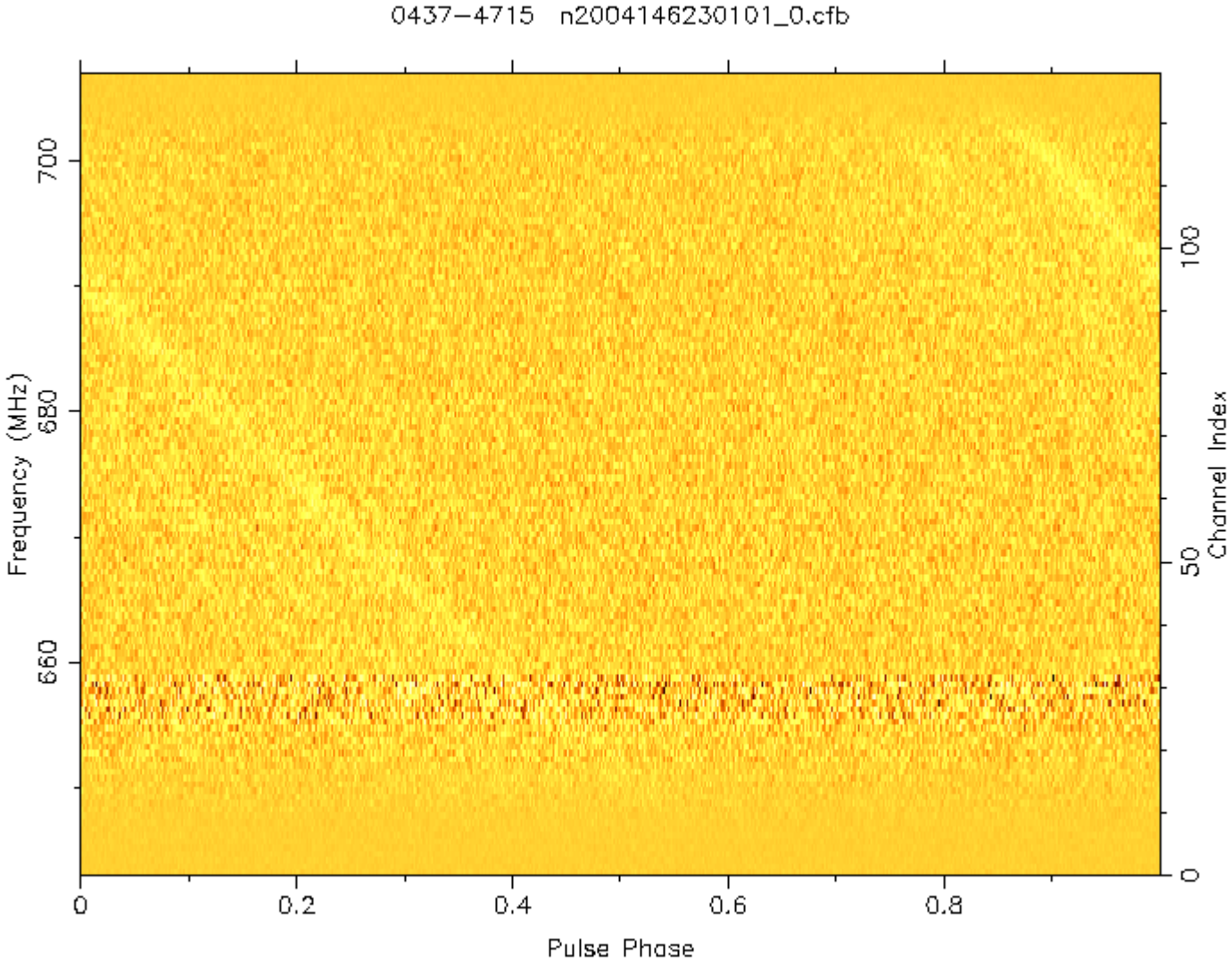
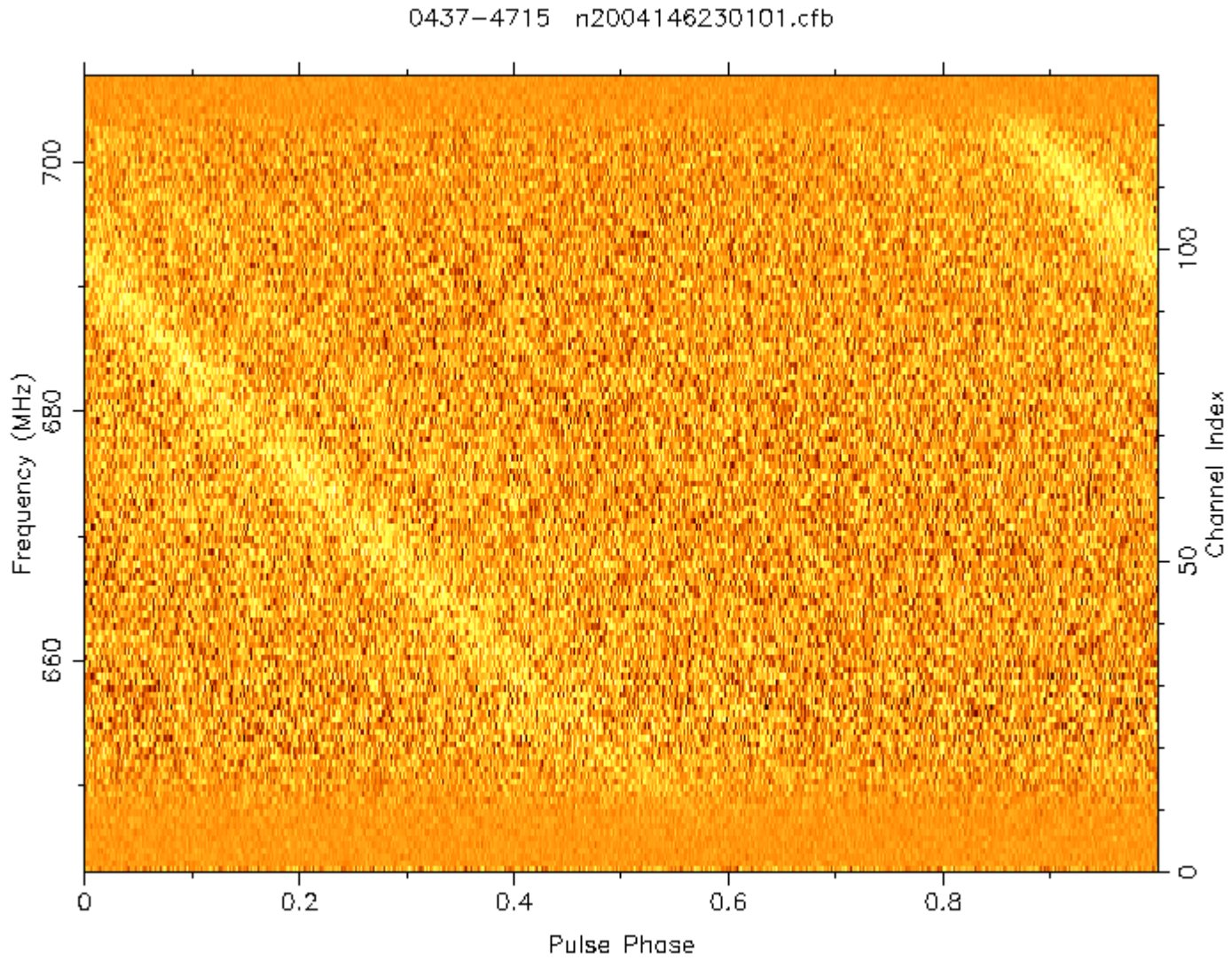
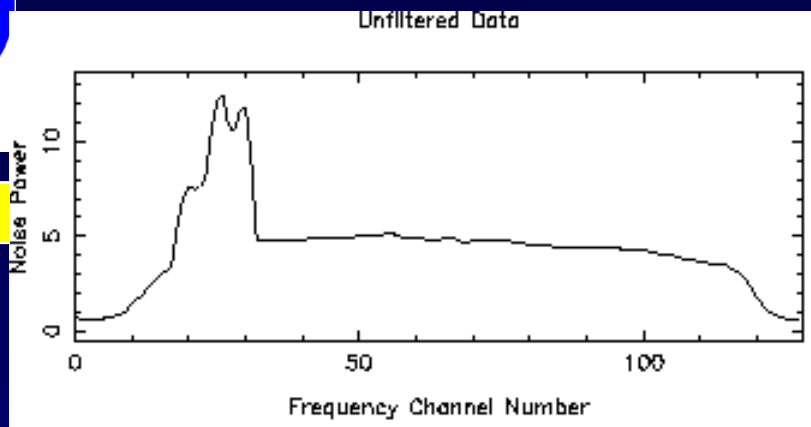


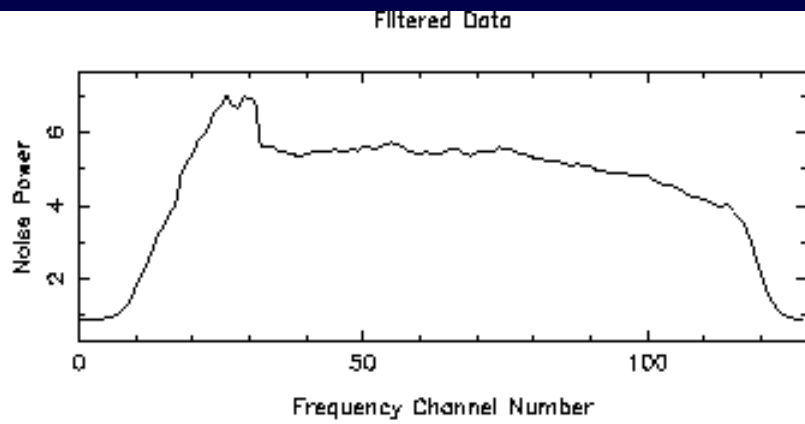
Folded data - unfiltered

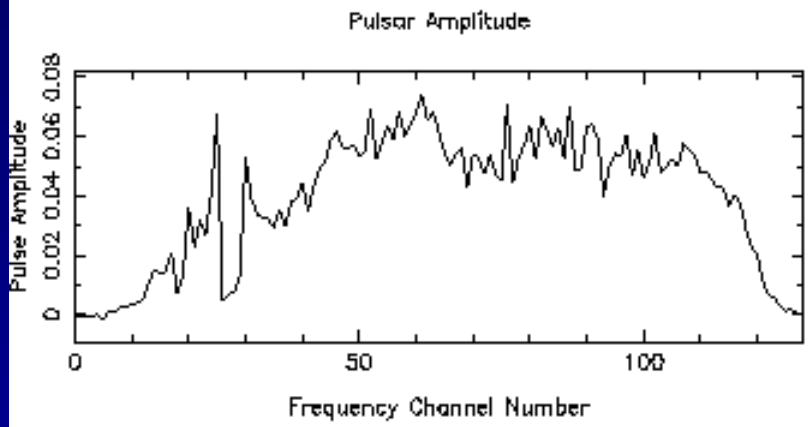


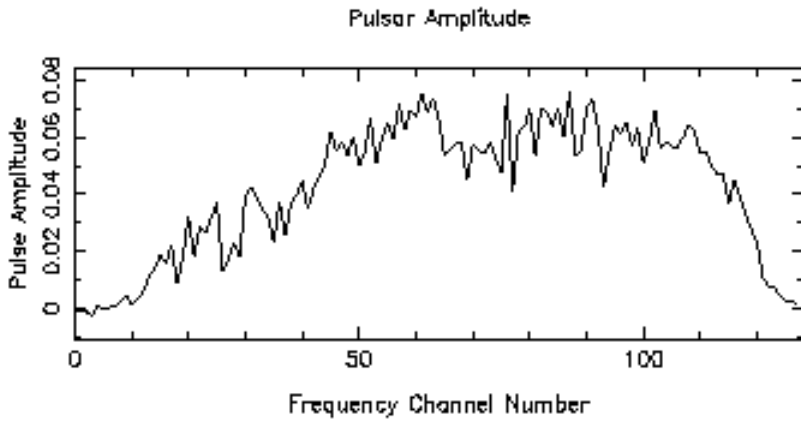
Folded data - filtered

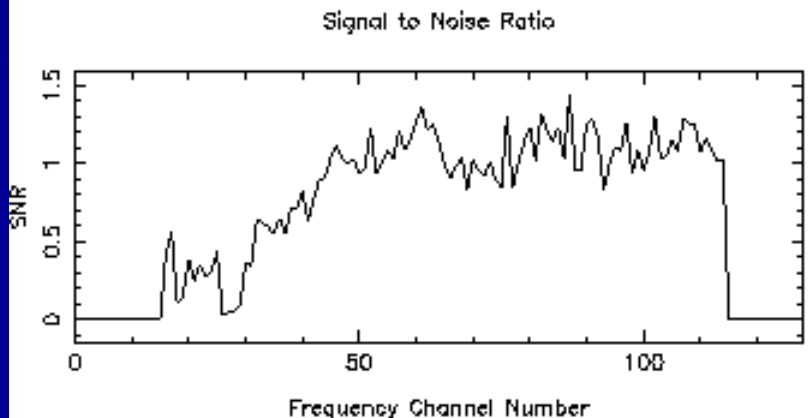


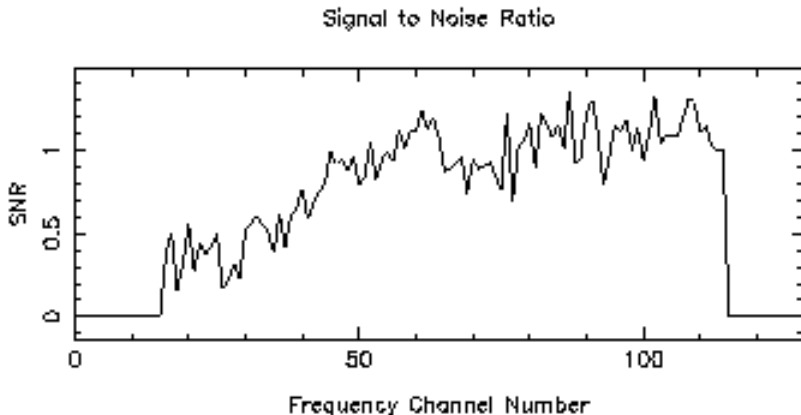

Unfiltered Data
Noise Power
0
5
10
0
50
100
Frequency Channel Number


Filtered Data
Noise Power
2
4
6
0
50
100
Frequency Channel Number


Pulsar Amplitude
Pulse Amplitude
0
0.02
0.04
0.06
0.08
0
50
100
Frequency Channel Number

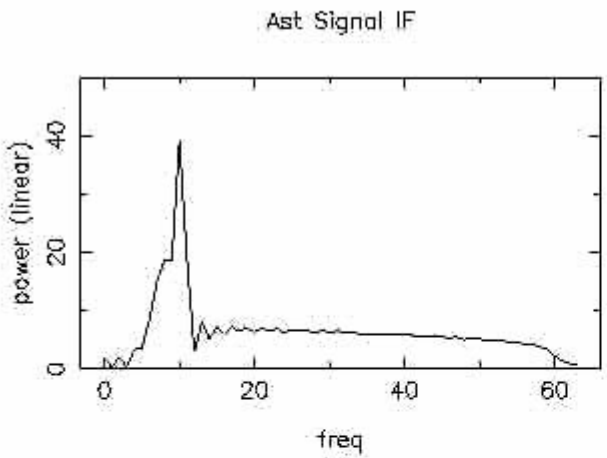

Pulsar Amplitude
Pulse Amplitude
0
0.02
0.04
0.06
0.08
0
50
100
Frequency Channel Number

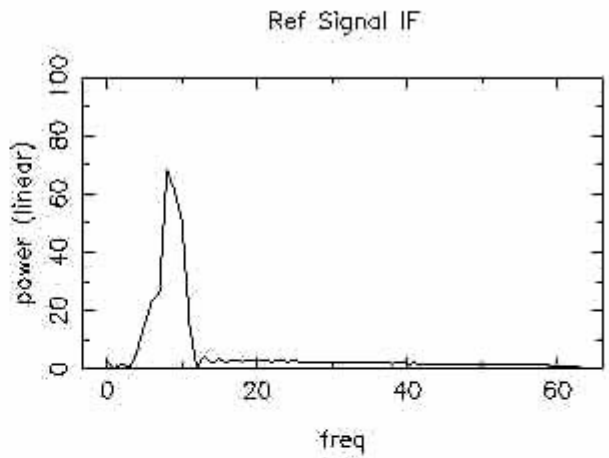

Signal to Noise Ratio
SNR
0
0.5
1
1.5
0
50
100
Frequency Channel Number

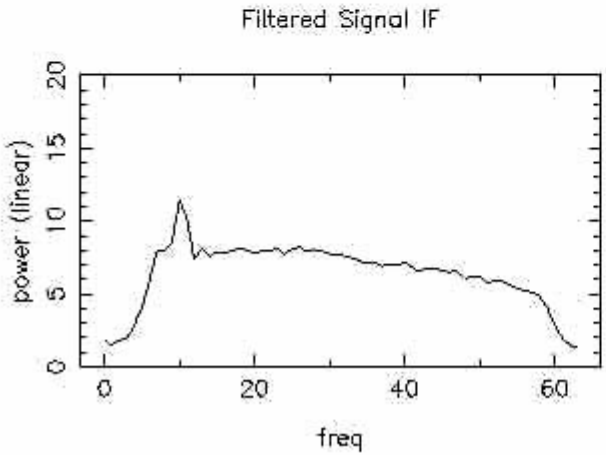

Signal to Noise Ratio
SNR
0
0.5
1
0
50
100
Frequency Channel Number

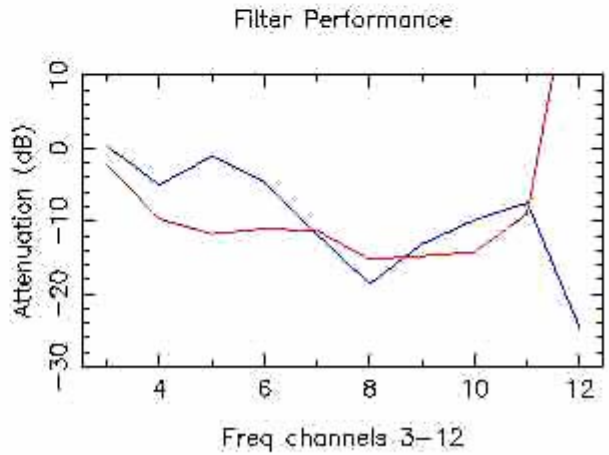
Problems

- Low INR – multipathing ?
  - Try bigger antenna (3m on tower)
  - Try spatial diversity (two reference antennas)
  - Try decoding the digital TV signal (this strategy worked on glonass)
- Multipathing
  - Sets lower limit on the update time in the filter

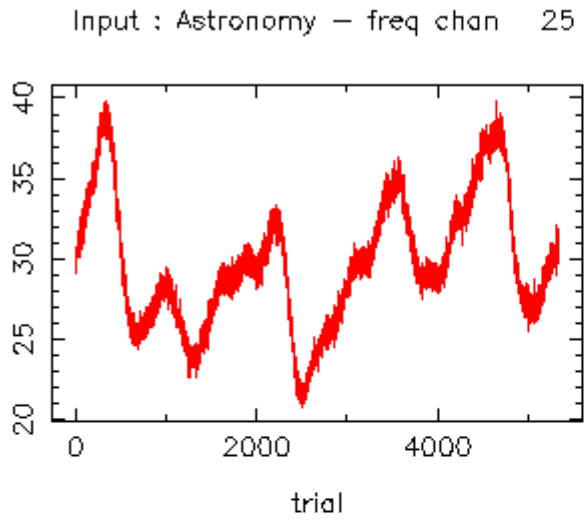

Ast Signal IF
power (linear)
0
20
40
0
20
40
60
freq

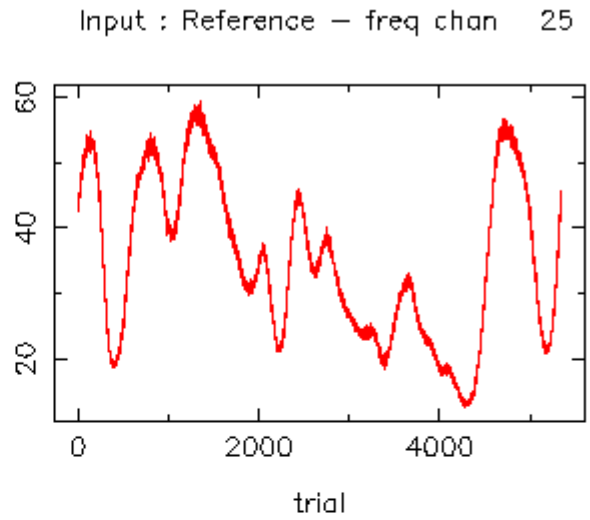

Ref Signal IF
power (linear)
0
20
40
60
80
100
0
20
40
60
freq

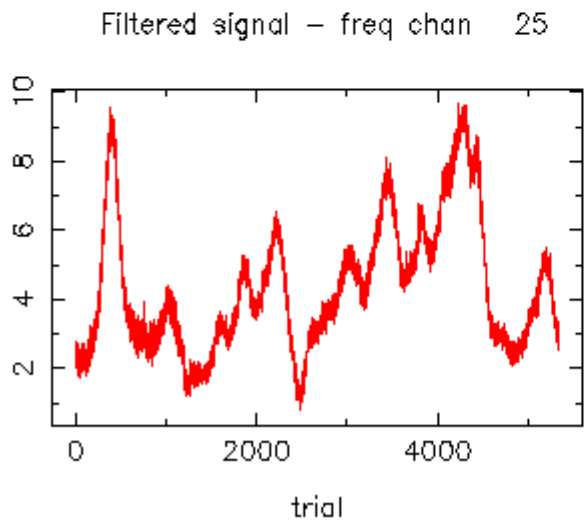

Filtered Signal IF
power (linear)
0
5
10
15
20
0
20
40
60
freq

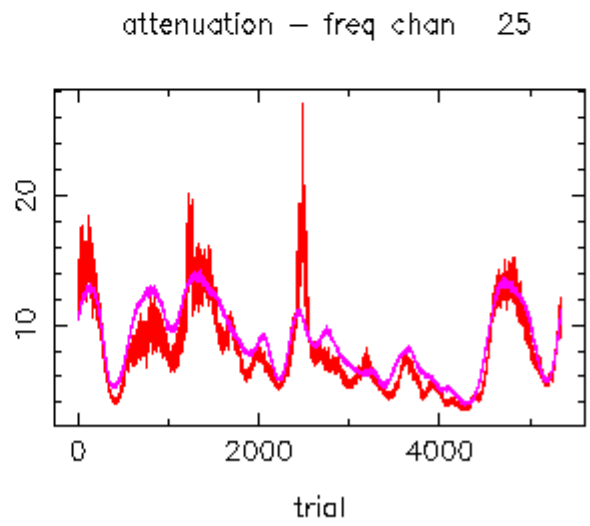

Filter Performance
Attenuation (dB)
−30
−20
−10
0
10
4
6
8
10
12
Freq channels 3–12

Filter performance over 15 secs – multipathing affects relative amplitudes and phase. Filter updated every 3 ms









Sampling issues

- S/N degradation at the initial sampling
- Non-stationarity
- S/N degradation at the resampling stage
- Dynamic range limitations

Problems (2)

- Resampling noise: 2-bit into filter; floating operations within the filter; 2-bit out for the down-stream processing.

- 2-bit sampling. Will be an issue when higher dynamic range is required. Current system has attenuation in the 10 to 1% range

Conclusions

- The adaptive filter works well for pulsar observations.
- We plan to start the hardware (FPGA) implementation.
- Maintaining a large INR is clearly a challenge, and is perhaps the main limiting factor.

Project plans

- Develop a hardware filter (FPGA) installed in the IF chain in front of the on-line processor (CPSR at Parkes).
- Improve our understanding of RFI mitigation problems.

Software Issue

- The software filter is slow - after some effort, it now takes 10 minutes to process 15 sec of data.
- The processing was much improved with the (Intel) IPP library.