Amateur Pulsar Detection Using the RTL2832U DVB-T and a 3m Dish

Peter East, with assistance from
Guillermo Gancio, Michiel Klaassen and Steve Olney

Introduction

- Background
- Why RTL SDR?
- RTL Radio Telescope
- Detecting Pulsars
- Challenges
- Improving Chances
- Conclusions

Amateur pulsar detection?

The Plan

Beg real Data from Experts

Write some software, check SNR

Understand Radio Telescope Performance

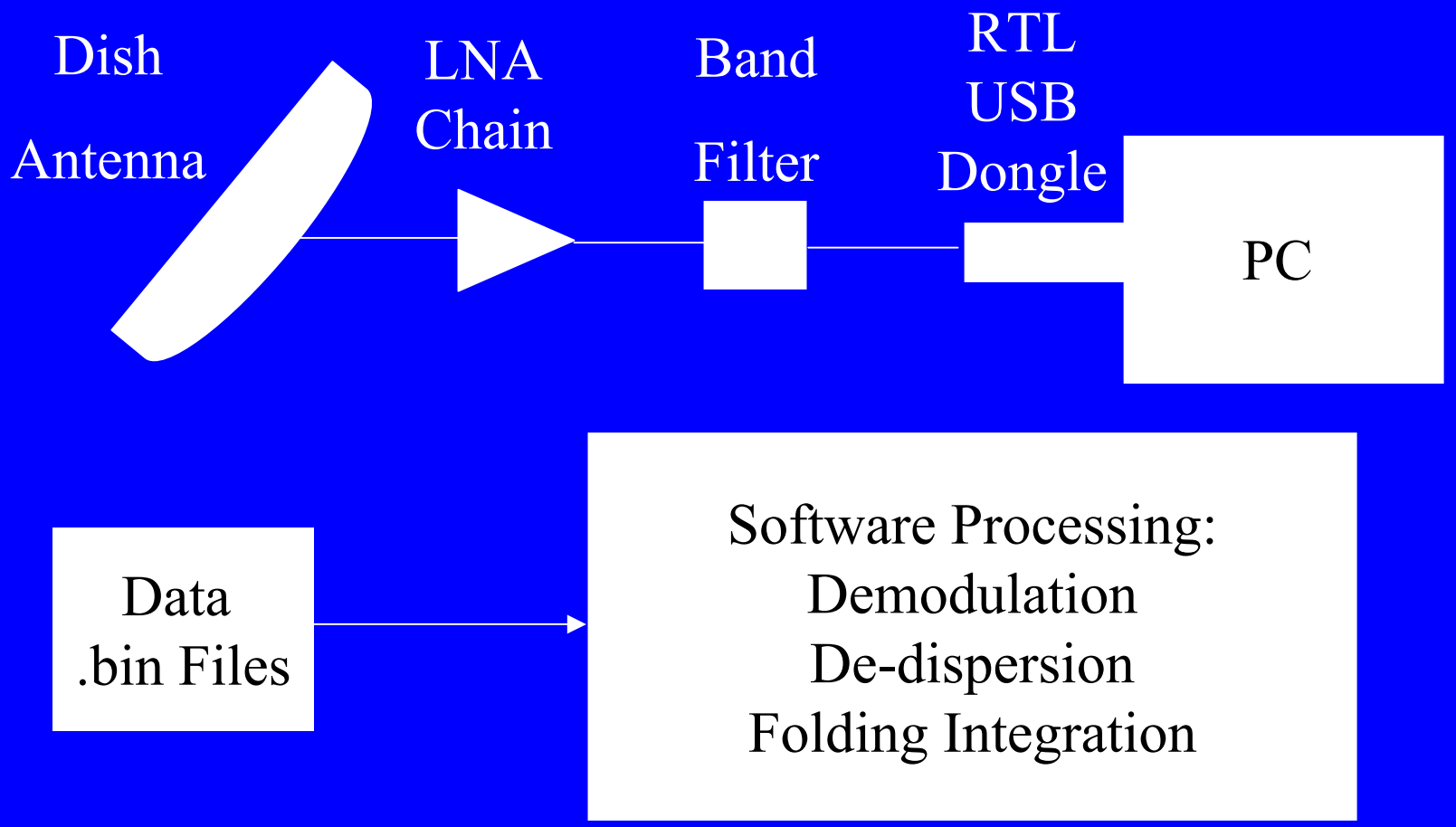
Scale the System Parameters

Try it out

RTL2832U USB Dongle

- The RTL2832U is a ‘high-performance’ DVB-T (Digital Video Broadcasting - Terrestrial) demodulator with a USB 2.0 interface.
- It outputs 8-bit I/Q-samples at bandwidths up to 2.4MHz and tunes over 25-1800MHz

RTL Pulsar Radio Telescope



Available Software

Testing: SDR# + Zadig Driver
from: sdrsharp.com

Data: Osmocom rtl tools rtl_sdr.exe
from: sdr.osmocom.org

Folding: rapulsar2.exe
from: y1pwe.co.uk/RAProgs

Display: Excel/MathCad

Professional: Tempo, Presto, Sigproc
from: pulsarastronomy.net

Digital SDR Features

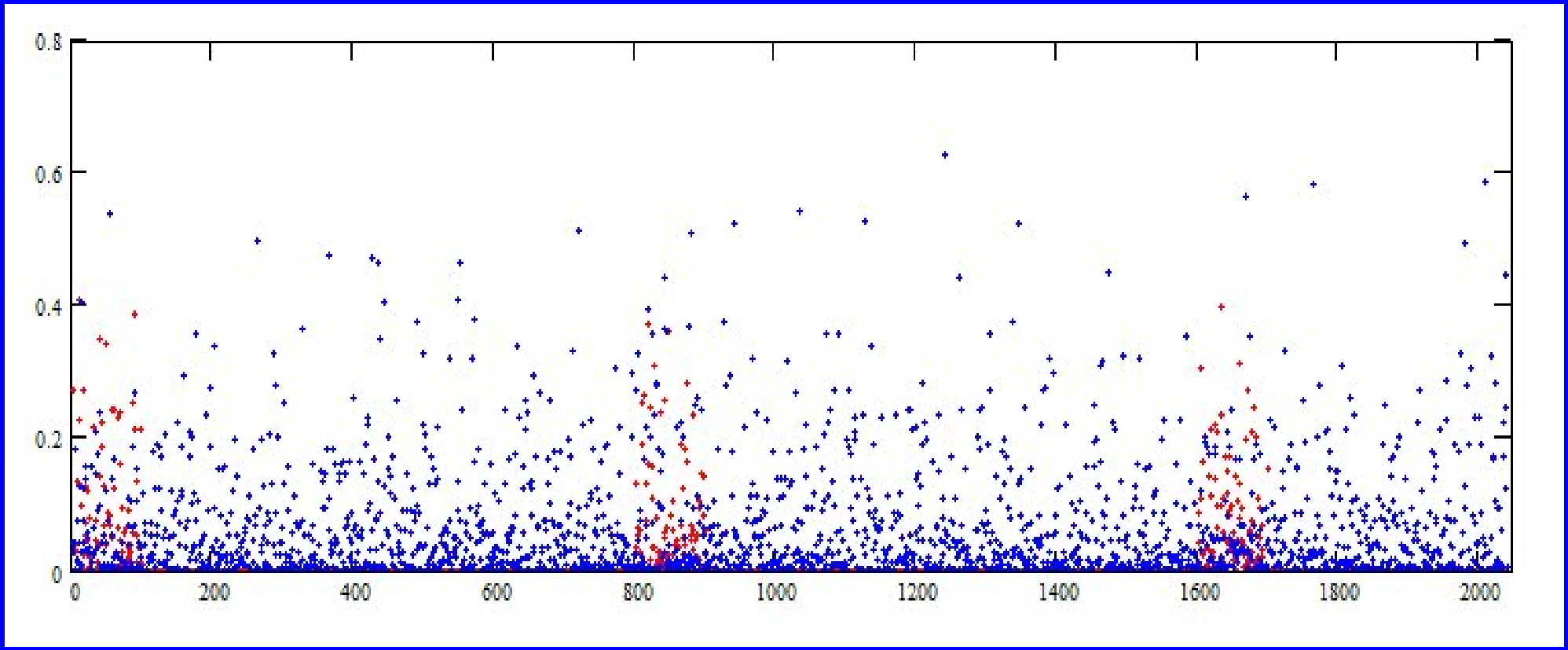
- RTL SDR is cheap, but can be better
- Data recording + post-processing
- Radiometer Equation:

$$\Delta T = Tsys/\sqrt{(BT/N)}$$

Comparison of H-Line and Pulsar Detection

H-Line		Pulsar	
100ºK cloud 5º x 5º say	4ºK	Point Source 25Jy Peak	4ºK
25º BW Yagi	0.5m 100sec	Large Dish	30m 100sec
100ºK Tsys	0.16 ºK	100ºK Tsys	0.071 ºK
512pt FFT	400,000	100bin Fold	140
2MHz RF RTL	SNR 25	2MHz RF RTL	SNR 56

RTL Detected Pulsar Data



Detection Process

Within the pulsar pulse:

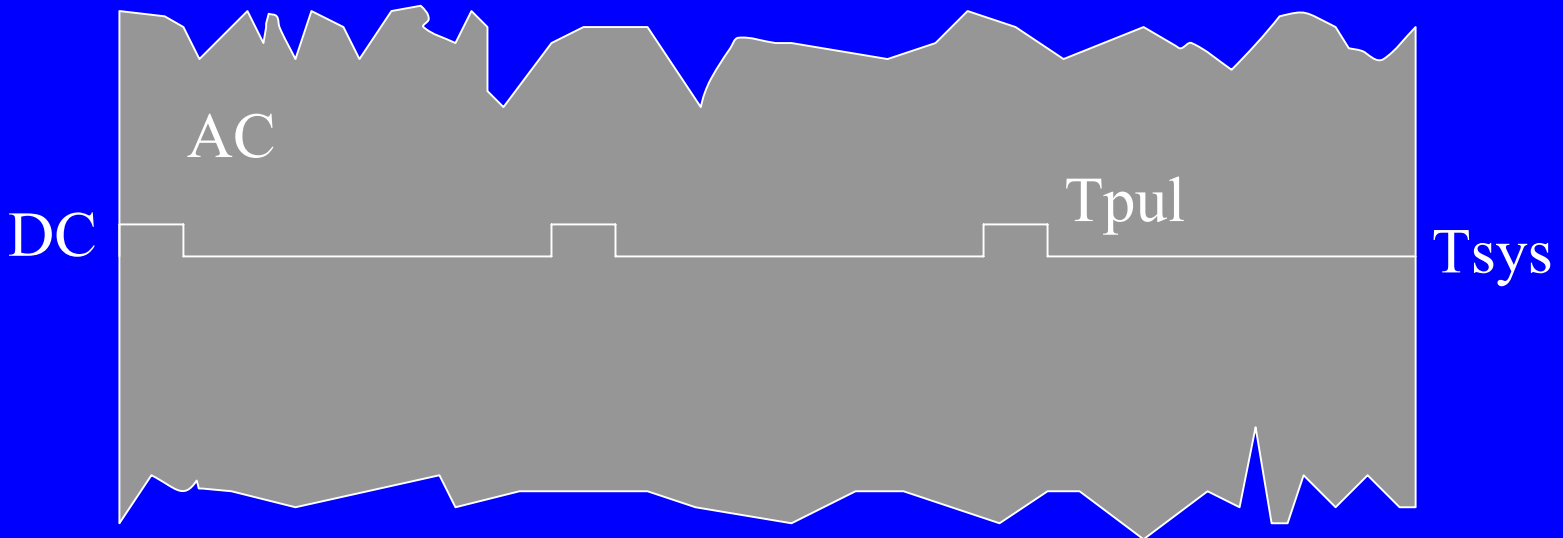
The receiver noise = k(Tpul + Tsys)B

and outside = k(Tsys)B

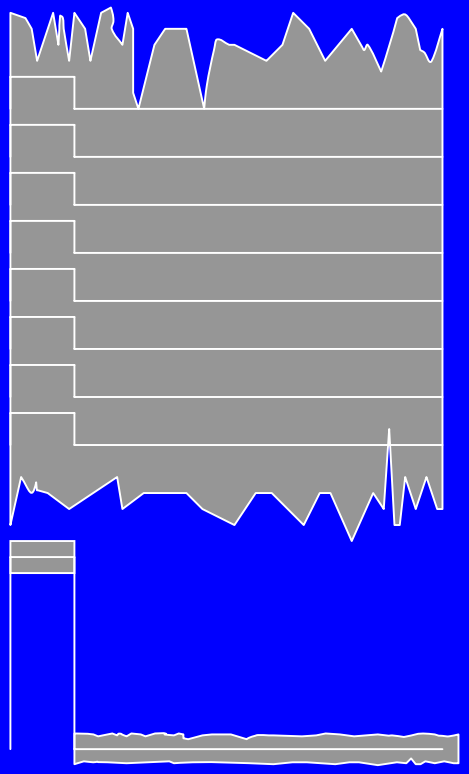
Tpul and Tsys are the pulsar and system noise temperatures.

k is Boltzsmann's Constant, B the RF bandwidth

Squaring the I and Q components (square-law detection) results in both AC (α BBv) and DC (α B^2) components.



Folding



* Pulse adds linearly
* Noise adds as square root
* SNR improves as √(No. Folds)

$$SNR = \sqrt{(BT/N)} \times Tp/Tsys$$

* Optimum No. bins = Period/Pwidth
* Highly tuned period filter

Data Processing – DOS cmd.exe

OsmoCom rtlsdr library & capture tool: ‘rtl_sdr.exe’.
The capture tool generates files containing raw IQ ADC data from the dongle in hex form (viewing software: ‘hexdump.exe’).

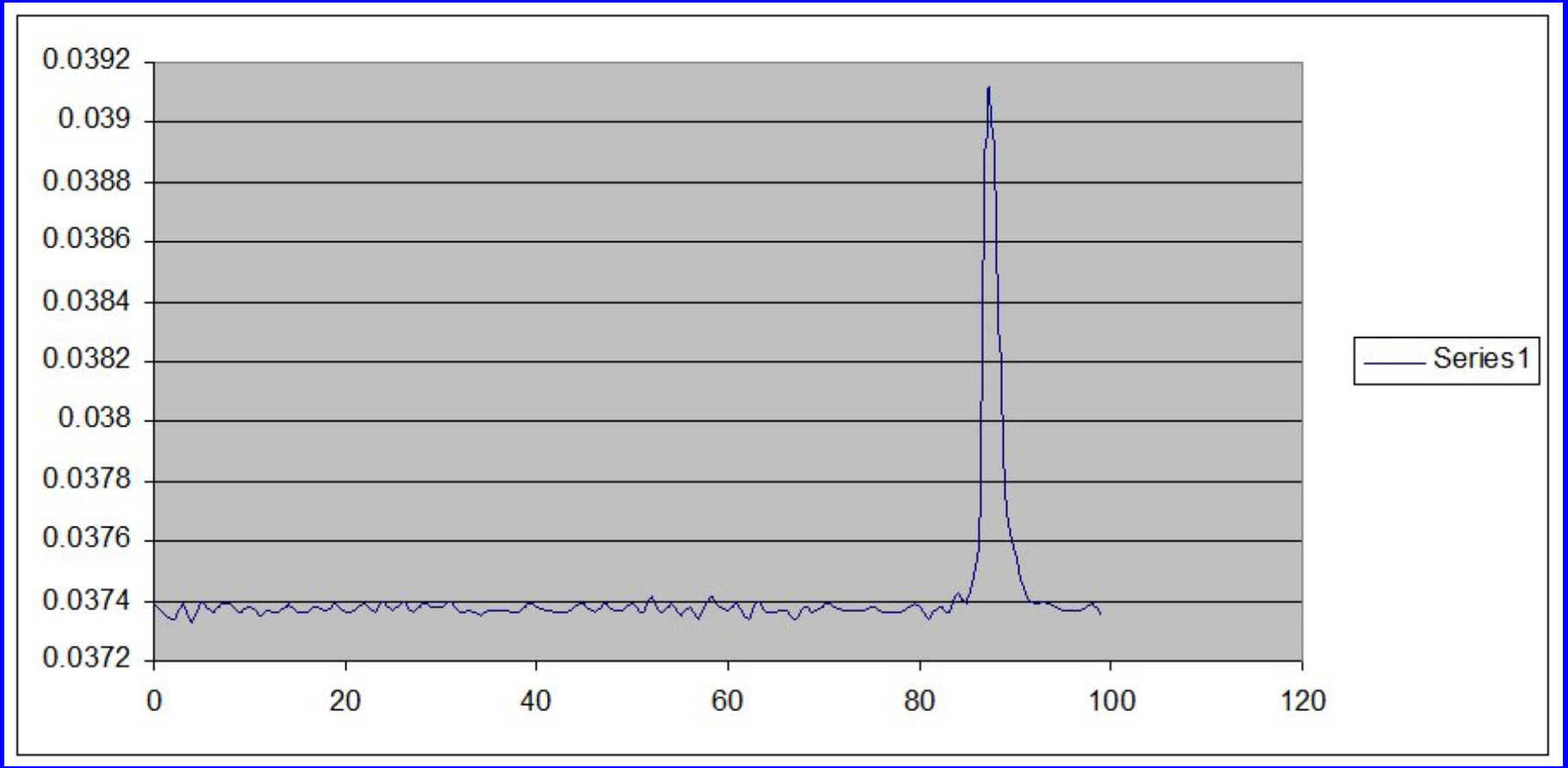
rtl_sdr ./data.bin -f 1420e6 -g 42 –n 1e9

rapulsar2.exe processes this to carry out folding.

- It breaks data into blocks equal in time to the pulsar period
- Sums the blocks.
- Outputs a text file that can be viewed in Excel or Math CAD.

rapulsar2 data.bin data.txt 100 89.39

Vela Pulsar B0833-45

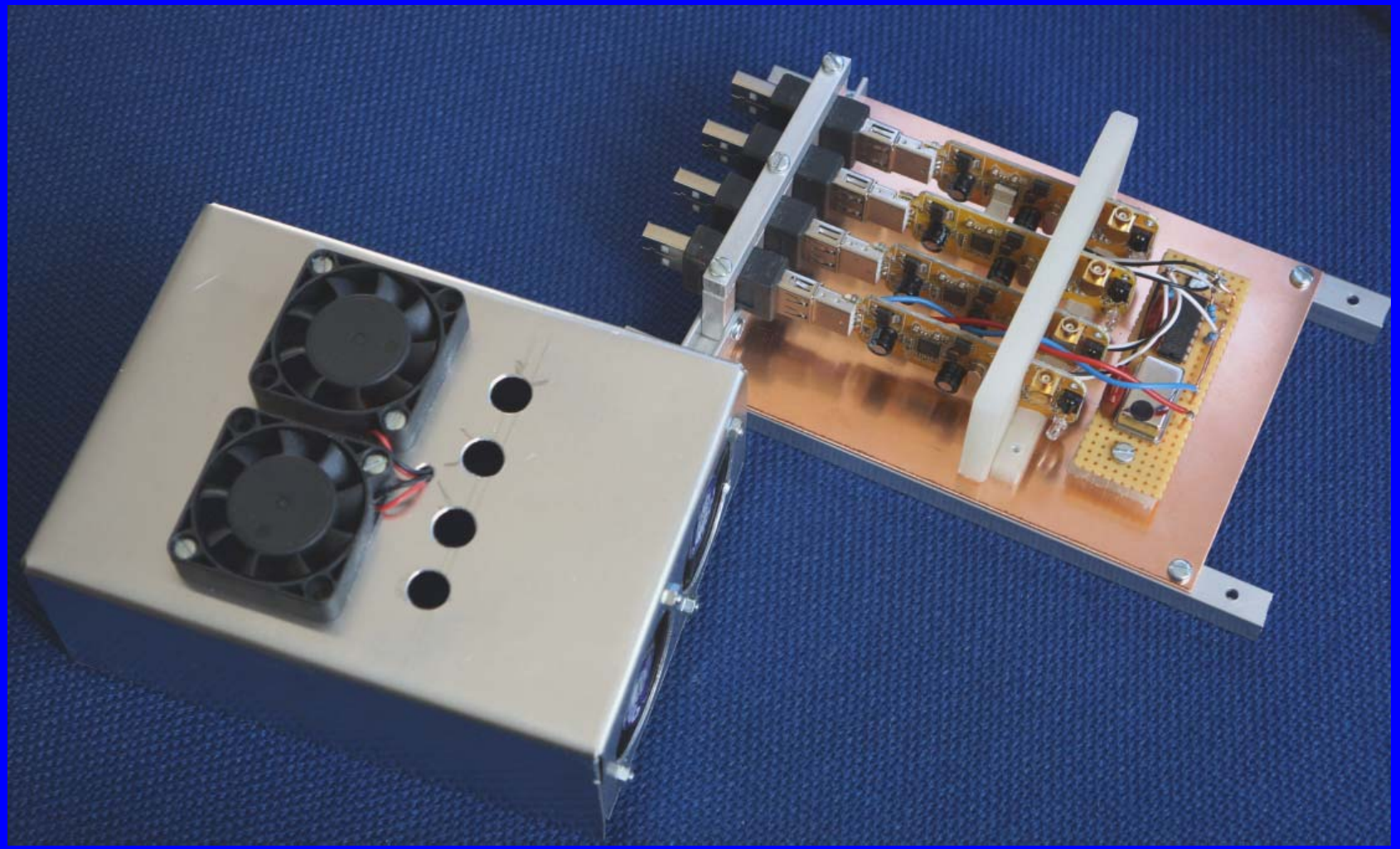


Data Source (30m): Guillermo Gancio

Amateur Pulsar Detection Systems

Pulsar	30m 2MHz RF	3.0m 2MHz RF	3.0m 10Mhz RF	3.0m 10MHz RF
25Jy Peak	4ºK	0.04ºK	0.04ºK	0.04ºK
30m Dish	500sec	10800sec	3600sec	1800sec
110ºK Tsys	0.035 ºK	0.0075 ºK	0.0058 ºK	50ºK Tsys 0.0037 ºK
100bin Fold	SNR 114	SNR 5.3	SNR 7	SNR 11

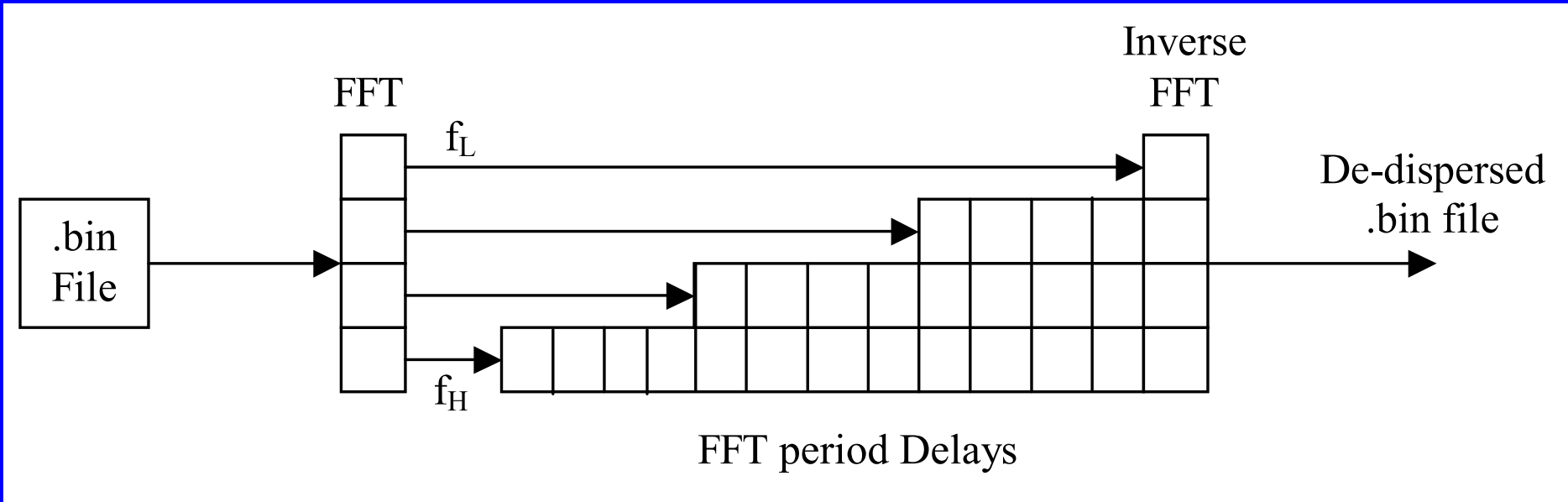
Quad RTL Rx



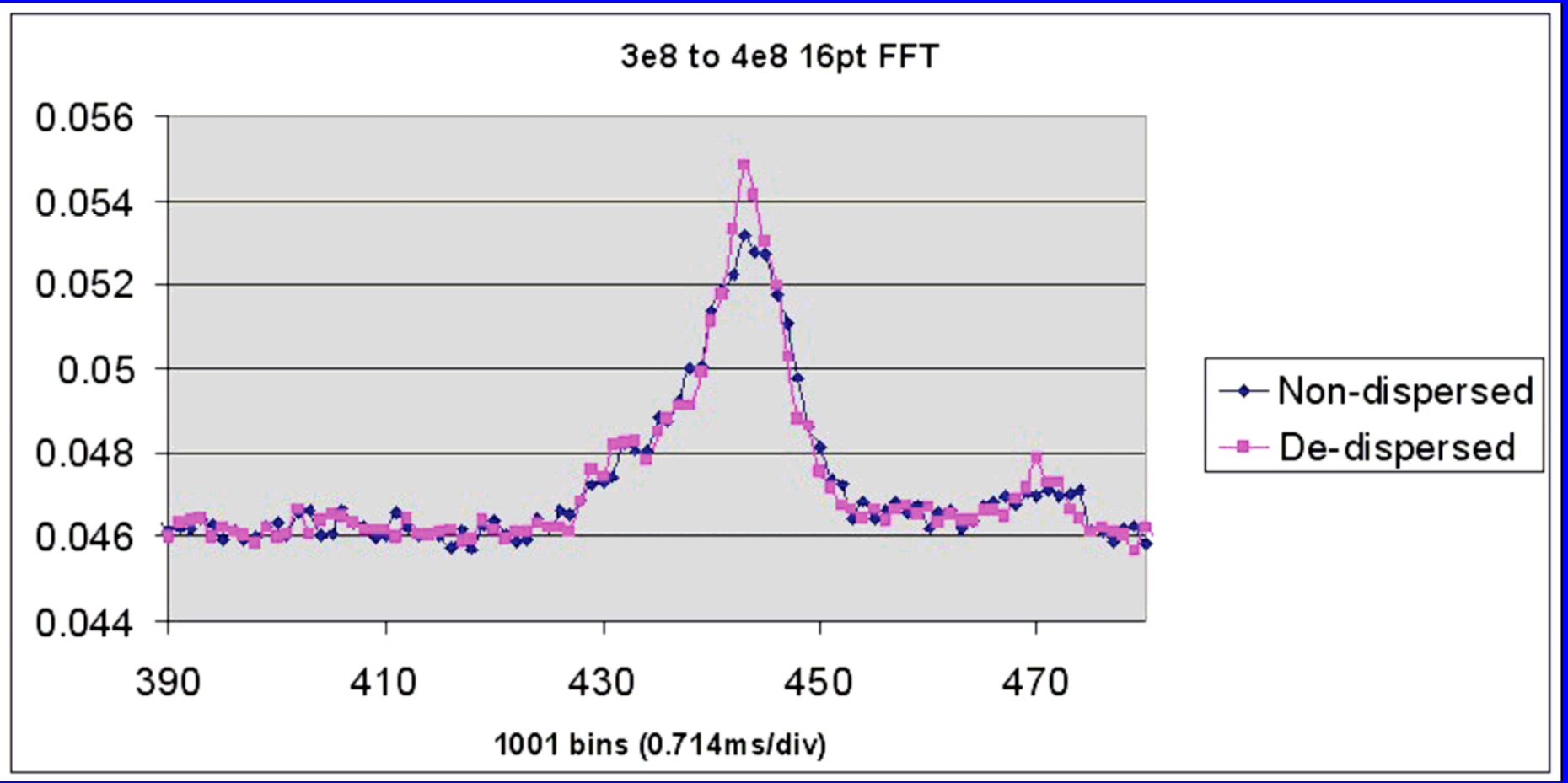
Homemade Software
www.y1pwe.co.uk

- Rapulsar2.exe – period folding
- Pdetect2.exe – square-law video detection
- Rafft2.exe – RF spectrum analysis
- Pafft2.exe – video spectrum analysis
- Amp_sts2.exe – ADC utilisation
- Filetrim2.exe – file trimming
- RFImit.exe – RFI spectral line blanking
- Pdetfilt2.exe – Video spectrum blanking
- De-dispers2Co.exe – de-dispersion

Digital De-dispersion



PSR B0329+24

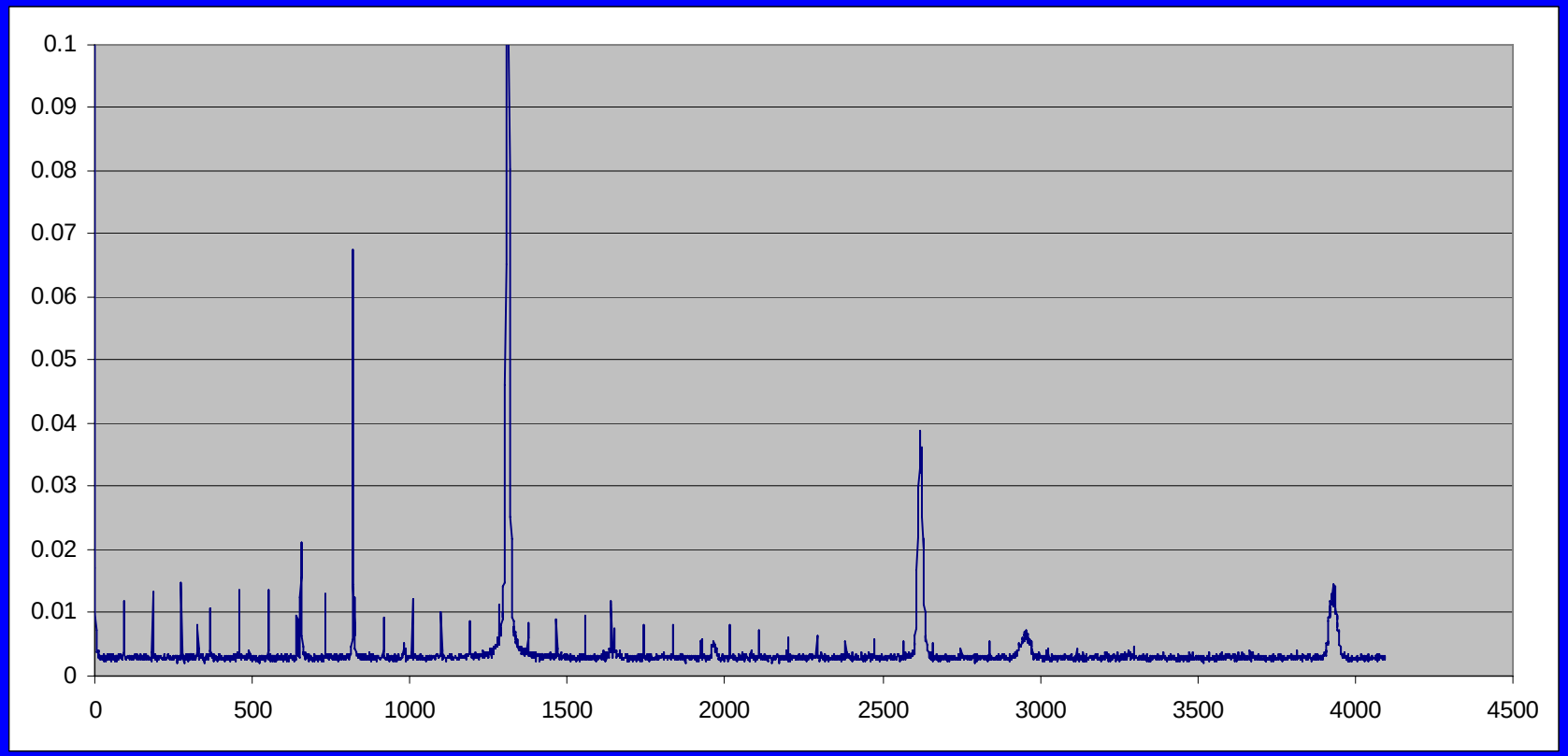


Data Source (25m): Michiel Klaassen

Challenges

- RF Interference - RF and Video
- Weak Signals - Folding process can find peaks in noise
- Validating Real Detections

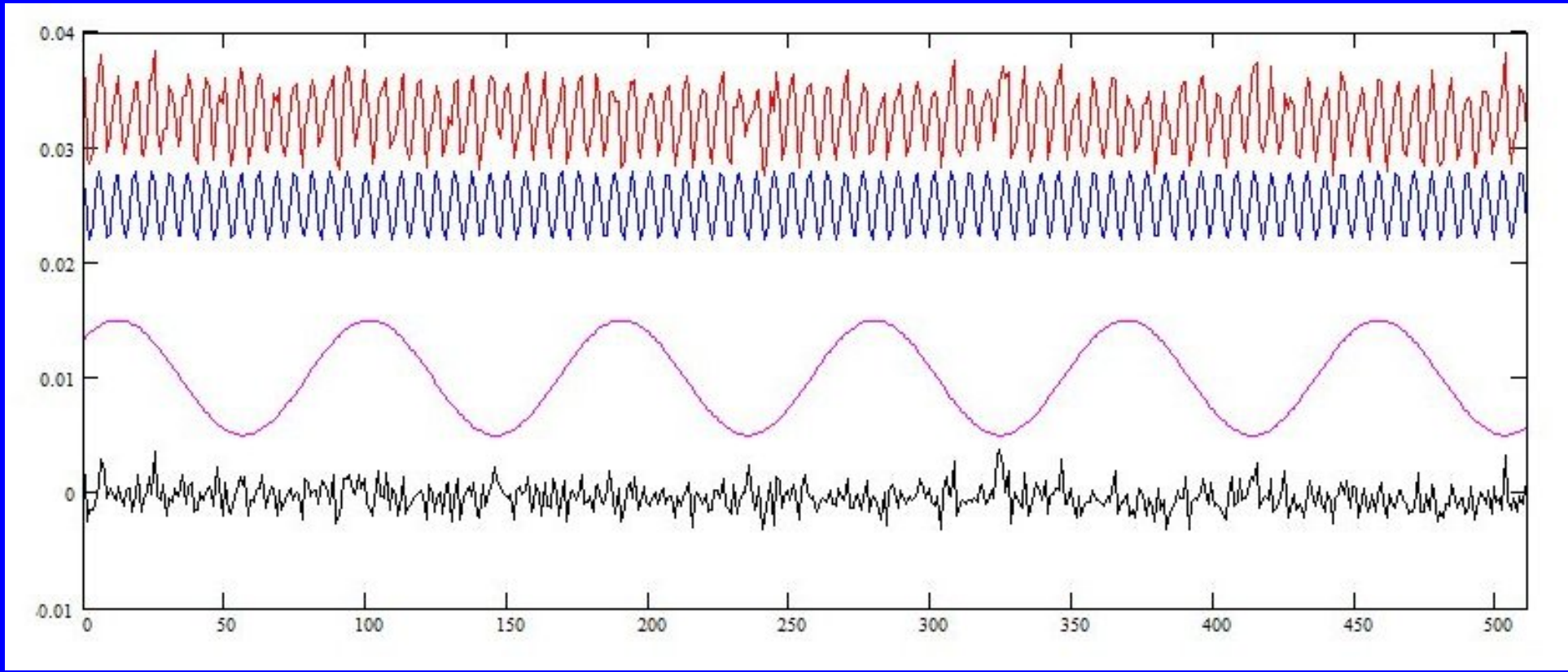
Vela Video Spectrum



pafft2 500.bin 500.txt 2 1 8192

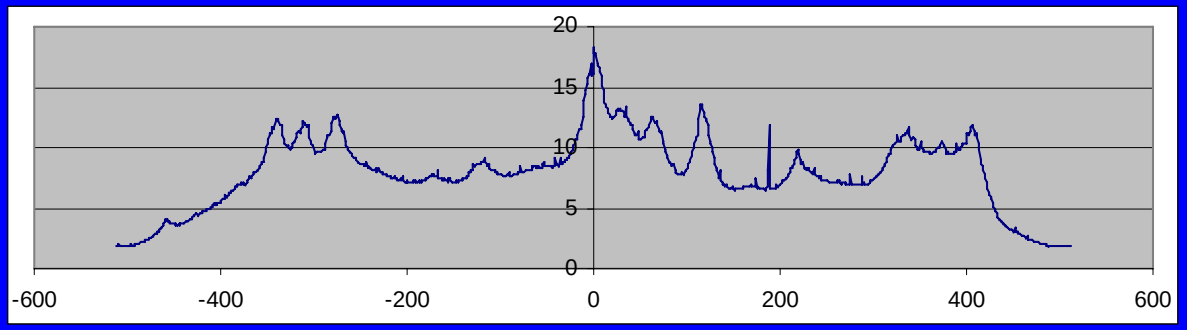
Data Source (30m): Guillermo Gancio

Vela Individual Pulses

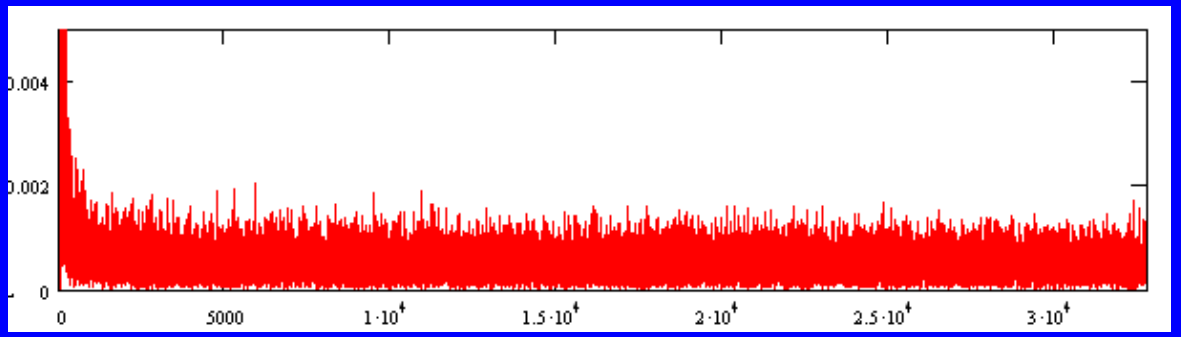


Data Source (30m): Guillermo Gancio

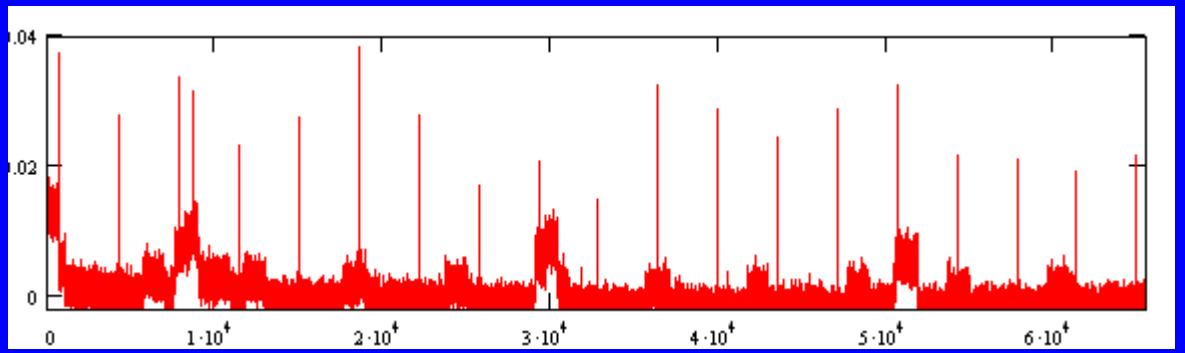
RFI – 400MHz (Sydney)



RF Spectrum



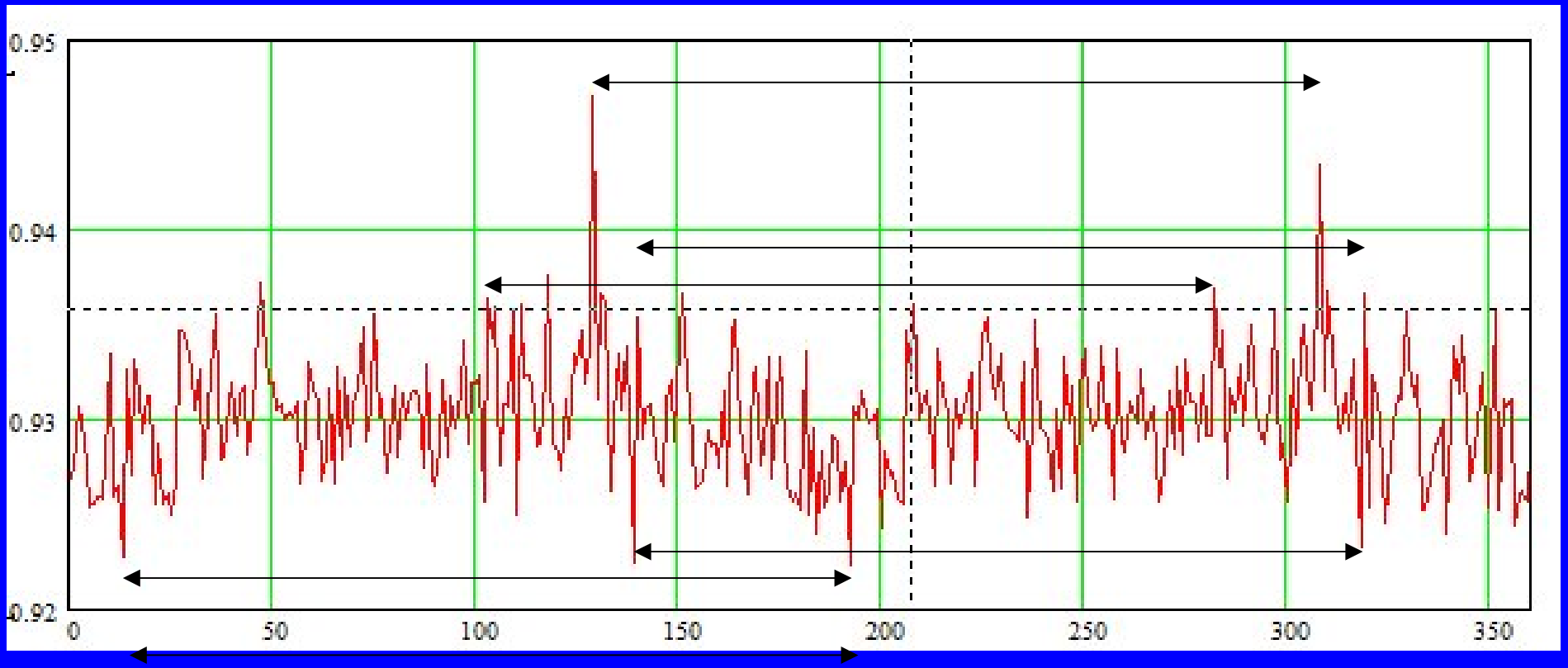
Video Spectrum



Video Timebase

Data Source (3m): Steve Olney

False Vela



Folding period = 2 x 89.39ms
Arrowed period = 89.39ms
SNR ~ 7

Data Source (3m): Steve Olney

Improvements

- Lower Tsys - direct SNR improvement
- RFI Mitigation
- Quad RTL - $\sqrt{4}$ improvement
- Longer Data Records
- Rubidium/GPS locking – multiple sessions

Conclusion

- Amateur Pulsar Detection with a 3m Dish is possible but not easy
- Inexpensive Receiver
- Freely Available Acquisition and Processing Software
- Find a friend with a BIG DISH