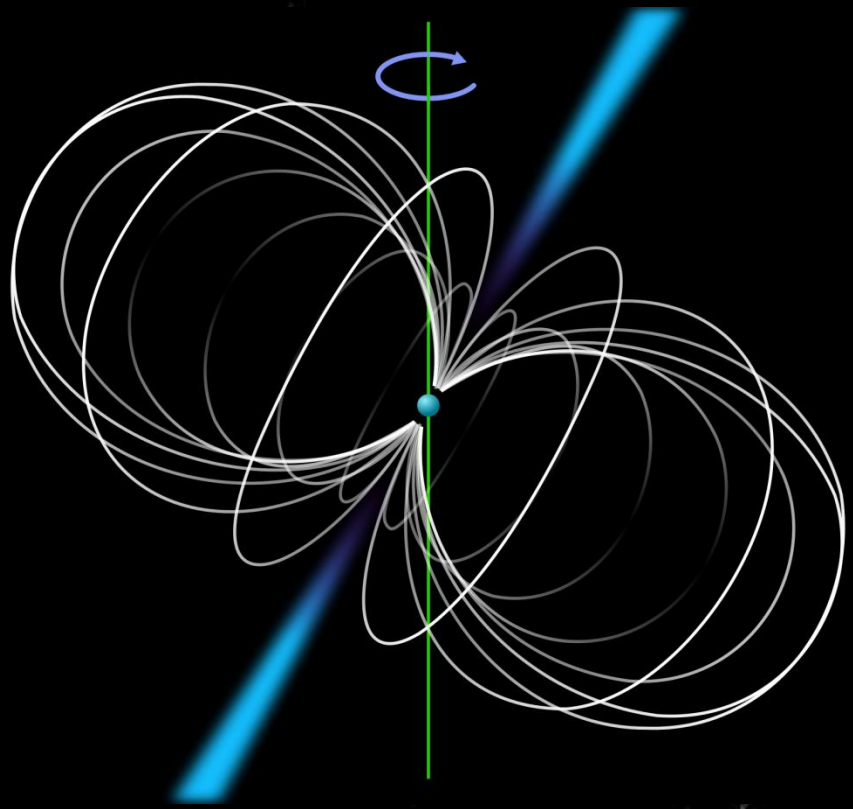
Amateur Pulsar Detection With EME Equipment

Pulsar:

Neutron star with offset between magnetic and rotation axis → emitting radio waves in a cone (lighthouse effect)



Neutron star

End of star lifetime:

Supernova explosion (can happen)

Core collapses →mass concentration
Diameter 10km…30km

Conservation of angular momentum
→ Rotation time: around 1 second

Radiation (power levels)

1 Jansky = 10^{-26} W/(m^2*Hz)

Sun: 500 000 Jy (23cm)

Moon: 500 Jy (23cm)

Cygnus A: 4700 Jy (70cm), 1500 Jy (23cm)

B0329+54 (strongest pulsar):

mean flux: 1.5 Jy (70cm), 0.25 Jy (23cm)

peak flux: 150 Jy (70cm), 25 Jy (23cm)

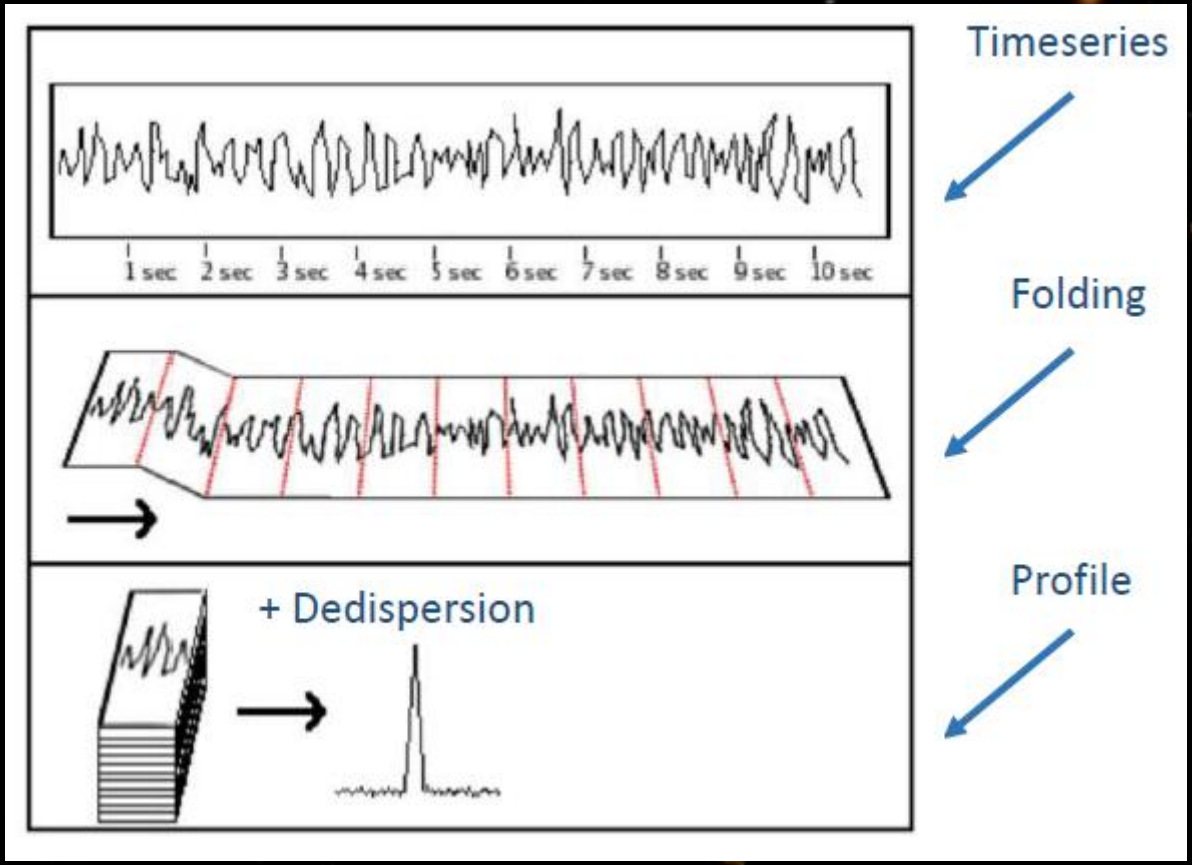
13 dB below moon noise on 23cm

weakest detected so far (by OE5JFL): 1 Jy peak → 27 dB below moon

First pulsar detected 1967 by Susan Jocelyn Bell Burnell

To hear the strongest pulsars a 75m dish is needed

To detect pulsars with EME equipment:
long time recording and ‚folding‘

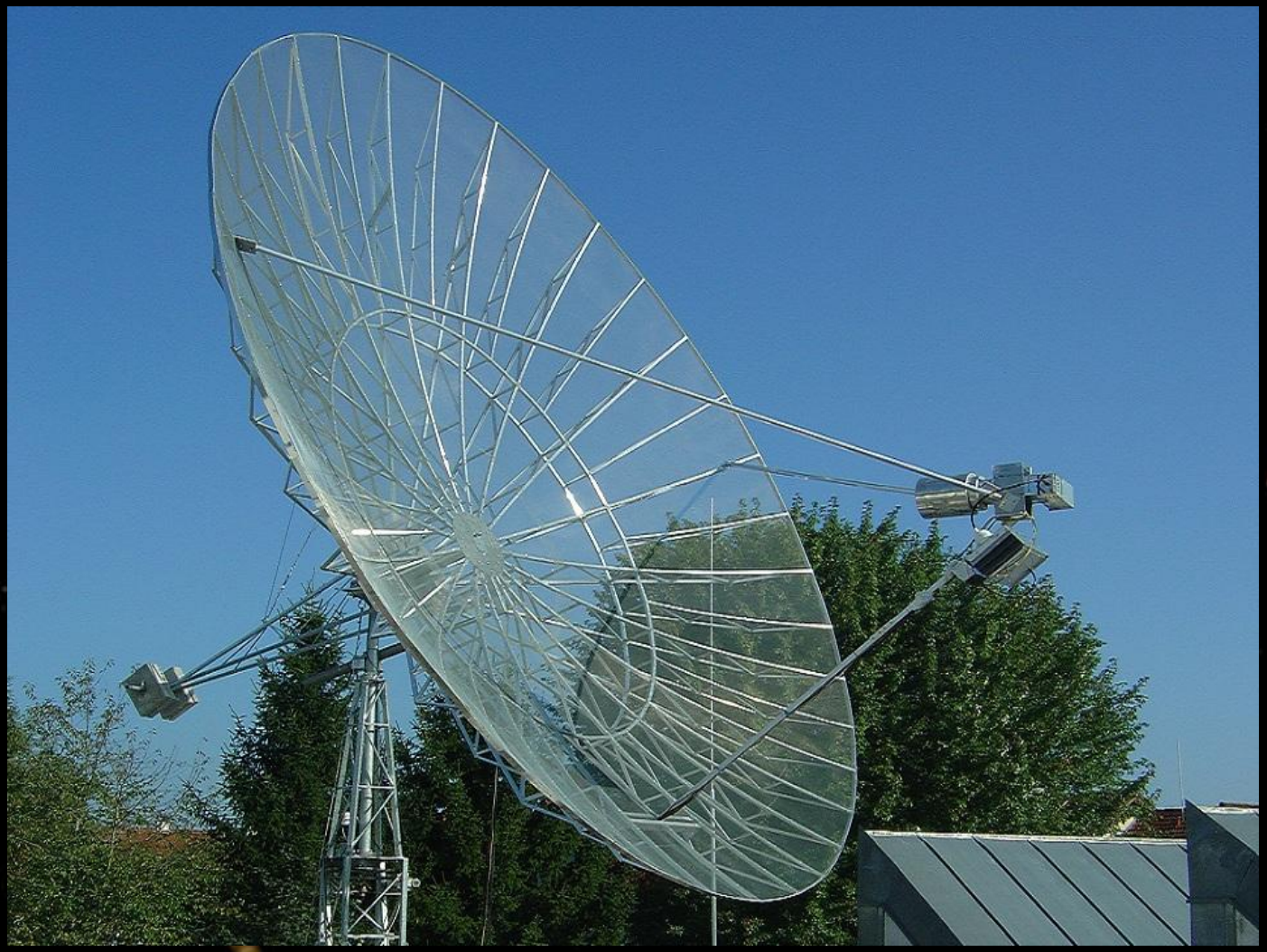


Precalculation of pulsar frequency with software Tempo

High accuracy of frequency necessary (<0.5ppm)

needed:
good antenna……and good software

Antenna:
7,3m
offset dish
own
design

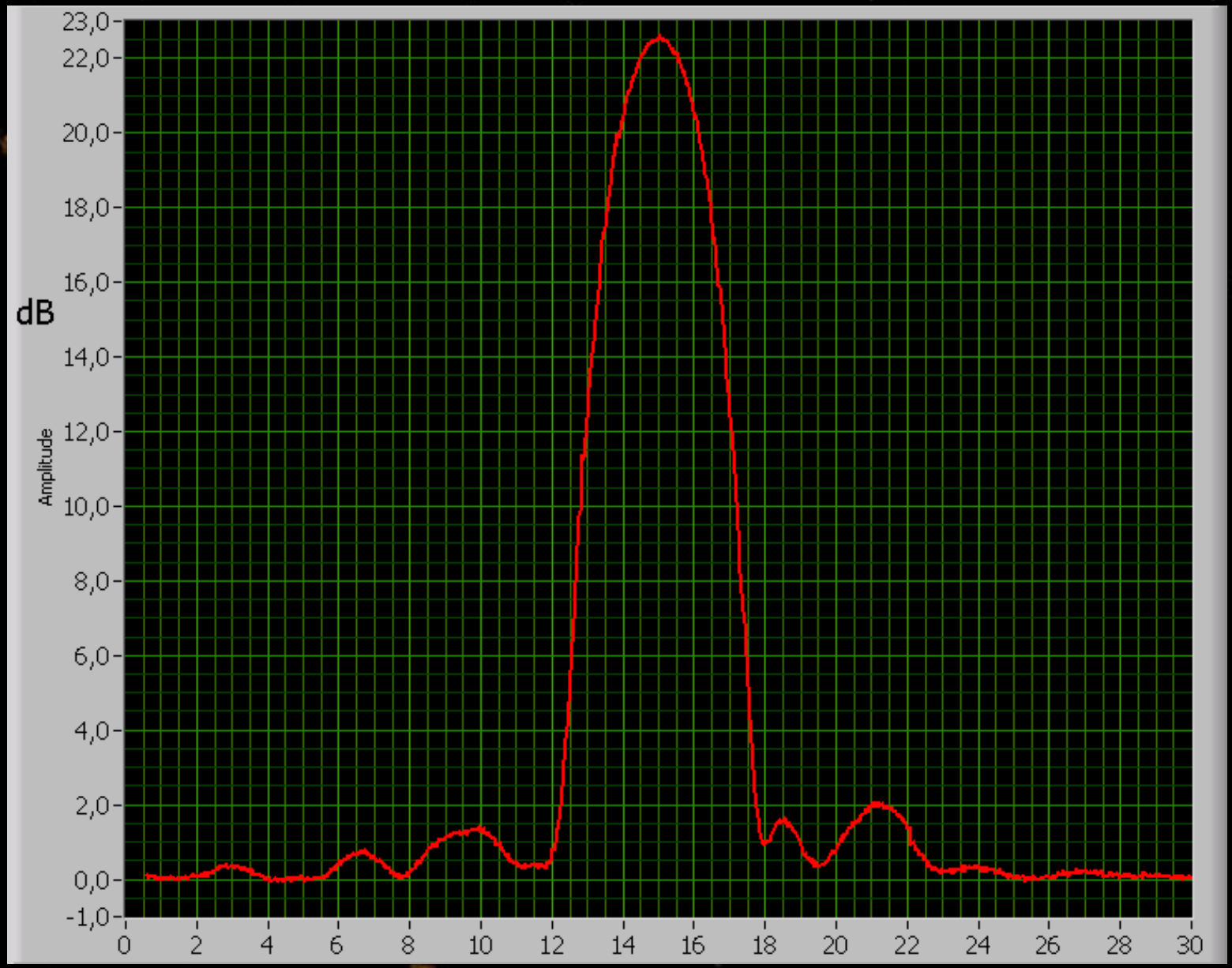


0 deg elevation and 40 deg elevation

easy access to the feed…..

….and also a platform for some cool drink

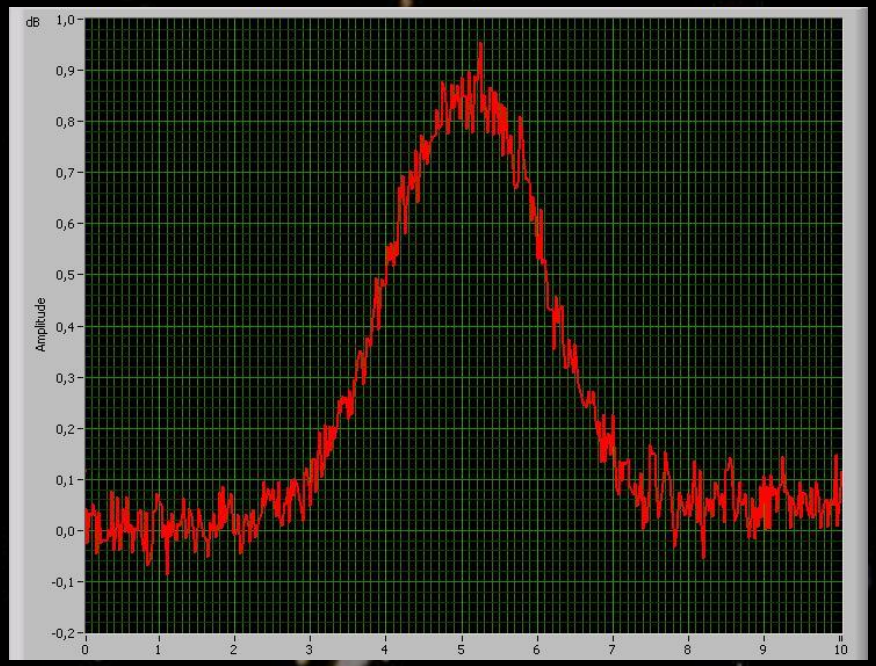
Sun noise measurement by drift scan on 23cm (SFI=107)



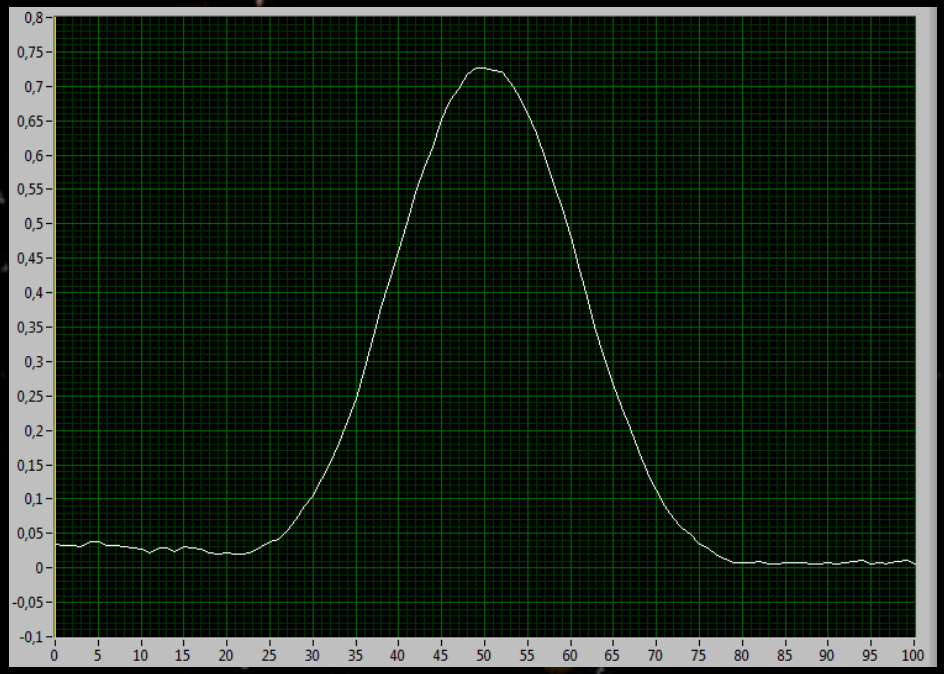
Measurement of low level broadband noise is better with large bandwidth

Moon noise on 1296 MHz

2,5kHz bandwidth



2 MHz bandwidth



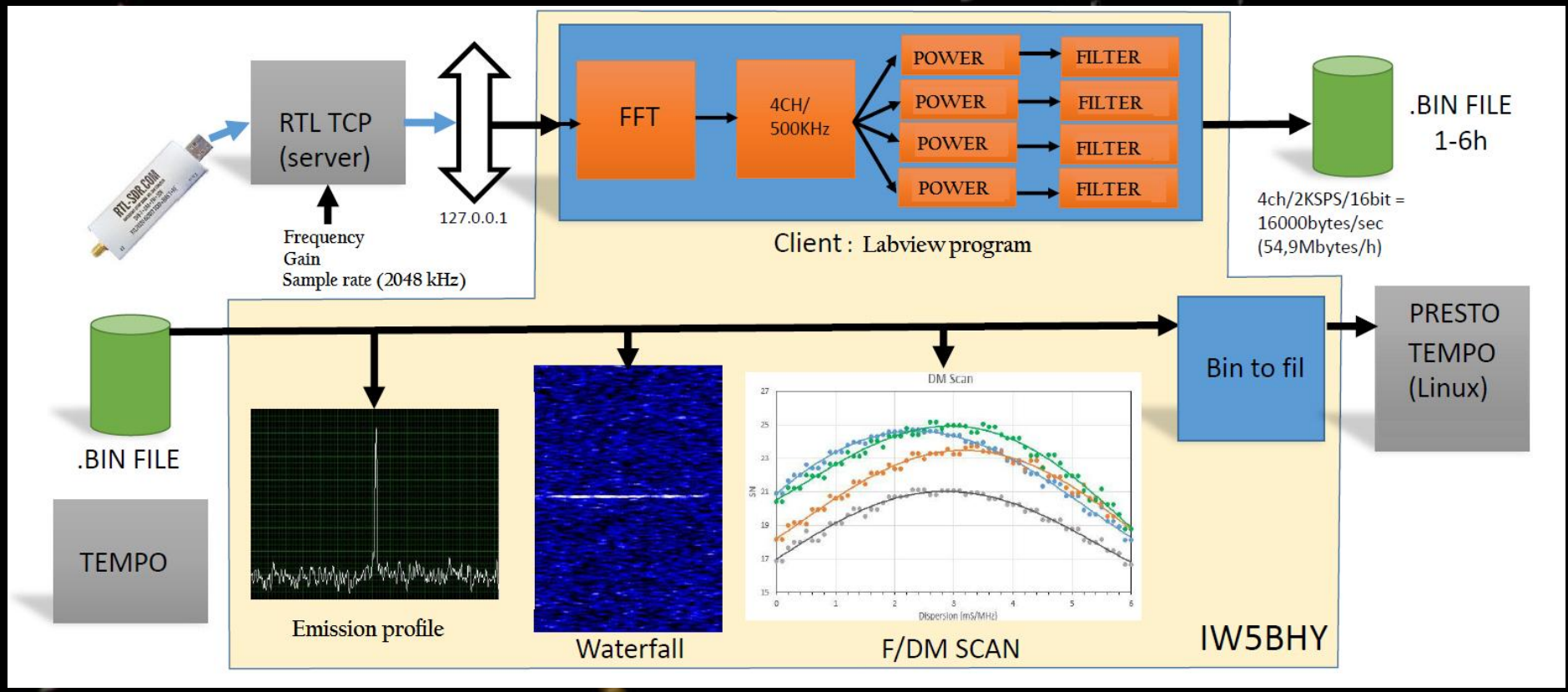
Hardware and Software:

Hardware:

Preamp, **INTERDIGITAL FILTER**, RTL-SDR (Airspy SDR), PC

Software for planning observations: Murmur by I0NAA

Software for analyzation and display: **IW5BHY** and Presto



List of received pulsars (April 4th 2017)

Pulsar	70cm (424 MHz)	23cm (1294 MHz)
B0329+54	110	85
B0531+21 (Crab) *	10	---
B0823+26	18	9
B0834+06	10	---
B0950+08	32	14
B1133+16	24	11
B1237+25	6	---
B1508+55	9	---
B1642-03	26	9
B1749-28	21	---
B1818-04	8	---
B1911-04	12	---
B1919+21	14	---
B1929+10	33	9
B1933+16	20	31
B1946+35	6	---
B2016+28 **	14	12
B2020+28 **	9	6
B2021+51	16	17
B2111+46	6	---
B2217+47	15	---
B2310+42	11	---

S/N values by IW5BHY software

note * :
The Crab pulsar was a challenge, 30 rotations/sec and high dispersion.

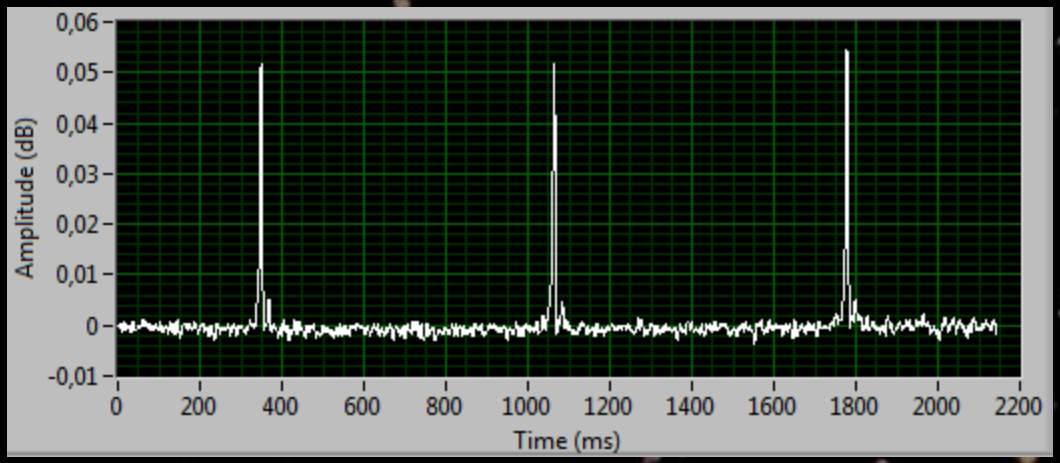
note ** :
The B2016+28 and the B2020+28 are only about 1deg apart from each other. 424 MHz profiles for both pulsars were obtained by analyzing the same recorded file.

The two weakest pulsars detected are:

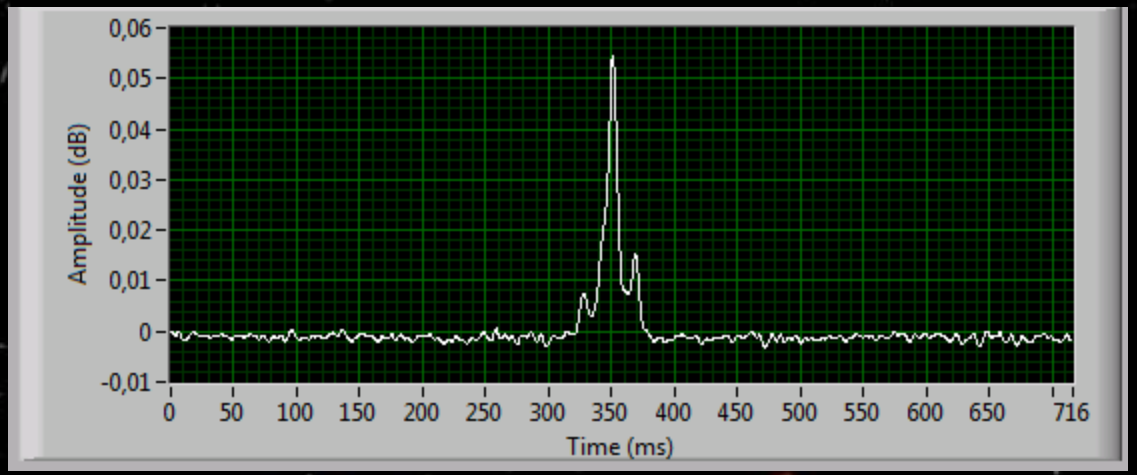
424 MHz: B1919+21 (S400 = 57 mJy)
1294 MHz: B0823+26 (S1400 = 10 mJy)

Pulsar B0329+54

Frequency 1,39 Hz → 714 ms period



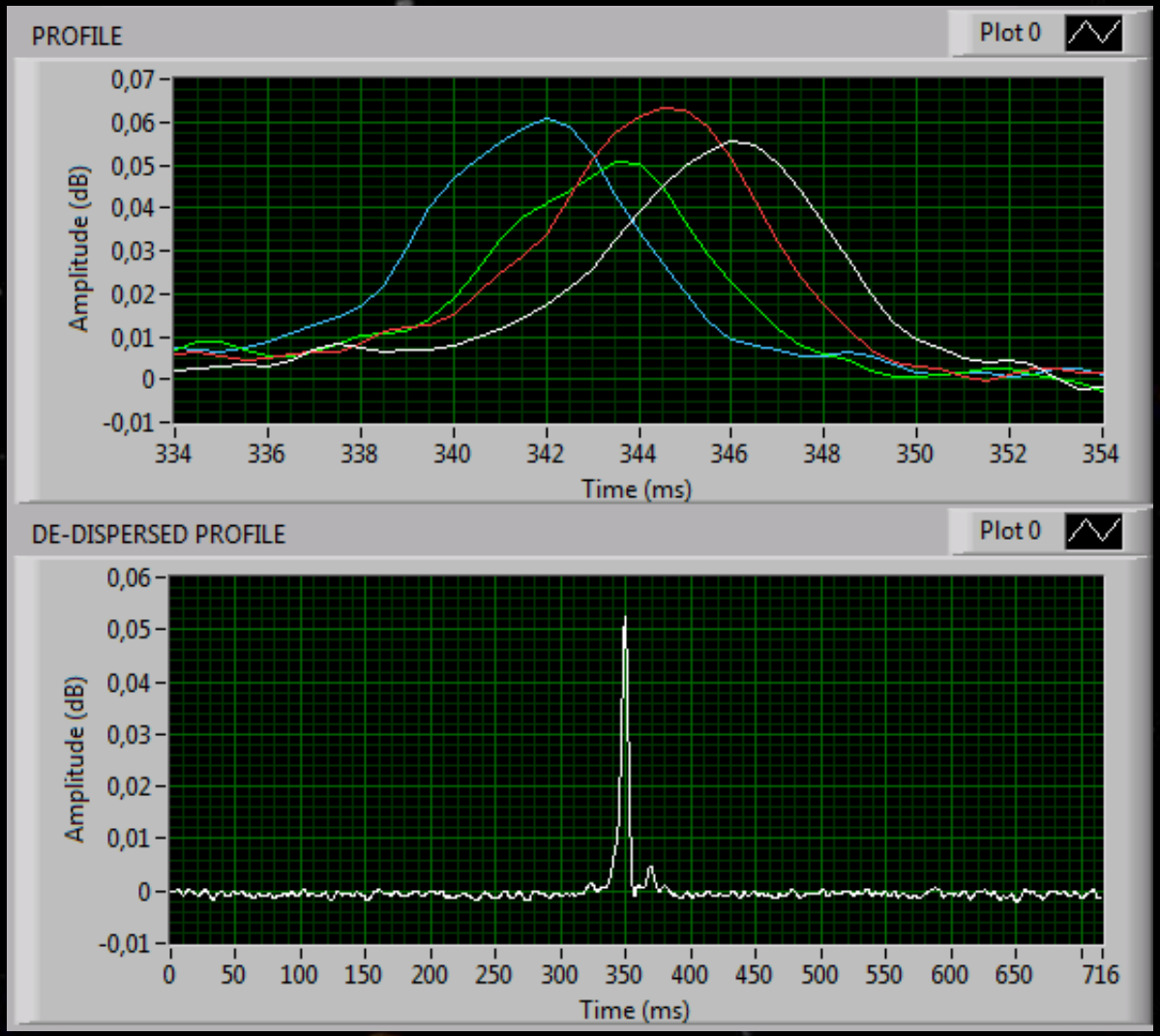
3 pulses 424 MHz



pre- and postpulse in normal mode 1294 MHz

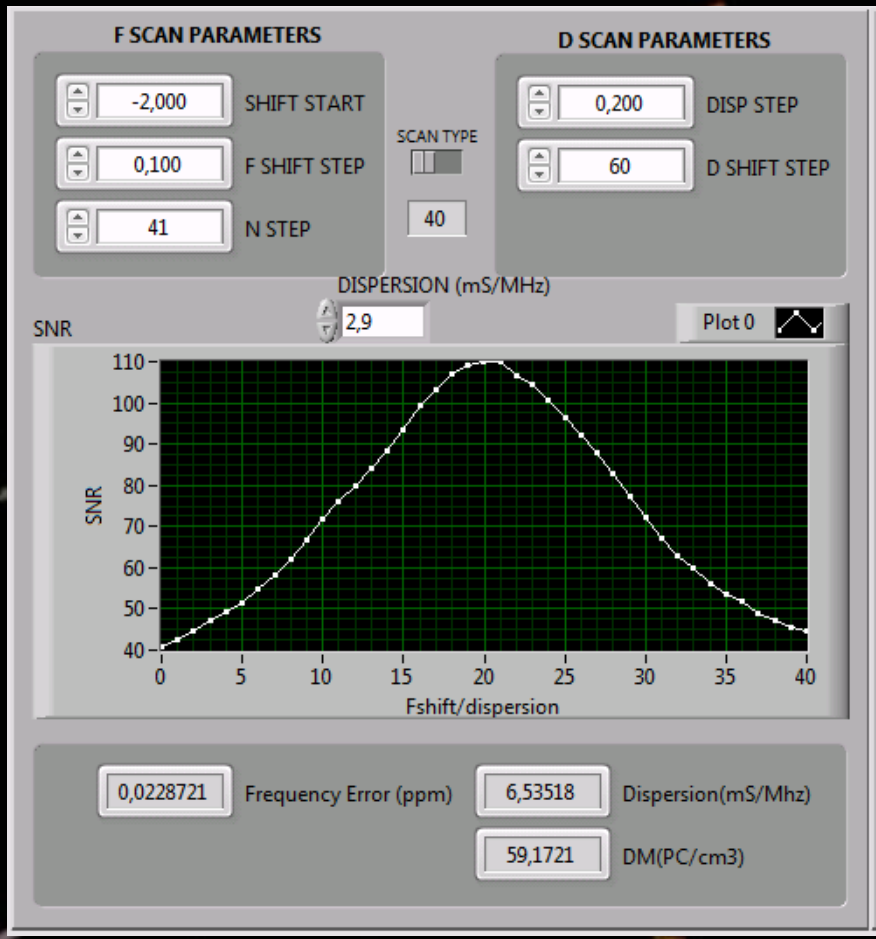
The upper graph shows the dispersion at 424 MHz

2 MHz bandwidth: 4 channels 500kHz each

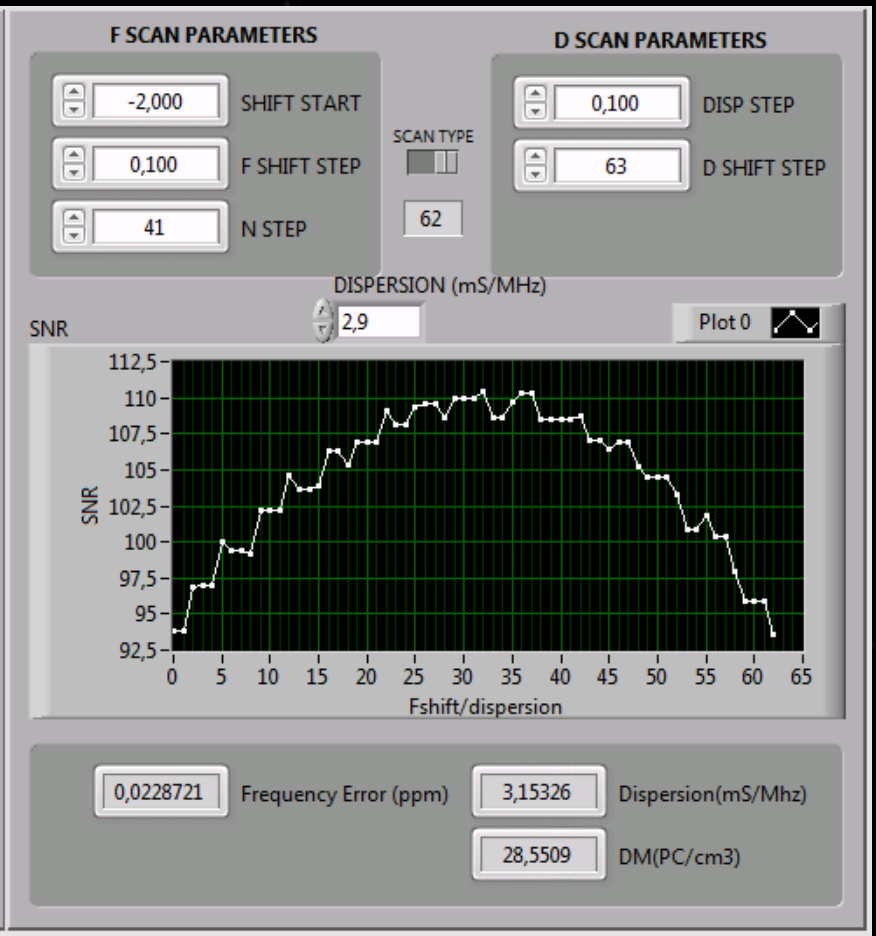


Verification Tests

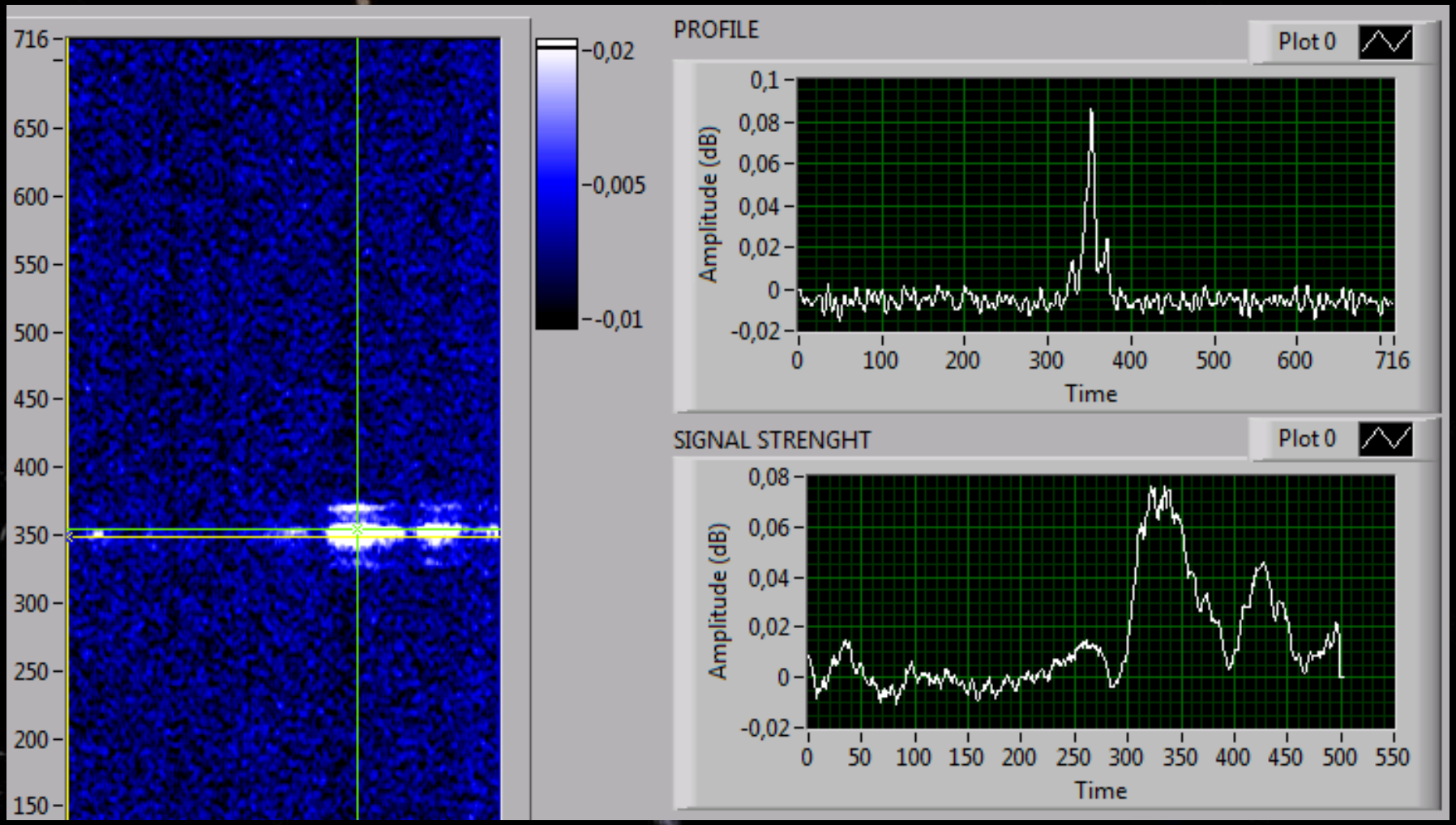
Pulse Period Check



Dispersion Measure Check



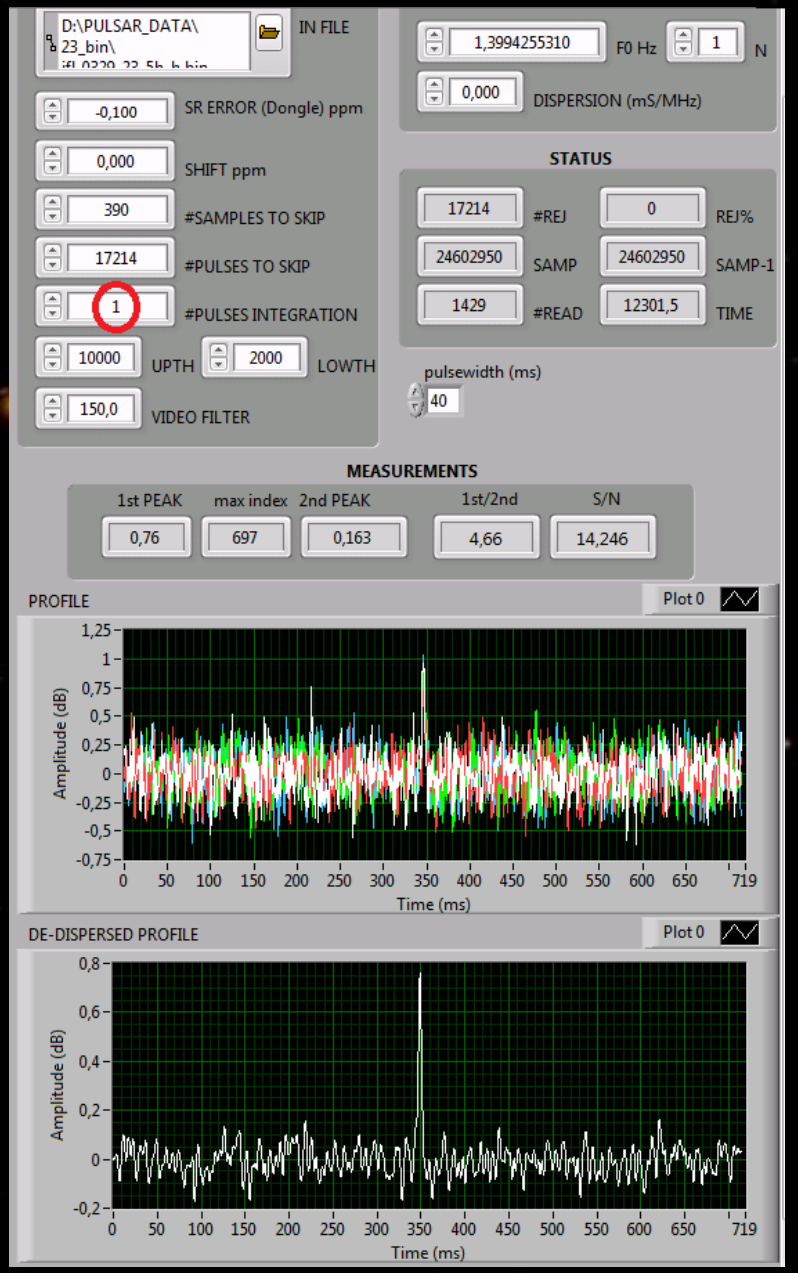
QSB by scintillation on 23cm



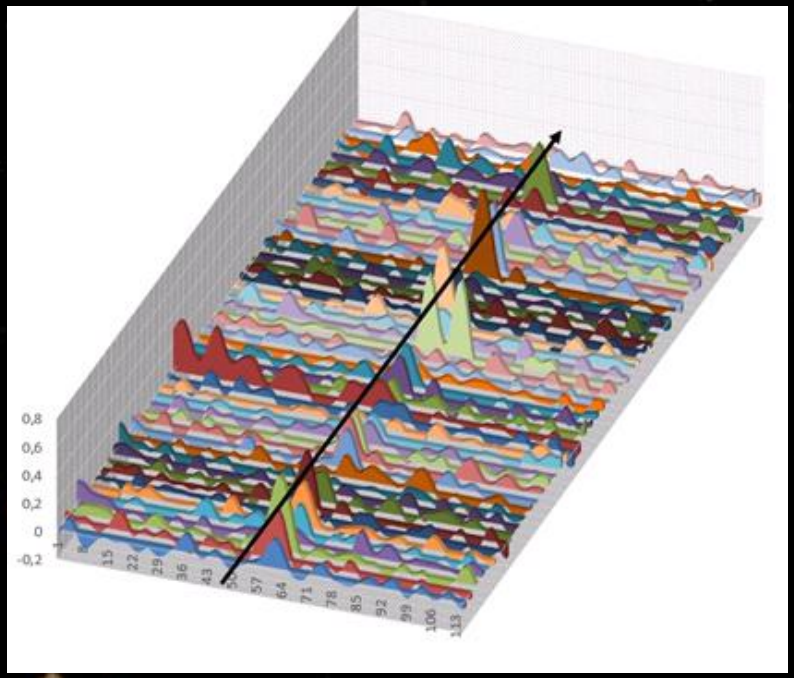
During signal peaks it is possible to receive single pulses

←70cm

23cm→



This 3D plot displays 50 consecutive periods at a peak of positive scintillation.



It is from one piece of observation of 36 seconds containing many single pulses.

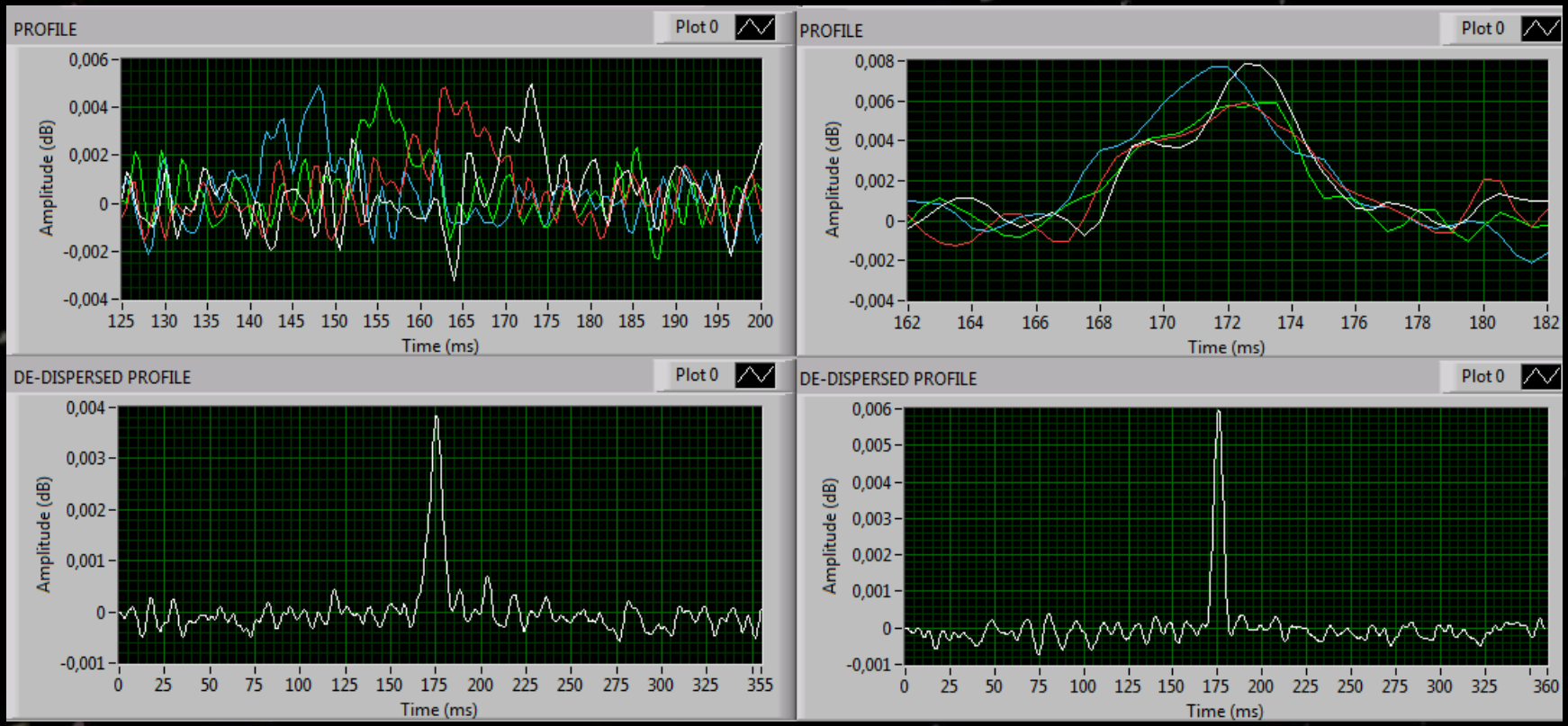
Andrea, IW5BHY, has found 50 single pulses in a one hour recording I made on 424 MHz. With a special written program he put the single pulses in a row, and generated an audio file from that. So you can even listen to the sound of the pulsar B0329+54:

Pulsar B1933+16, high dispersion

The channels are separated by slightly more than 8ms to each other on 424MHz (left).

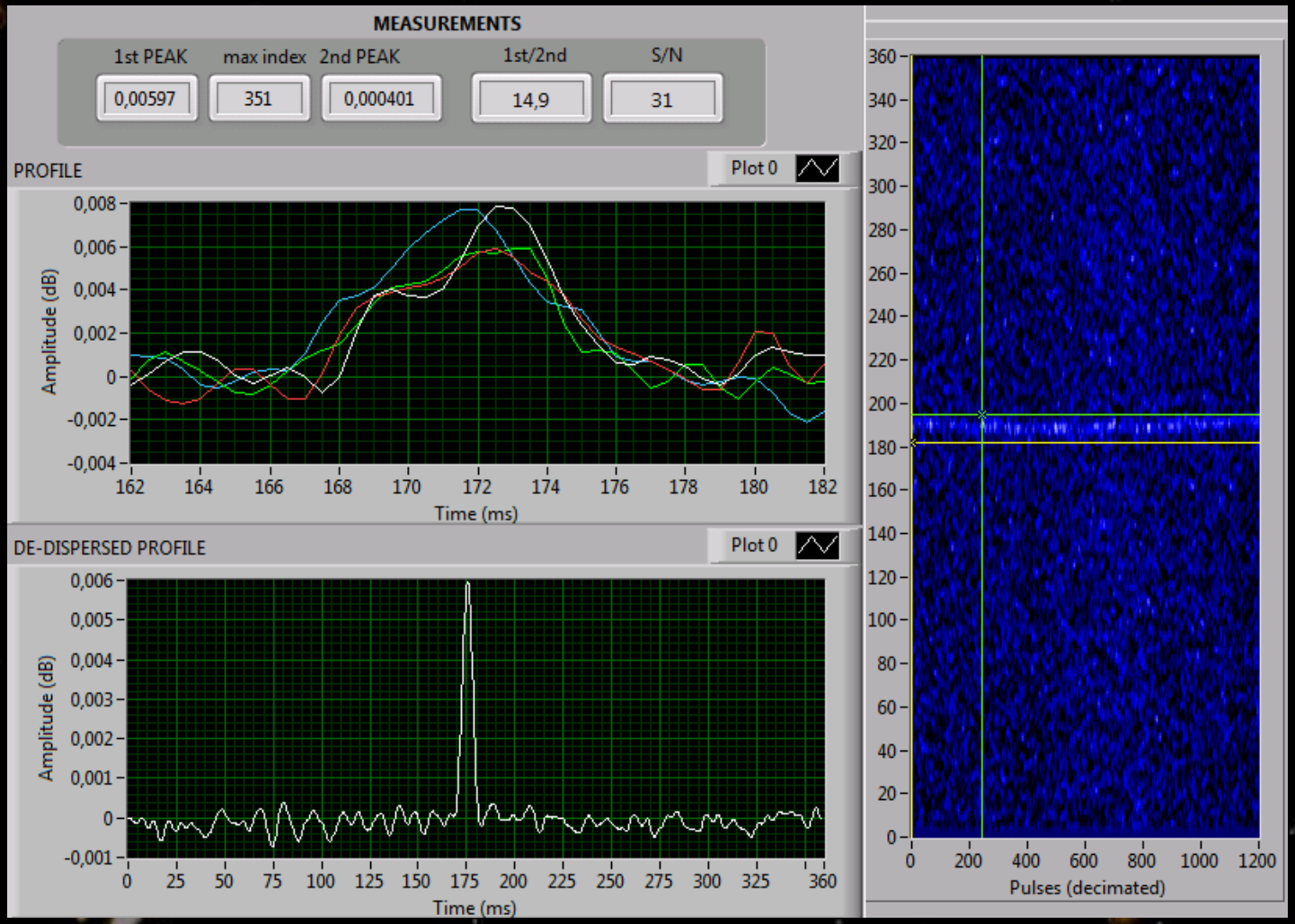
This is nearly as much as the pulse width itself.

The dispersion is even visible on 1294 MHz (right)

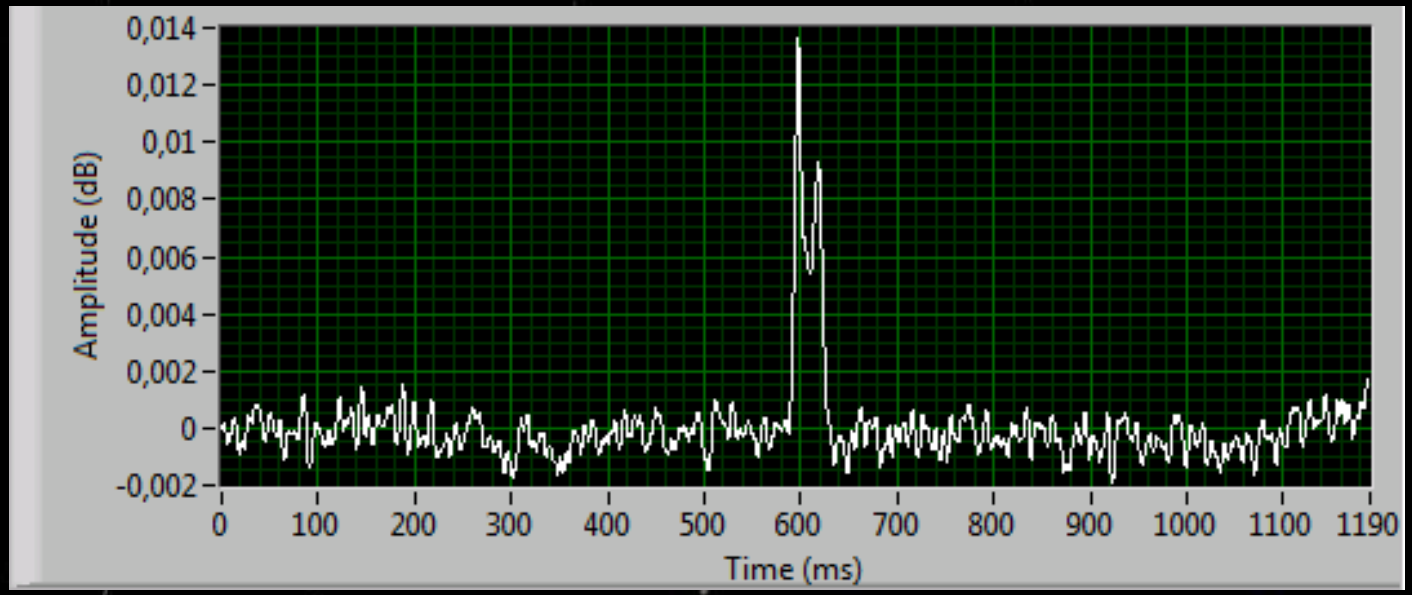


Pulsar B1933+16, 6 hours observation

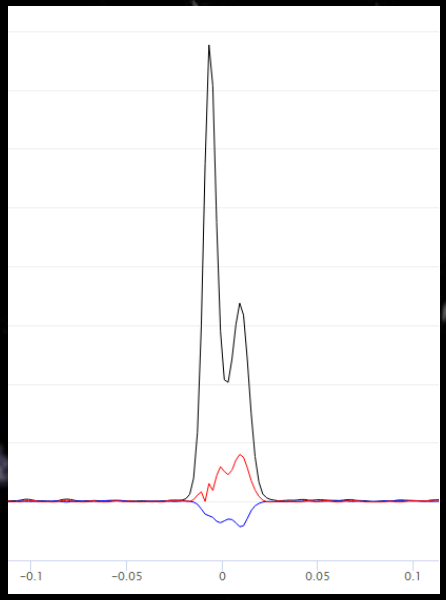
frequency change by Doppler (1294 MHz)



Pulsar B1133+16 double pulse (424 MHz)



measured pulse profile confirmed by EPN profile catalogue



Crab-pulsar B0531+21

Young pulsar, exists since a supernova explosion in 1054
(observed on earth as a star even visible at daylight for about two years)

Rotates 30 times per second, fast speed slowdown

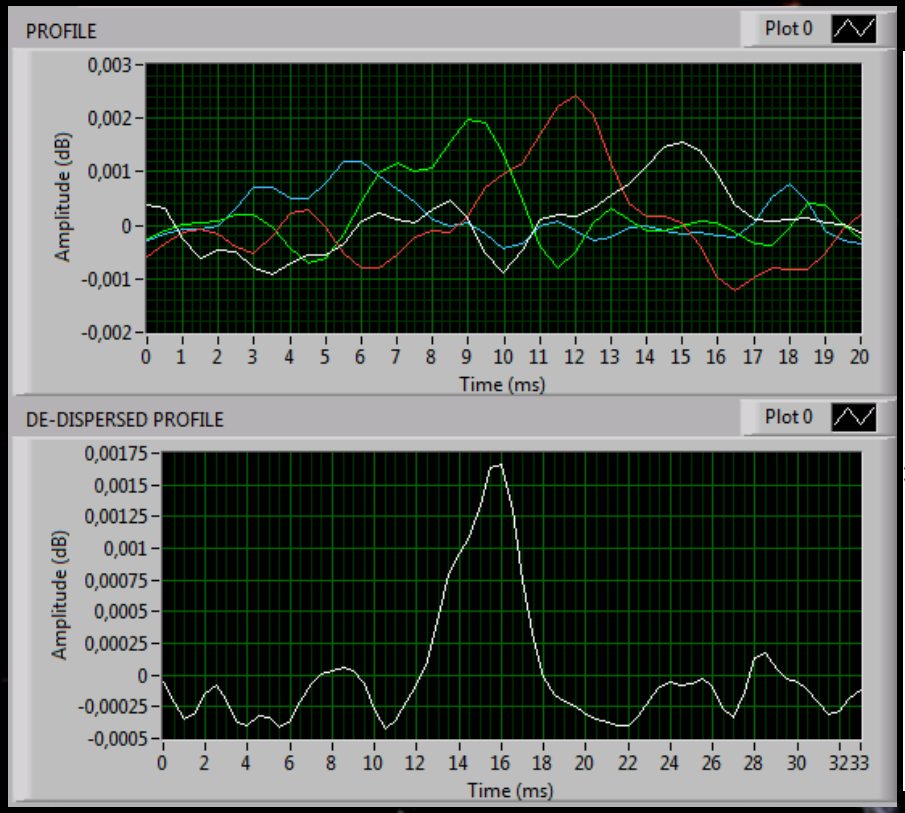
Highly dispersed (3 ms per channel is the same as the pulse width)

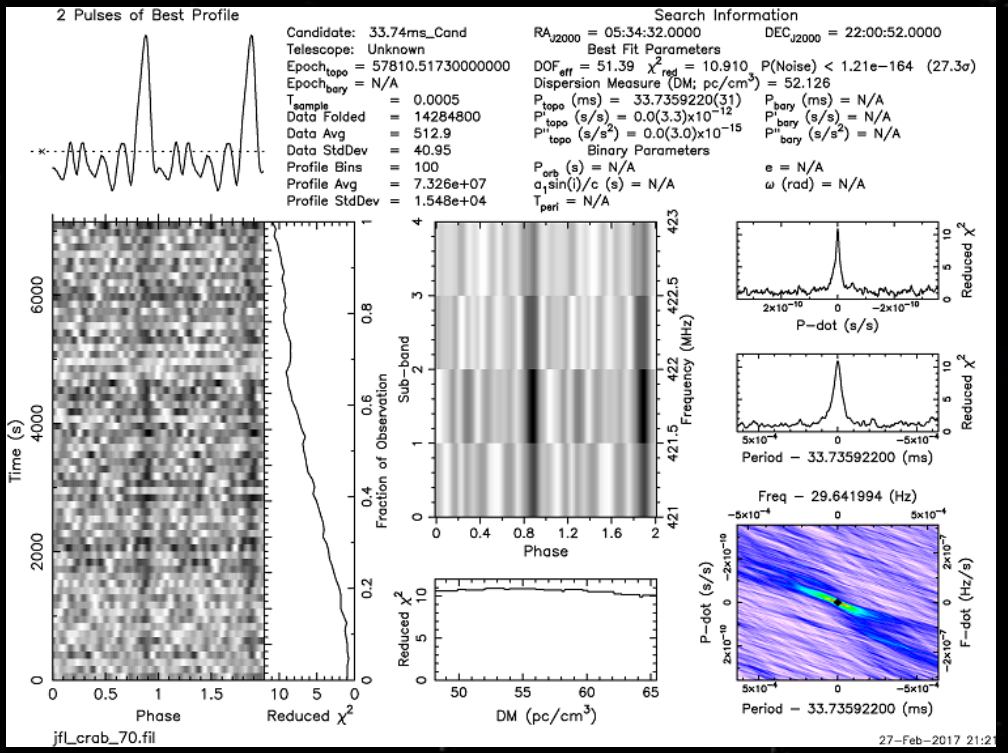
Nevertheless, the pulsar reception was positive even on the very first attempt!
The observation time was 2 hours.

Crab pulsar

(424 MHz)

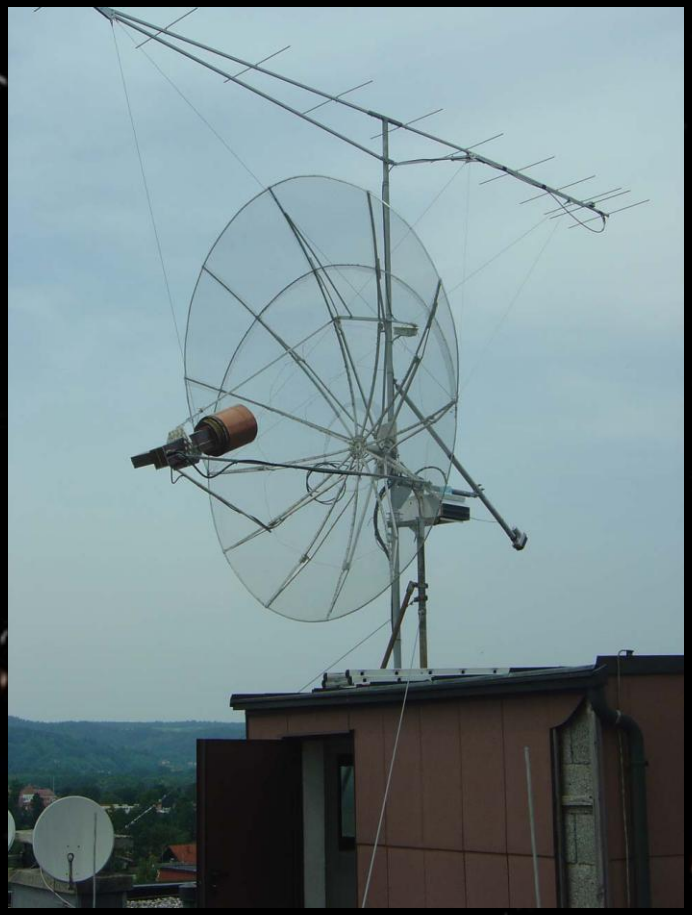
analyzed with IW5BHY software and Presto

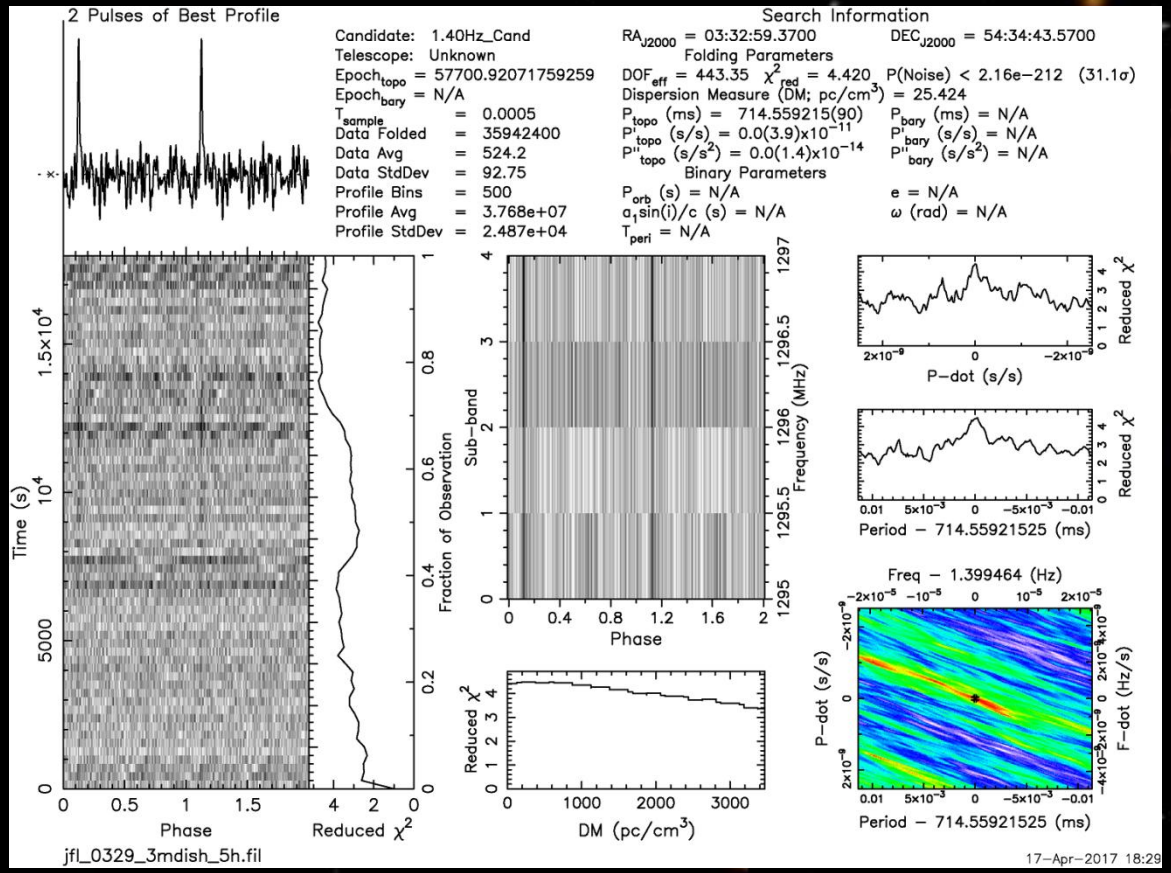


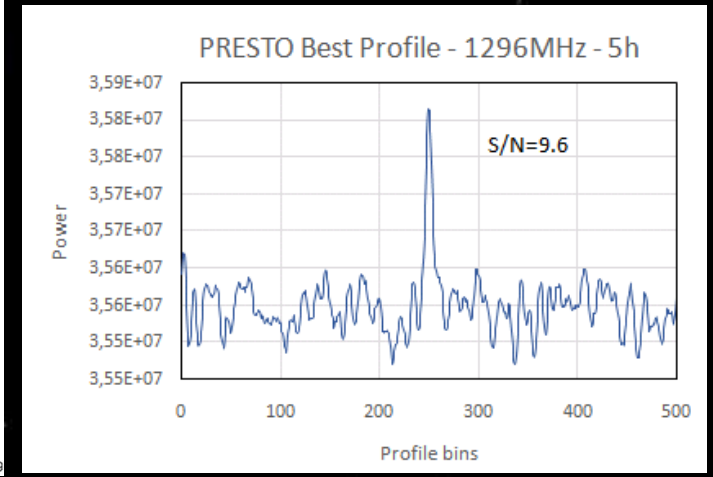


Reception of B0329+54 on 23cm with my 3m dish.

(10,5dB sun noise @ SFI=74)

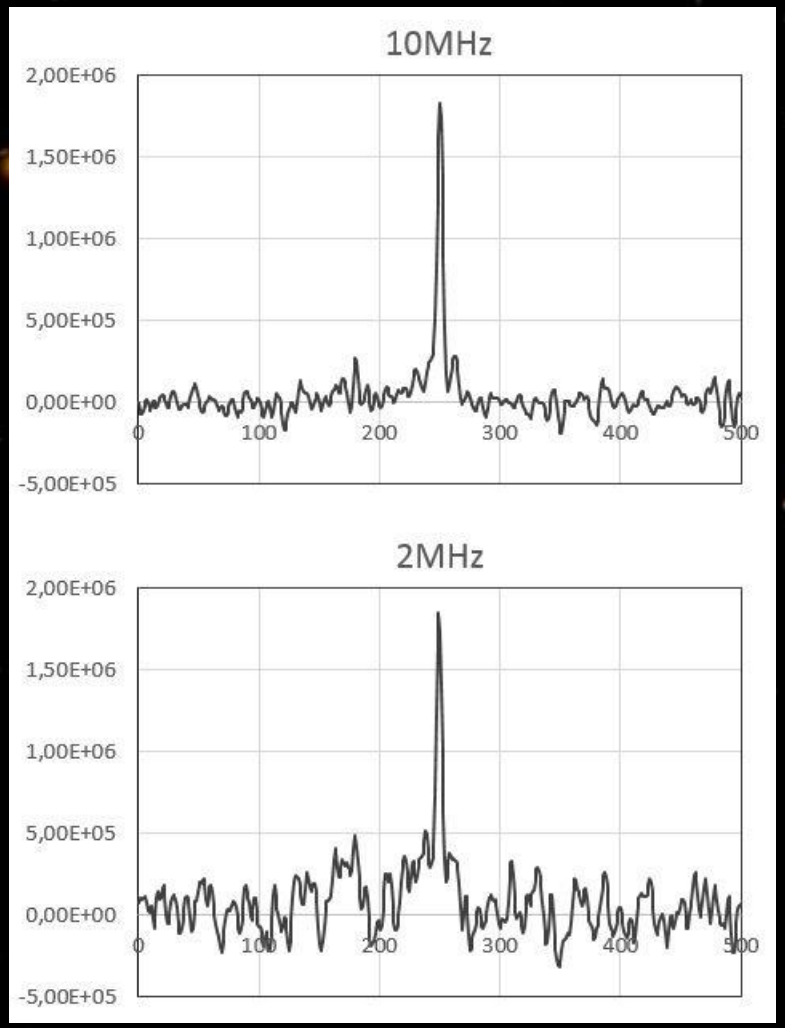






Reception of B0329+54 on 70cm by IW5BHY with corner reflector antenna (18dBi)

Comparison using 10 MHz and 2 MHz bandwidth



Planning observations

Finding candidates using ATNF pulsar catalogue

S400 and S1400 values might be not correct, confirmation by other sources recommended

Check pulse shape by EPN pulsar profile catalogue

Pulse shape depends on frequency, W50 can be calculated for the planned observation band

Check results obtained by other stations (Astropeiler 25m dish)

Own chances can be stimated looking at the S/N ratio (example: B0823+26 S1400=10mJy)

Use Murmur (=Pulsar Planner) to see possible observation times

RFI might depend on direction, time of the day. Also nighttime hours can cause less sleep ;-)

Do not give up when an observation was negative!!

On one occasion I needed up to 10 observations, 5 hours each, before I had a positive result

thank you
for your
attention