

Pulsars – How To Detect

In the following article I will describe how you can detect pulsars, at least the strongest, using amateur radio EME equipment.

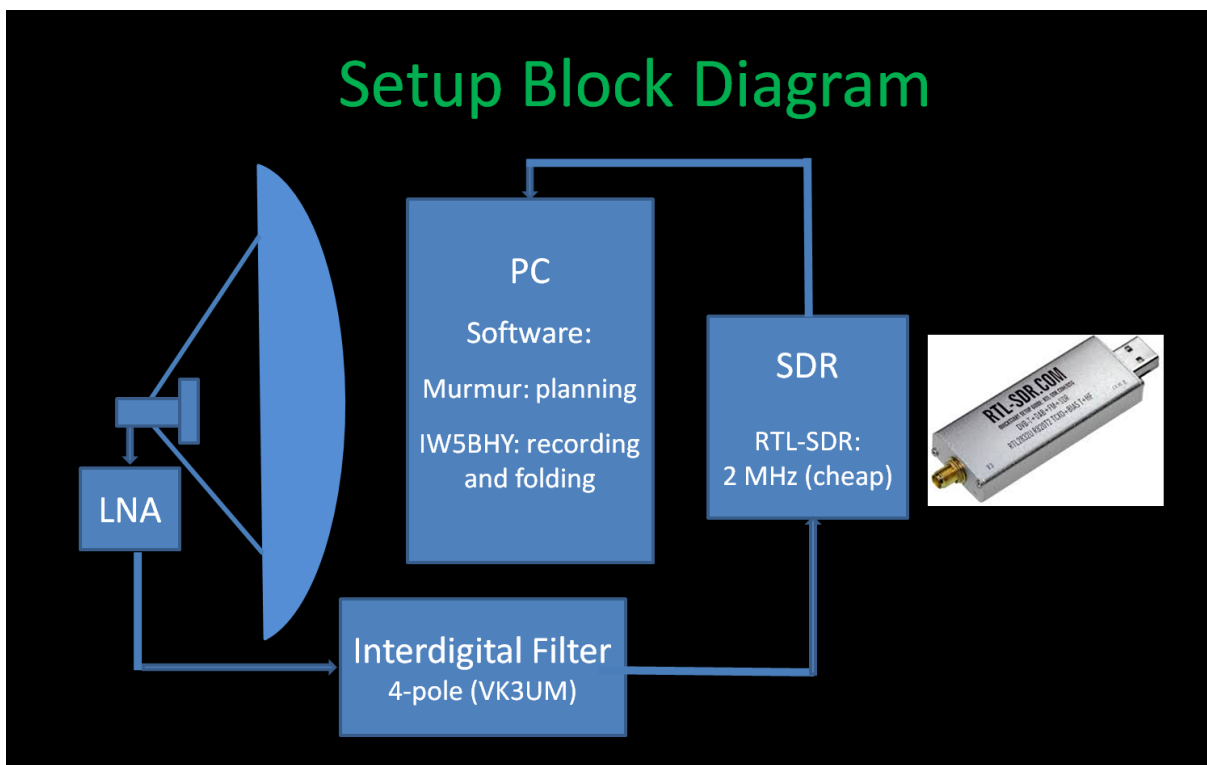
The first question is which hardware and band to use:

Pulsars are stronger on 70cm than on 23cm, therefore this is the band to choose, unless you have too much RFI there. In my case the best frequency with low interference is between 422MHz and 424MHz.

With my 3m diameter dish I can detect the strong pulsar B0329+54 on every attempt, a 70cm yagi group is probably less effective if you do not stay exactly on 432MHz, for a dish it is easy to adjust a feed for different frequencies.

If you are using a dish on higher frequencies and not on 70cm yet, I recommend a dual dipole feed. It is good for $f/D=0.35$ up to $f/D=0.55$, and you can just mount it at the 'mouth' of the 23cm feed for example.

EME stations have most of the hardware already, not much is needed additionally, as you can see from the block diagram below.

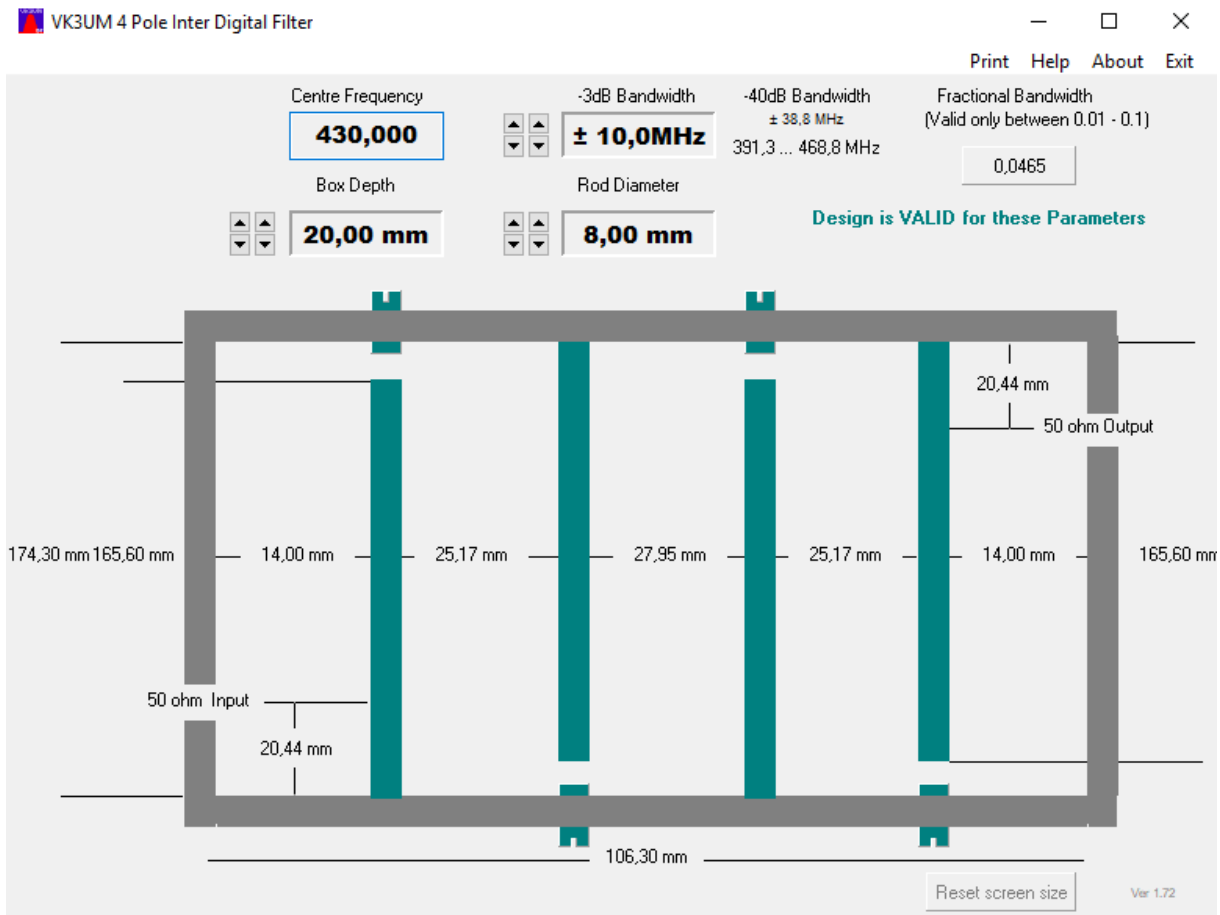


Using a SDR has become standard for amateurs, for detecting pulsars the minimum bandwidth is 2MHz, therefore I recommend the cheap RTL-SDR based on RTL2832U chip.

Possible sources for a high accuracy SDR (needed for long time observations) are:

<https://shop.technofix.uk/supe<>r-stable-1ppm-tcxo-r820t2-tune<>r-rtl2832u-rtl-sdr-usb-stick-<>version-3>
or <http://www.astroradio.com/es/1<>23001>

A good filter in front of the SDR is essential. I built a 4-pole interdigital filter following the VK3UM design.



It is an advantage if you can adjust the filter, because if the gain of your preamplifier is not constant enough over the 2MHz, you can get the overall frequency response flat. The preamplifier should have <0.5dB noise figure and around 30dB gain, normal for EME.

Software:

Presto is professional pulsar software for Linux and a bit tricky to use. In my opinion it is better to start with the **Labview software for Windows OS, written by Andrea dell'Immagine, IW5BHY**

He kindly gave permission for amateurs to use his software. All pulsars I could detect in 2MHz bandwidth using Presto, I could detect as well with Andreas software, just great!

I will describe a step by step procedure how to install and test the SDR, and install and use the pulsar software.

First install USB drivers and SDR# software, following these instructions:

<http://www.rtl-sdr.com/rtl-sdr<>-quick-start-guide/>

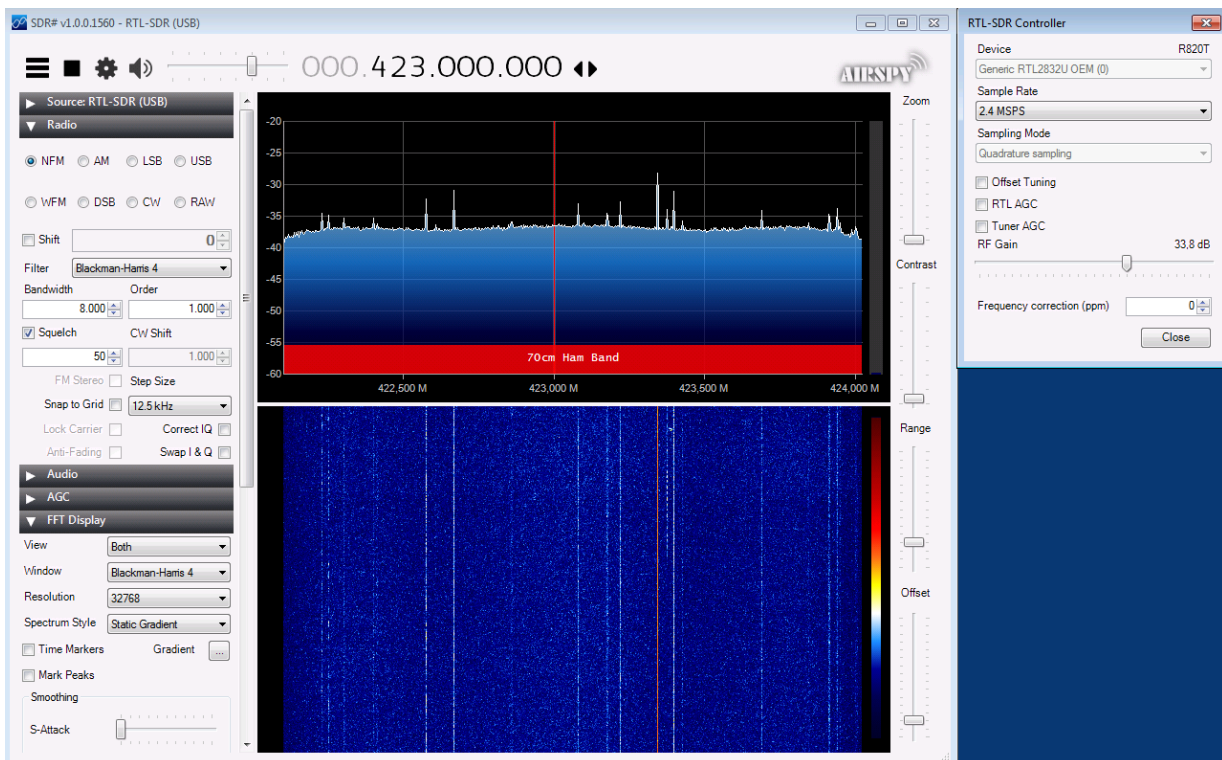
Next step is to test the hardware, running SDR# software.

Adjust RF-gain to a value that you see a noise difference of minimum 15dB, switching ON/OFF the preamplifier.

Check sun noise, using a 3m diameter dish it should be around 6dB at SFI=70.

Look for the best 2MHz with low RFI, constant carriers are less a problem compared to (for example) intermittent broadband noise.

If necessary and possible readjust the filter for a flat noise floor within the 2MHz passband. An example for the settings and how the waterfall looks like you can see from the screenshot below.



Now you need the software for

1. Recording
2. Calculating pulsar frequency
3. Analyzing

First install Labview Runtime Engine 2012:

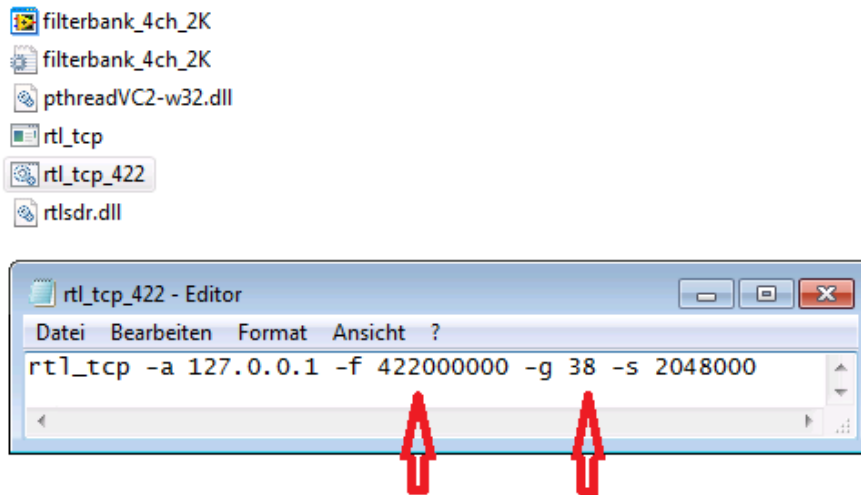
<http://www.ni.com/download/labview-run-time-engine-2012-sp1/3710/en/>

Instead I can provide you an installable version of **filterbank_4ch_2k** for recording, the Runtime Engine 2012 is included and usable for the analyzing software as well.

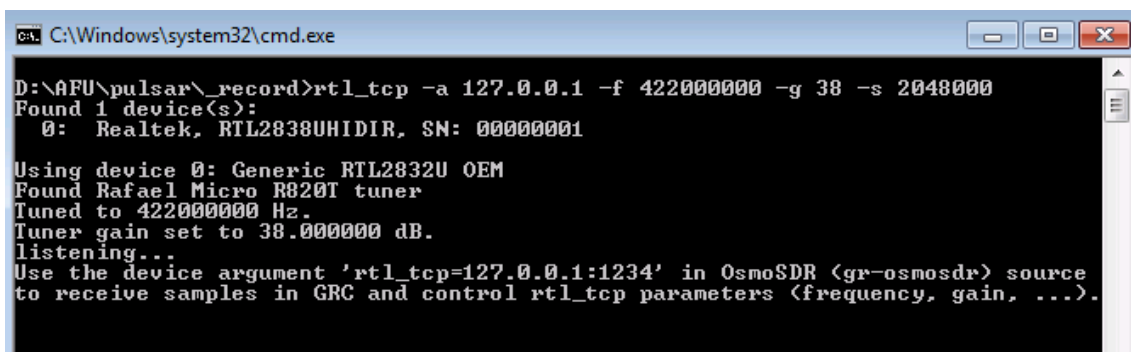
All Labview EXE files you can get from me or IW5BHY, but Andreas EXE are compiled under Labview2013, in that case you need Labview Runtime Engine 2013 instead of 2012.

Additional files needed for 1. (recording) you see from the screenshot below.

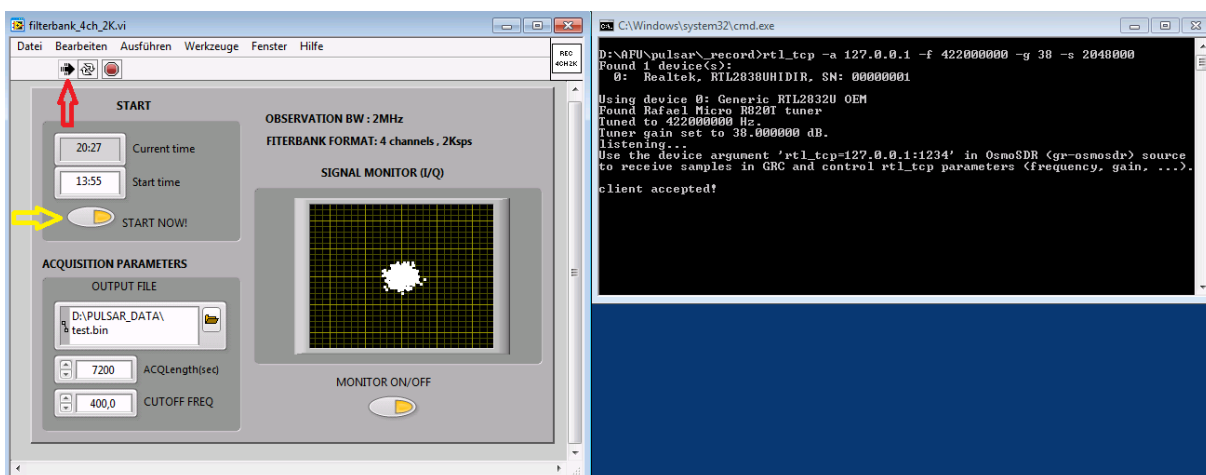
Edit **rtl_tcp.bat** and modify frequency and gain. (422MHz and 38dB in my settings)



Now start **rtl_tcp**, a window should open with the following content:



Next open **filterbank_4ch_2k**, modify recording length (example 7200 seconds), choose a bin data filename in an existing folder and if you like the start time.



Start the Labview recording software (red arrow), and if you want to start the recording immediately click at **START NOW** (yellow arrow).

In the DOS window you should read now **client accepted** and in the Labview window a cloud with rather constant amplitude should show up.

File length of the *.bin will be 57,6 MByte per hour of recording.

For a recording time up to two hours and a 3m diameter dish it is not necessary to track the pulsar, you can make a drift scan instead.

For longer observation times you should have a tracking system with the possibility to choose RA and DEC of the target.

If not, you can track manually. The software **Murmur** written by Mario, IONAA, provides beside lots of other useful information Azimuth and Elevation of pulsars for your location. Download site is:

<http://i0naa.altervista.org/index.php/downloads/summary/2-downloads/9-murmur-7-1-0>

Now, if you have recorded a *.bin file and you are very curious about the result, you can send it to me and I will do analyzing for you first before you do 2. and 3. yourself.

For both, calculating pulsar frequency (2.) and analyzing (3.) you can get the software in form of ZIP files from me (compiled for Labview2012) or IW5BHY (Labview2013).

Pulsar frequency calculation for the date and time of the observation is done by a software called '**tempo**', together with some more Labview programs written by IW5BHY.

It is not necessary to install something, just place the folder **tempo** directly to drive C:\

Open the folder and edit **obsys.dat** and **tz.in**

obsys.dat - Editor

Datei	Bearbeiten	Format	Ansicht	?		
882589.65	-4924872.32	3943729.348	1	GBT XYZ	1	GB
422333.2	722040.4	306.		QUABBIN	2	QU
2390490.0	-5564764.0	1994727.0	1	ARECIBO XYZ (JPL)	3	AO
-424818.0	-1472621.0	50.0		Hobart, Tasmania	4	HO
402047.7	743853.85	43.		PRINCETON	5	PR
-1601192.	-5041981.4	3554871.4	1	VLA XYZ	6	VL
-4554231.5	2816759.1	-3454036.3	1	PARKES XYZ (JER)	7	PK
3822252.643	-153995.683	5086051.443	1	JODRELL BANK MkIA	8	JB
382546.30	795056.36	893.7		GB 300FT	9	G3
382615.409	795009.613	880.87		GB 140FT	a	G1
382545.90	795036.87	835.8		GB 85-3	b	G8
340443.497	1073703.819	2124.		VLA SITE	c	V2
443118.48	-113848.48	25.		NORTHERN CROSS	d	B0
-352219.00	-1492525.00	500.0		MOST	e	M0
4324165.81	165927.11	4670132.83	1	Nancay	f	NC
4033949.5	486989.4	4900430.8	1	Effelsberg	g	EF
3822473.365	-153692.318	5085851.303	1	JODRELL BANK mkii	h	JB
3822294.825	-153862.275	5085987.071	1	JODRELL BANK 42ft	i	JB
355615.0	1060230.0	200.		K550	j	S0
481830.0	-130620.0	360.		OE5JFL	k	JF
524900.0	-062300.0	020.		PI9CAM	l	PI

tz.in - Editor

Datei	Bearbeiten	Format	Ansicht	?
k 9 1080 5 422				
Name Nspan Ncoeffs (1st line: defaults for nsite,maxha,nspan,ncoeff,freq)				

0329+54				

In **obsys.dat** add a new line containing your personal data (lat.,lon.,alt etc), the corresponding letter will be **m**. You have to modify obsys.dat only once.

Then change the letter in tz.in from k to **m**. Default pulsar is B0329+54, that will be the one to start with in the northern hemisphere.

Now starting **tz.bat**, a DOS window will show up.

```

C:\WINDOWS\system32\cmd.exe

C:\tempo>set TEMPO=c:\tempo\

C:\tempo>tempo -z
TZ source list for site = k

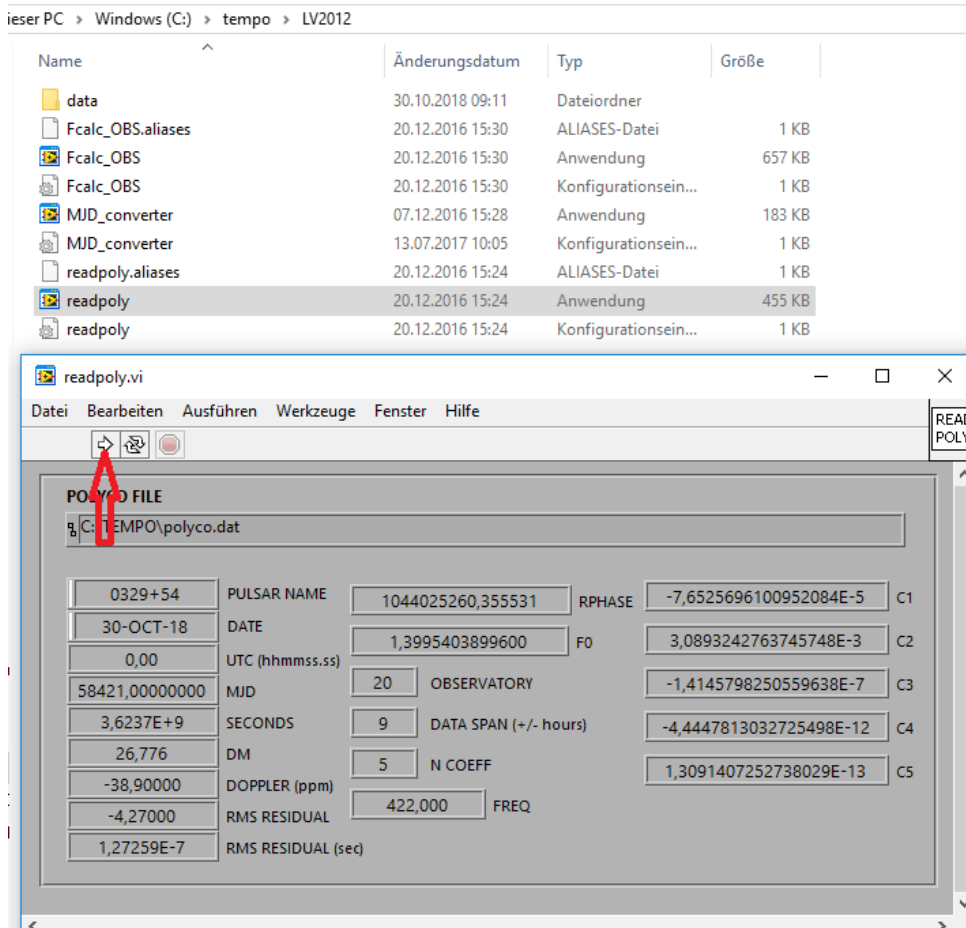
  PSR      Nspan  Ncoeffs  Maxha   Freq
-----
0329+54    1080      5      9.00  422.00000

Current date is 30-OCT-18, or MJD 58421.433
Enter first and last MJD, or hit return to run for today:
58421 58421

```

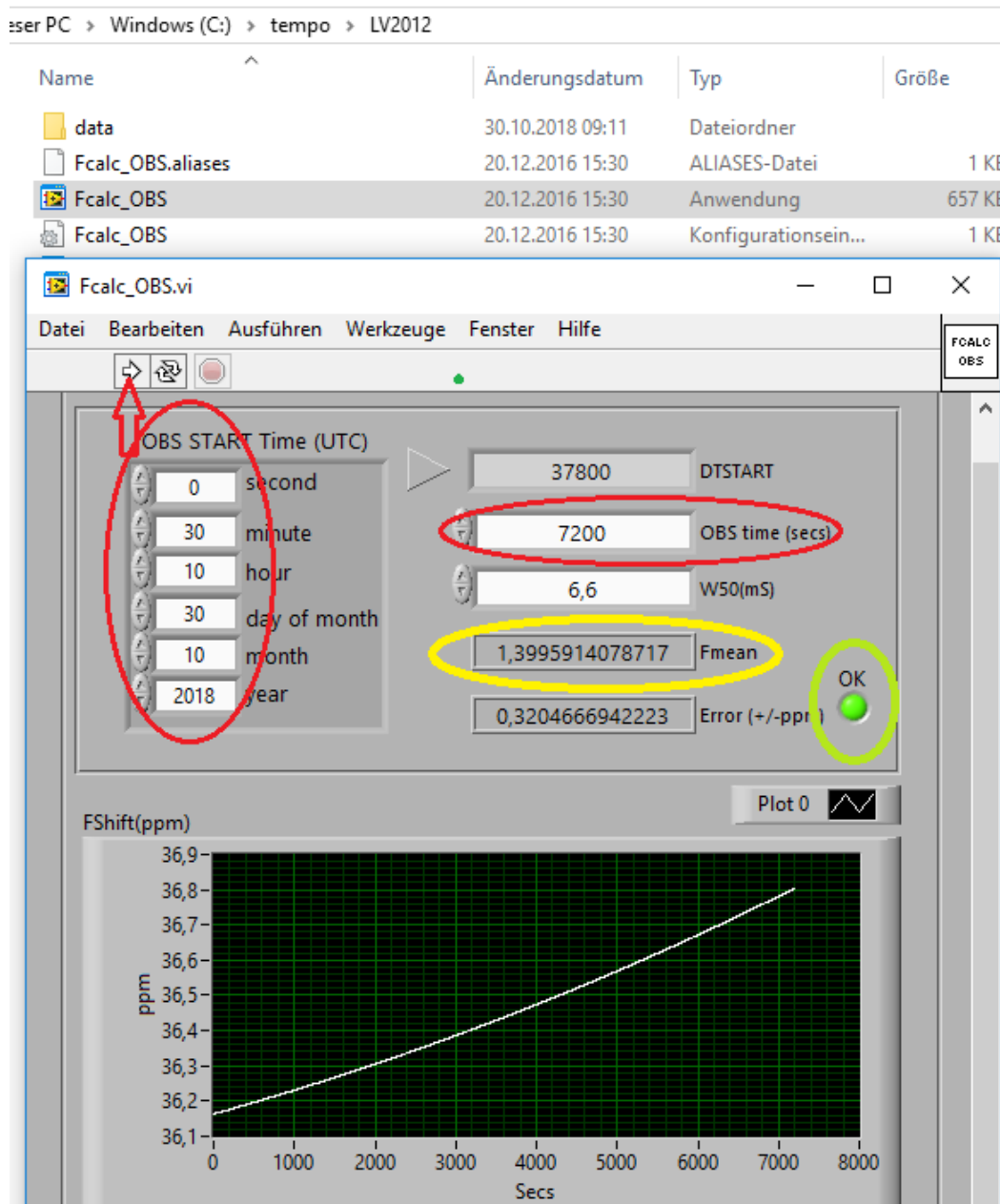
Insert the MJD two times, for the current date it is indicated already, normally only the integer values are needed, sometimes also the decimals. Now hit ENTER, the DOS window disappears. For a different date you can calculate MJD using the MJD converter in the subfolder LV2012.

Now open **readpoly** in the subfolder LV2012 and run it, be sure the right date is indicated, otherwise modify decimals of MJD running tz.bat again.



It might happen that readpoly.exe does not read C1...C5, the program needs a 'comma' as a delimiter. In case of problems try in Windows: Settings. ...Time & Language. ...Related settings.Additional time & regional settings.Region. ...Change date, time or number format.select Italian.Additional settings.change decimal symbol to ','

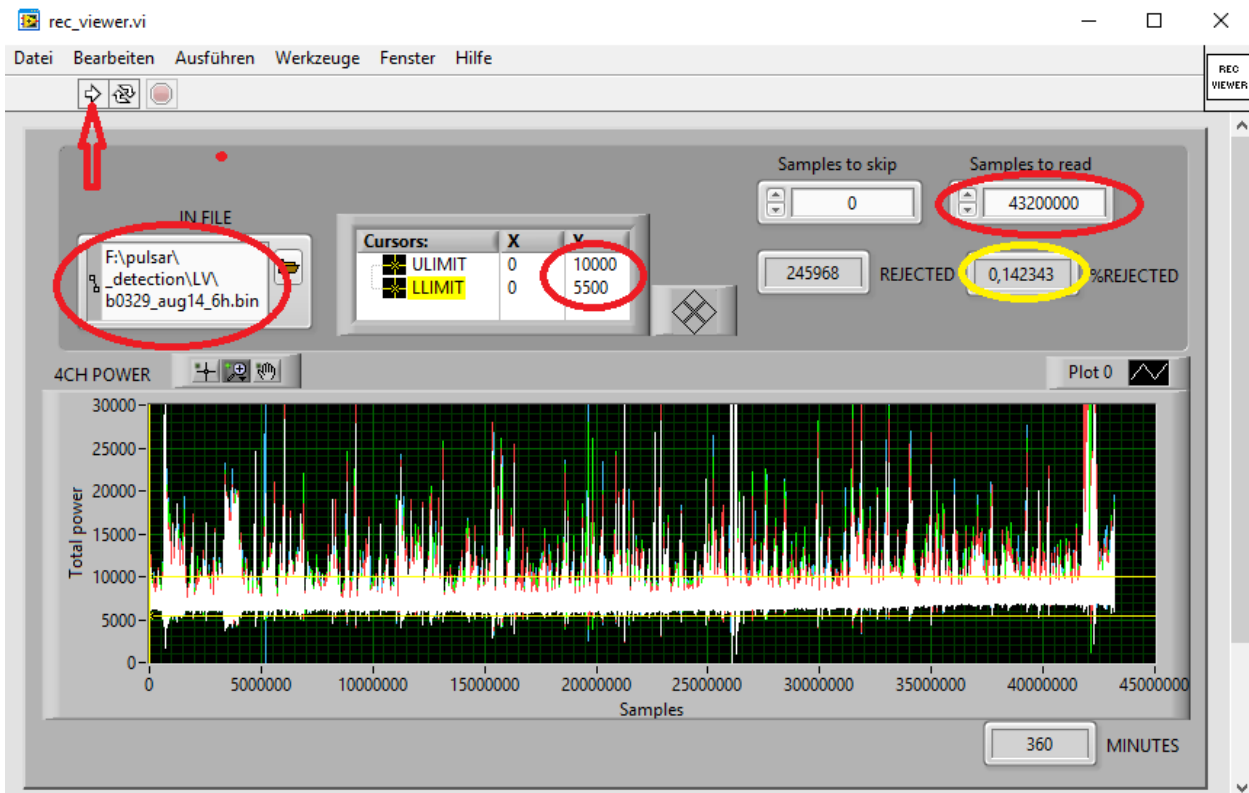
To calculate the pulsar frequency now open **Fcalc_OBS** in the same directory. Run it after setting date, time and OBS time (2 hours in the example).



The result **Fmean** you can use for (3.) analyzing. If the little OK lamp will not be coloured green but black instead, the observation time might be too long or some mistake was made doing the previous steps.

For analyzing the recorded *.BIN file I recommend to check it first with **recviewer**, to see how to set upper and lower limits for the folding process. This is important for example to suppress pulses caused by RFI, and to avoid indication of fake pulses.

As an example I took a 6 hours observation of B0329+54 I made Aug.14th 2018.



The value Samples to read is observation time in seconds multiplied by 2000. Running the program another time after setting ULIMIT and LLIMIT, the percentage of rejected samples to be 0,14% is indicated. Rather low, although we can see strong RFI. Obviously the interference is short pulses only.

Now all is prepared to try to find a pulse in the observation *.BIN file!

Open **simple_folding**, for some values you can use default numbers.

Insert the value for #PULSES INTEGRATION, for the B0329+54 this is 5000 per hour.

Then set upper and lower limit from recviewer, in the example 10000 and 5000.

For F0 take Fmean from calculation by tempo (note the difference between the values of Aug.14th to Oct.30th).

Now run the program, hopefully you see a pulse!

#SAMPLES TO SKIP is for centering the pulse in the display.

Especially for long observations the frequency error of the RTL-SDR can be an issue.

In the example the value for compensation is -0,08 ppm. To measure the error of the SDR, I used the ON0EME beacon on 23cm. Any other exact RF source will do the job as well.

It is worth the effort to change the parameters in small steps to achieve an improvement of S/N. But stay within +/-1ppm for F0. If you see a pulse for example with F0 offset 10ppm, it is for sure a fake pulse!



FOLDING PARAMETERS

F:\pulsar_detection\LV\ b0329_aug14_6h.bin IN FILE

-0,080 SR ERROR (Dongle) ppm

0,000 SHIFT ppm

750 #SAMPLES TO SKIP

0 #PULSES TO SKIP

30000 #PULSES INTEGRATION

10000 DEPTH 5000 CUTOFF

120,0 VIDEO FILTER

PULSAR PARAMETERS

1,3996471843 F0 Hz 1 N

3,000 DISPERSION (mS/MHz)

STATUS

2519 #REJ 8,4 REJ%

42867943 SAMP 42867943 SAMP-1

1429 #READ 21434 TIME

pulsewidth(ms)

40

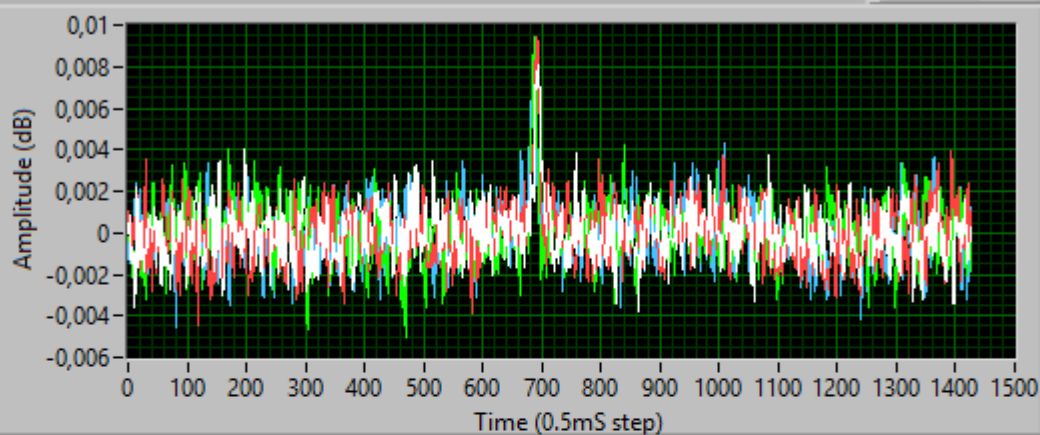
MEASUREMENTS

1st PEAK max index 2nd PEAK 1st/2nd S/N

0,00783 699 0,00105 7,48 20,022

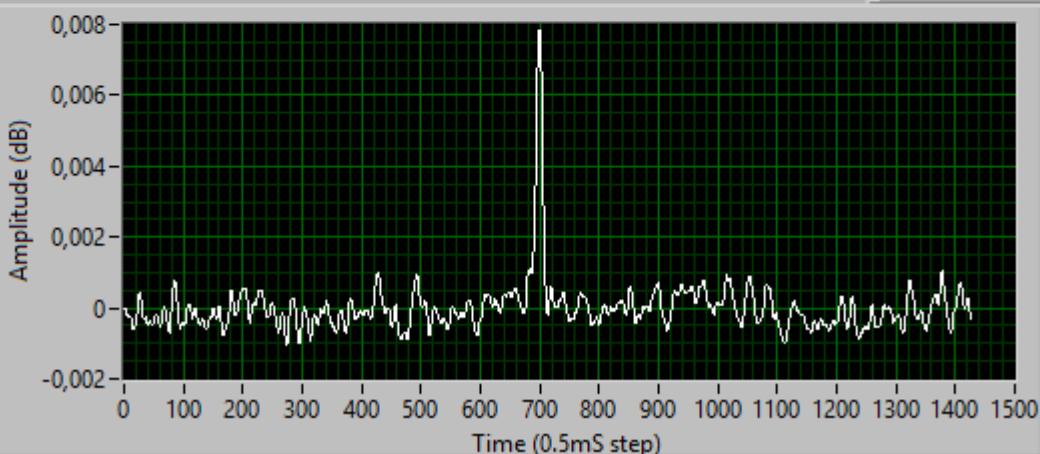
PROFILE

Plot 0



DE-DISPERSED PROFILE

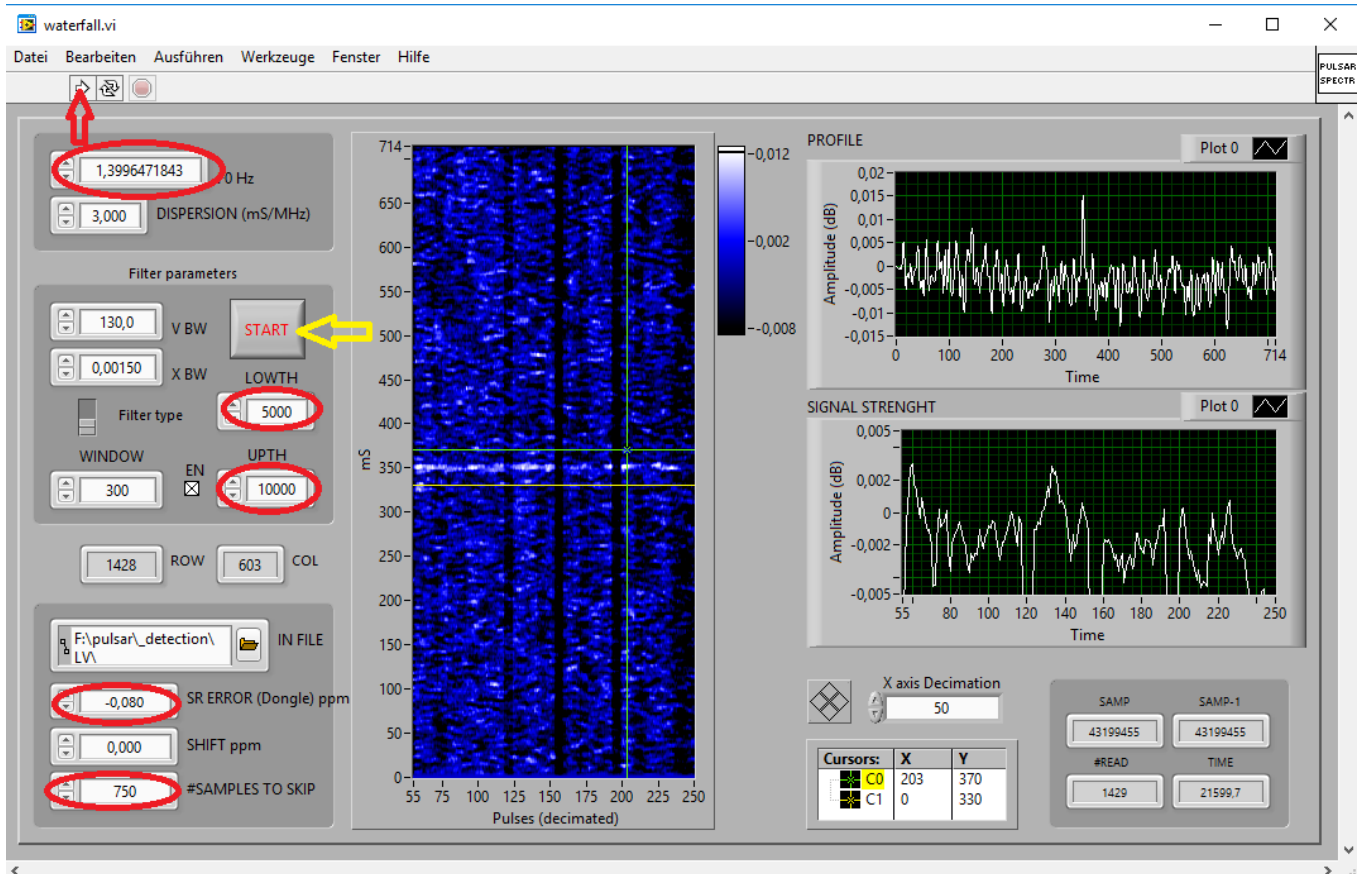
Plot 0



A nice tool is also **waterfall**, insert the same F0, upper and lower limit, ERROR ppm and #SAMPLES TO SKIP as in simple_folding.

Then start the program (red arrow), wait until all samples are loaded and now click at the START button (yellow arrow).

In the example you see that during the observation there was strong RFI several times. The second part was worse in general, therefore the displayed time is abbreviated.



To keep this article short, I did not describe all options in detail.

But following the steps, everybody should have first success!

Try it and have fun!

Special thanks go to Andrea, IW5BHY and his son Giorgio for making the software available!!