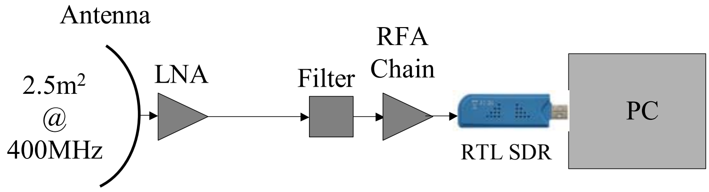
Starter Guide to Using the RTL2832U TV Dongle for Detecting the B0329+54 Pulsar.

Sources for purchasing some receiver components are noted below, but some mechanical build experience is necessary for the antenna and filter. However, on-line design tools are available as listed to guide this process.

The 400Mhz frequency band is chosen for pulsar signal strength reasons; the relevant Radio Astronomy band 406-410MHz and Radio Amateur band 430-440MHz are possible but the range should be scanned before selecting your antenna design and operating band to find the region of lowest local radio frequency interference (RFI). Using the RTL SDR with free ***SDR#*** software downloaded from https://airspy.com/download/ is useful for a low RFI spectrum search.

For actual measurements, experience shows that lowest RFI occurs with night-time observations although propagation variation in the interstellar medium may conspire to impact successful results. Persistence will be rewarded.

Basic Pulsar Radio Telescope - low-cost entry



"The real killer is wideband RFI noise, so do the simple test of replacing the antenna with a 50Ω load while pointing the antenna at the elevation that you intend using - hopefully the noise level rises with the load but if it goes down significantly ....!" PK Blair(G3LTF)

LNA - low noise amplifier
SDR - software defined radio
RFA - radio frequency amplifier

Software Processing:
Data Recording
Detection/demodulation
Period Folding
Data Plotting

Antenna Options - self build, 2.5m² effective aperture around 400MHz required

3-D Corner Reflector
$A_e = 5\lambda^2$
$= 2.5m^2$ @ 400MHz

Twin Yagi
$A_e \fallingdotseq 1.2L\lambda$
L=2.5m, $A_e = 2.2m^2$
@ 400MHz

Dish
$A_e \fallingdotseq 0.55A$
D = 2.4m,
$A_e = 2.5m^2$
@ 400MHz

3D Corner reflector design:
https://blog.freifunk-mainz.de/wp-content/uploads/2013/08/Shortened-3D-Corner-Reflector-Antenna.pdf

Yagi design:
https://www.yagicad.com/
https://www.qsl.net/dk7zb/70cm/70cm-kurz.htm

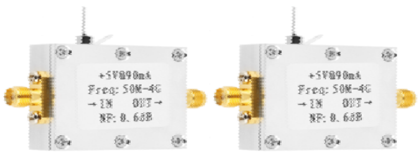
Dish Feed design:
https://www.changpuak.ch/electronics/cantenna.php

Code:-
A_e= effective area; L= length;
D= diameter; λ= wavelength

RF Components - NF<0.5dB for the first LNA, close coupled to antenna feed

LNA: Minicircuits type,
ZX60-P103LN+
~ 20dB gain and
0.5dB noise figure

Filter Bandwidth
5MHz, Loss 2.5dB



RF Chain: Ebay/Aliexpress
Packaged low noise RF amplifiers
~25dB gain, 0.6dB noise figure

Self-build the narrow-band-defining filter. *Filter Design Tool:* https://www.wa4dsy.net/cgi-bin/idbpf/

RTL 2832U TV dongle - low-cost entry

The RTL device is available from a number of sources, but it is important for this application that it is of the right quality and in particular frequency and temperature stable.
The Noolec NESDR SMArt v5 is a good choice.

RTL Software - Osmocom rtl-sdr software tools for Windows

OsmoCom have produced an '*rtlsdr*' library & capture tool. The data capture tool, *rtl_sdr.exe* produces binary files (.bin) containing raw IQ 8-bit data for analysis.
A link for the rtlsdr tools download versions is given in reference 1, below.

The USB driver (zadig) for the RTL SDR is downloaded and installed as reference 2.
The Osmocom RTL tools for 'Windows', the zadig driver and folding software are all in the .zip file reference 3.
Software References:-

1. Osmocom RTL Software, https://downloads.osmocom.org/binaries/windows/rtl-sdr/
2. Zadig Windows Driver, https://zadig.akeo.ie/
3. Zipped 1+2, 32bit Package Including a Folding Program *at:* http://www.y1pwe.co.uk/RAProgs/winrtl.zip

Antenna Directing - *drift scan or tracking*

Programs such as *Stellarium* or *Radio Eyes* can locate B0329+54 and help direct the antenna.
Optimum time for small antenna drift-scan measurements is at culmination, the highest target elevation at due North. Observation data collection times of 2 to 3 hours may be required.

Recording Data Files *- test observation*

First, unzip *winrtl.zip* files (reference 3) to your working directory.
The data recording procedure is:- Open Windows command terminal *cmd.exe* and initialise to the working directory. To record data to a binary file, *capture1.bin*, type on the command line…

rtl_sdr.exe capture1.bin –f 425e6 –s 2400e3 –g 42

This command tunes the rtl dongle to 425MHz, samples both I and Q measures at 2.4MHz rate, sets the dongle gain at 42dB and records 8-bit bytes of *I* and *Q (in-phase and quadrature)* samples interlaced to the .bin file. This output file, *capture1.bin* grows at 17.28GB per hour and is stored in the current folder; user-terminated at the end of observation by pressing the keys 'Cntrl C'.

Analysing Data Files - *observed topocentric period*

Due to the Earth rotation and orbit round the sun, the pulsar pulse frequency and indicated pulse period will be Doppler shifted. This is called the topocentric period and is relative to the observers position and observation time; the observed period can be found from the professional astronomer's program, TEMPO.
A Windows on-line TEMPO calculator with instructions is available from Joe Martin (K5SO) at the browser address:

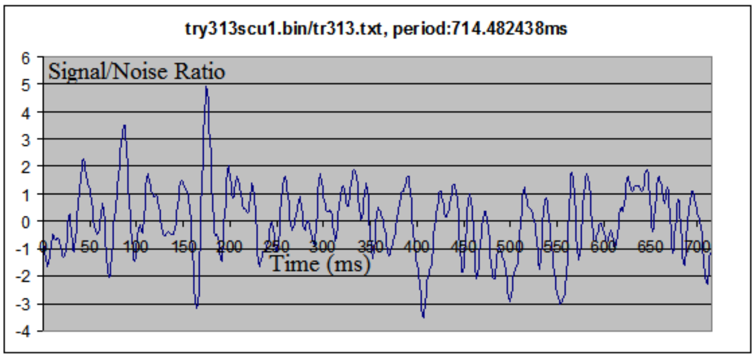
http://www.k5so.com/documents--and-downloads/download-tempo_calc.html

Data Plotting - *basic integrated period plot*

A basic data folding analysis program for Windows using the TEMPO-derived topocentric period is available in reference 3 above, ***rapulsar2con.exe.*** This program folds and integrates the data at the noted pulsar topocentric period, filters the data to pass the pulsar pulse bandwidth and outputs the data in .txt form of bin number versus instantaneous signal-to-noise ratio. Warning: Large binary files take a long time to process.
The program command line for Windows working directory, *cmd.exe* terminal is:-

rapulsar2conv.exe <infile> <outfile> <data clock rate (MHz)> <output data points> < pulsar topocentric period(ms)> <pulsar pulse width(ms)>

Example: ***rapulsar2con.exe try313scu1.bin tr313.txt 2.4 1024 714.482438 6.5***



The example text file *tr313.txt* from a 611MHz acquisition using a pair of 2.5m Yagis, is opened in Windows Excel, selecting columns A, B and clicking on the Chart Wizard + XY Scatter produces the above plot.

Notes:
1. The frequency stability of the RTL2832U SDR is not all that great and you may have to tune the period value by + or - a few parts per million to optimise the pulse amplitude.
2. In this basic guide the data is not de-dispersed so some broadening and pulse amplitude reduction will be evident.
3. The displayed plot bandwidth is matched to the video pulse and is independent of the chosen data points/bins number.
4. Other tests are necessary to positively prove true pulsar detection in this case.

The Next Stage.....- for more in depth pulsar analysis, RFI reduction and detection proving, go to:-
M. Klaassen: Windows, 3pt analysis tools for RTL SDR , http://parac.eu/projectmk17b.htm
A. & G. Dell'Immagine, Linux, Pulsar-Distro-Guide, https://github.com/gio54321/pulsar-distro-guide
M. Leech: Linux/Windows, GNURadio data collection and processing, https://github.com/ccera-astro/pulsar_filterbank
TEMPO: Linux, TEMPO, http://pulsarastronomy.net/pulsar/software/tempo
PRESTO: Linux, PRESTO, Pulsar Analysis Software, https://www.cv.nrao.edu/~sransom/presto/

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