Amateur Pulsar Observations using Inexpensive Equipment

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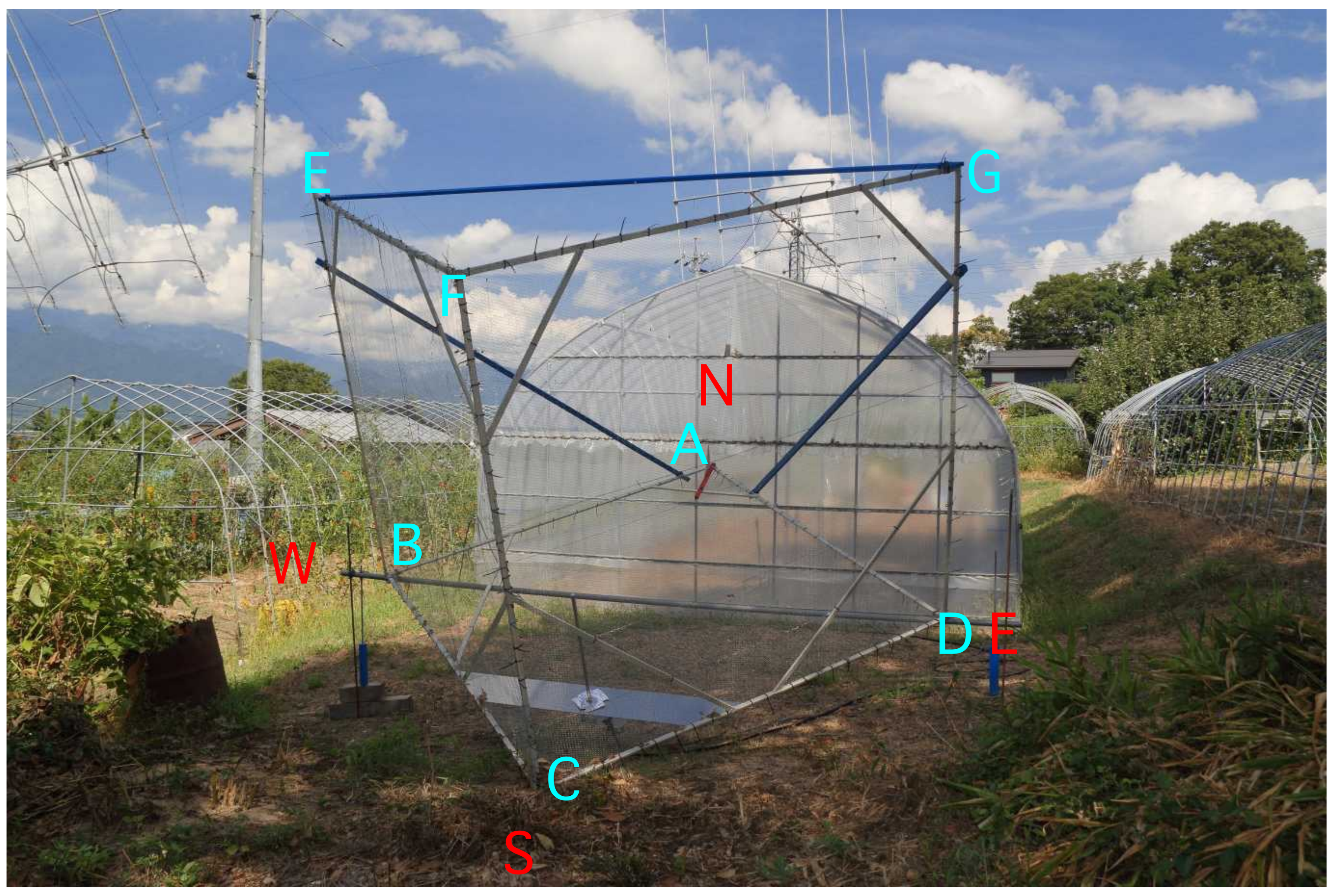
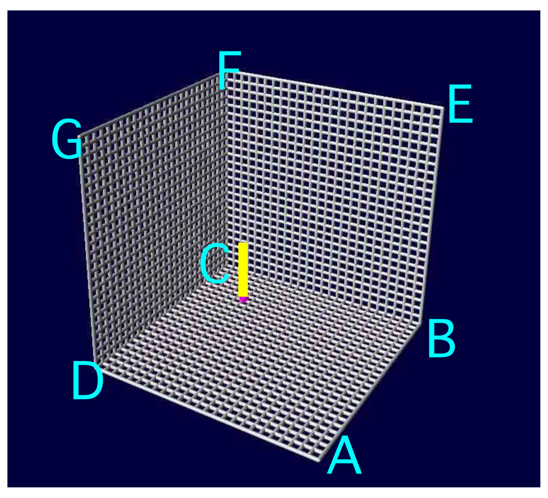
As an avocational activity between amateur radio and radio astronomy communities in Japan, the brightest radio pulsar visible in the northern sky (PSR B0329+54) was detected at 418MHz using a 3D Corner reflector antenna with an SDR.

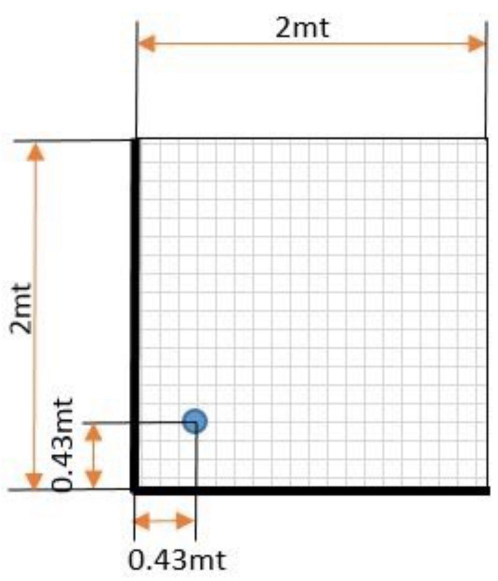
System Description

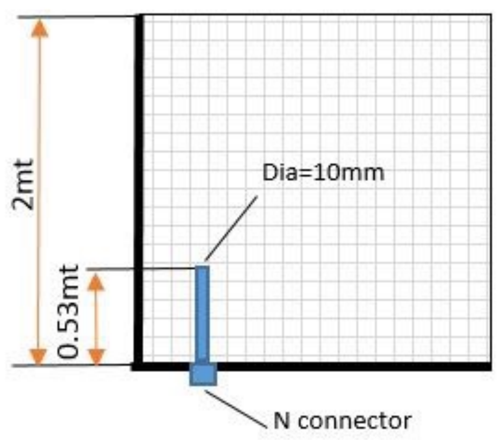
3D Corner Reflector Antenna

- A 3D corner reflector antenna is basically a monopole antenna with a metallic 'corner' reflector placed behind it. The reflector helps the monopole collect signals over a wider aperture resulting in signals coming in stronger from the direction that the corner is pointing at.
- The 3D Corner reflector antenna radiates along the bisector of the 3D angle and the main beam takes off at an angle of about 45° to the bottom plate.
- 418MHz was chosen from RFI monitoring results. A 2-meter 3D corner reflector was out of readily available metal pipes and mesh.



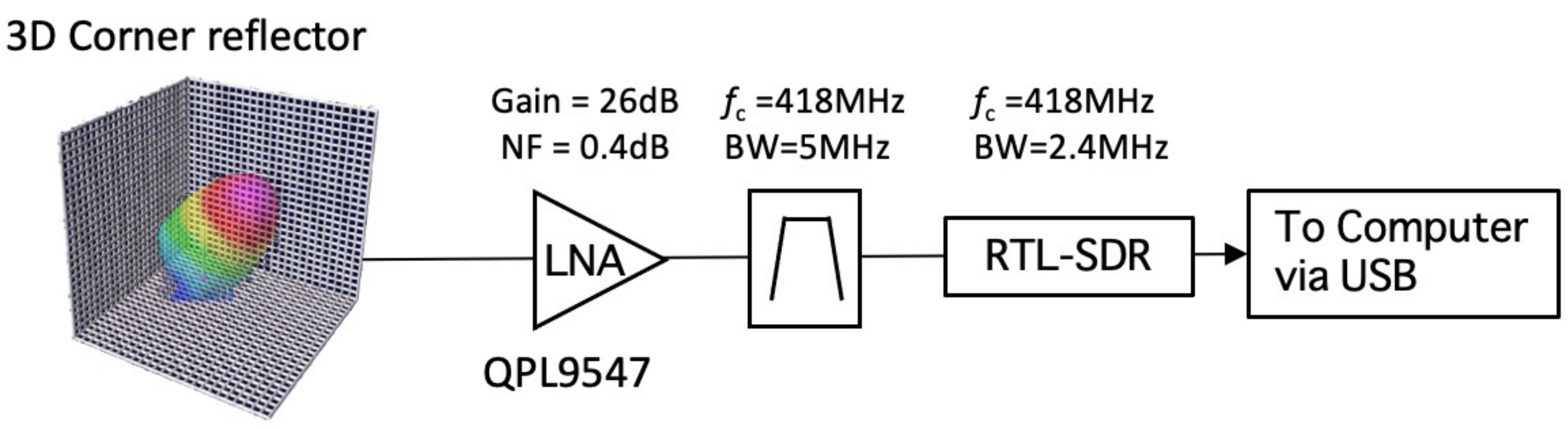






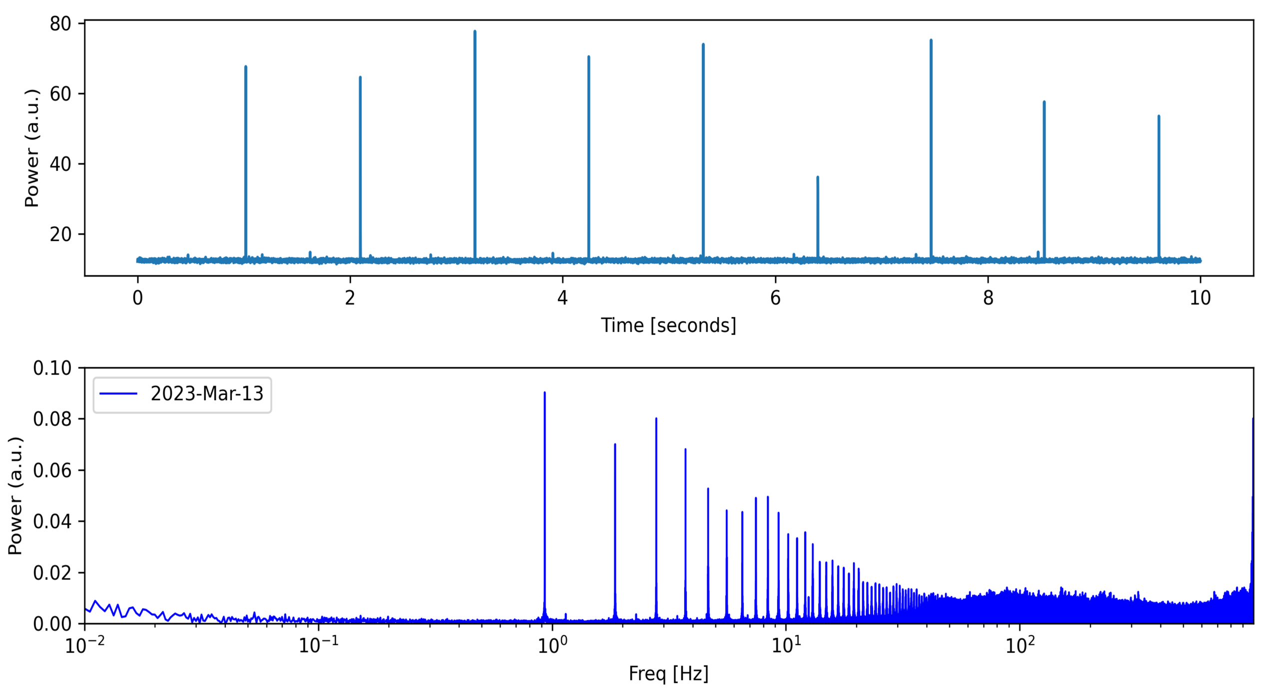
Block Diagram

- After being amplified by a Low-Noise Amplifier (QPL9547), the RF signal from the antenna passes through a BPF and is sampled by an SDR receiver (RTL-SDR Blog V3).
- An interdigital filter was designed using the online tool by A. Changpuak [1]
- The system noise temperature is about 100K.



Electric Fence Interference

- An electric fence could behave like a spark transmitter, creating noise that could be heard a mile away[2].
- Clipping the ~1Hz noise in data reduction.

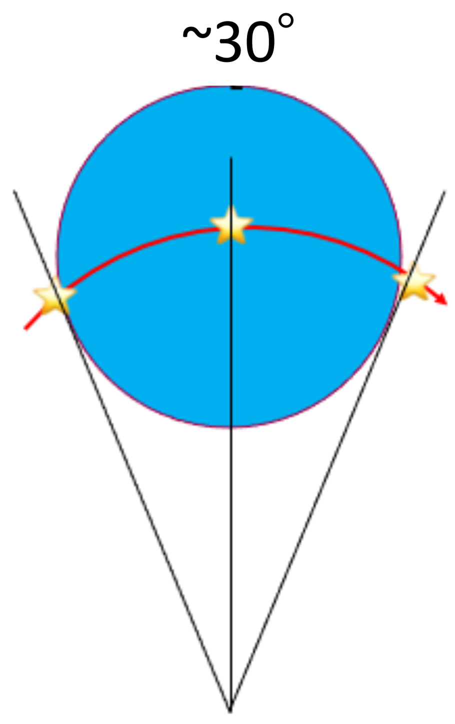


B0329+54 @418MHz Drift Scan Observation

PSR B0329+54 @ 420MHz												
RF Freq [MHz]	Effective Area [m^2]	Gain [dBi]	Beam Size [Deg]	Tsys [K]	Pol	BW [MHz]	Flux [mJy]	Width of pulse @50% peak [ms]	Period [s]	Beta	Integration time [s]	S/N
420	2.5	17.9	30	100	1	2.4	1500	6.6	0.71452	0.8	7200	14.8

From [3]

$$SNR = \frac{S_p A_e \sqrt{n_p t_{\rm int} \Delta f}}{2\beta k_b T_{sys}} \sqrt{\frac{P-W}{W}}$$



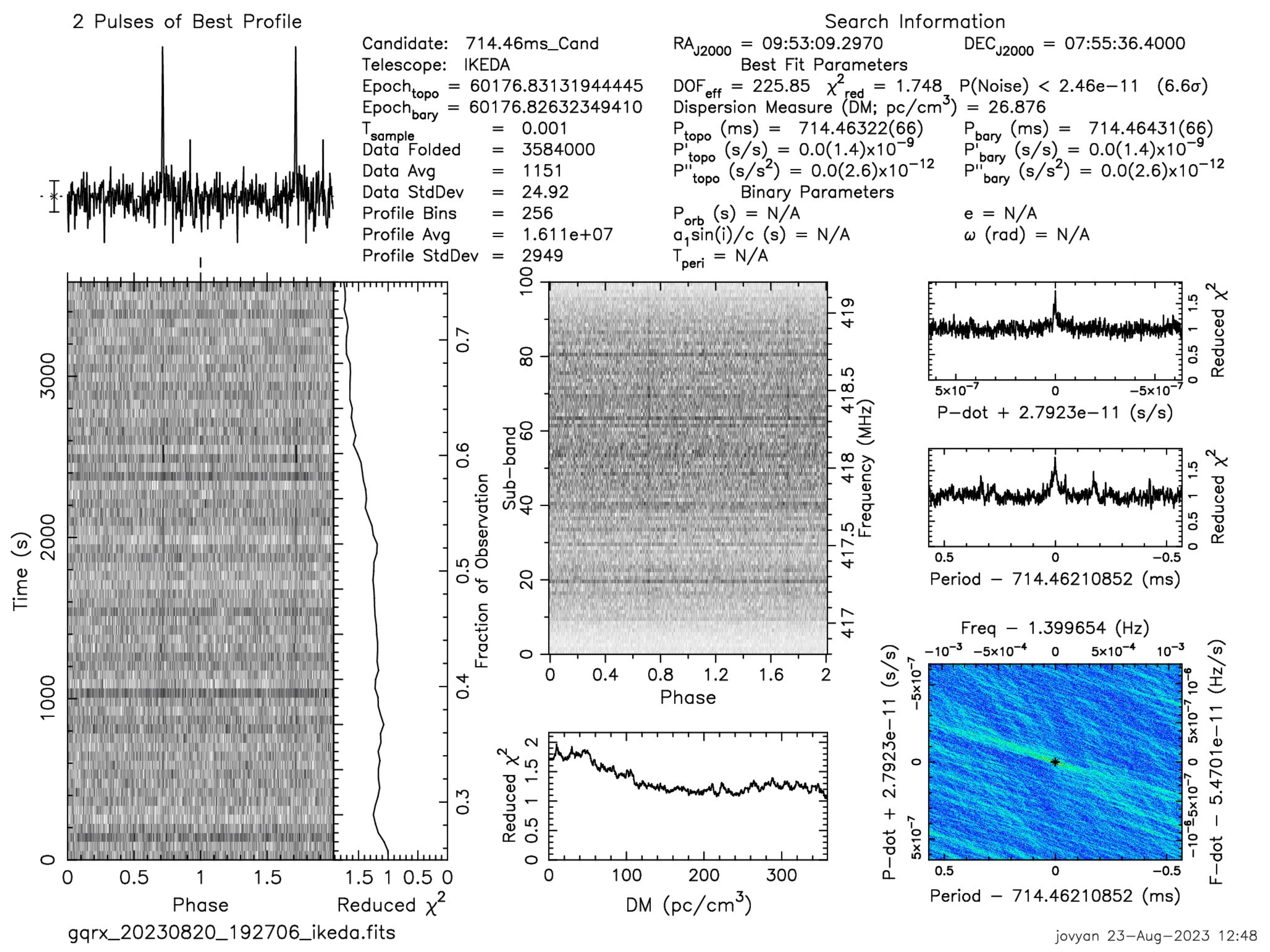
～beam size[deg]/15[deg]*3600[s]

A_e is the receiving antenna effective collecting area in m^2.
n_p is the number of polarizations received.
t_{int} is the total integration time in seconds.
Δf is the receiver RF bandwidth.
P is the pulsar period.
W is the pulsar half-height pulse width.
factor 2 halves the pulsar flux to conform with the flux with a single polarization.
β is a modifying factor to account for digitization losses for coarser digital increments.
k_b is Boltzmann's constant.
T_{sys} is the receiver system noise temperature.

- These are ideal conditions; natural pulsar scintillation and local RF interference limits success in real observations.
- In order to successfully detect pulsars, the target observed signal-to-noise ratio (S/N) > 10 is preferable

Pulsar Detection

- RTL-SDR USB platform and allows a typical sampling frequency of 2.4 MS/s.
- Power spectrum is computed via Fast Fourier Transform (FFT) from raw 32-bit complex IQ samples.
- SDR data converted to *PSRFITS* format by the software package *YOUR* [4] Data reduction was performed by *PRESTO* [5]



Reference

[1] https://www.changpuak.ch/electronics/interdigital_bandpass_filter_designer.php
[2] https://www.gb.nrao.edu/IPG/Fence.shtml
[3] Lorimer, D. R., & Kramer, M., 2005, Handbook of Pulsar Astronomy, 4（Cambridge University Press)
[4] Aggarwal, K., et al., 2020, Journal of Open Source Software, 5, 2750
[5] Ransom, S., 2011, Astrophysics Source Code