RFI studies using the Parkes ultra-wide bandwidth receiver and implications for future instruments

George Hobbs
17th November 2022

The Parkes Pulsar Timing Array project

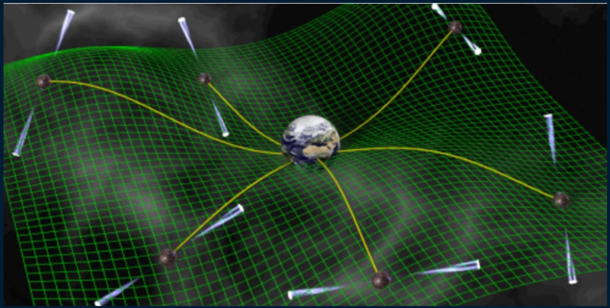

Image: David Champion

- Observe pulsars using the Parkes telescope
- Searching for gravitational waves!

https://sciencesprings.wordpress.com/2021/01/11/from-green-bank-observatory-and-nanograv-nanograv-finds-possible-first-hints-of-low-frequency-gravitational-wave-background/international-pulsar-timing-array/

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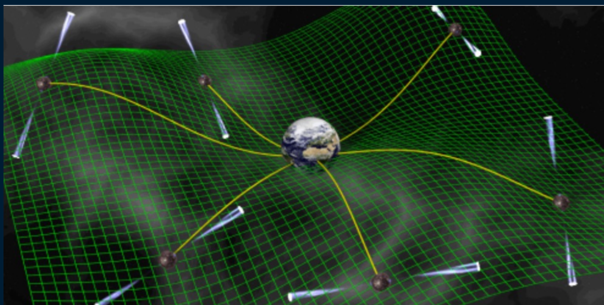

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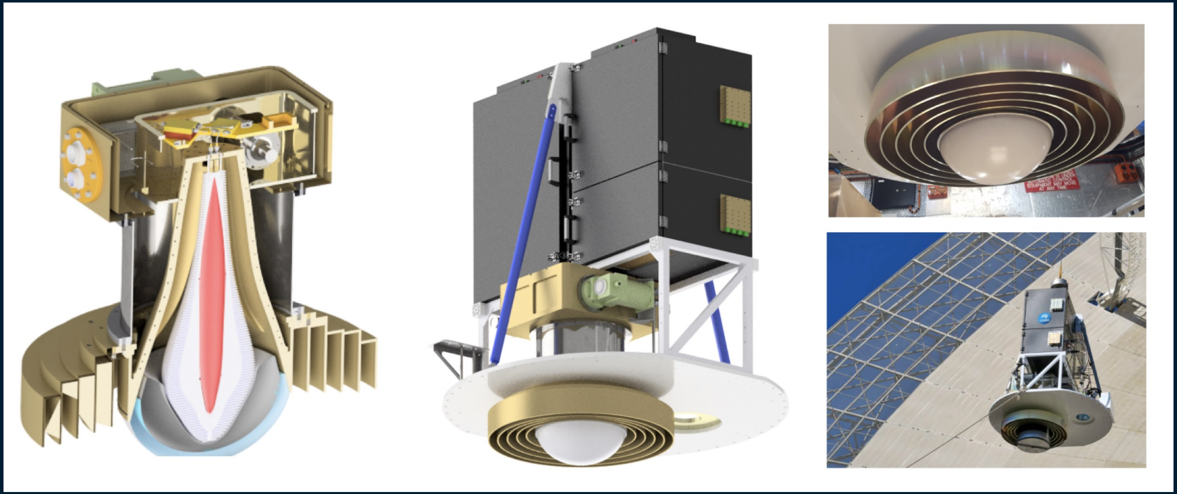
- Lots of other telescopes also doing similar projects (including FAST and MeerKAT)
- What's special for Parkes?

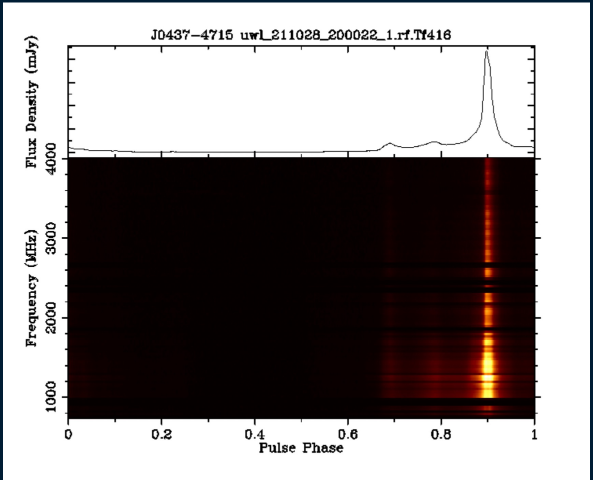
Why is Parkes special?

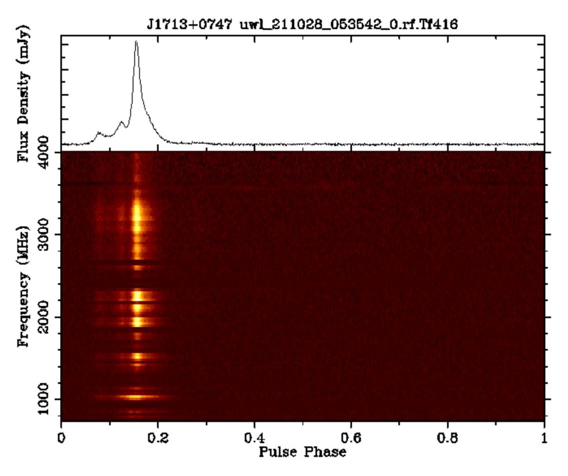
- Since end of 2018: Has an ultra-widebandwidth receiver!



Why is Parkes special?

- Provides frequency coverage from 704 to 4032 MHz
- Tsys ~ 22 K
- FPGA and GPU-based signal processors.





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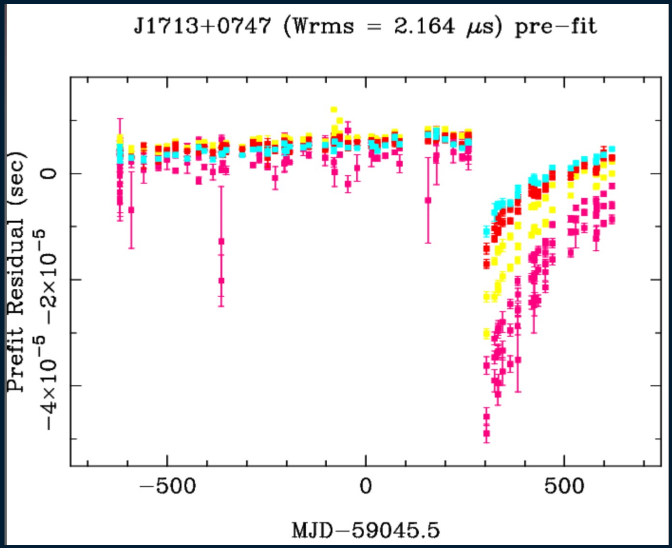


But …

- Radio frequency interference! Major problem with wide-bandwidth receivers!

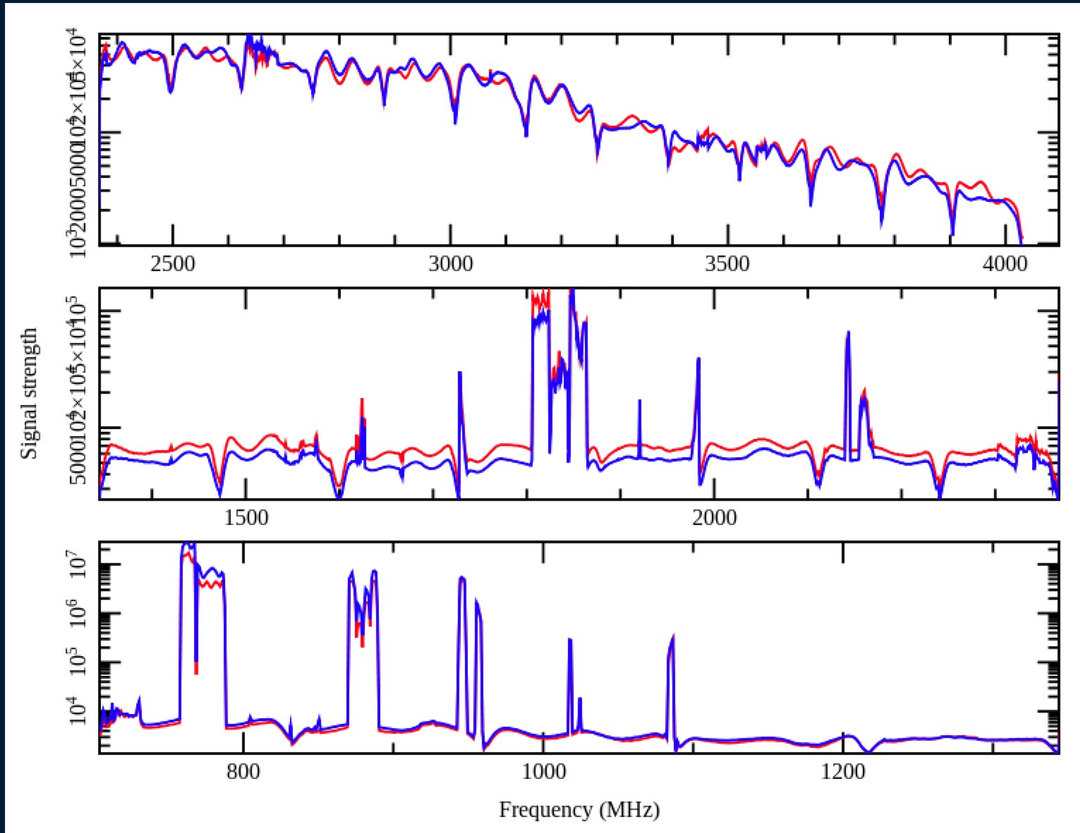
The bad …

- Parkes is not a well-protected site (in terms of RFI)
- Visitor centre => mobiles, WiFi, Bluetooth
- Aircraft, satellites …
- Mobile communication systems
- Self-generated signals

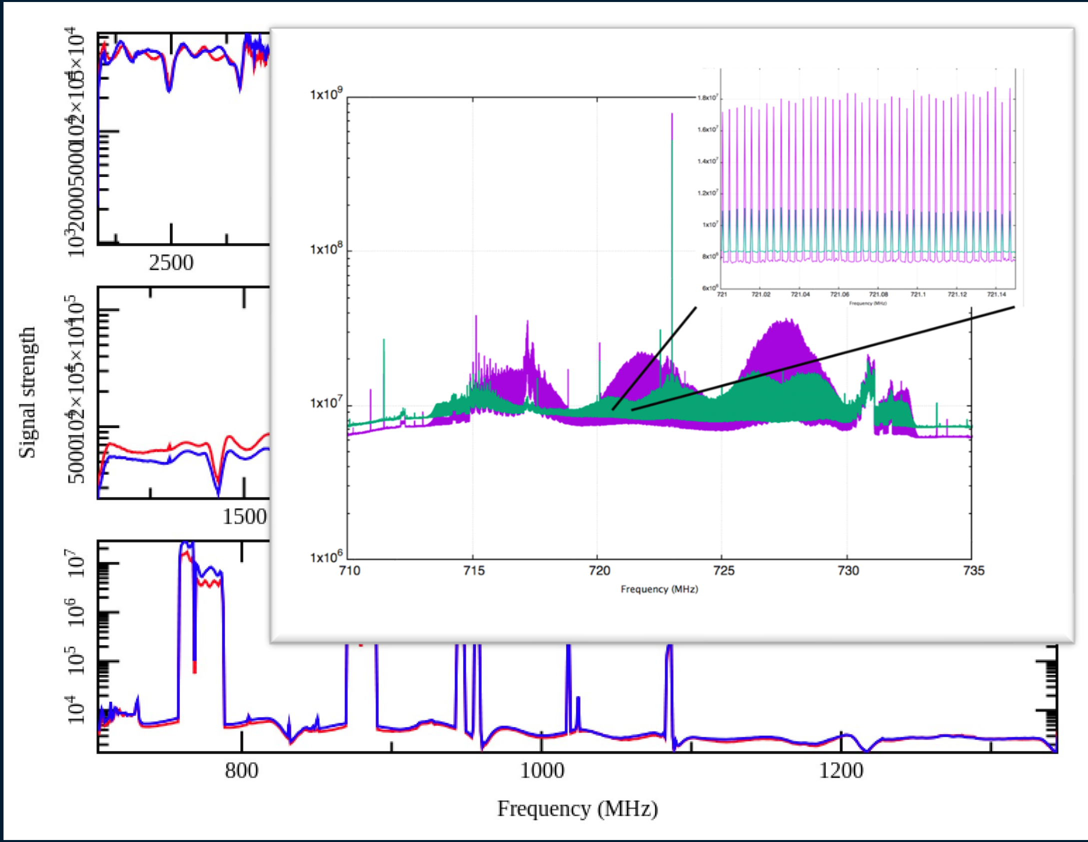
- Single dish telescope, currently single-pixel receivers

The good …

- Flexible data products (including voltage streams)
- Generally frontend and digitizer-system does not saturate
- High dynamic range.
- Lots of observations
- Most RFI explained
- Have reference antennas
- Multiple back-end systems



Can see: handsets, transmission towers, aircraft/airport, satellites, wifi and bandpass shape from critically sampled filterbanks


Signal strength
Frequency (MHz)
800
1000
1200
1500
2500
1x10^9
1x10^8
1x10^7
1x10^6
710
715
720
725
730
735
Frequency (MHz)

The RFI is getting worse …

~710 MHz: lost 20 MHz from handsets
~1830 MHz: lost 20 MHz from mobile transmission towers
~2160 MHz: lost 10 MHz from a transmission tower
~2300 MHz: lost 20 MHz from NBN transmissions
~2640 MHz: lost 40 MHz from NBN transmissions
~3450 MHz: lost 20 MHz from transmission towers
~3550 MHz: lost 20 MHz from transmission towers

Since 2019 to now we have lost an extra 150 MHz (mostly transmission towers) + wifi/BlueTooth is more present now (~ 80MHz)

Amount of the band currently flagged during PPTA observations

- 850MHz (out of 3328 MHz = ~25%)

Amount of the band we have recovered for astronomy use ...

- 0 MHz (so far)

A smorgasbord of RFI

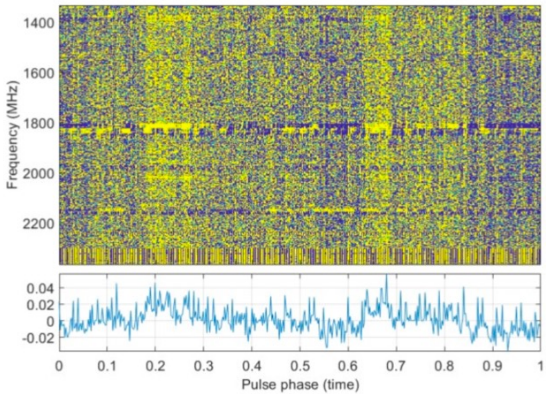


Figure 4. Uneven noise floor after pulsar folding due to self-generated broadband interference from broadband spreading from sample clock jitter of a strong and time-varying bandlimited interferer centered at 1820MHz.

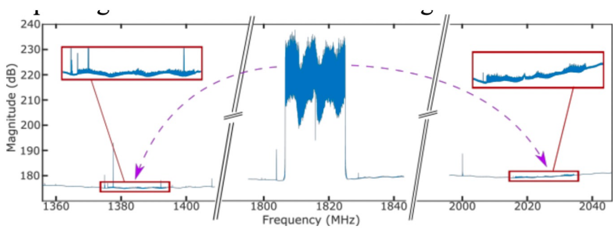
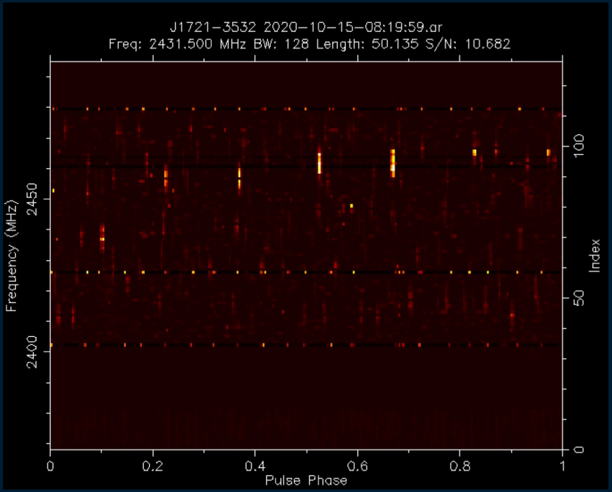


Figure 6. ADC interleaving artefacts resulting from strong, bandlimited RFI from 1815MHz to 1825MHz.

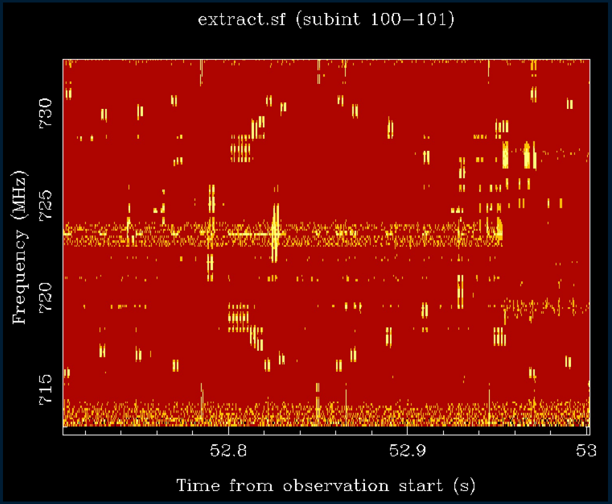
Wide Band RF ADC Conversion Artefacts and their Impact on Radio Astronomy

John Tuthill(1), Paul Roberts (1), Samantha Gordon(2) and George Hobbs(1)

A smorgasbord of RFI

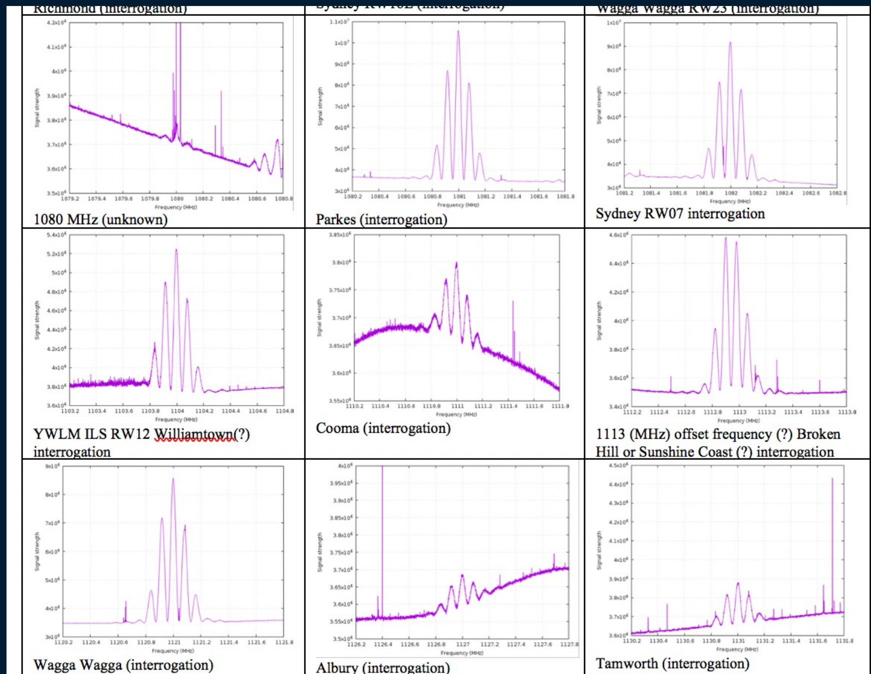


WiFi signal



Mobile handset

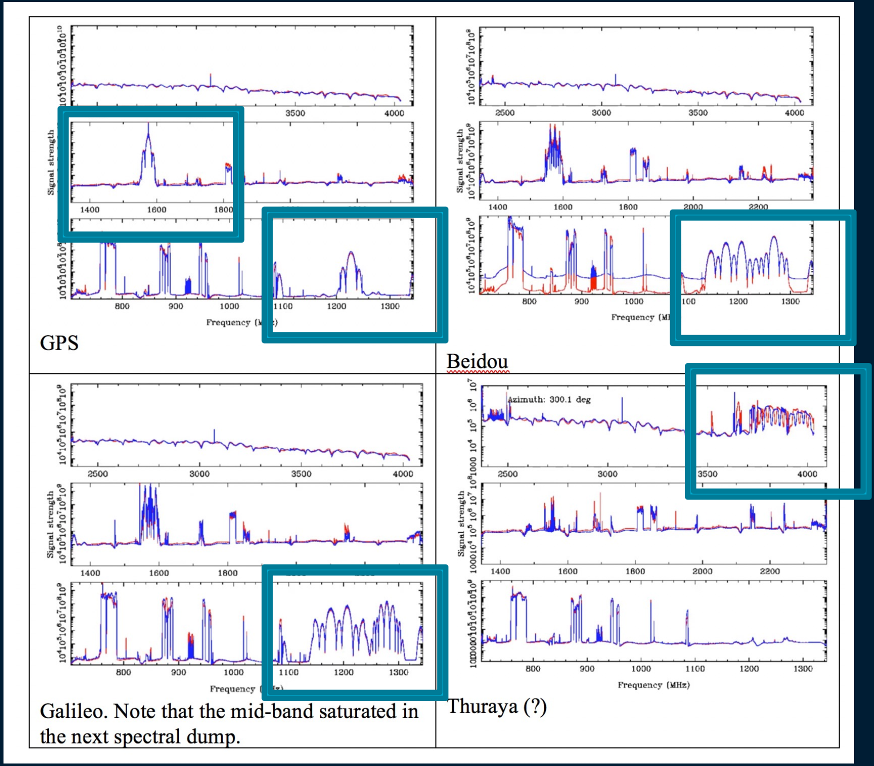
A smorgasbord of RFI



Aircraft distance measurement equipment

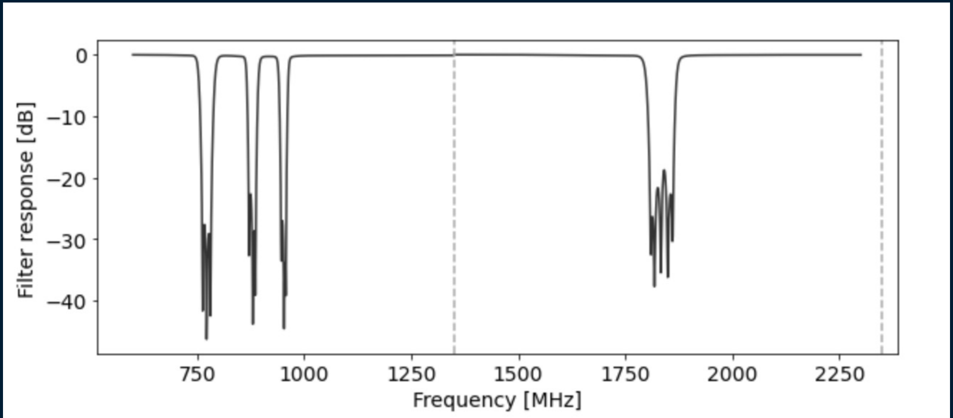
A smorgasbord of RFI

Satellites:



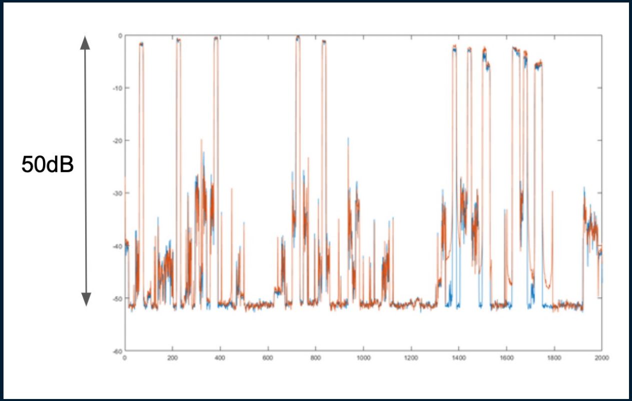
What are we doing about it?

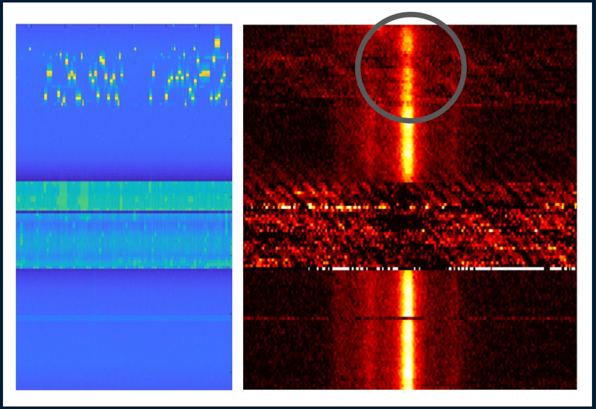
- Previously tried reference antennas for mobile transmission towers – has not been successful
- Now notching out the strong RFI:



The RFI is highly impulsive

Even though the impulsive RFI due to handsets is very strong, pulsars can be seen through the noise with some simple time/frequency blanking





Implications for the cryo-PAF on Parkes

- All the really tough RFI (except WiFi/Bluetooth) is also in the PAF observing band

- Cannot use notch filters on the PAF - notch filters fixed a lot of issues on the UWL

- PAF elements more susceptible to RFI

- RFI mitigation methods likely possible, but:
  - Haven't demonstrated any online yet!
  - Need FPGA/GPU/CPU processing power to carry out the mitigation (hard on 70+ beams)
  - Voltage simulation is easy and shows up a lot of issues! Also have "real" voltages relating to the RFI in the PAF band

  - Need a "goodness measure" to compare different algorithms

Thank you

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