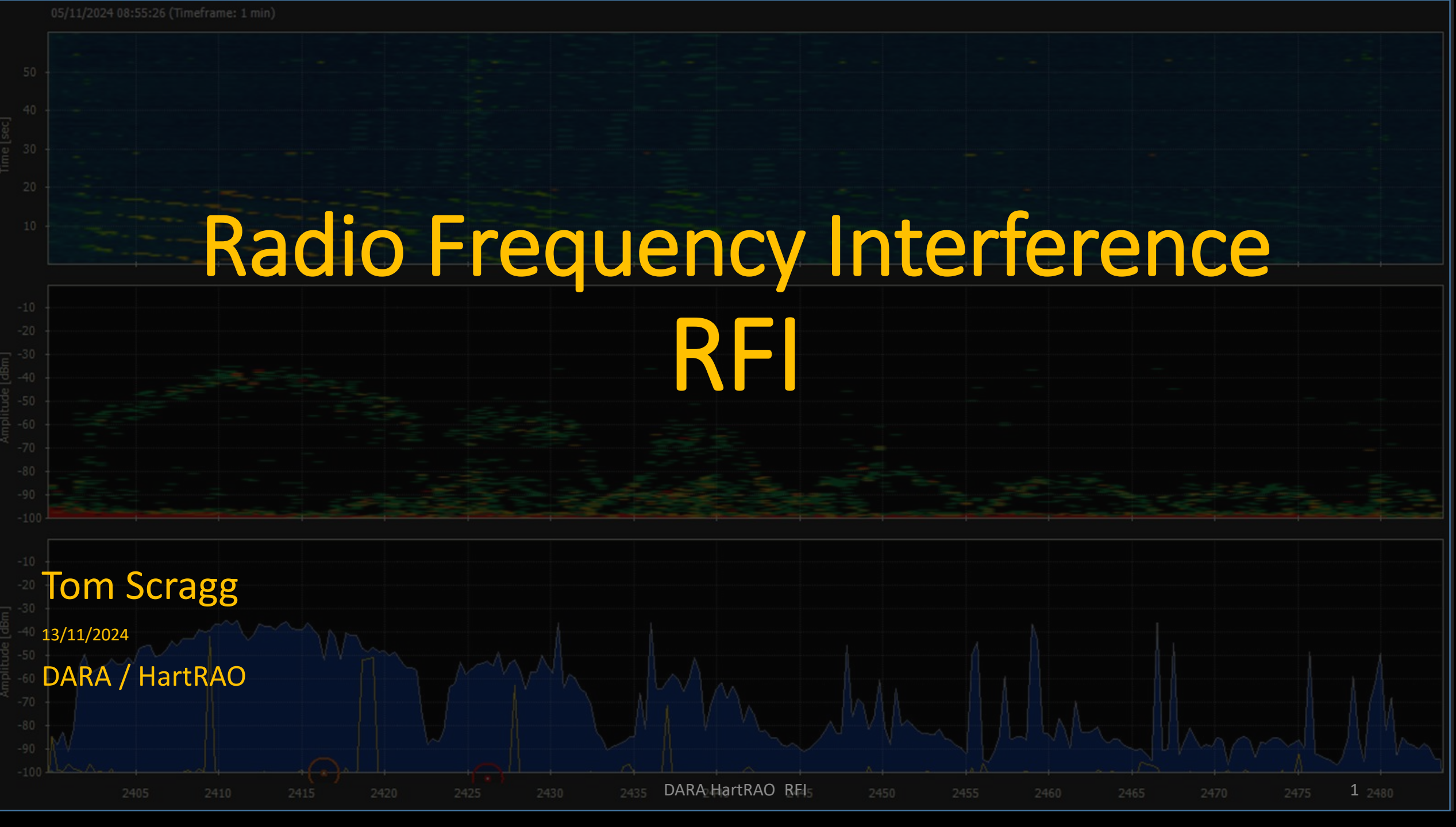


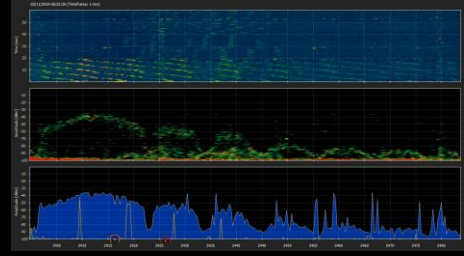
Radio Frequency Interference
RFI

Tom Scragg

13/11/2024

DARA / HartRAO

Radio Frequency Noise



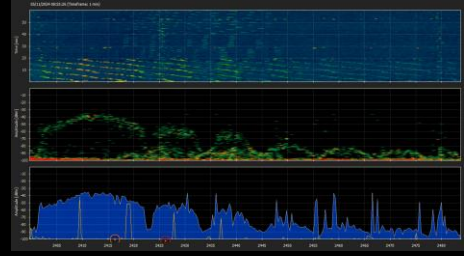
Noise in a telescope can be considered as having two components:

- Background or Noise Floor.
  - Tsys = Tsky + Trec + Tatm + Tspill

- Impulse or time domain specific noise
  - Radio Frequency Interference (RFI)
  - Generally ‘man-made’

We will talk a little more about (RFI)

Radio Frequency Interference



- RFI is noise from man made sources of typically local origin but can include transmissions from passing aircraft and satellites
  - typically narrow band but could also be
  - high intensity broadband from, for example, radar.
- RFI is variable in time from a few seconds to persistent, sporadic or periodic.
  - Sources of local RFI range from poorly shielded motors, pumps, engines, radio communications links, radar and even flickering floodlights.
  - Cellular and WiFi are sources of increasing problems to radio astronomy
- Some times RFI can be easy to identify and excised from digitised data by manual or computational means and other times it may manifest as a general increase in the noise floor and be difficult to compensate for.

Noise Spectrum: Intensity vs Frequency vs Time

Image credit:
Tom Scragg

WiFi and Bluetooth

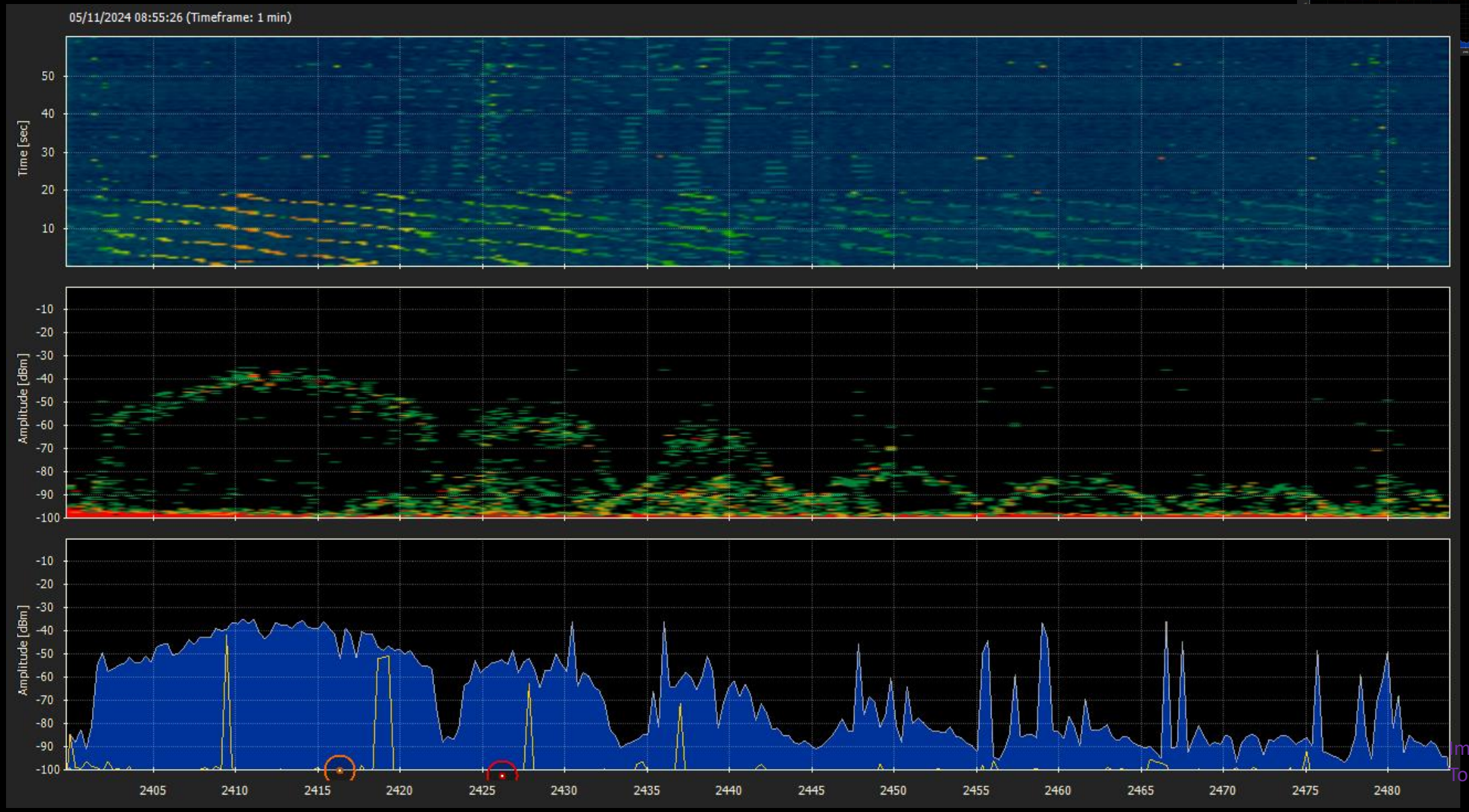
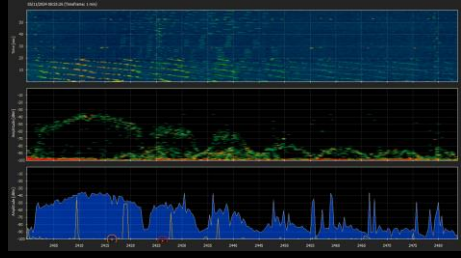


Image credit:
Tom Scragg

RFI during an Observation of Pulsar PSR B0329



RFI in a 10 minute observation of a pulsar: PSR B0329+54 with 64MHz of bandwidth.

Showing intensity (depth of colour) vs frequency and time.

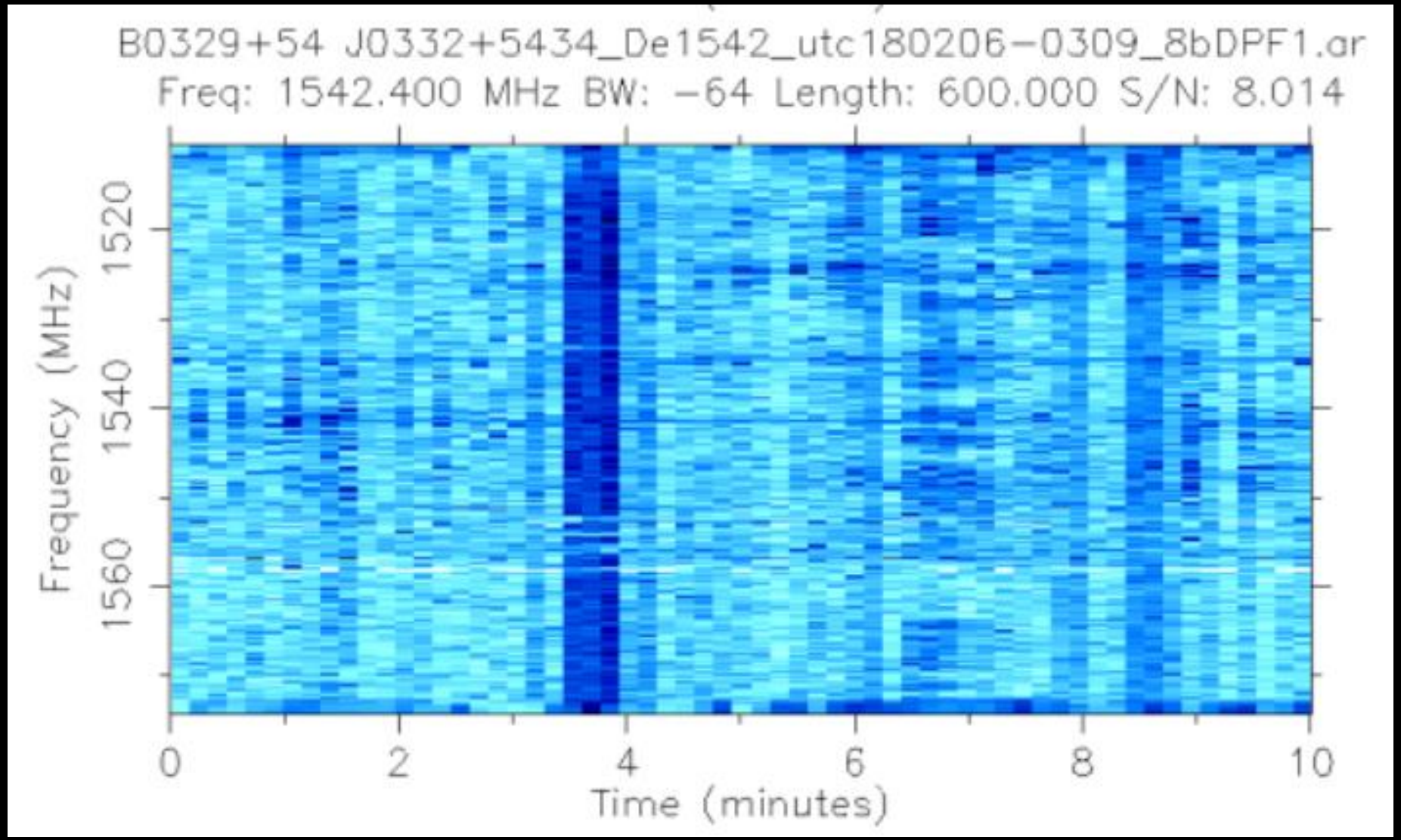
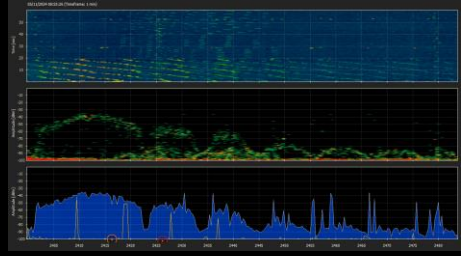


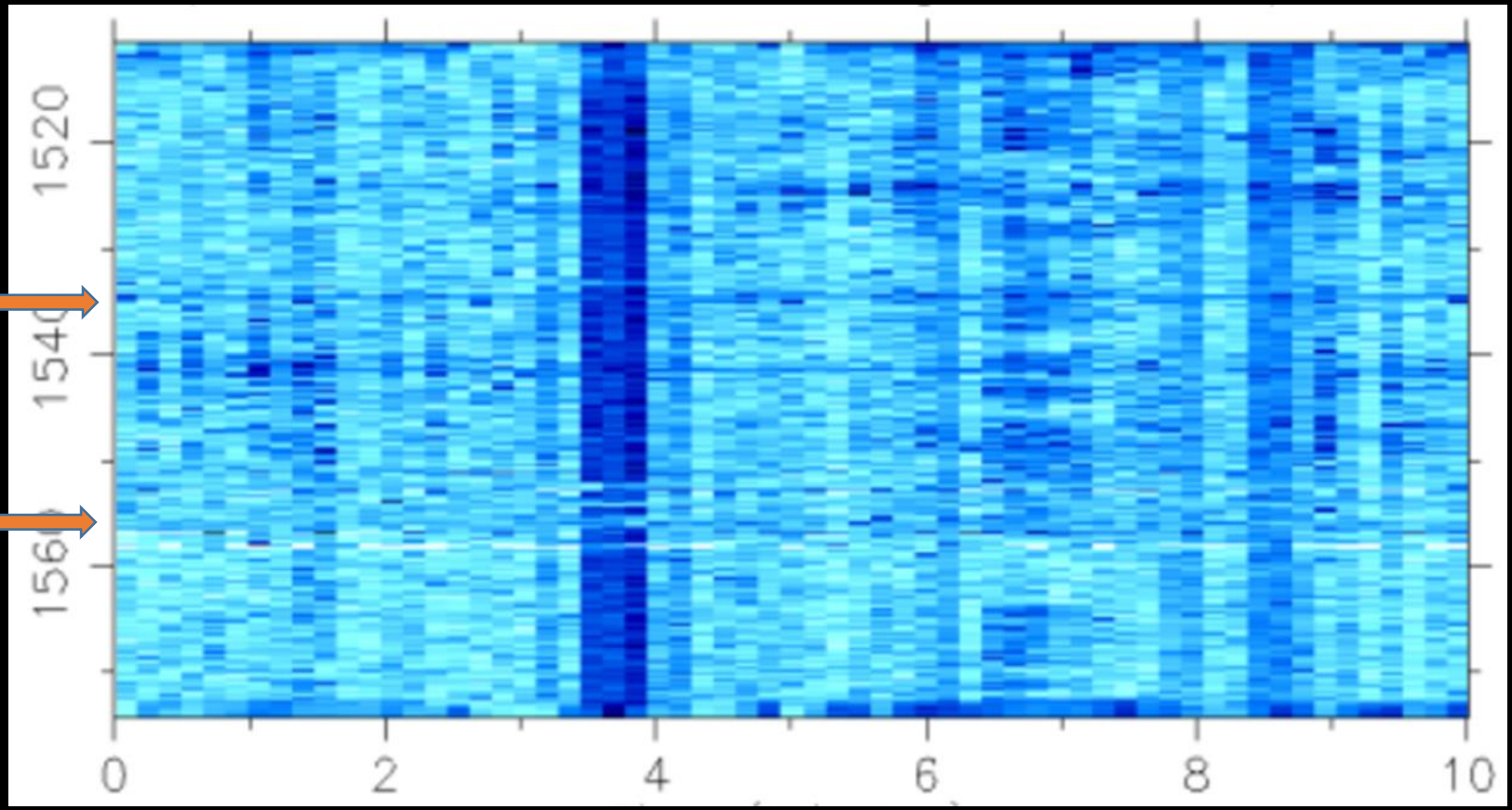
Image credit:
Thesis T W Scragg 2020

Persistent RFI



At 3:4 minutes into the observation we can see a 30 s burst of RFI covering the whole bandwidth.

There is also some persistent narrow frequency band RFI at 1558 and 1535MHz



And intermittent bursts of RFI at the top and bottom

Image credit:
Thesis T W Scragg 2020

Folded Pulse Profile

Pulse generated from the raw data shown earlier.

Very low S/N affects the accuracy of the determination of the Time of Arrival of the pulse

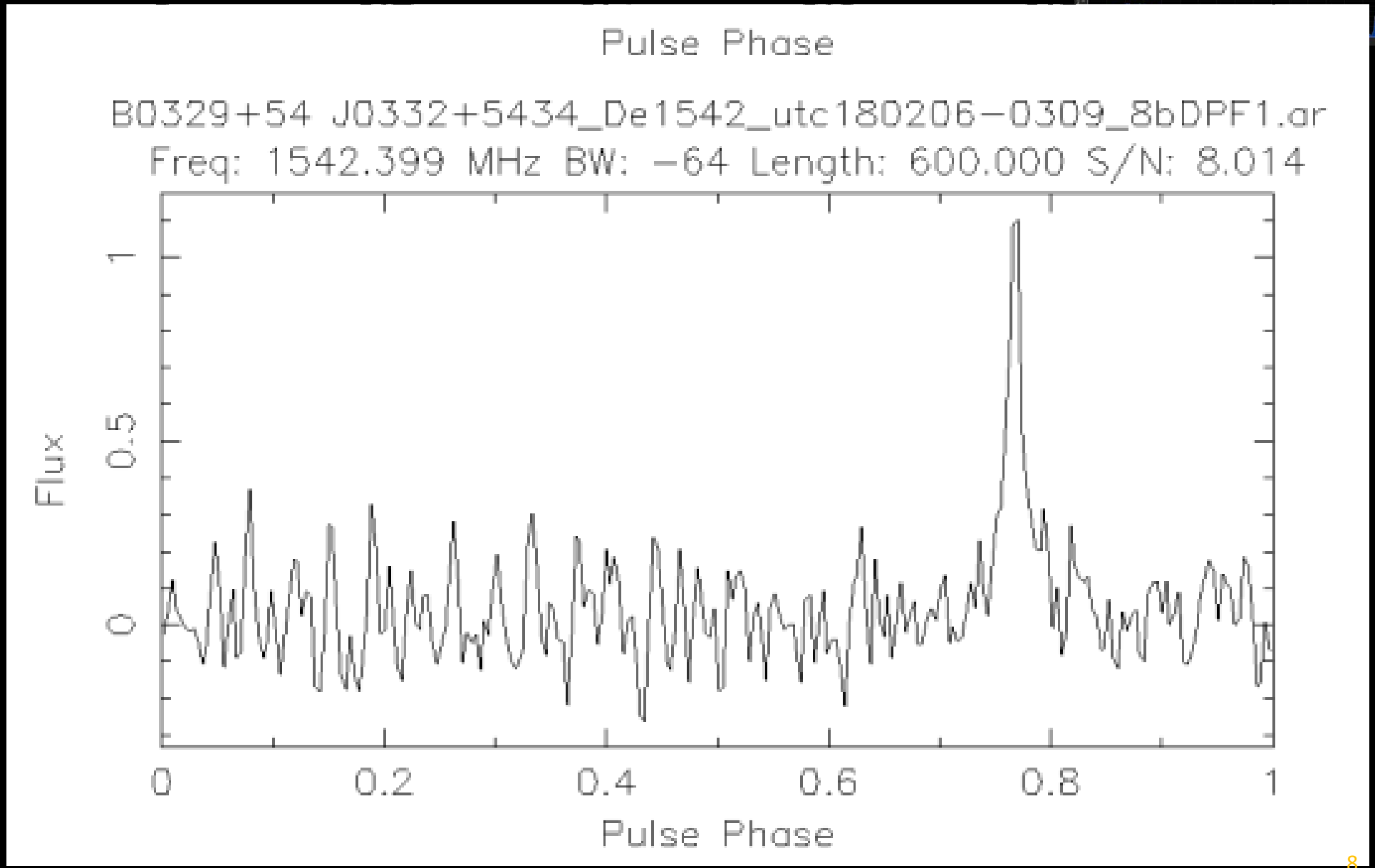
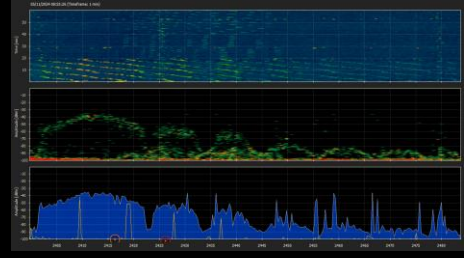


Image credit: Thesis T W Scragg 2020

Manual excision of RFI



Time series data after manual excision of RFI

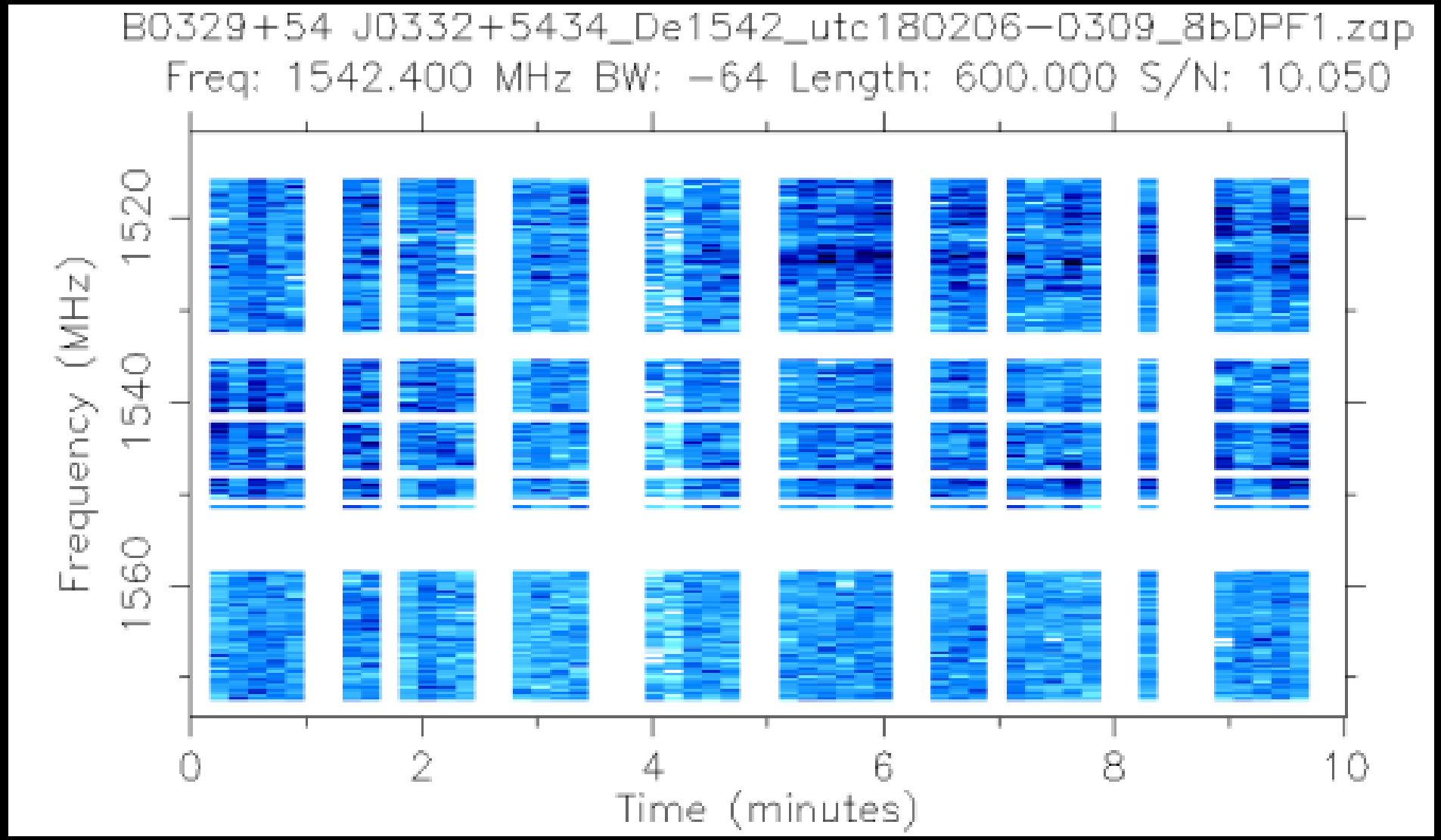


Image credit:
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Folded Pulse Profile - 2

Pulse profile after RFI excision with a S/N 10.

To improve the S/N by 25% we removed

- 25% of the duration
- 30% the bandwidth

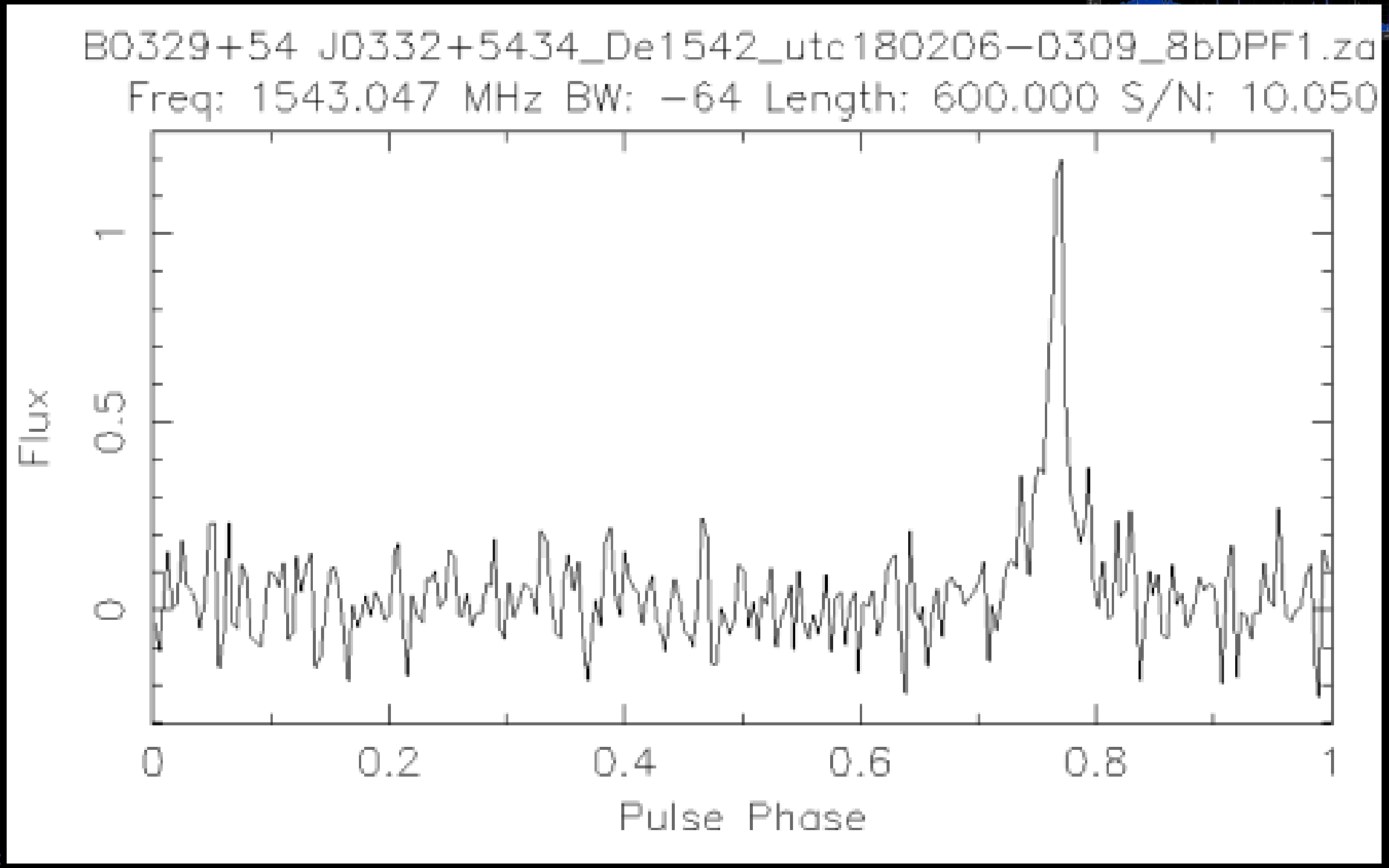
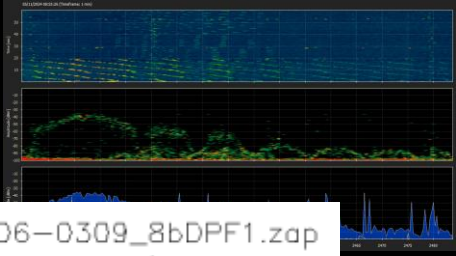
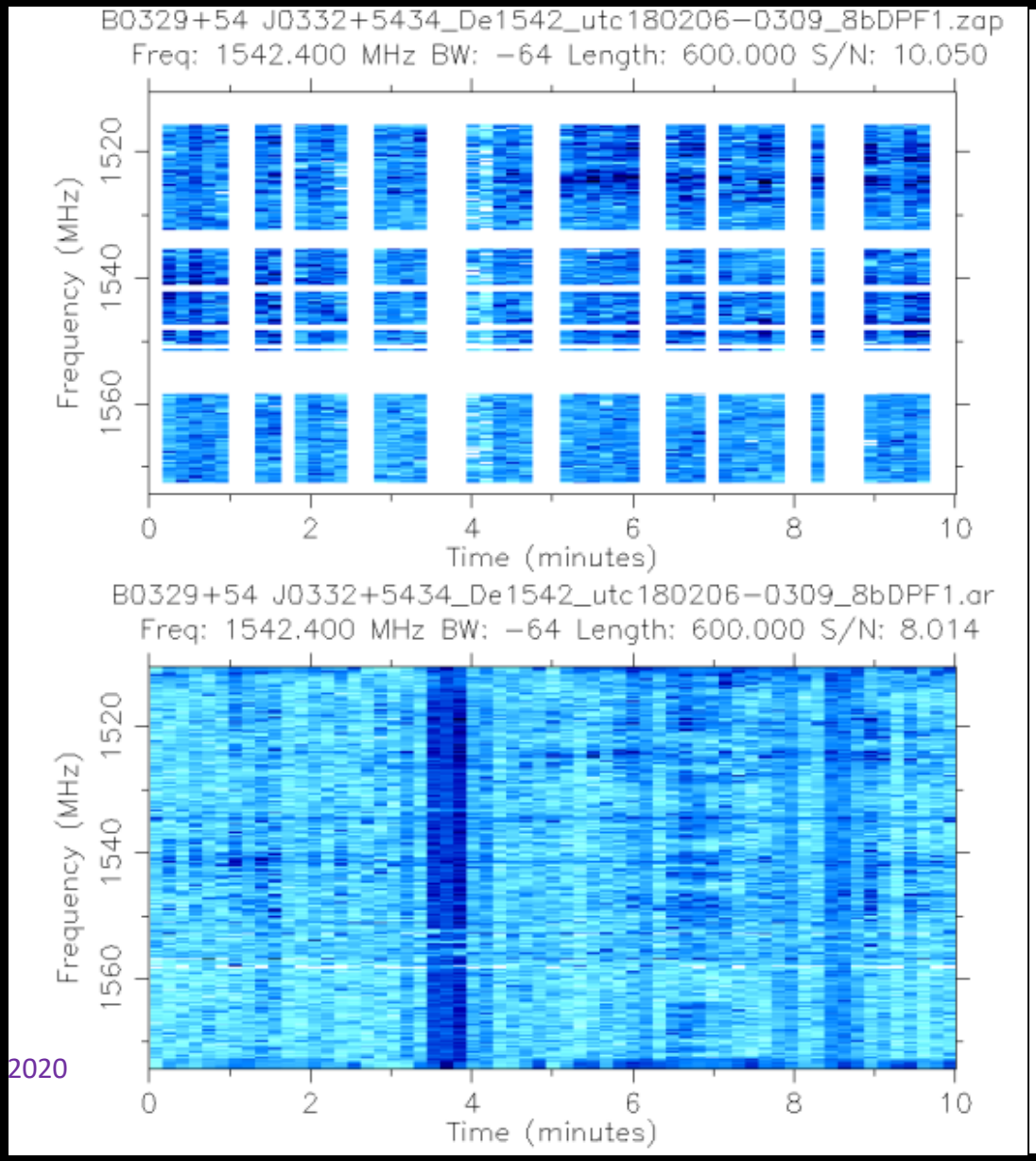


Image credit:
Thesis T W Scragg 2020

After manual excision of RFI





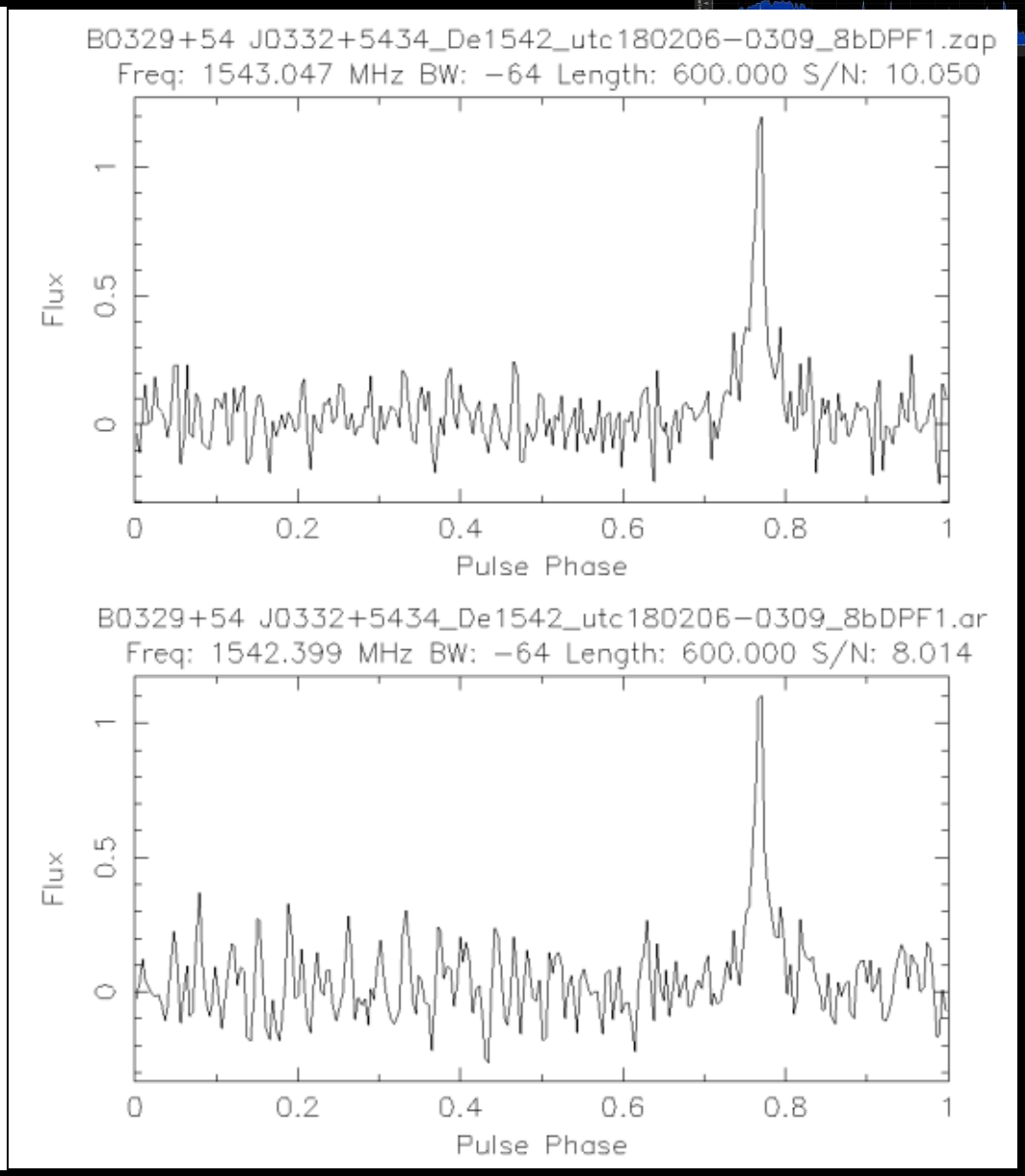
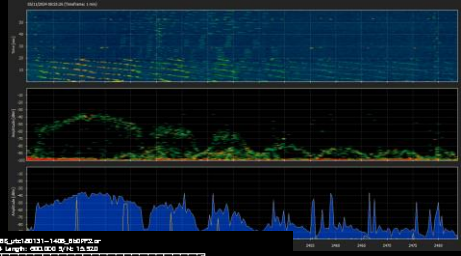


Image credit:
Thesis T W Scragg 2020

Frequency and Time dependant



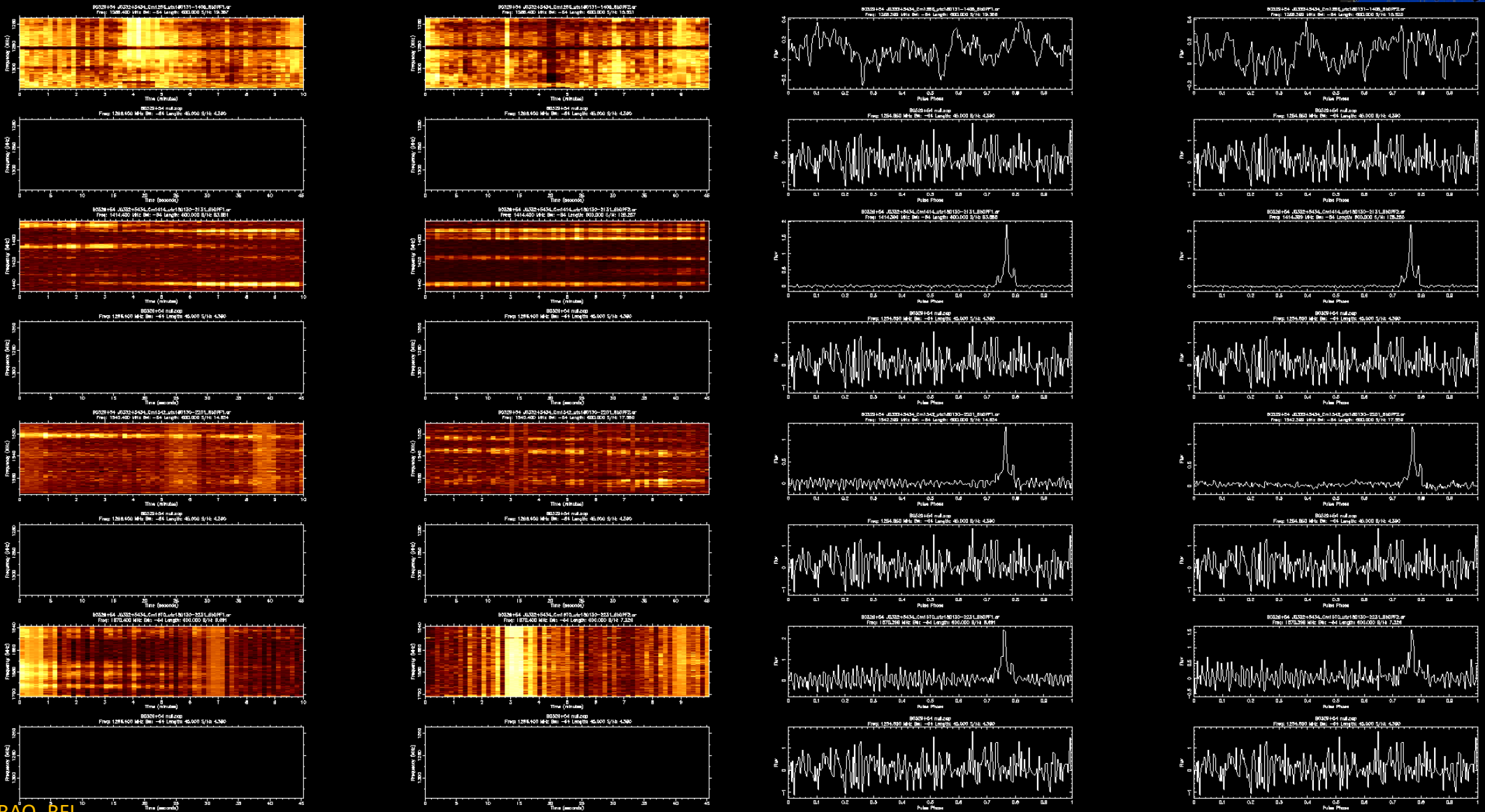
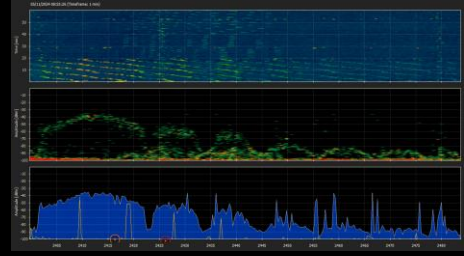
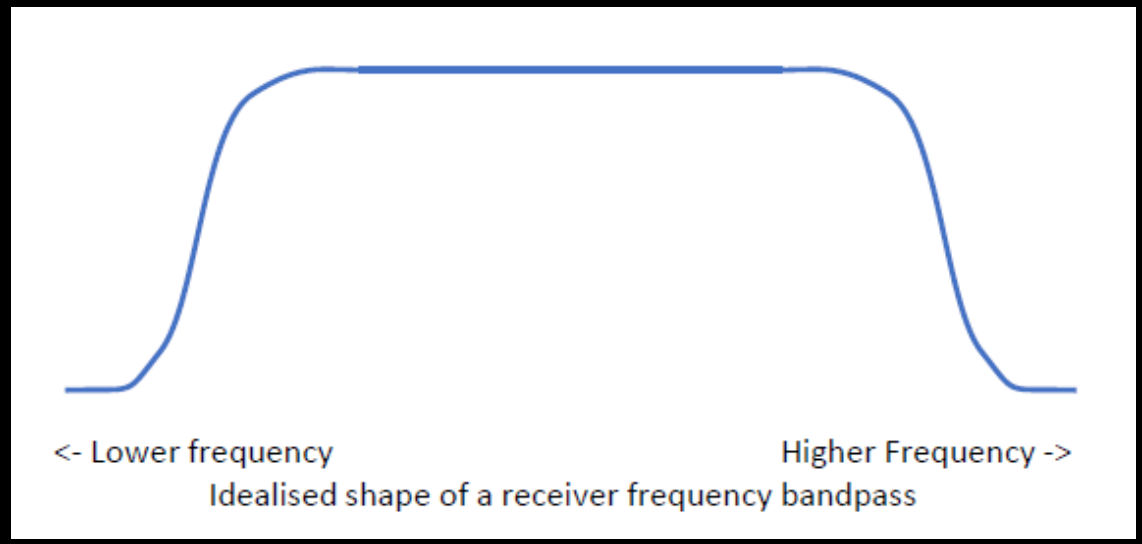


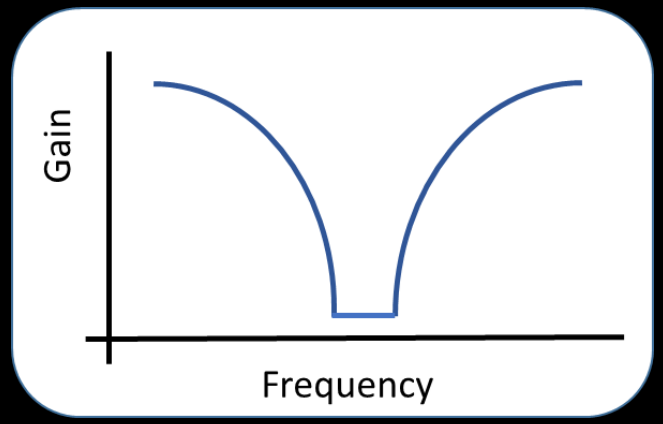
Image credit: Thesis T W Scragg 2020

Other Sources of Noise



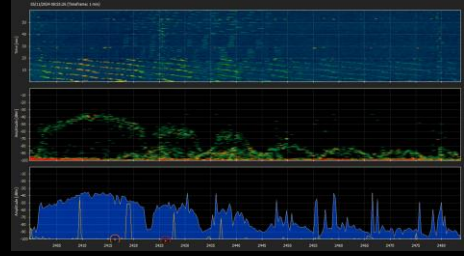
- Frequencies higher than the bandpass of the receiver are also partially sampled and will be ’aliased’ into the digitised representation unless the analogue signal is bandpass filtered, also known as anti-aliasing filtering





- Persistent RFI typically only affects a narrow frequency band. Therefore a common method to improve the S/N is to use narrow band rejection filters (or ‘notch filters’) to block radio frequency bands known to contain high levels of interference.

Digitisation Error / Noise



- The digitiser must replicate the amplitude information in the signal with an accuracy determined by the number of quantisation (discreet) levels in the Analogue-to-Digital Converter (ADC).
  - An 8 bit ADC has 2^8 or 256 quantisation levels.
- An ideal ADC will sample the analogue signal with a flat probability density function where every sample level is an equally sized increment from the previous level.
- The sampling process will introduce rounding, or quantisation, noise into the data the size of which will vary with the number of quantisation levels. Called the ‘digitisation factor’ typical values are
  - 0:9999 for 8 bit (Lovell)
  - 0:8812 for 2 bit (e-MERLIN)

Quantisation error in a two bit ADC system

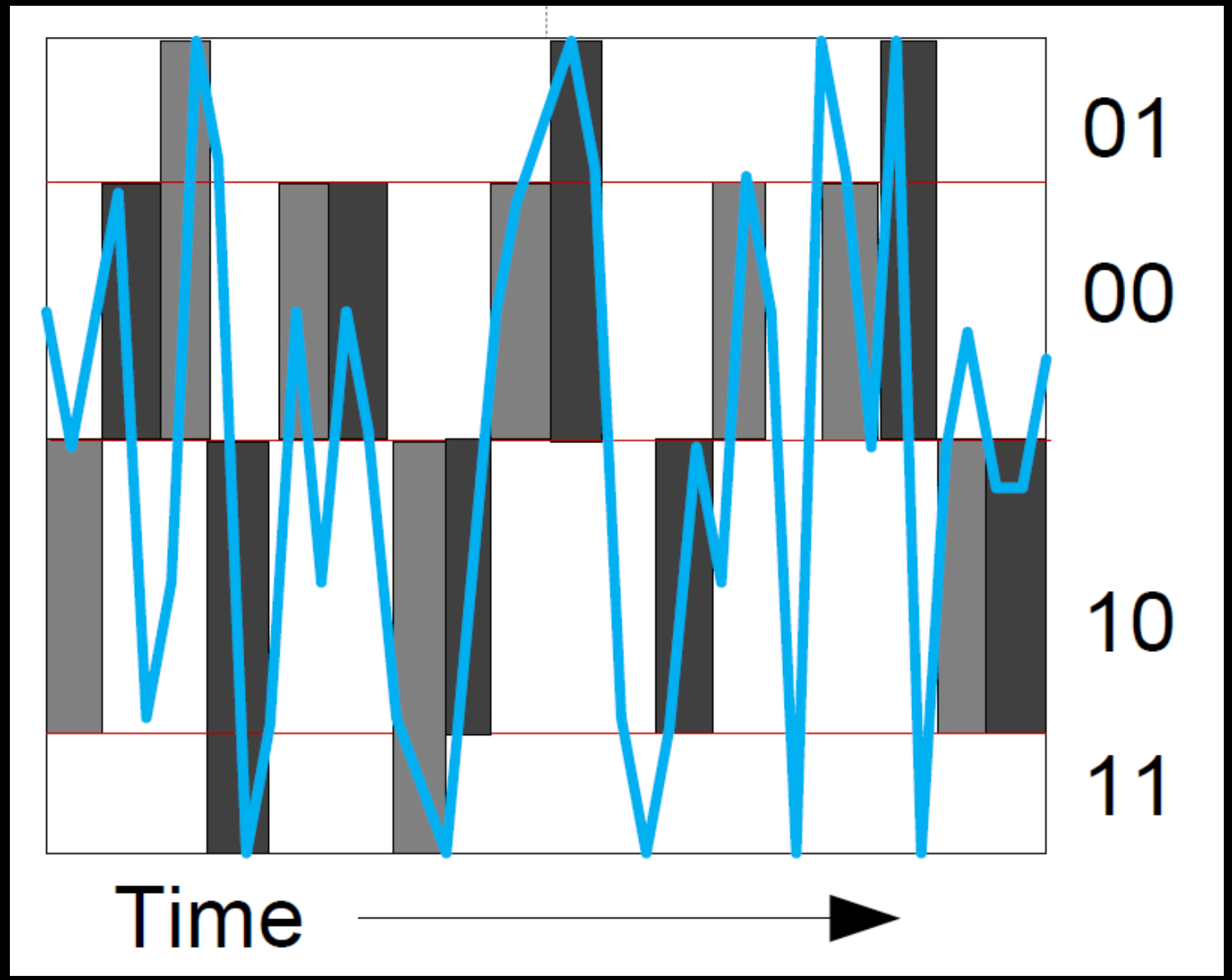


Image credit:
Thesis T W Scragg 2020