REAL-TIME RFI MITIGATION FOR THE BEAMFORMER MODE OF THE UPGRADED GIANT METREWAVE RADIO TELESCOPE (GMRT)

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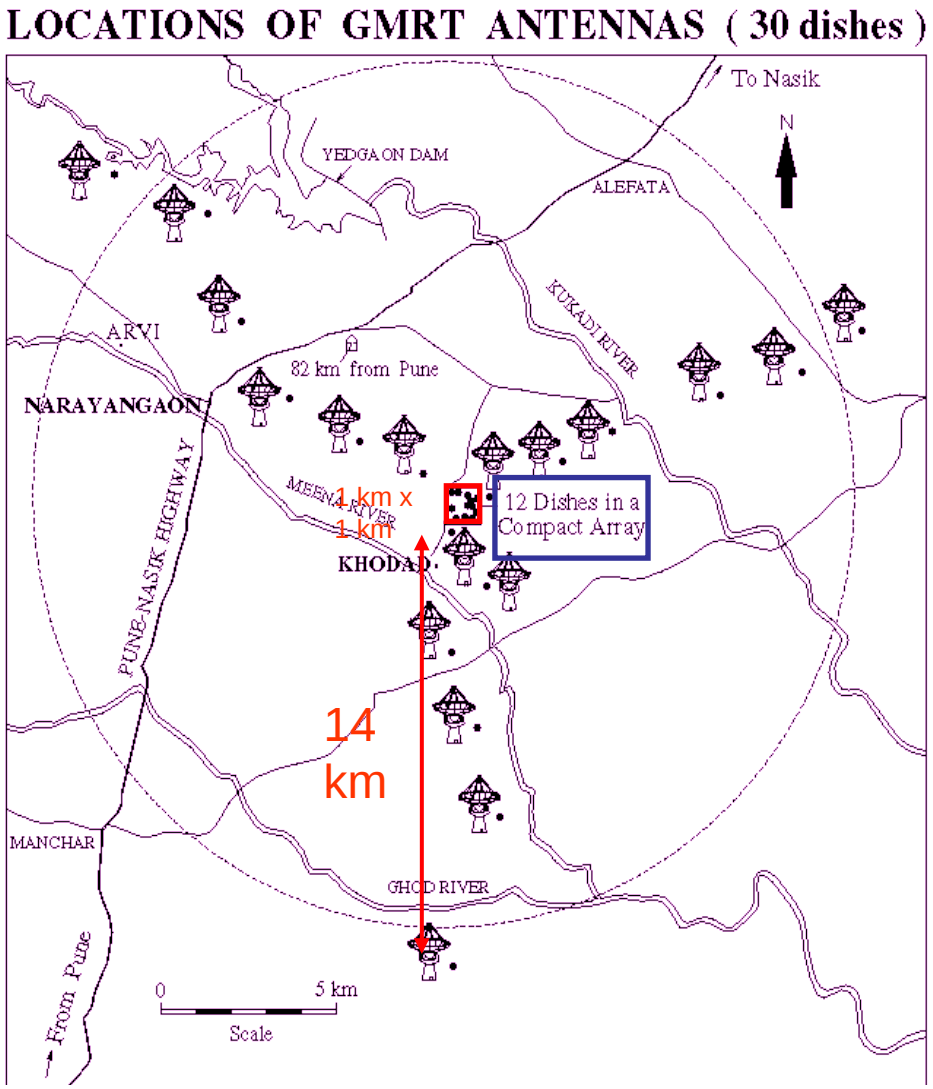
- 30 dishes, 45 m diameter each
  - 12 dishes in a central 1 km x 1 km region (central square)
  - remaining along 3 arms of Y-shaped array
  - baselines : ~ 200 m (shortest);
    ~ 30 km (longest)
- Frequency range :
  - **130-170 MHz**
  - **225-245 MHz**
  - **300-360 MHz**
  - **580-660 MHz**
  - **1000-1450 MHz**
  - **max instantaneous BW = 32 MHz**
- Effective collecting area (2-3% of SKA) :
  - 30,000 sq m at lower frequencies
  - 20,000 sq m at highest frequencies
- Supports 2 modes of operation :
  - Interferometry, aperture synthesis
  - Array mode (incoherent & coherent)



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- Frequency range :
  - **125-250 MHz**
  - **250-500 MHz**
  - **550-850 MHz**
  - **1050-1450 MHz**
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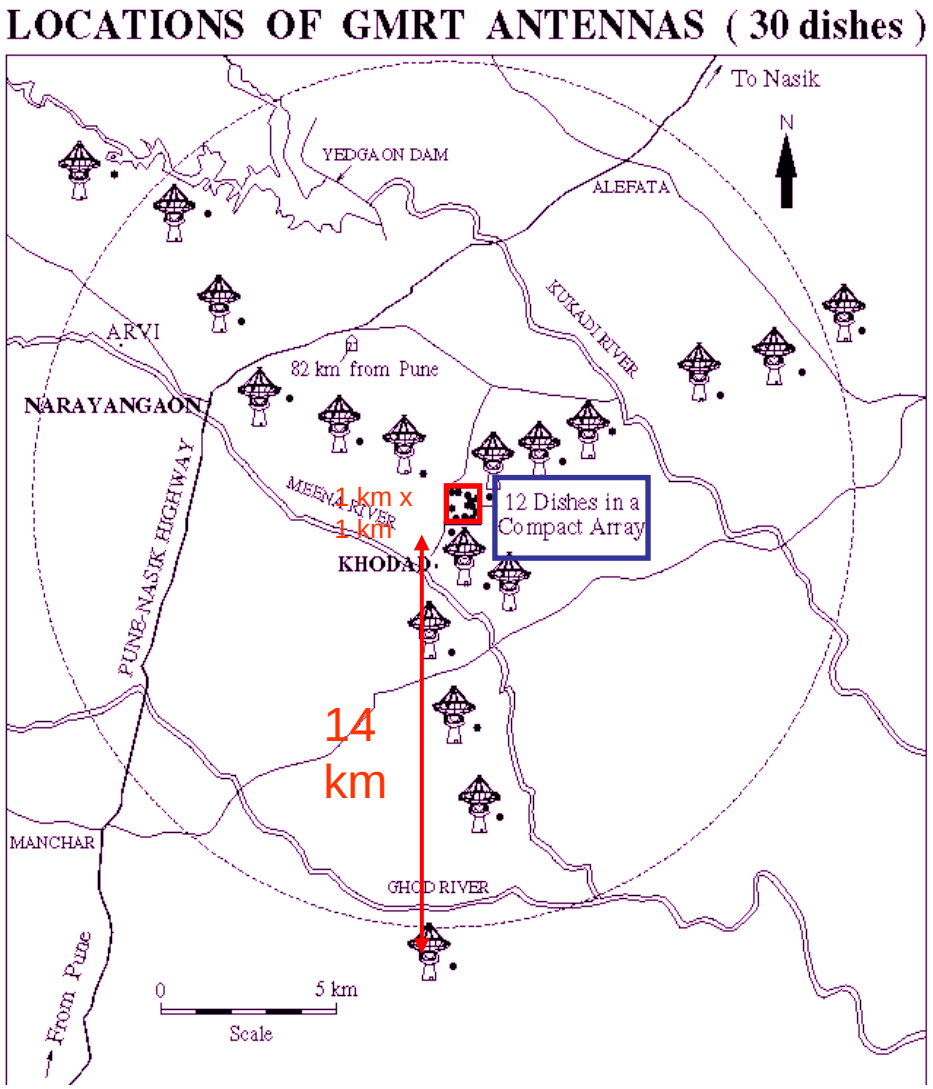
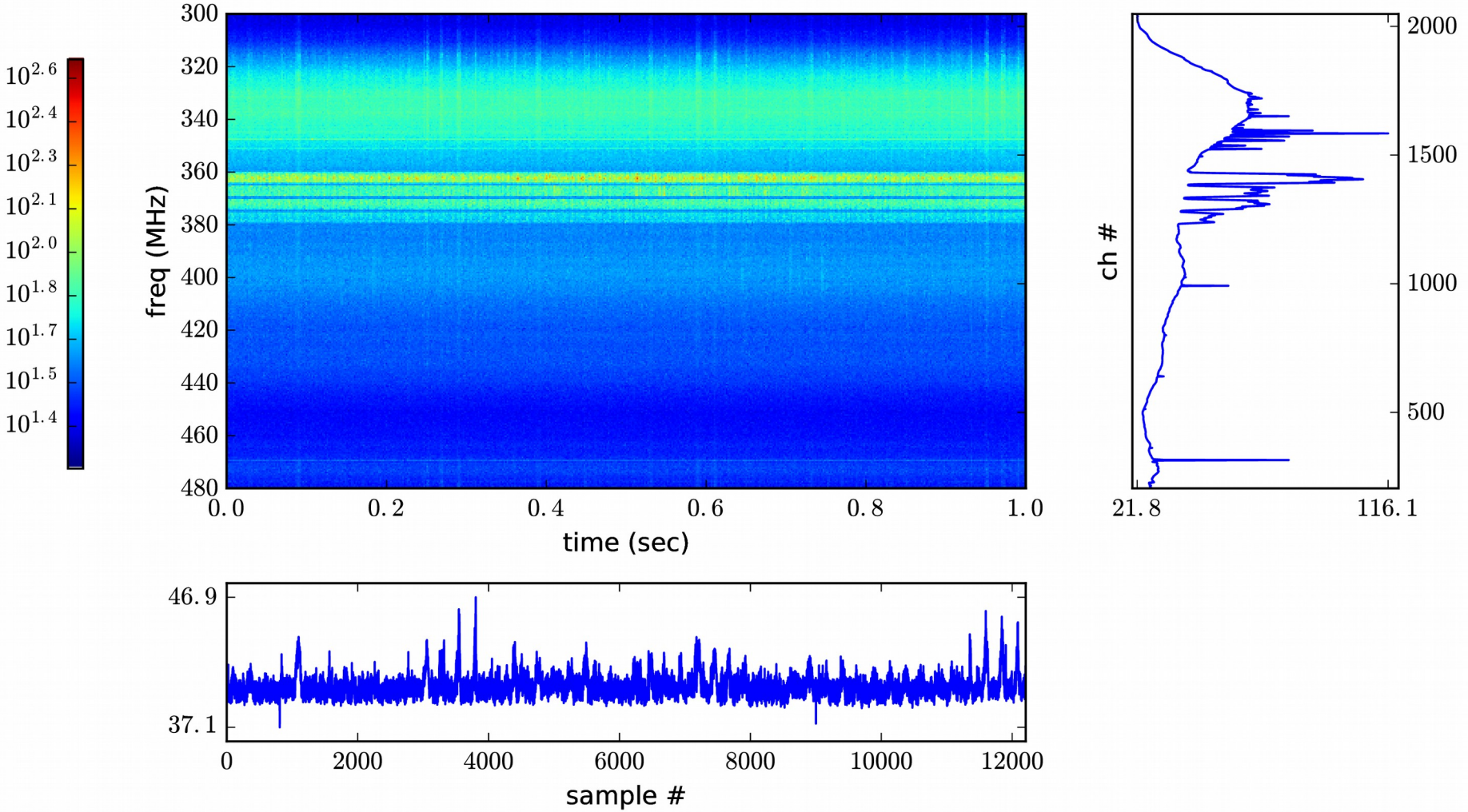


- Signals from all antennas added either coherently or incoherently.
- Used mostly to study unresolvable objects - pulsars and transients.



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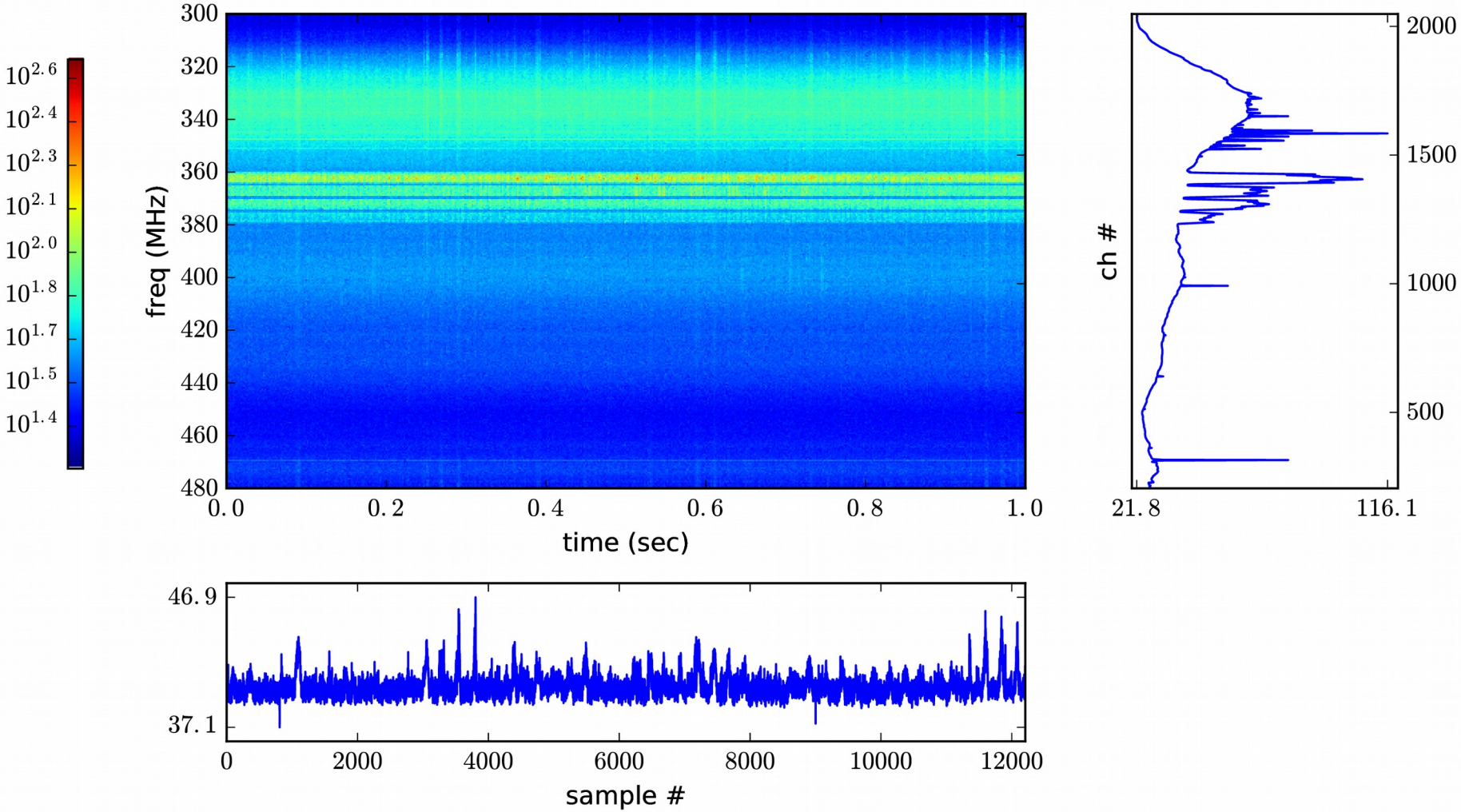

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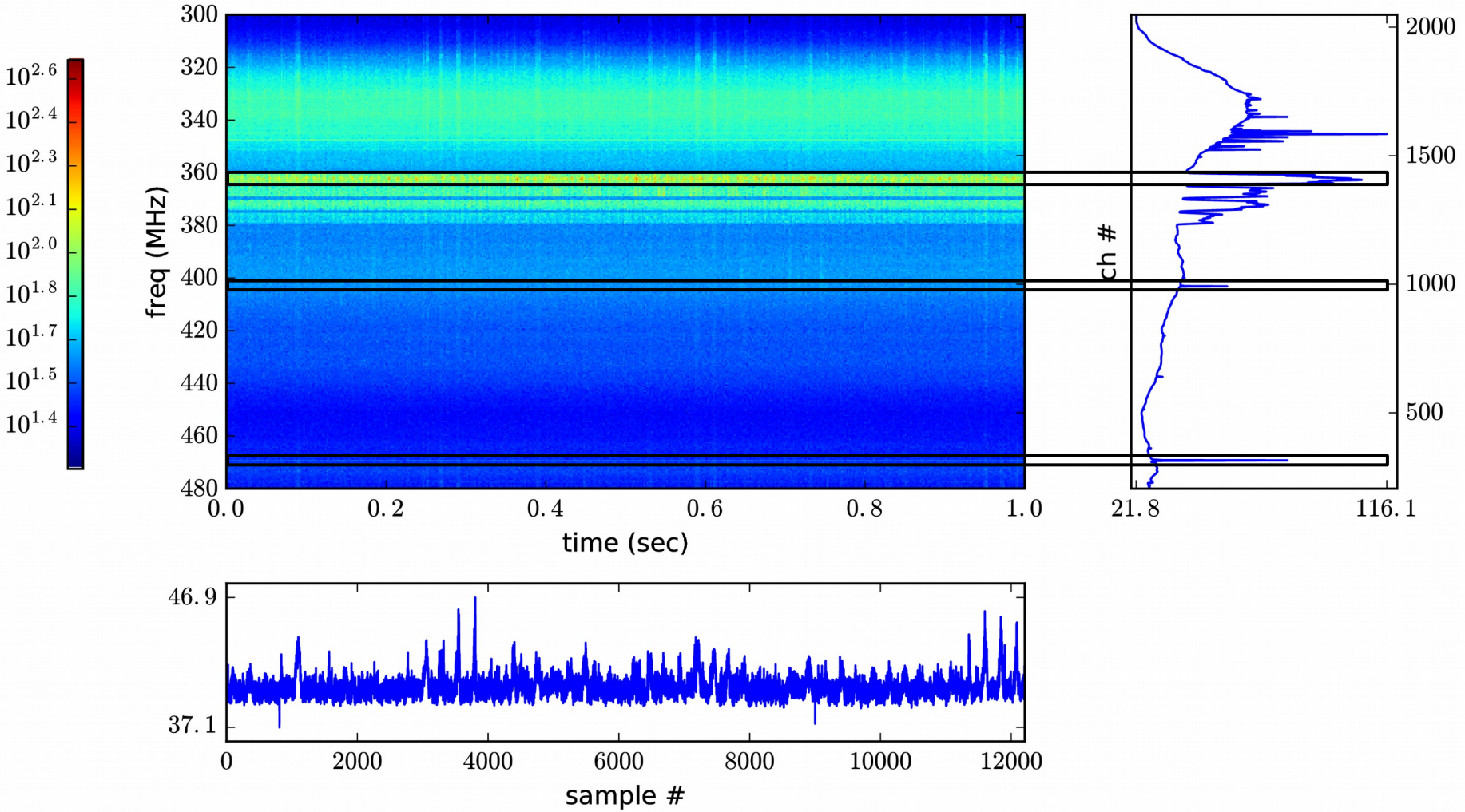

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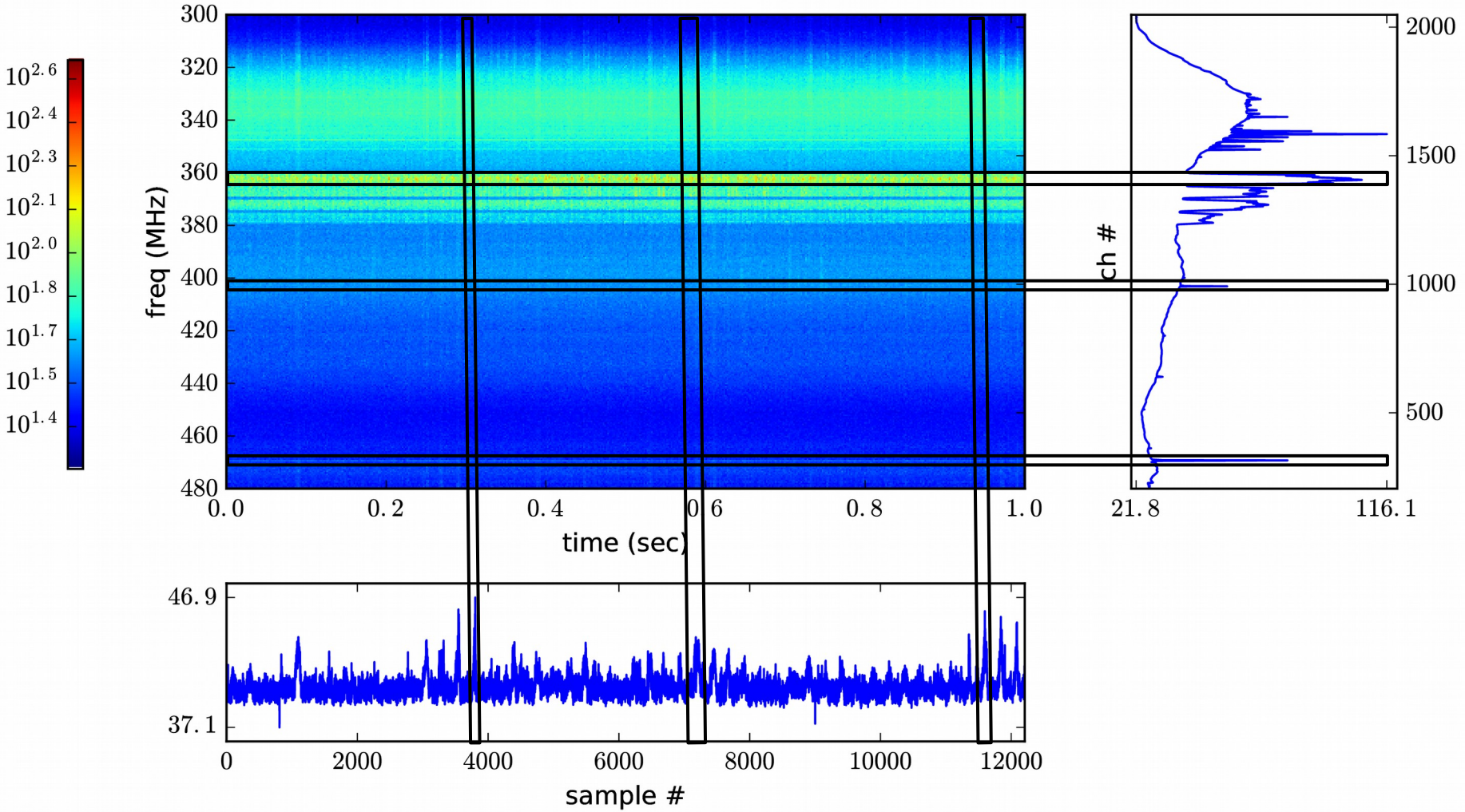
- “Narrow” band
- “Wide” band



Detecting Outlies in a Series

Objective*: An algorithm that can detect the "true" mean and std. dev. of N samples derived from a gaussian distribution with p% corrupted data. Usual mean and RMS is a very rapid function of p.*

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- **Median Absolute Deviation:**
  - Median is taken as the estimate of mean.
  - Median of Absolute Deviation from the median is used to estimate std. dev.

$$\sigma = 1.4826\, median_i\left(\left|X_i - median_j\left(X_j\right)\right|\right)$$

  - Computationally O(n log n) because of a sort operation.

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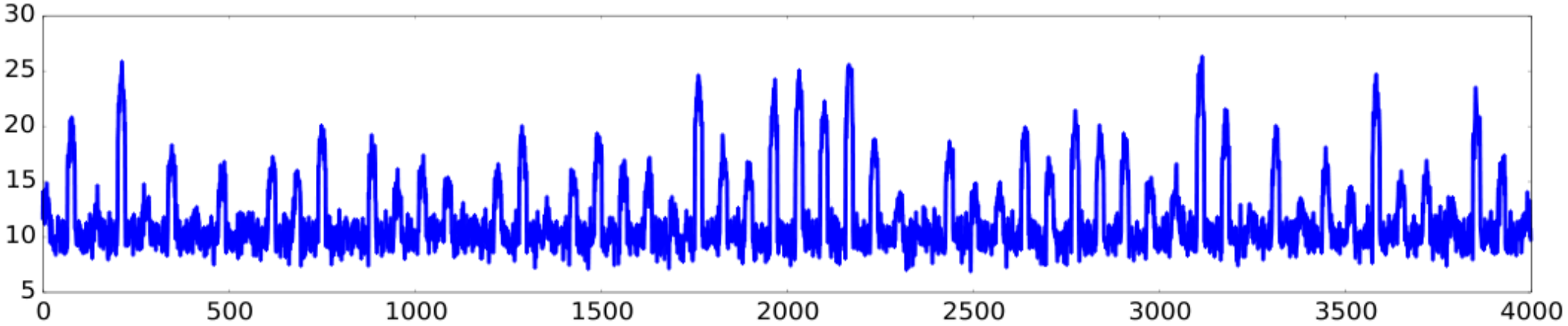
- **Can we do better? Certainly!**

Detecting Outlies in a Series : Smarter than MAD

A simulated time series with 30% corruption:



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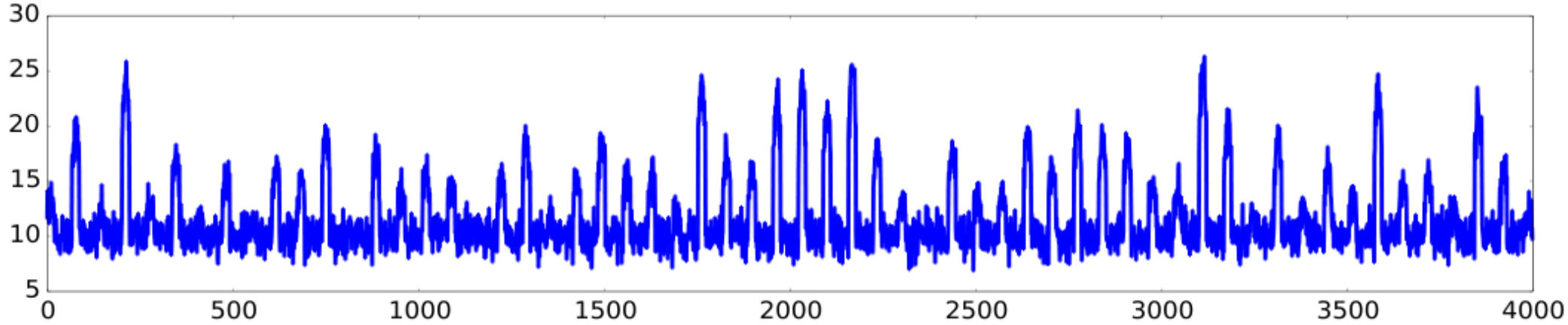

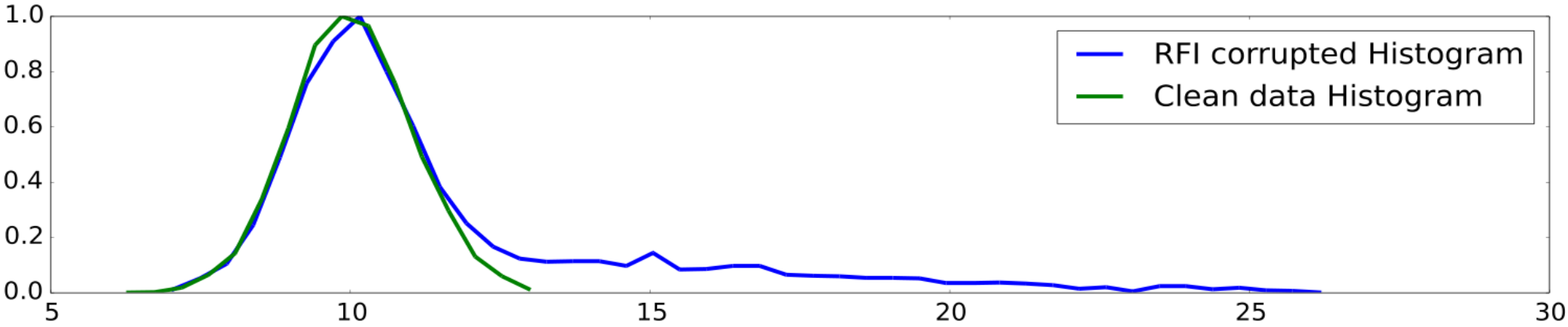

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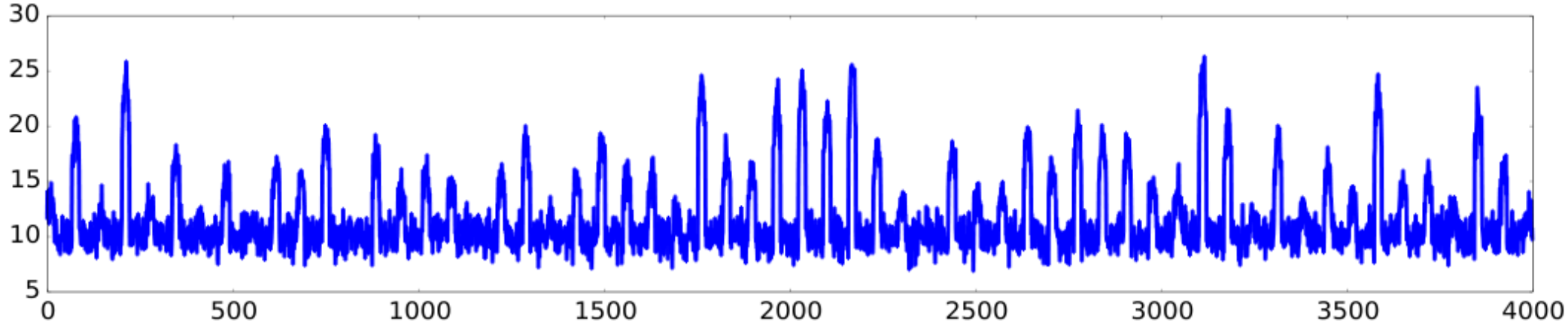

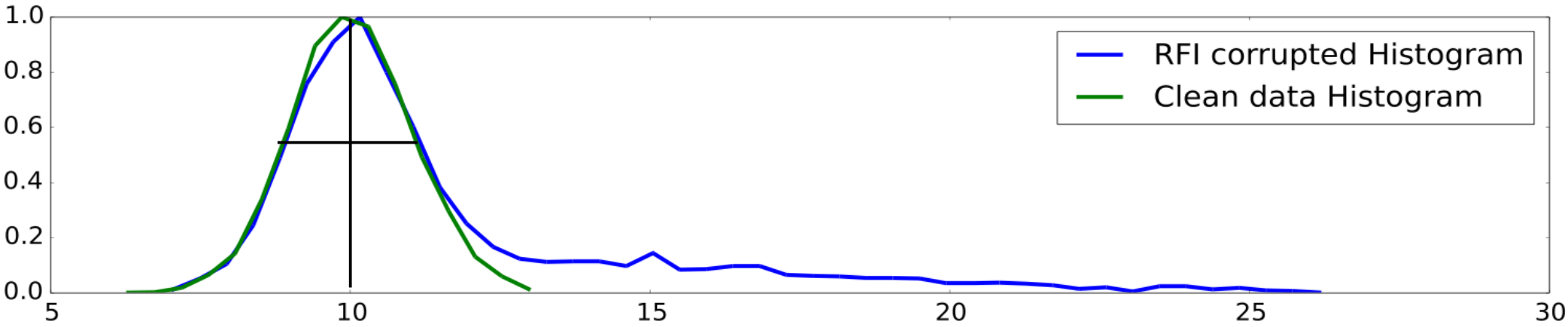

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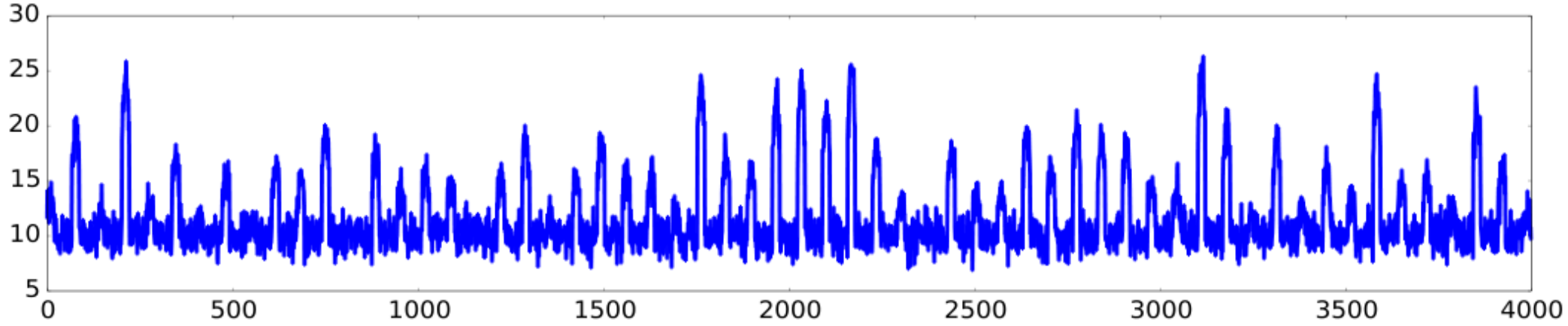

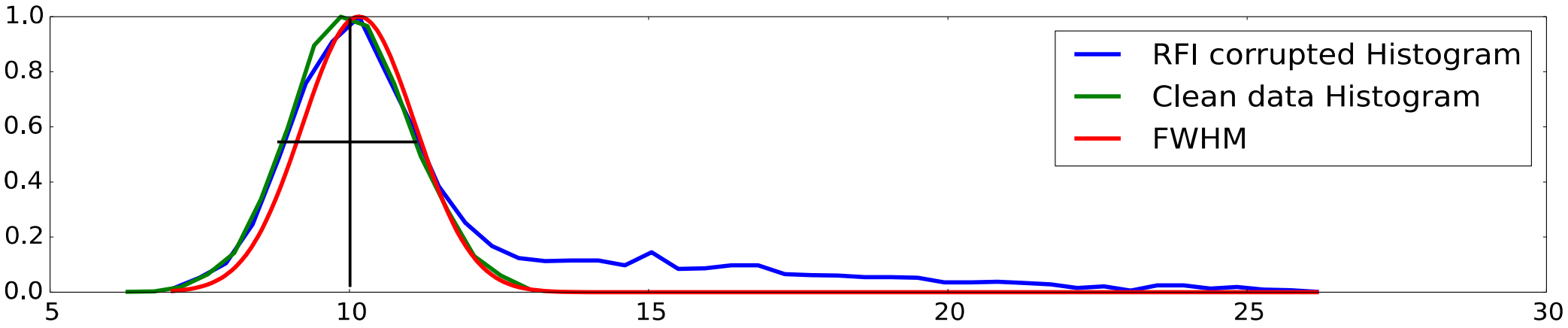

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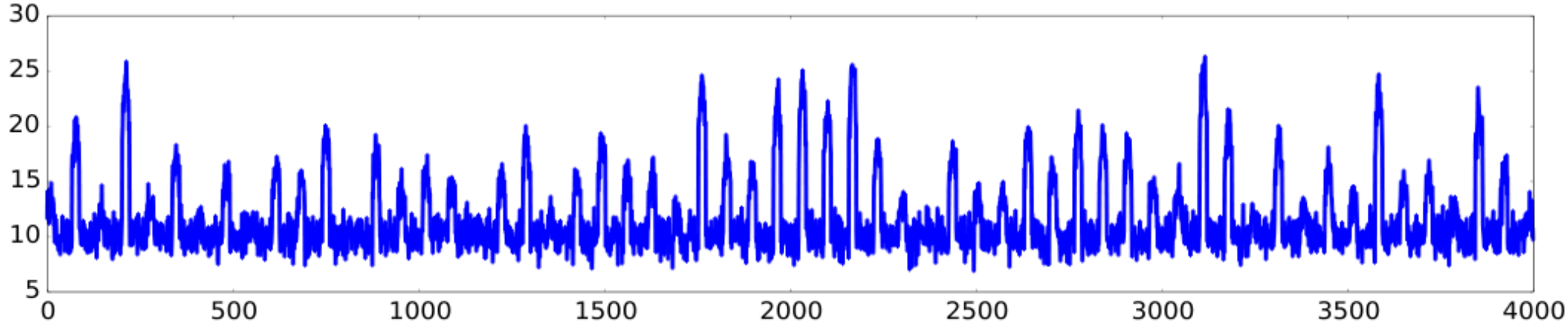
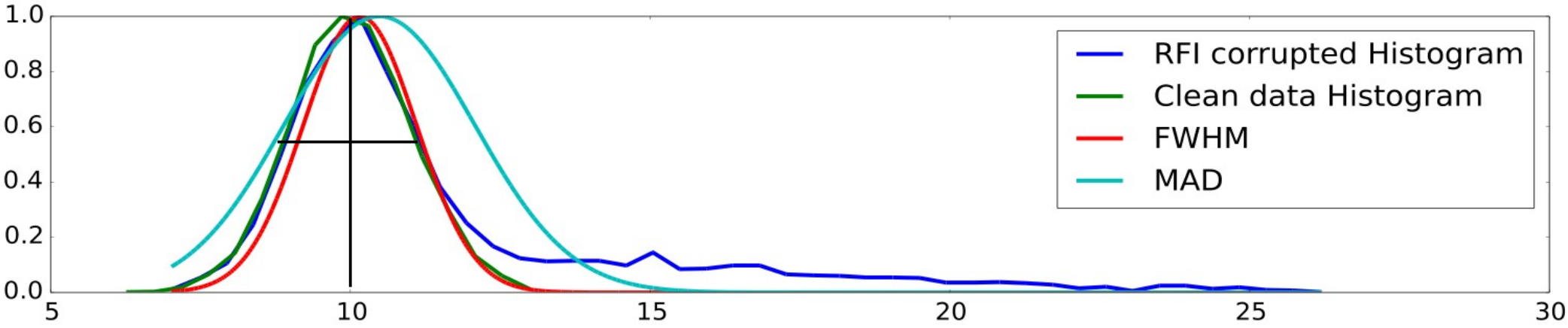
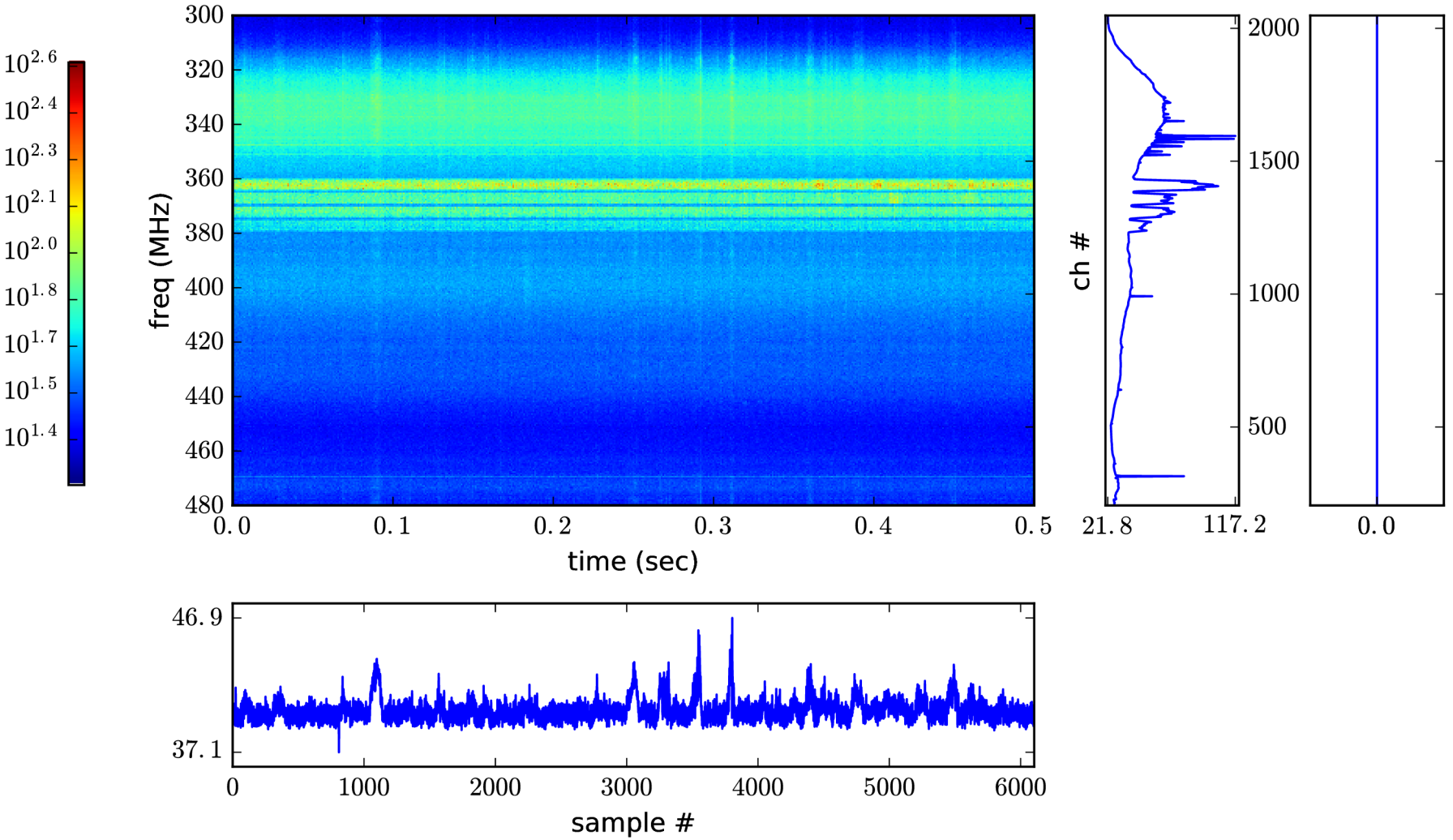




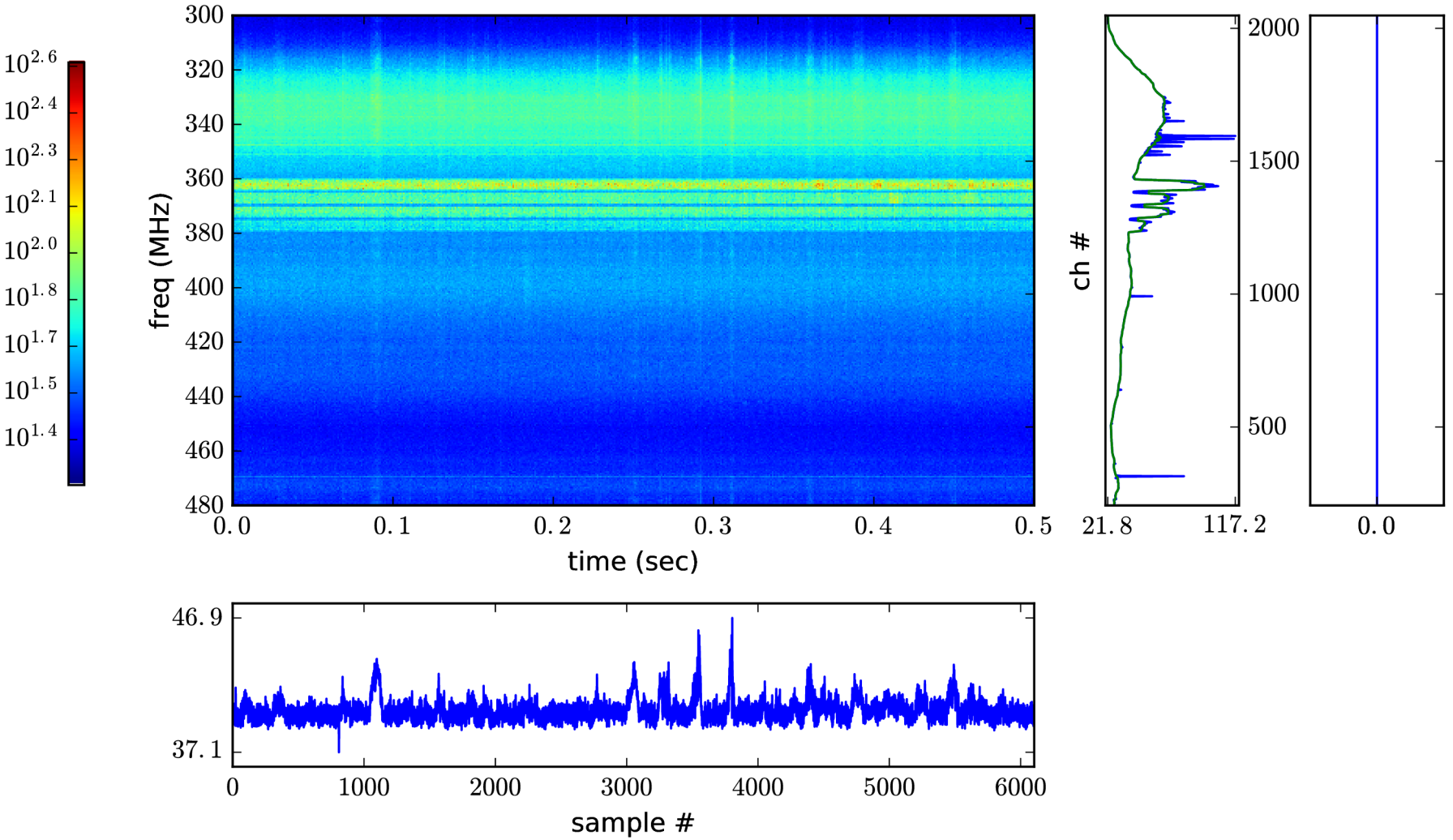
Detecting RFI in Beamformer Data

- Beamformer Data



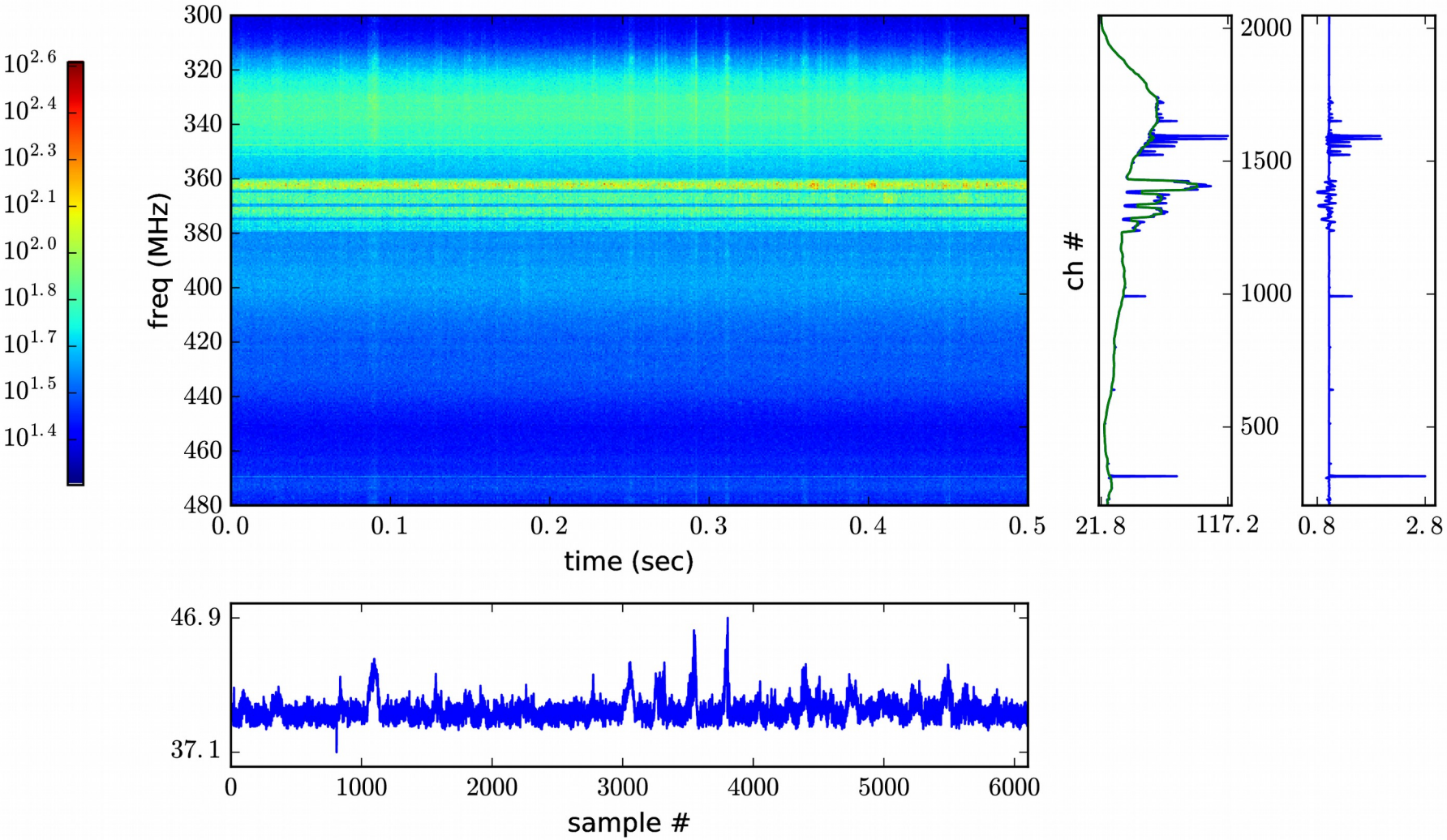
Detecting RFI in Beamformer Data

- Detecting Narrow-band RFI: Smooth bandshape.



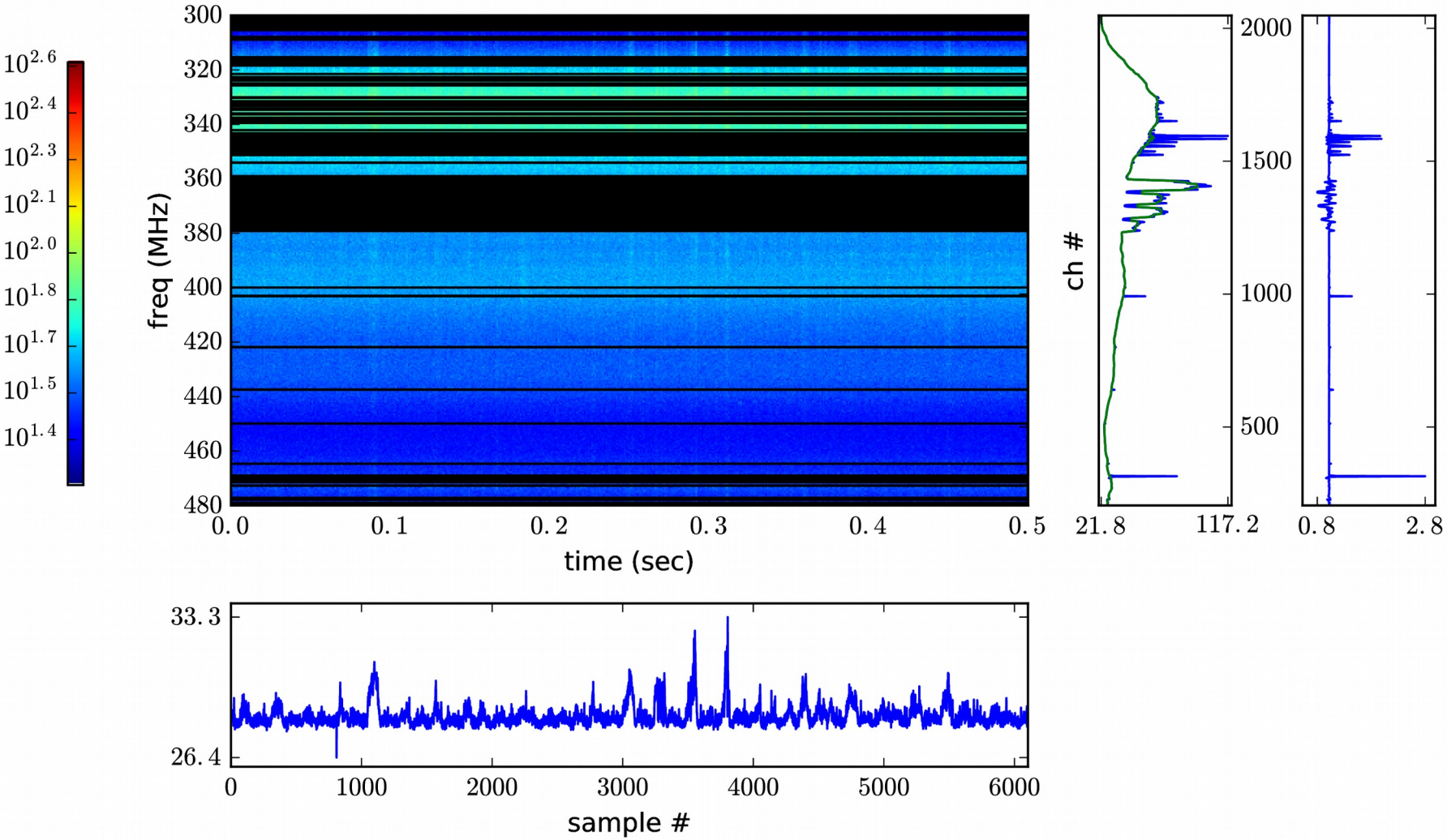
Detecting RFI in Beamformer Data

- Detecting Narrow-band RFI: Get power normalized bandshape.



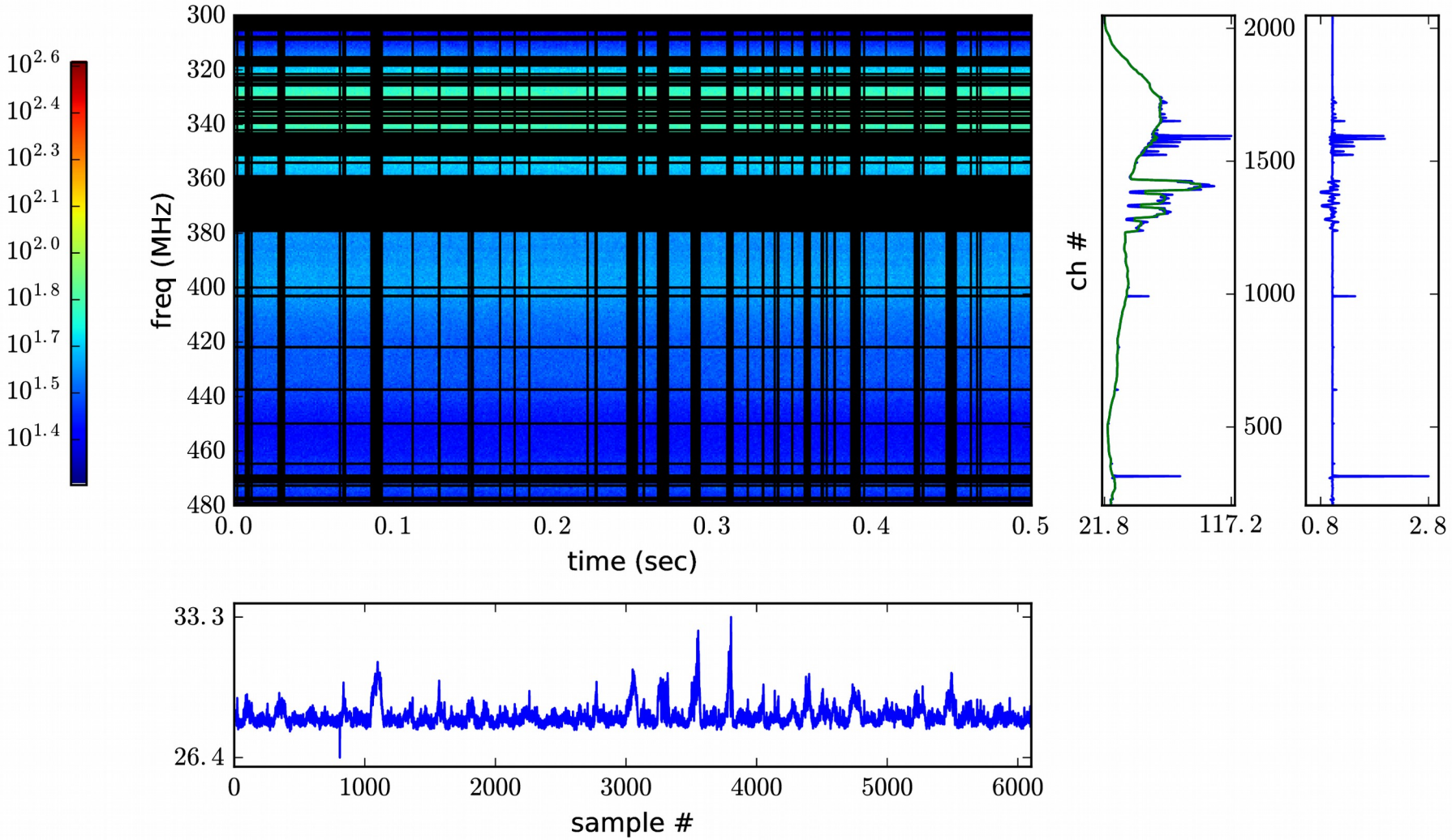
Detecting RFI in Beamformer Data

- Detecting Narrow-band RFI: Outlier detection on power normalized bandshape.

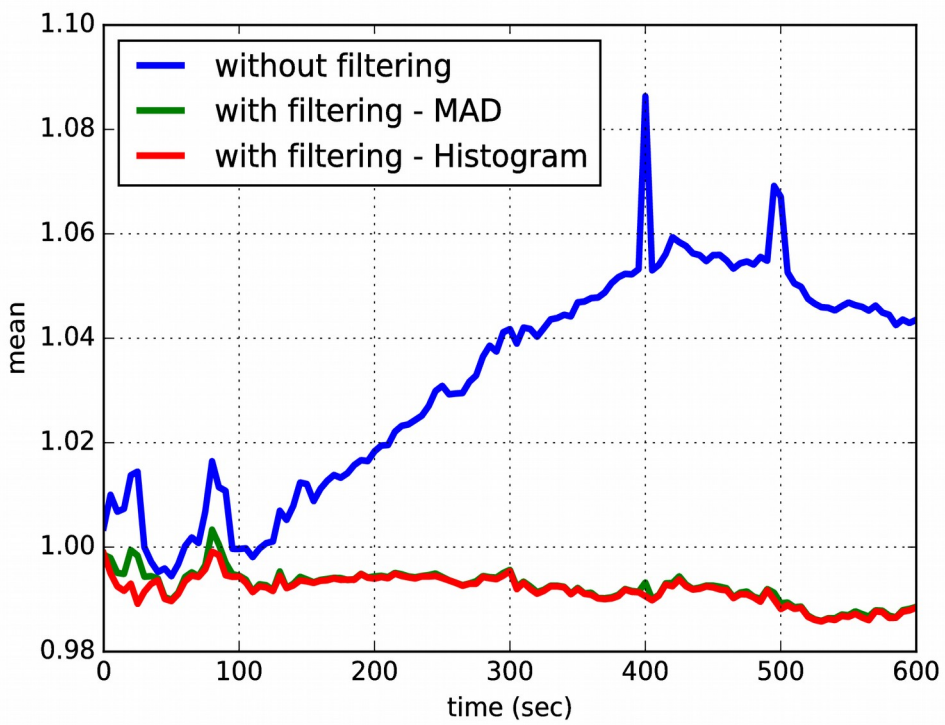


Detecting RFI in Beamformer Data

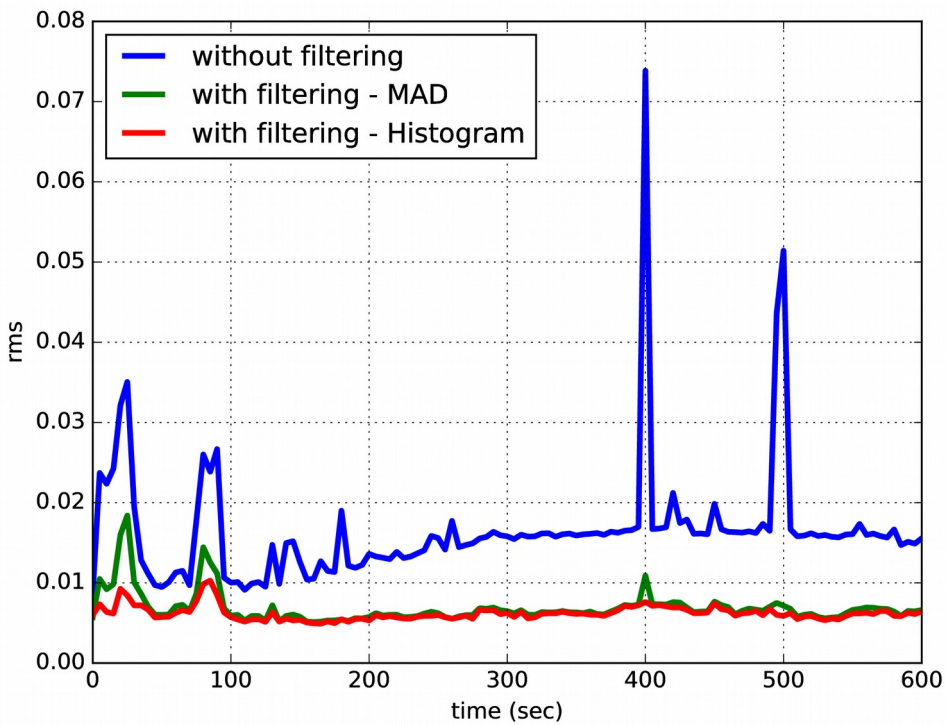
- Detect broad-band RFI from resultant time-series



Results – Stability of Mean and RMS



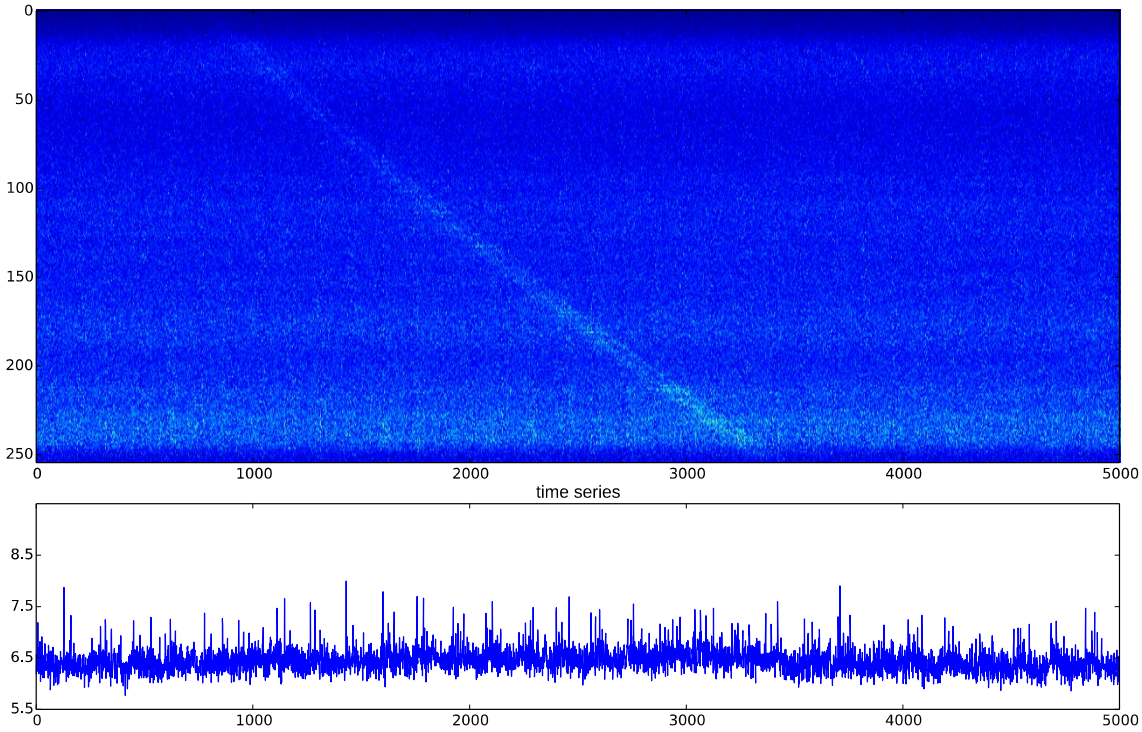
Mean Variation



Mean Variation

Introduction to Pulsar signal processing

- Pulsars are fast rotating neutron stars that emit periodic signals.
- Interstellar medium causes dispersion of pulse
- Different time of arrival of the pulse between two frequency channels.
- Needs to be corrected for to prevent smearing.
- For most pulsars, signal buried in noise in uncorrected time series.



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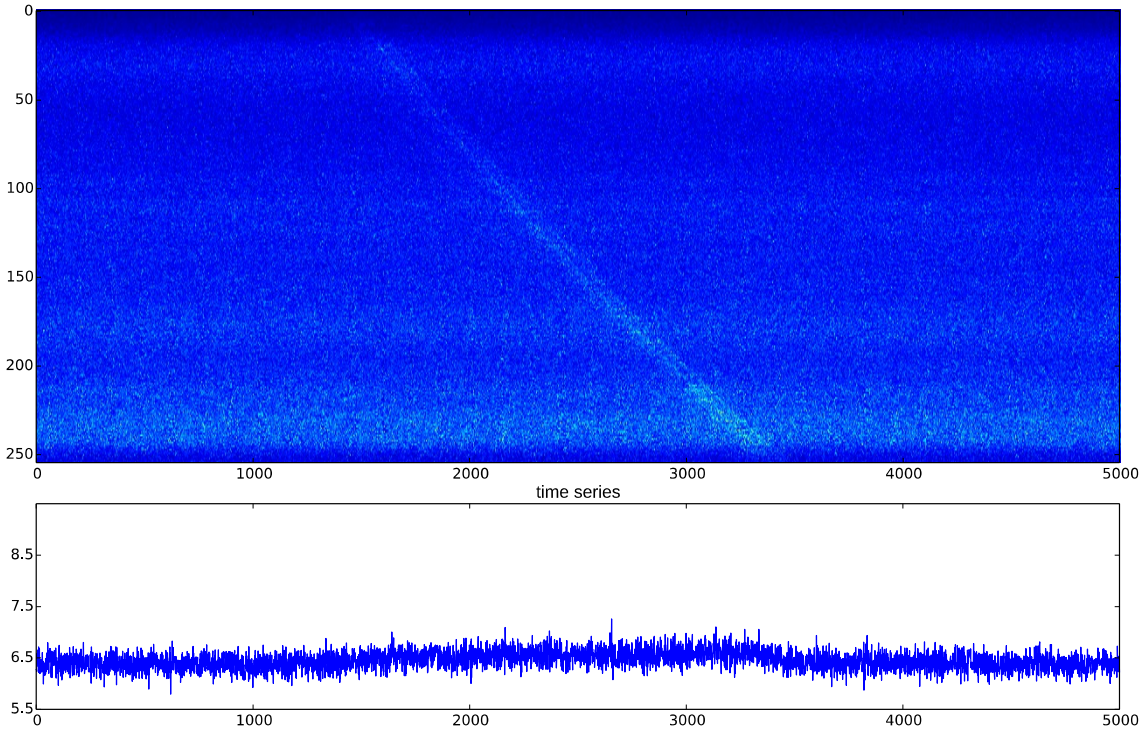

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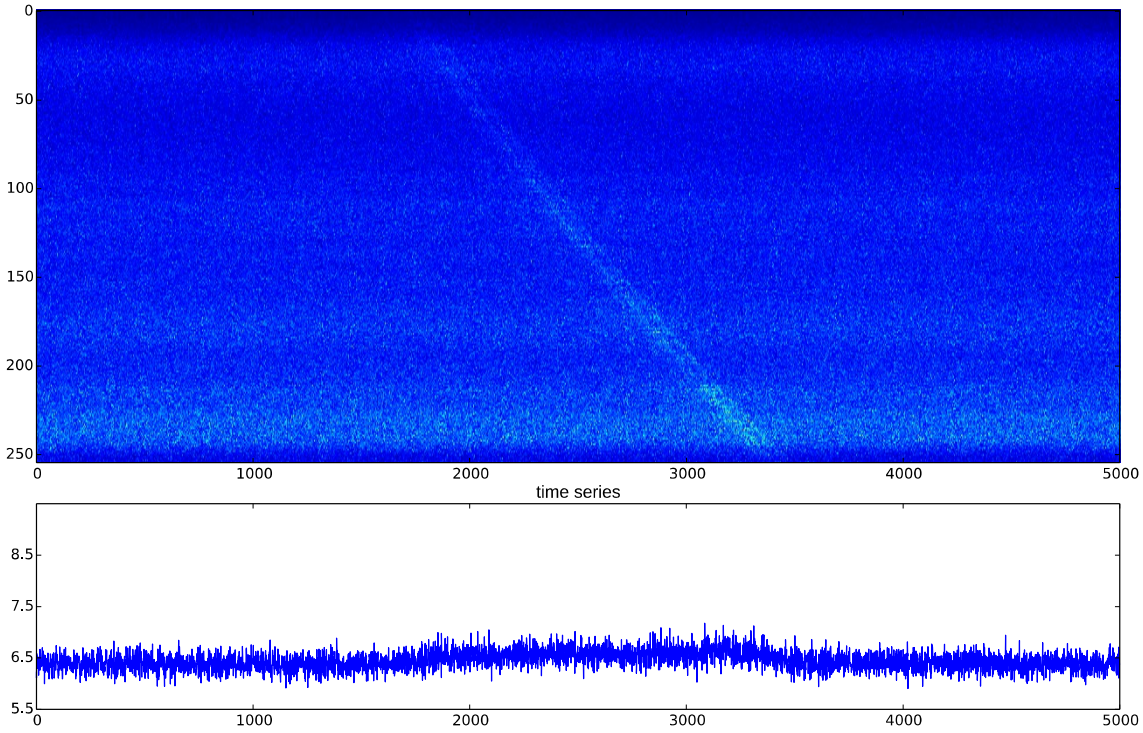

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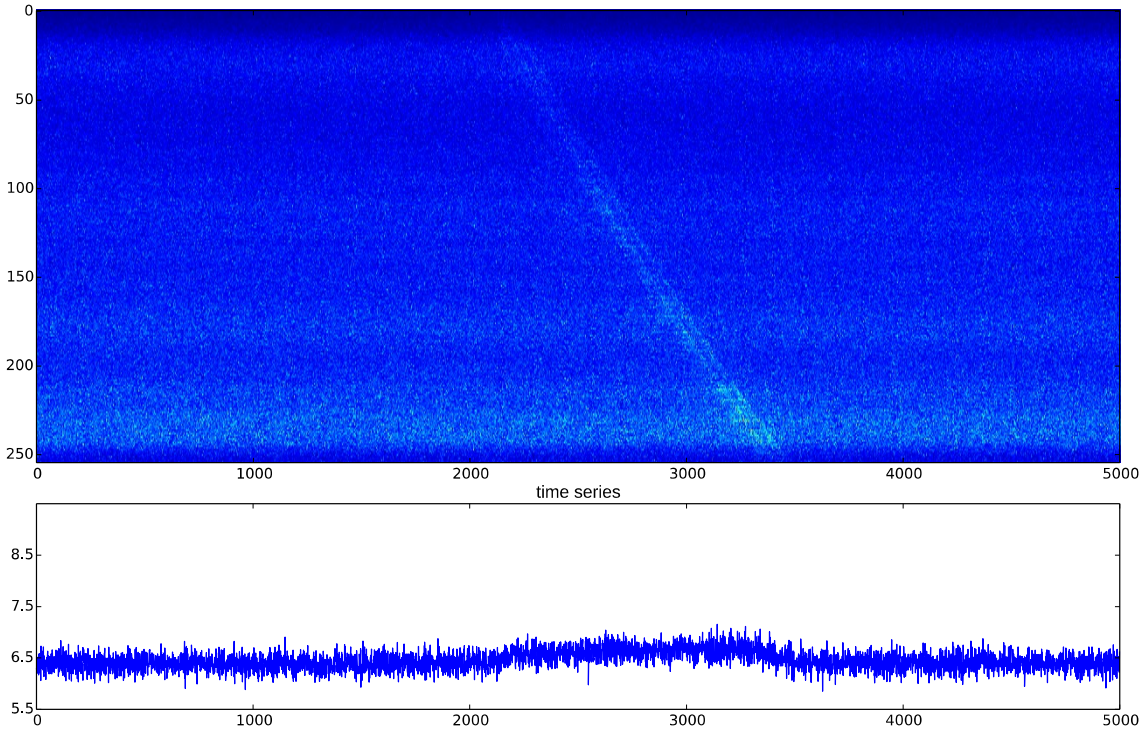

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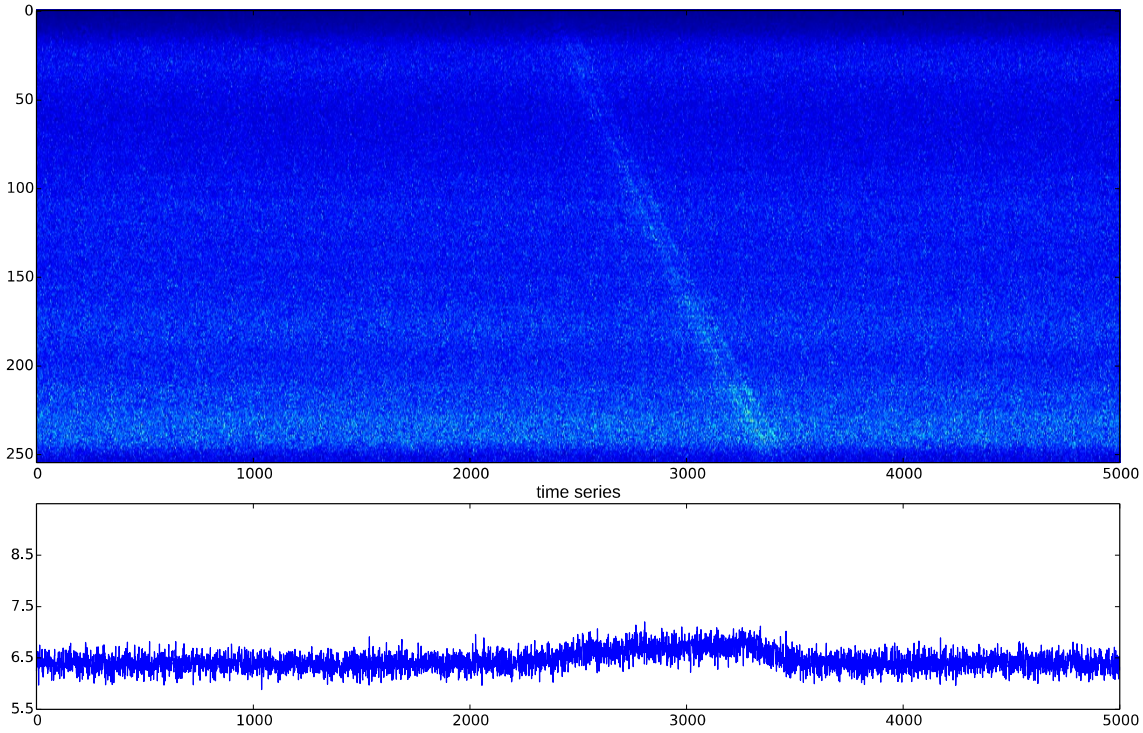

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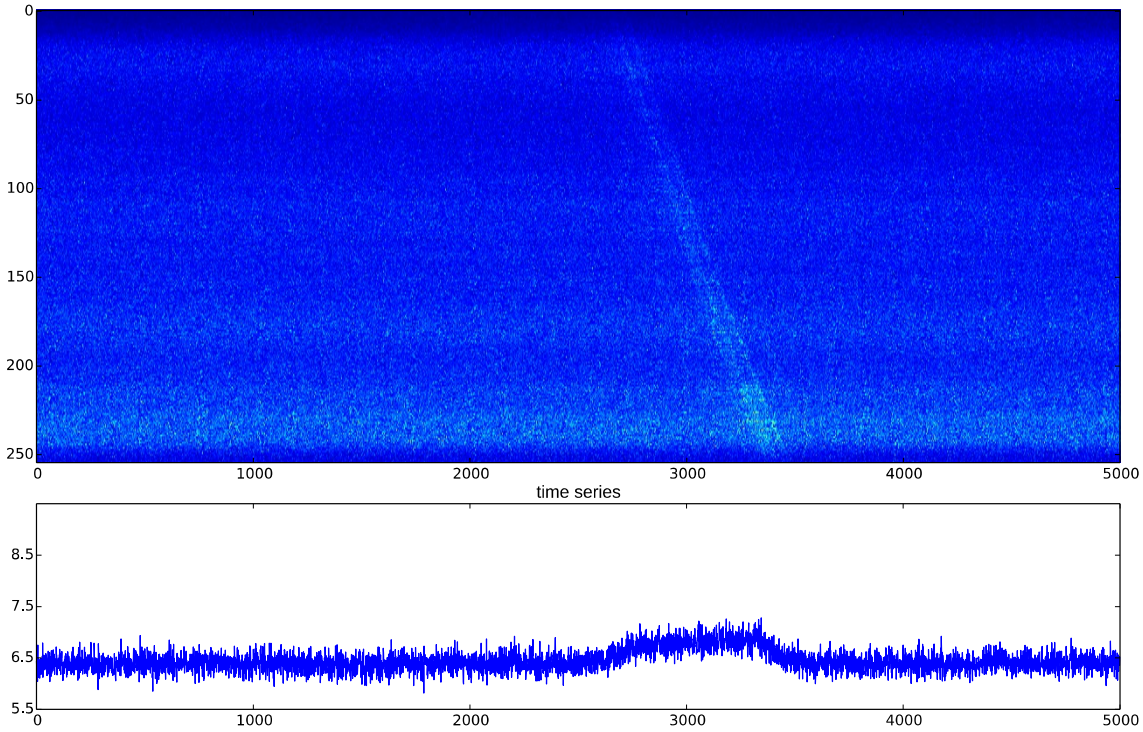

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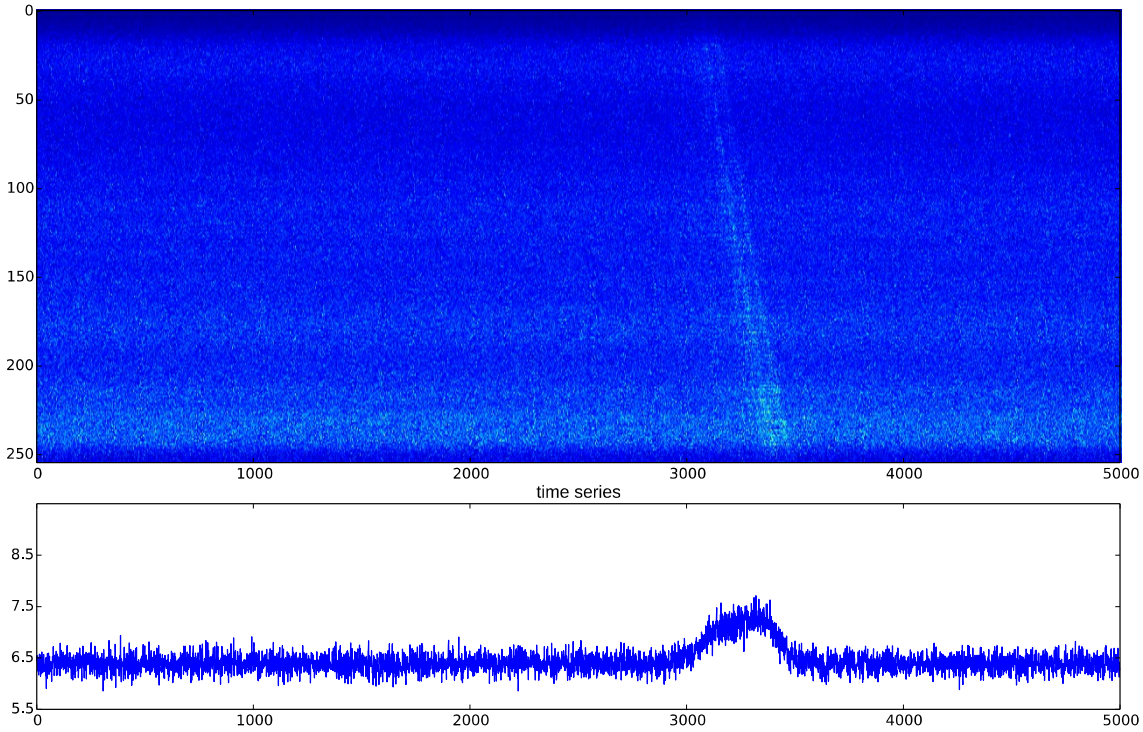

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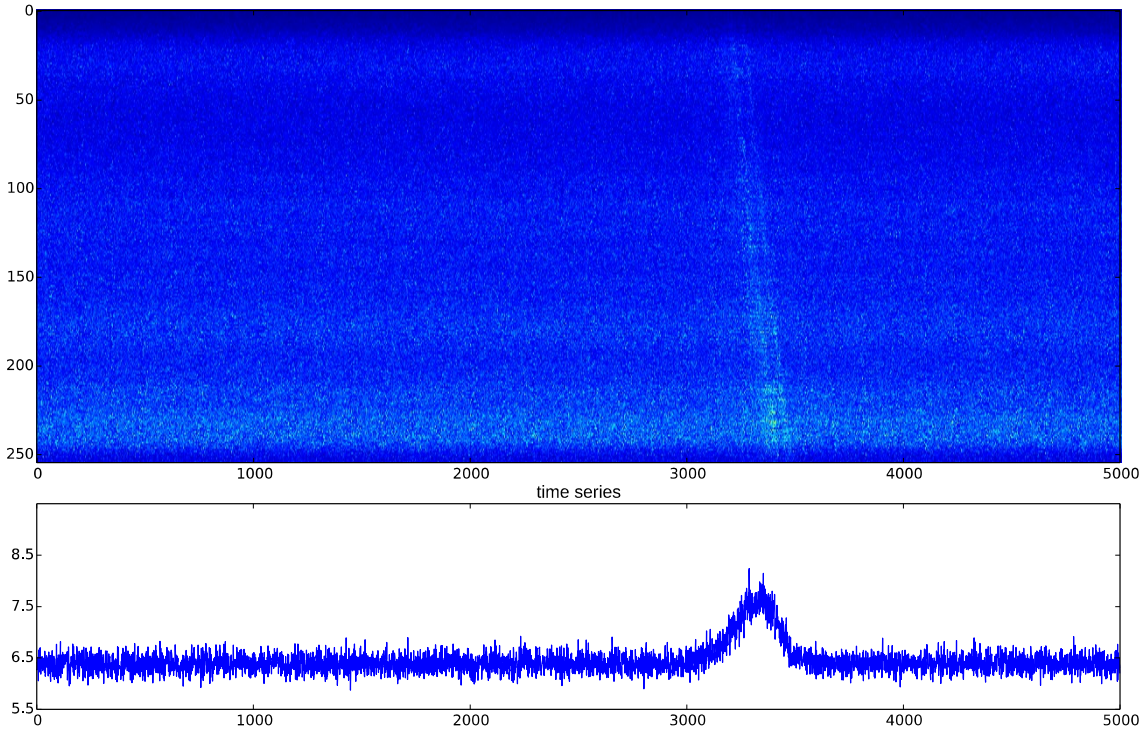

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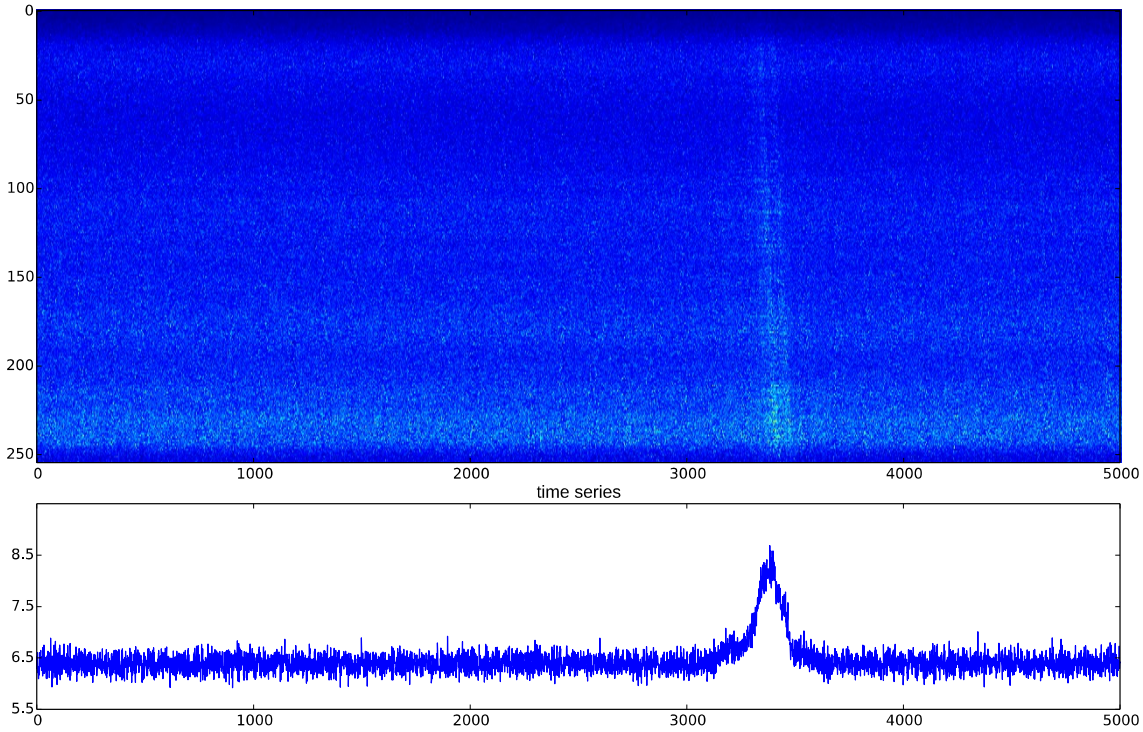

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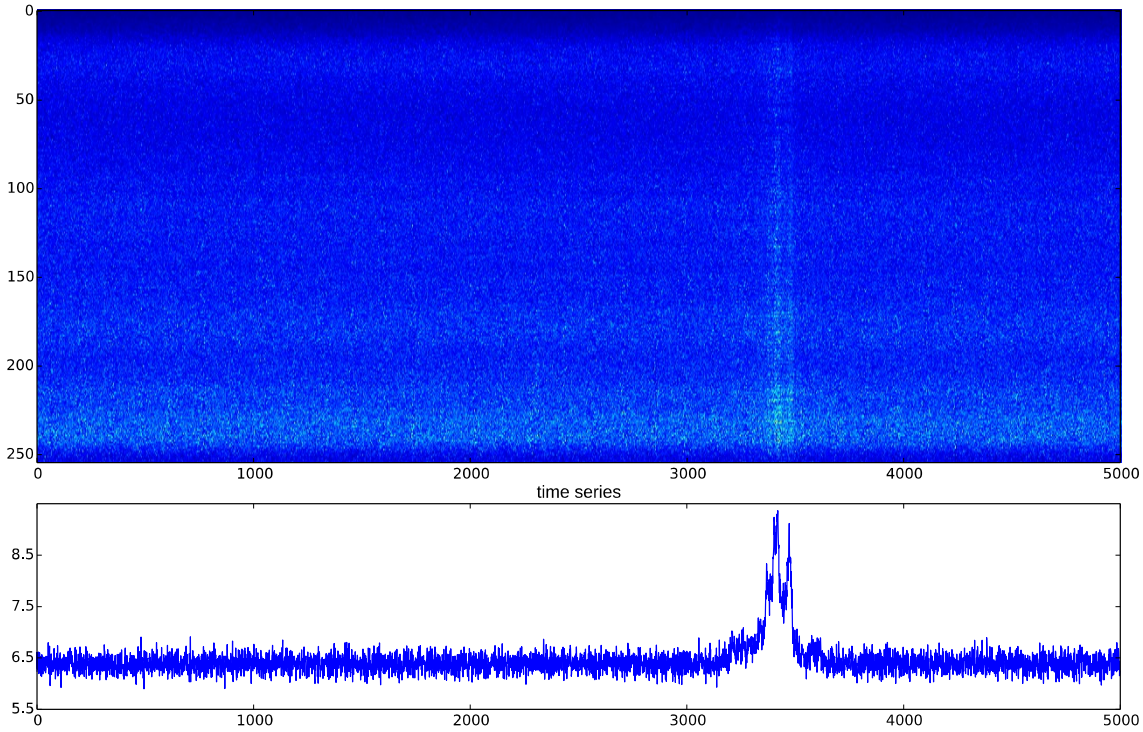

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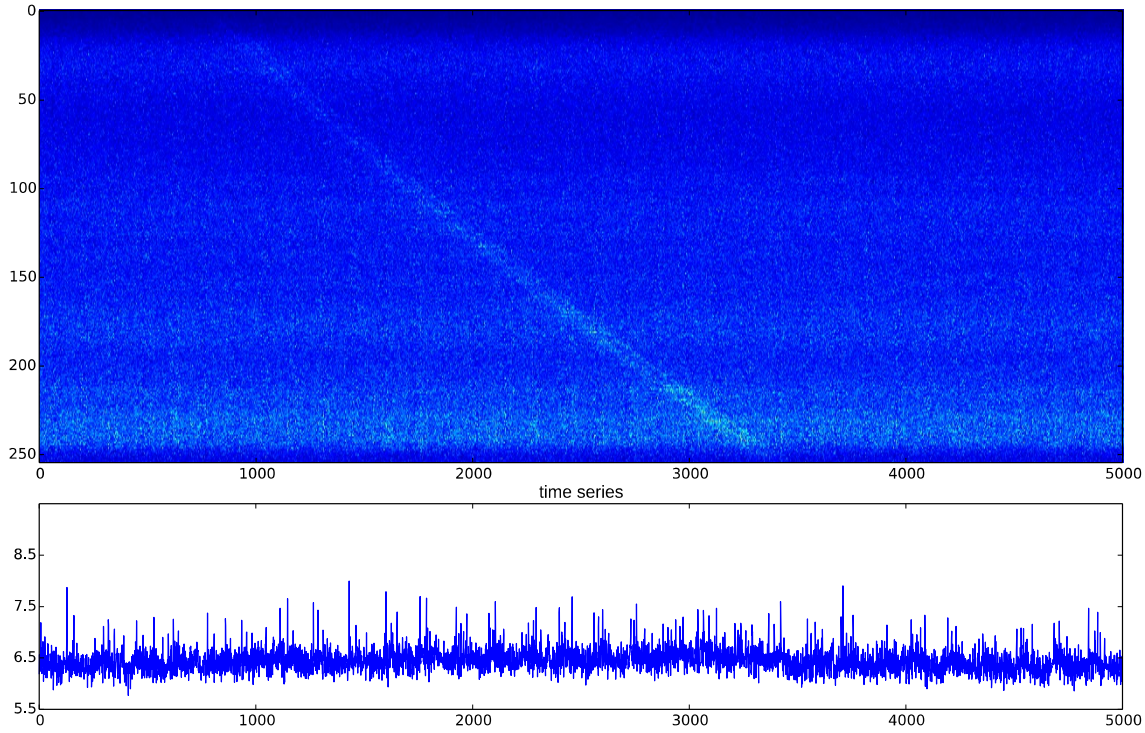
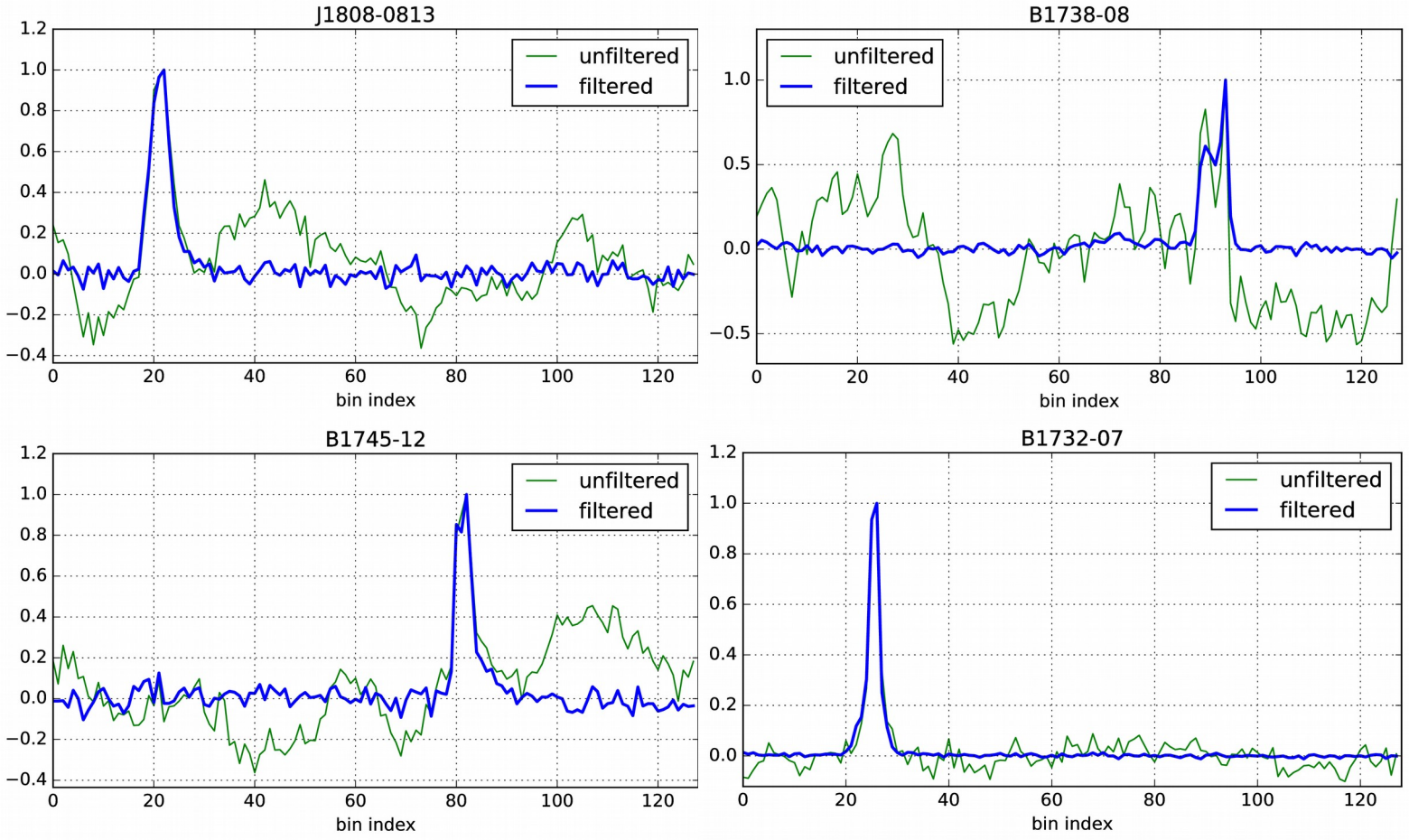


Impact on Pulsar Data

- The tool is regularly being used at GMRT for pre-processing of pulsar data, both for timing and survey.
- On-going pilot survey for pulsars and transients using the uGMRT.
- Results from 32 known pulsars in the field :



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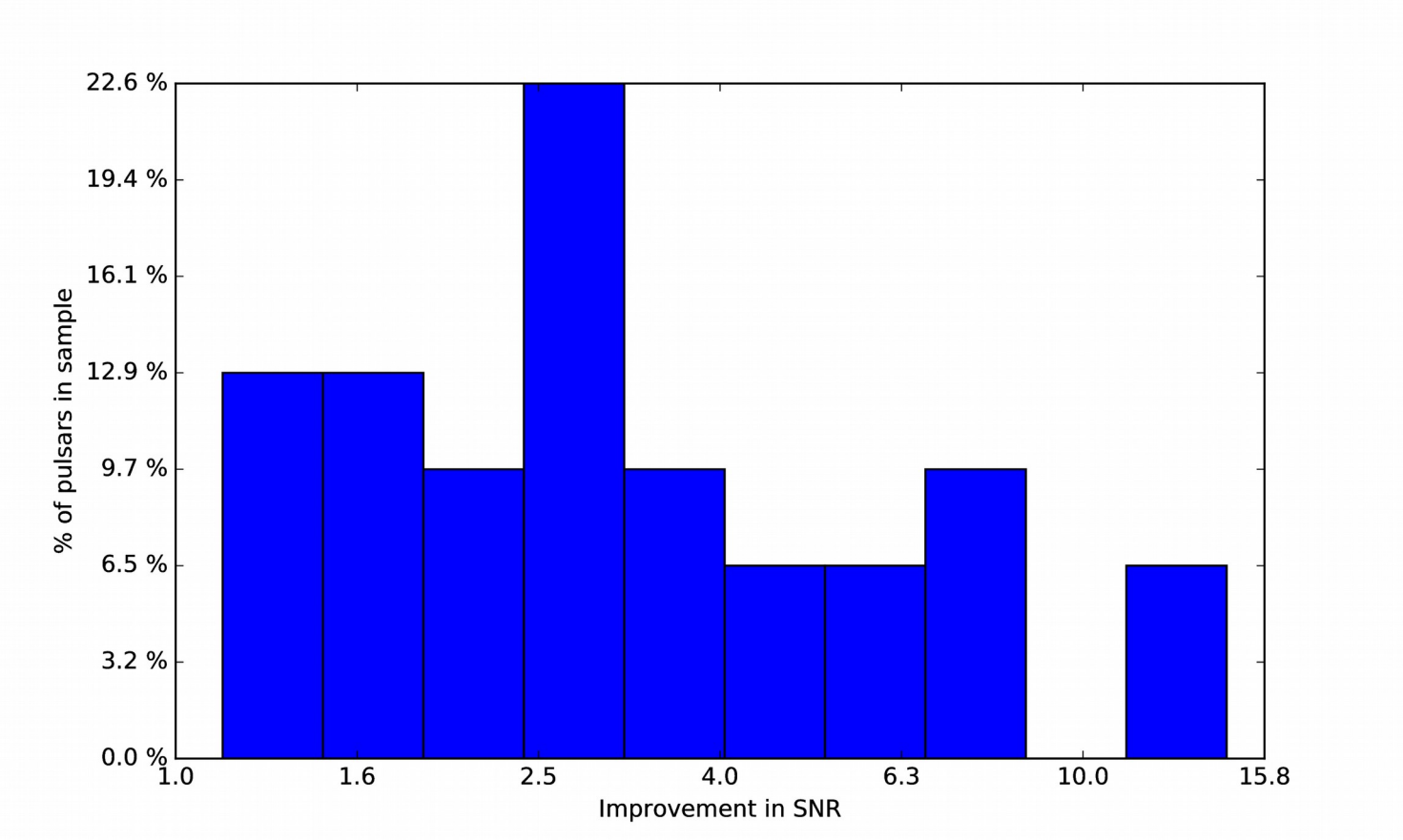
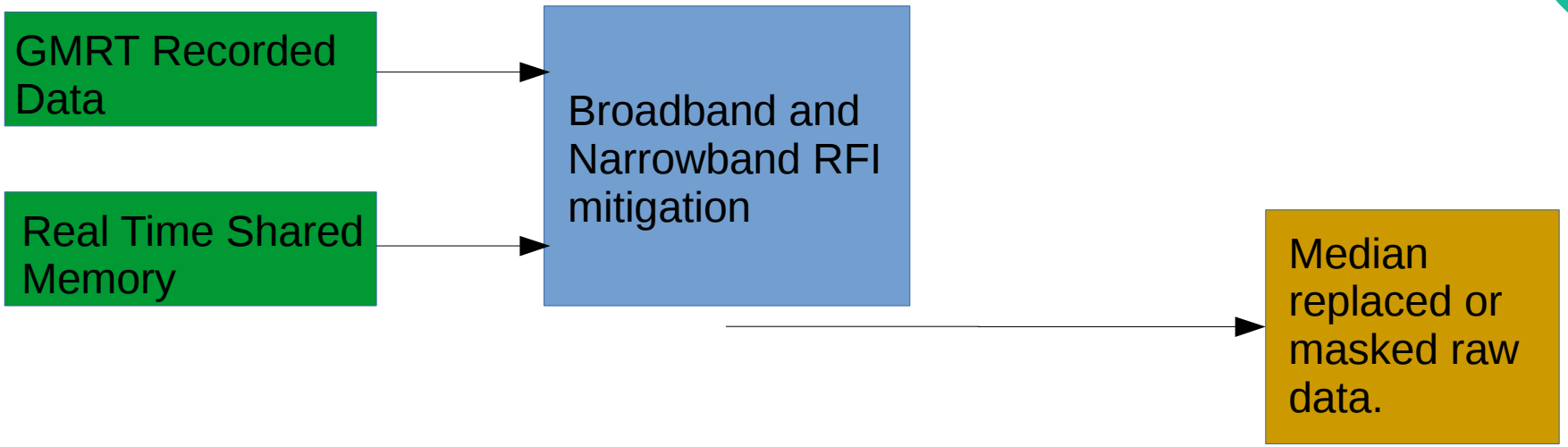


Implementation – The GMRT Pulsar Tool (gptool)



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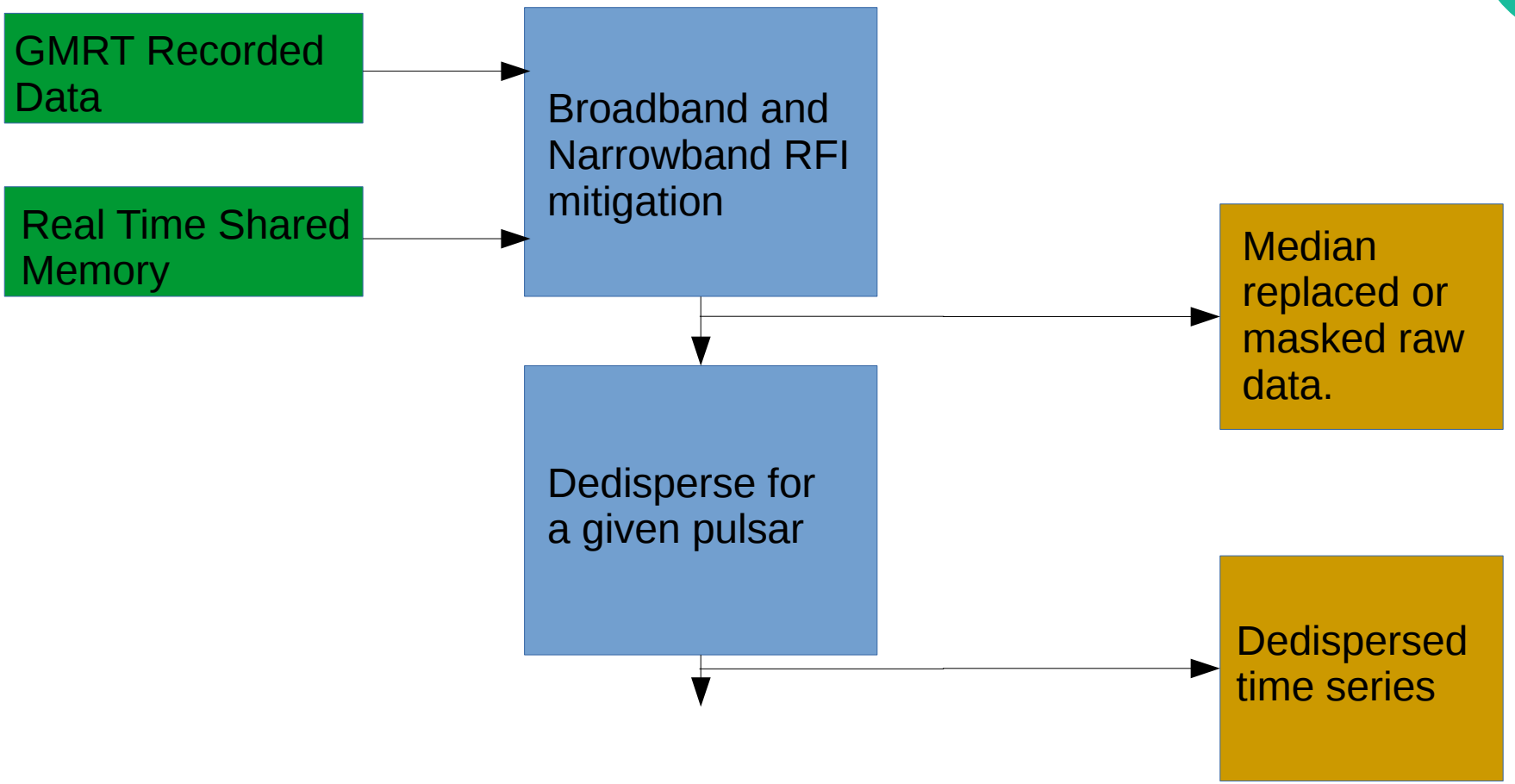

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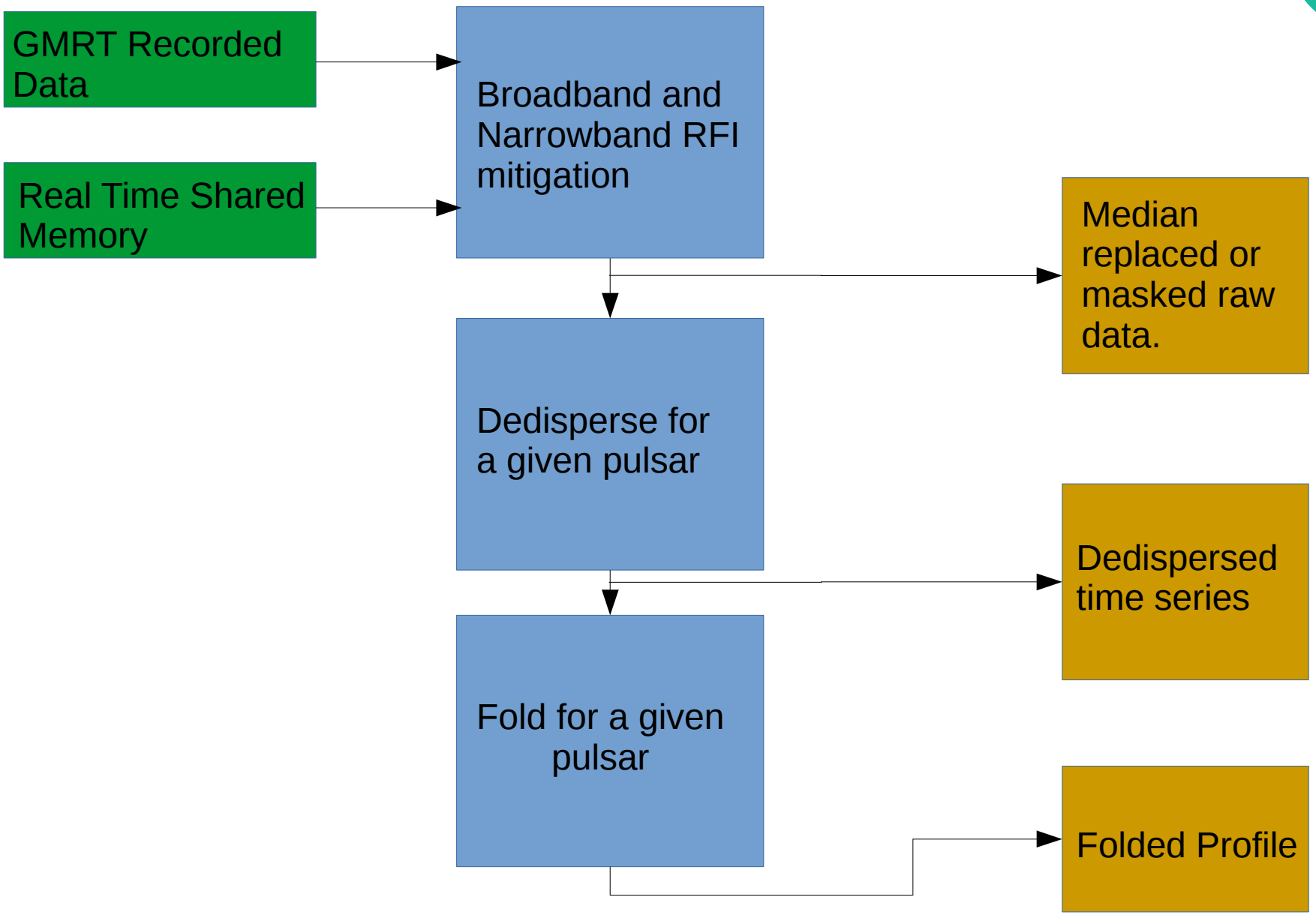
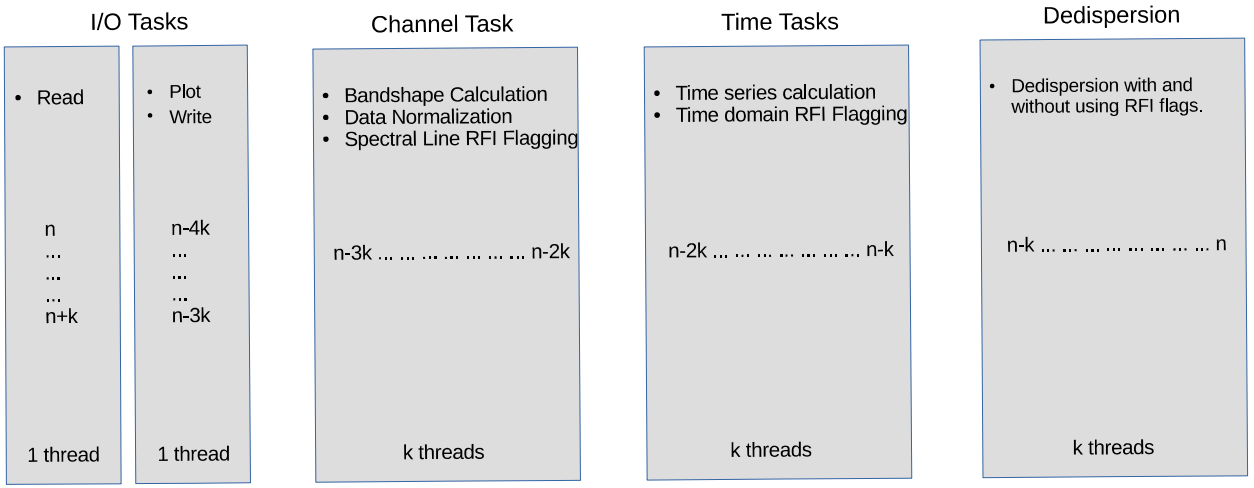


Need for a Real Time Tool

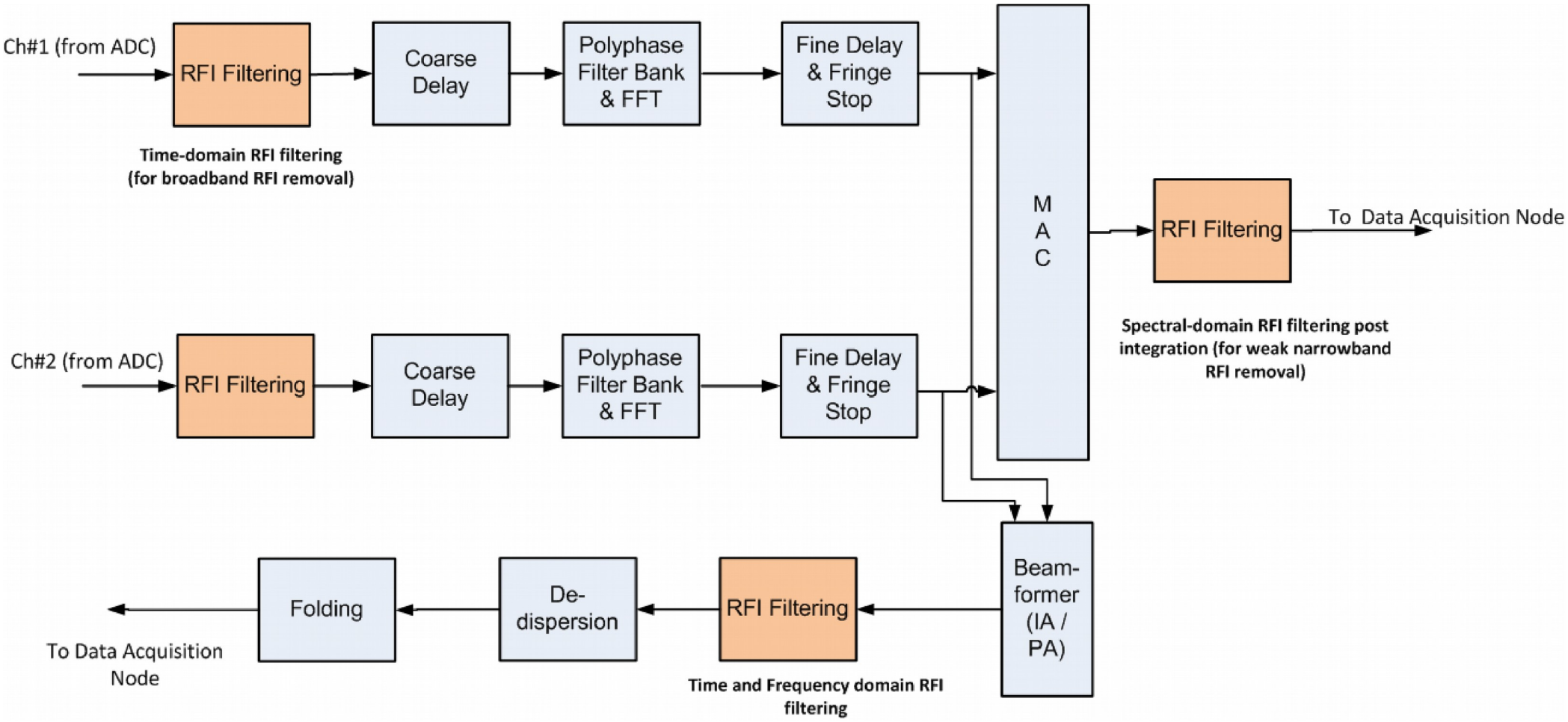
- ➔ Nyquist data rate using 200MHz bandwidth of the uGMRT – 400Mb/s
- ➔ Can go down to 10 microsecond sampling with 2k spectral channels.
- ➔ The resolution can be very useful for pulsar timing studies.
- ➔ Writing out full data will be bottlenecked by i/o access.
- ➔ Can full time-frequency information be reduced and dumped out in real time?
- ➔ **Yes – only if RFI mitigation is efficiently done and only dedispersed time series is dumped out.**

Implementation – The GMRT Pulsar Tool (gptool)

- Written in c++ ; parallelization using OPENMP
- Real time performance:
  - 5 threads by default.
  - Can comfortably process (RFI mitigate -> Dedisperse -> fold -> dump dedisperse series to disk) at a rate of **100 Mb/s**.
  - **40.96 microseconds with 2k spectral channels.**
- Scalability – Use 5xN threads, effectively handling 100xN Mb/s.



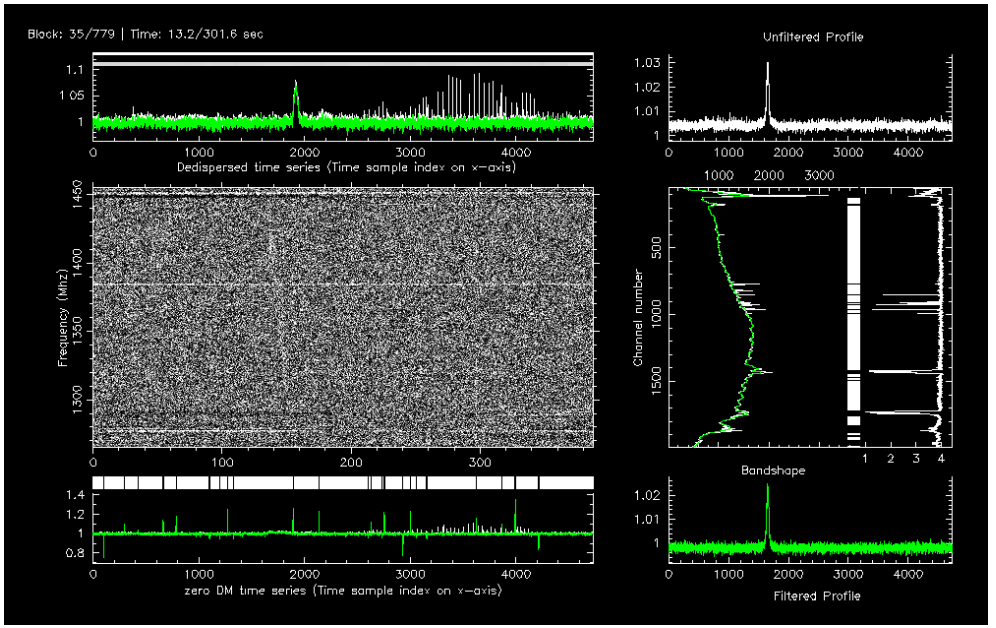
Real Time RFI Mitigation at GMRT



Advertisement

THE GMRT PULSAR TOOL

- Reliable and proven RFI mitigation strategy with easy to access customization for the user.
- Bundled with basic pulsar processing routines.
- All of it efficiently implemented to run in real time.
- Easy performance scalability – use as much resource as you need!
- Feel free to get in touch for a demo!



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