



Current Status and Plans for the uGMRT Real-time RFI Filtering System

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Digital Backend Group

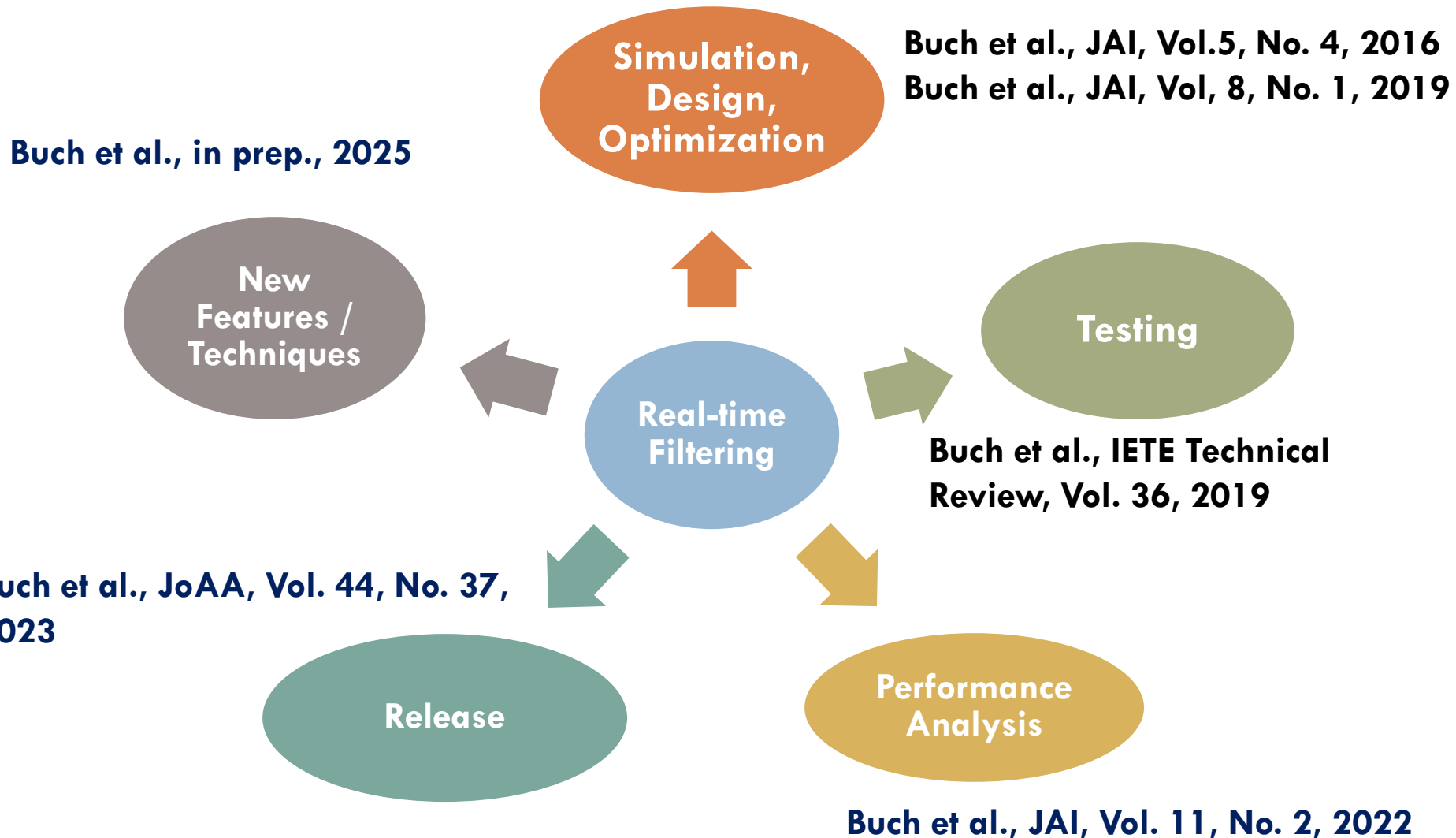
Giant Metrewave Radio Telescope (GMRT), NCRA-TIFR,
Pune, India

kdbuch@gmrt.ncra.tifr.res.in

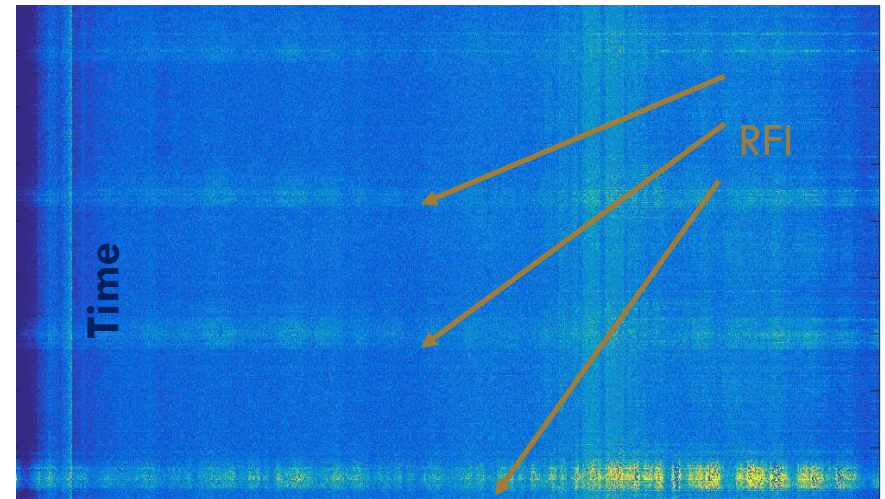
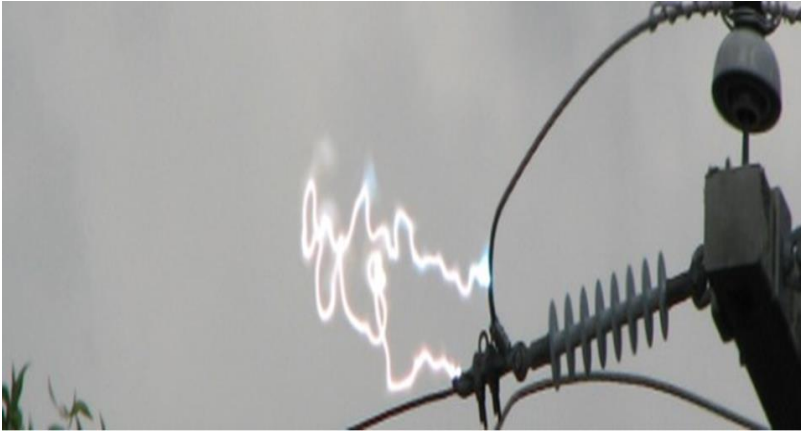
Radio Frequency Interference (RFI) 2025

Online, 22nd October 2025

RFI Filtering Development at uGMRT: Various Activities



Sources of Broadband RFI



Frequency

Stray Wire on 440 kV HT Line



Image Courtesy: RFI group GMRT

RFI from 11kV Transformers



Potential sources of interference (due to sparking)



Major sources of powerline RFI

GMRT Array

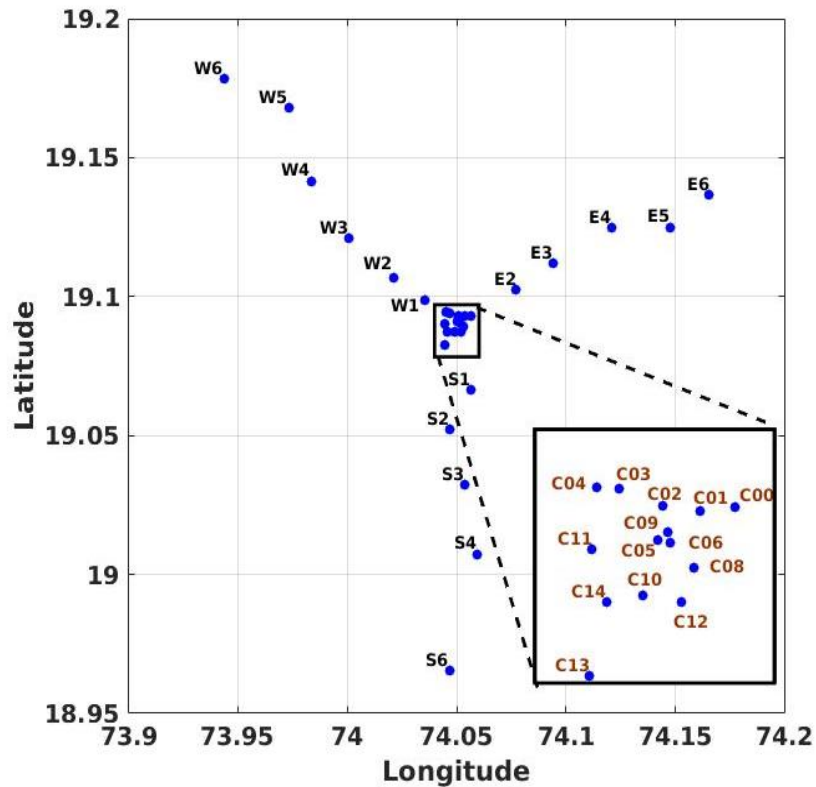
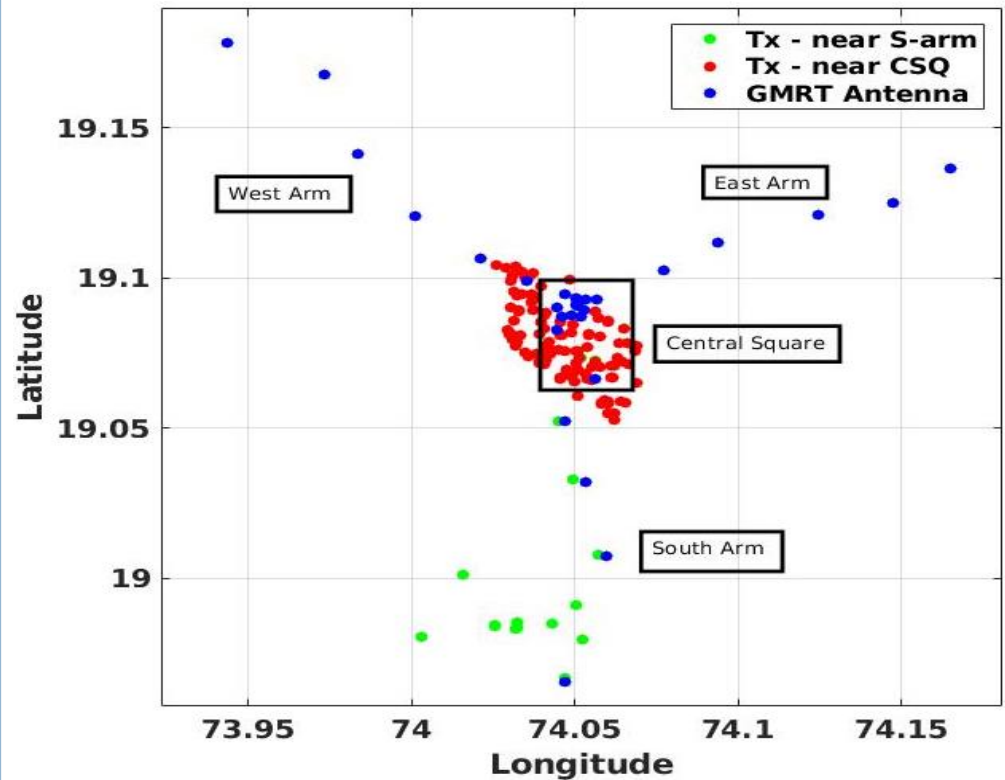


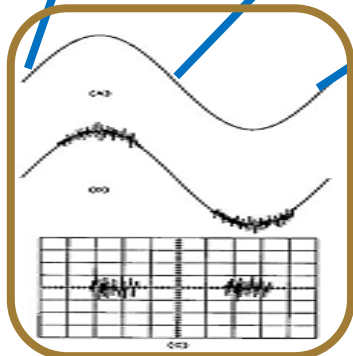
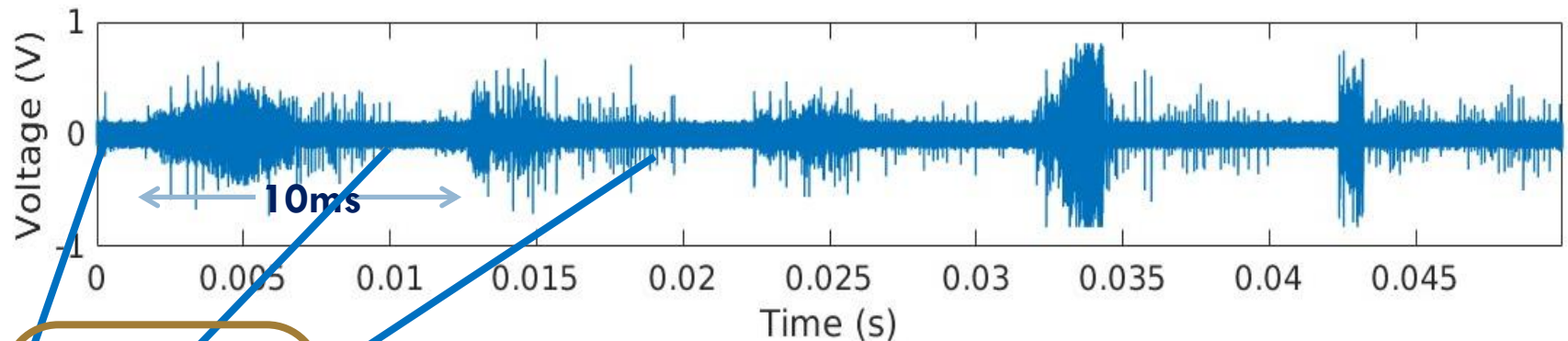
Image Courtesy: Bela Dixit

Potential Sources of Powerline RFI around Central Square and South-arm of GMRT



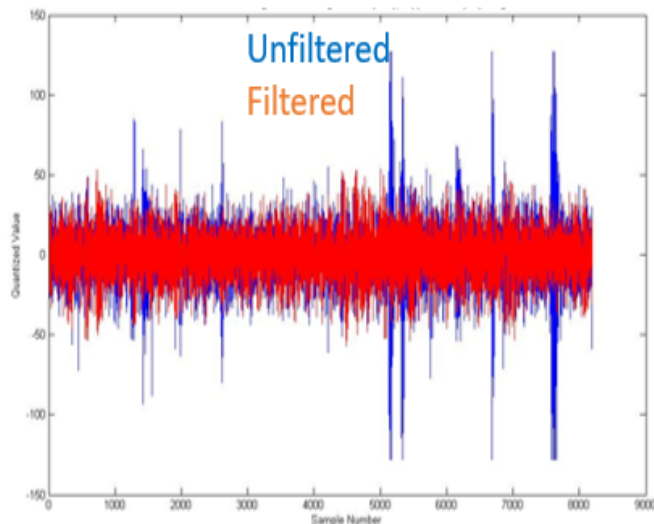
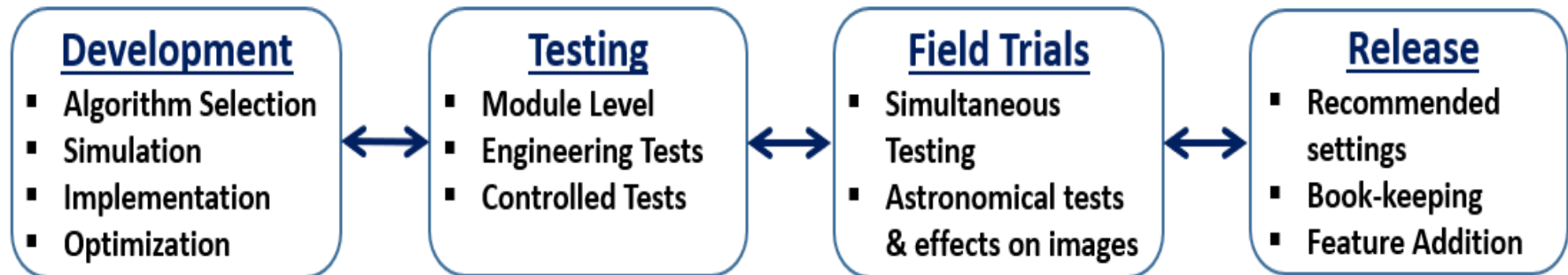
Data Courtesy: Pravin Raybole, RFI Group, GMRT

Powerline RFI at GMRT – Timeseries at 325 MHz

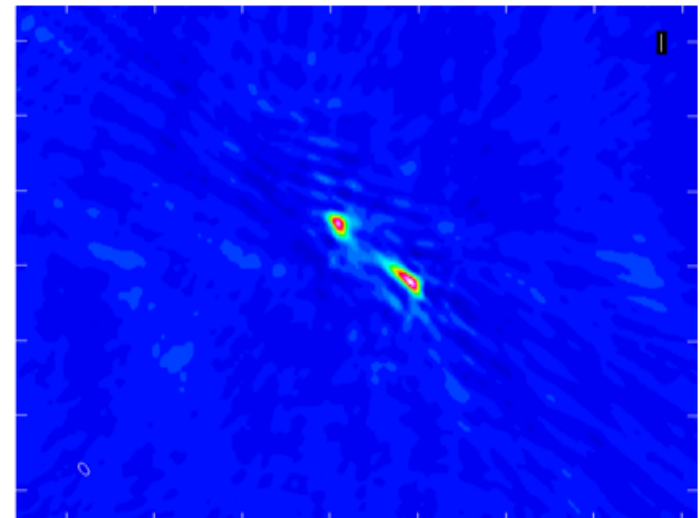


Time-domain excision (pre-correlation) prevents corruption of data in the downstream signal processing.

uGMRT RFI Filtering System: Development Flow



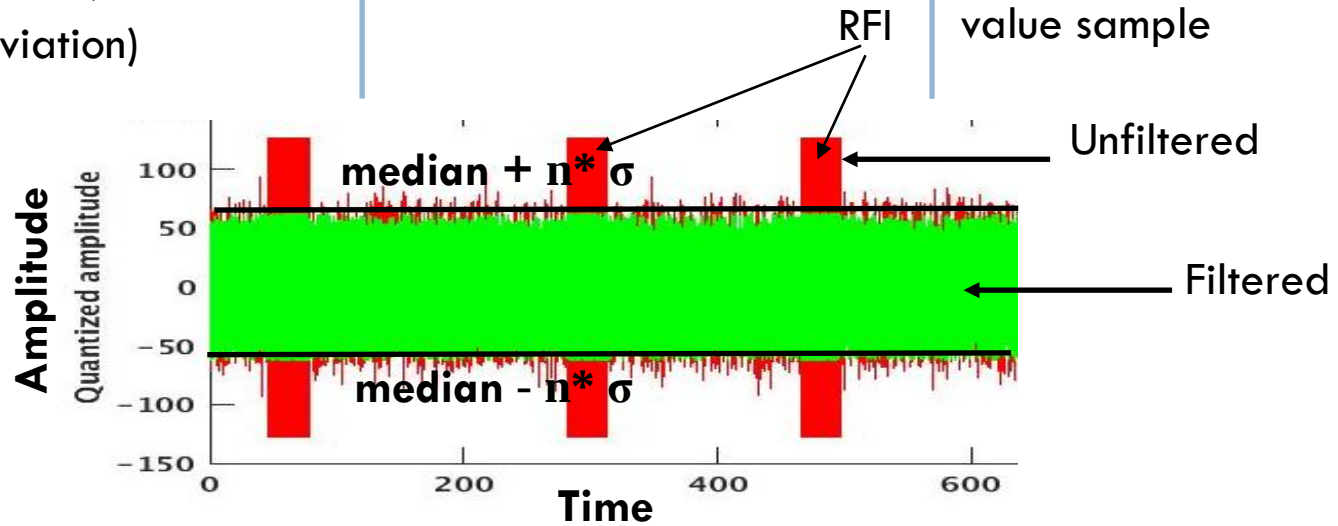
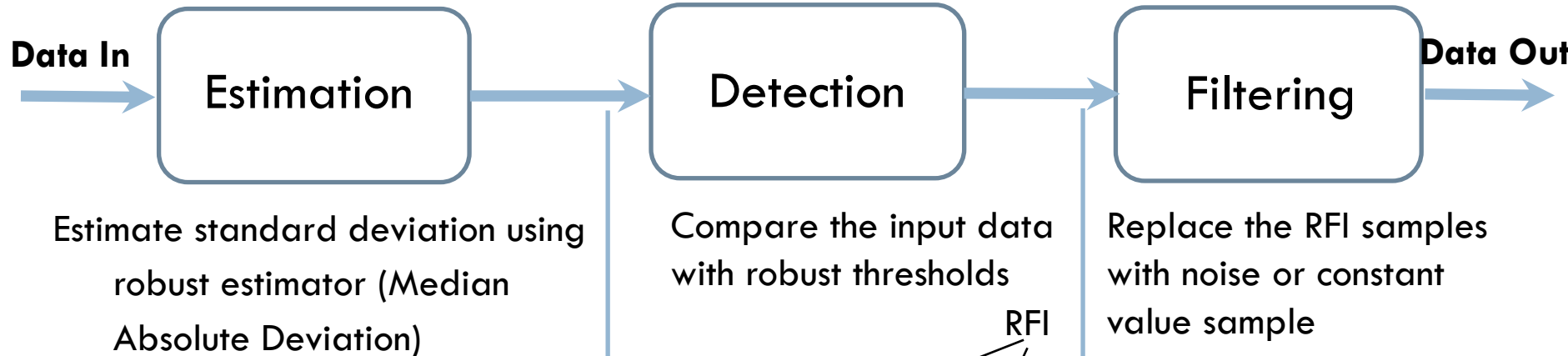
Initial plot: uGMRT Timeseries (~2013)



RFI-Filtered Image uGMRT (~2018)

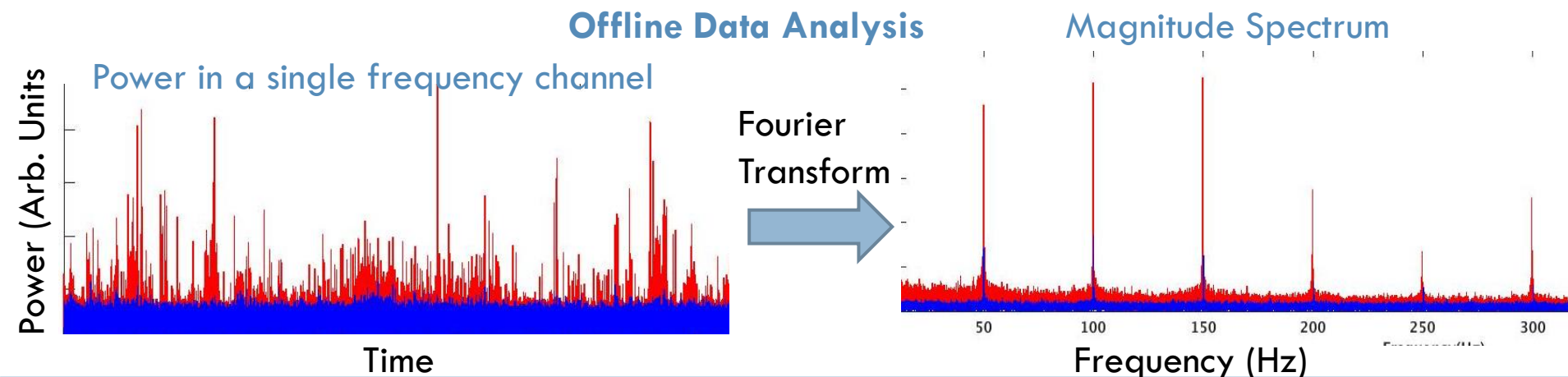
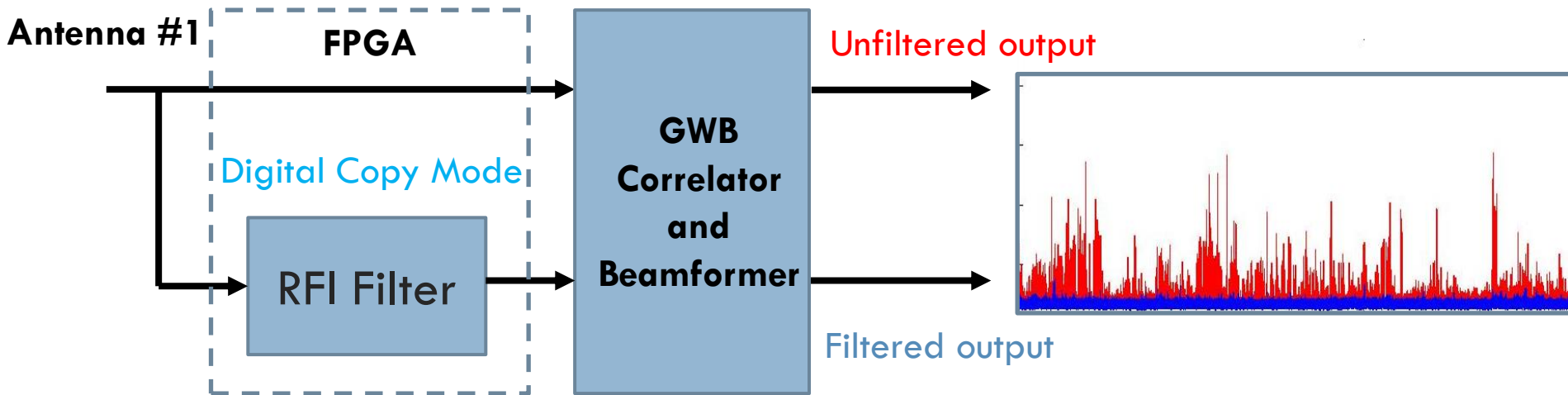
The Filtering Algorithm – Detecting and Removing Outliers

Operates in time-domain on each antenna (and polarization)

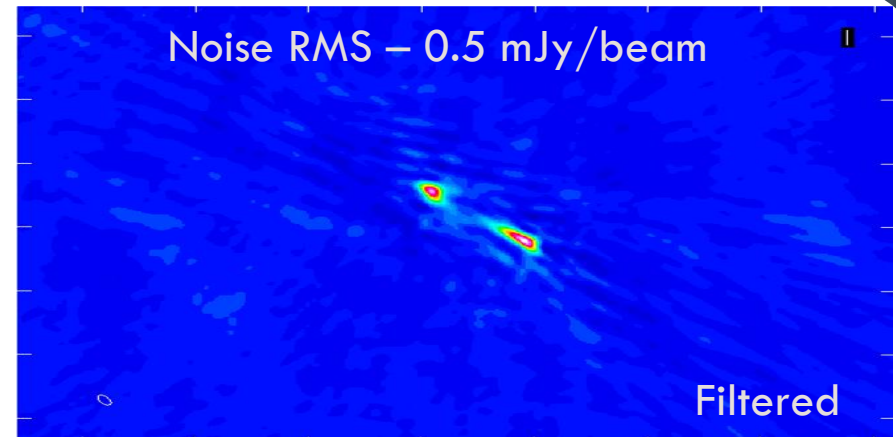
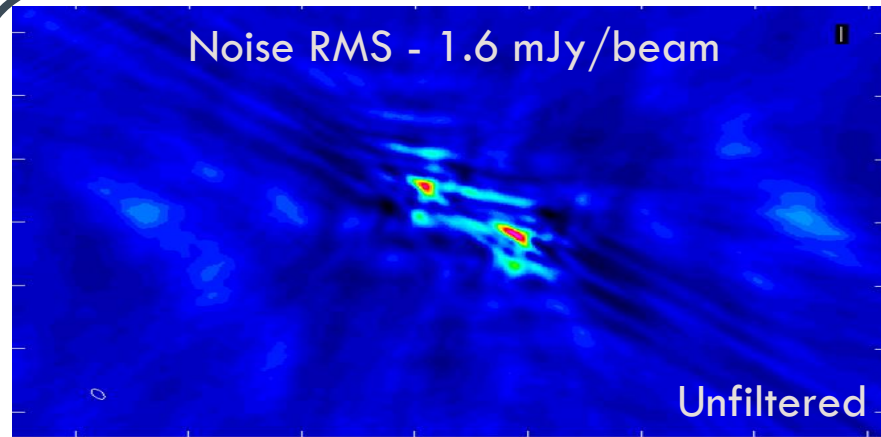


Computing recursive median in real-time was the most challenging aspect of this system

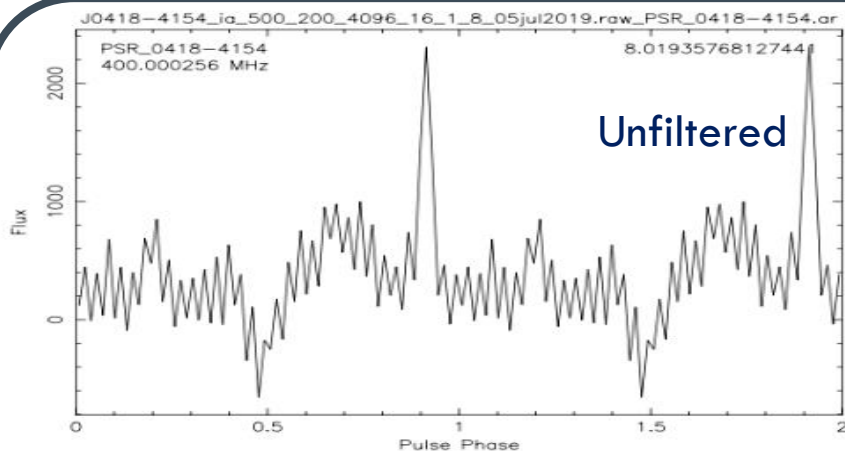
Simultaneous Testing: Digital Copy Mode



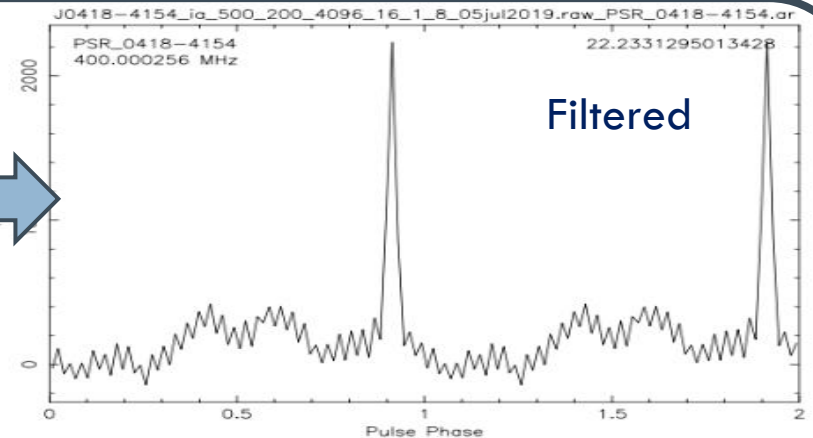
Example Results from the released system (Simultaneous Testing)



uGMRT Band-4, 550-850 MHz, 200 MHz RF bandwidth, 2k spectral channels, Imaging for baselines $< \sim 0.5$ km



3x
SNR



Pulsar (J0418-4154) uGMRT Band-3 Incoherent Array beam 4096 spectral channels 327.68 μ s integration time.

Image Courtesy: Ruta Kale, Bhaswati Bhattacharyya, Jayanta Roy, NCRA

Commissioning in the GMRT Wideband Backend (GWB)

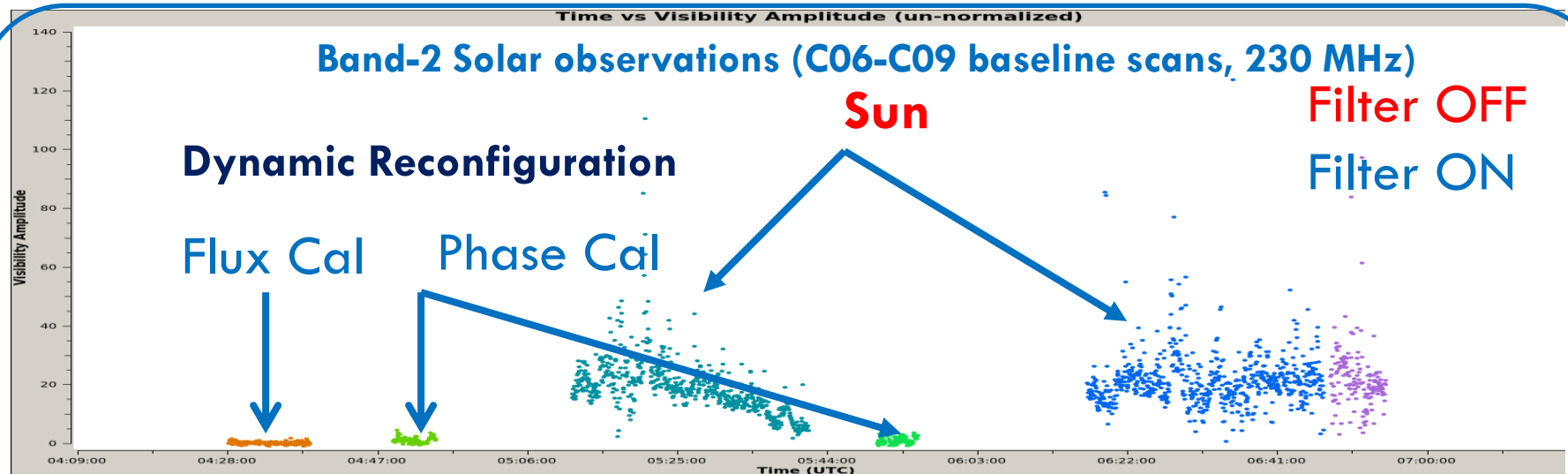
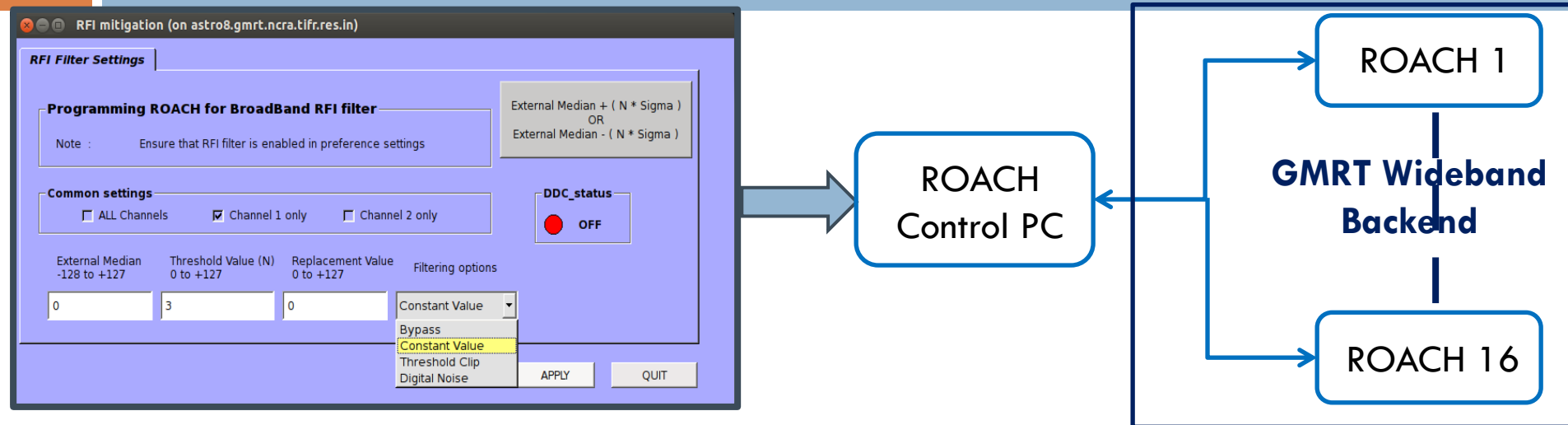


Image Courtesy: Devojyoti Kansabanik, NCRA

Book-keeping

```
gts'0521+166'  
sndsacsrc(1,12h)  
sndsacsrc(1,12h)  
stabct  
/(gotosrc)
```

Command file

```
strndas      Counter reset
/(/home/observer/bin/g4_rfi_cntr_rst)
time 5m      Counter hold
```

Counter reset

```
time 5m Counter hold
/(/home/observer/bin/g4_rfi_cntr_hld)
stpndas
```

Counter hold

RFI counter is reset and hold at user-defined intervals

GMRT M&C
system

ROACH
Control PC

.csv file

ROACH 1

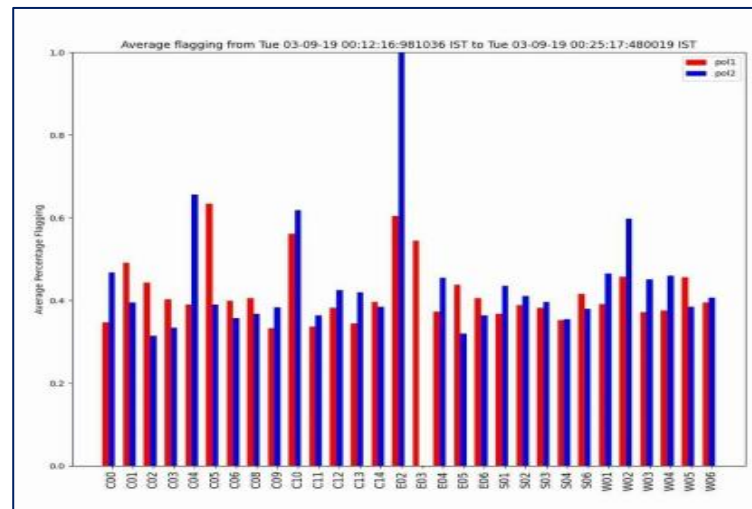
GMRT Wideband Backend

ROACH 16

15	13 Fri	18-08-23	04:09:37:03256	IST		0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	14 Fri	18-08-23	04:09:37:58378	IST		0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	15 Fri	18-08-23	04:09:38:253104	IST		0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0 Fri	18-08-23	04:16:30:171359	IST	337078941304	2386114375	337078941304	1909102969	337078941304	1860333225	337078941304	2056285761							
19	1 Fri	18-08-23	04:16:30:911673	IST	337206391584	1812491838	337206391584	2236279452	337206391584	2136637078	337206391584	2712404025							
20	2 Fri	18-08-23	04:16:31:590041	IST	337061784656	2355805084	337061784656	1847182436	337061784656	2174160107	337061784656	2395355103							
21	3 Fri	18-08-23	04:16:33:141395	IST	33733629824	1624609477	337733629824	2556447530	337733629824	1845535338	337733629824	2012689403							
22	4 Fri	18-08-23	04:16:33:741323	IST	337775117856	2248361778	337775117856	2102912057	337775117856	1836516034	337775117856	1802868509							
23	5 Fri	18-08-23	04:16:34:287245	IST	337772965148	2722237175	337772965148	2374196845	337772965148	1821976732	337772965148	2407334358							
24	6 Fri	18-08-23	04:16:34:891333	IST	337817821312	2235619421	337817821312	1409563728	337817821312	1974378454	337817821312	2780904185							
25	7 Fri	18-08-23	04:16:35:710922	IST	338035101664	2732829223	338035101664	2746648642	338035101664	1780418147	338035101664	1870166987							
26	8 Fri	18-08-23	04:16:36:671756	IST	338278780400	1607549497	338278780400	2256957222	338278780400	1706147732	338278780400	3938101251							
27	9 Fri	18-08-23	04:16:37:240954	IST	338294289960	2942841000	338294289960	2294203724	338294289960	2044249012	338294289960	1188954629							
28	10 Fri	18-08-23	04:16:38:091938	IST	338462427568	2214370222	338462427568	2854912407	338462427568	3402626819	338462427568	1747264109							
29	11 Fri	18-08-23	04:16:38:701389	IST	338285896624	2008743716	338285896624	2420776273	338285896624	91777231446	338285896624	74064639406							
30	12 Fri	18-08-23	04:16:39:781743	IST	338622233984	1769497121	338622233984	3428404185	338622233984	1973880444	338622233984	3607538895							
31	13 Fri	18-08-23	04:16:40:327437	IST	338619964916	3876845002	338619964916	2306604698	338619964916	2233481591	338619964916	1455047675							
32	14 Fri	18-08-23	04:16:41:369870	IST	339013920160	2399196892	339013920160	2670071068	339013920160	3147106250	339013920160	2264169105							
33	15 Fri	18-08-23	04:16:42:291570	IST	339214790192	1963541425	339214790192	2654306600	339214790192	0	339214790192	127385916872							

Operational System at GMRT

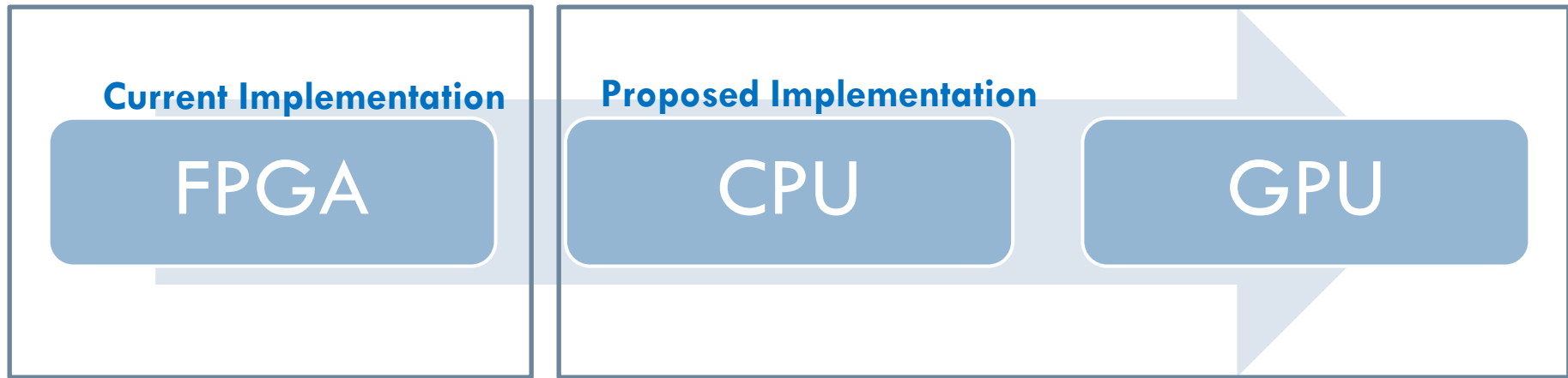
- Full release (April 2022) with facilities like:
 - Book-keeping through fractional flagging count
 - Configurable threshold and replacement options
- Typical flagging rate of 0.5-5% at 3σ threshold
- Recommended options:
 - 3σ (pulsar), 4σ (continuum)
 - Replacement by digital noise
 - Recording counter every five minutes



Cycle 47: ~ 750 hours
(~35-40% of time) with RFI
filtering: Continuum, Pulsar,
FRB, Sun observations

Porting the system on other platforms: Ongoing development

CPU or GPU platform (GMRT Wideband Backend)



Tile Processing Module – Low Frequency Aperture Array SKA

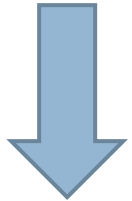


AMD-Xilinx Kintex Ultrascale+ FPGA (Implementation using VHDL)

CPU Implementation: Challenges

Algorithm same as FPGA released system

Robust Threshold
Computation

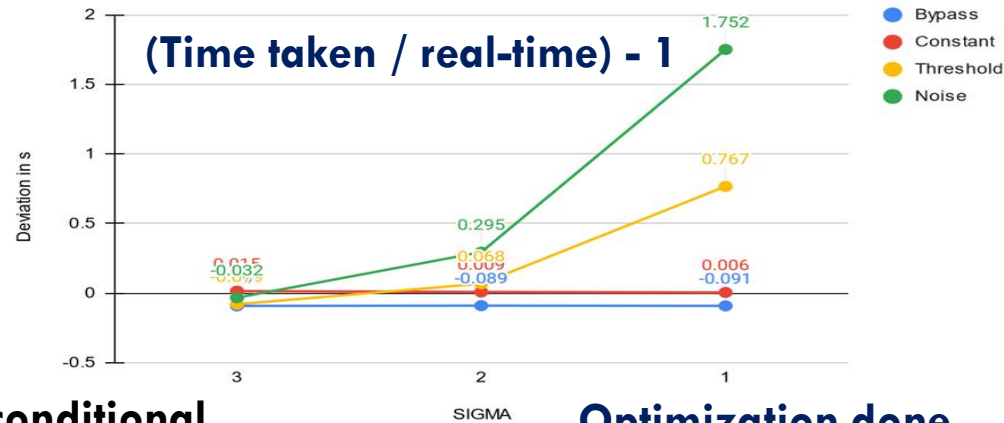


Filtering

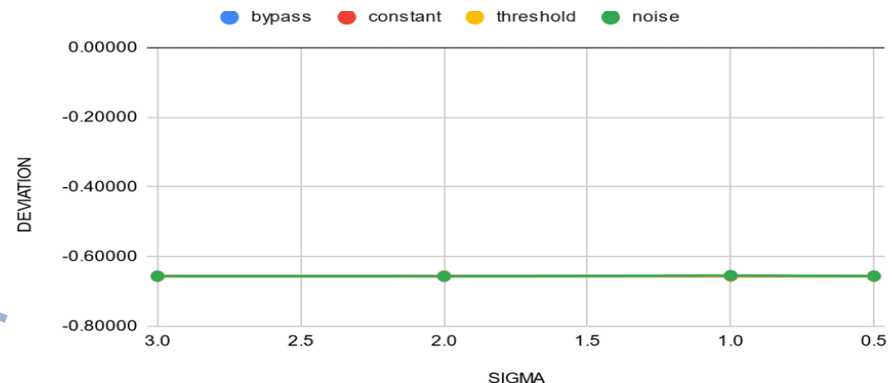
Filtering loop (conditional
branching instructions)
bottleneck for real-time
operation

Challenge:

**Make it work on existing CPUs and
limited resources available in the GWB**



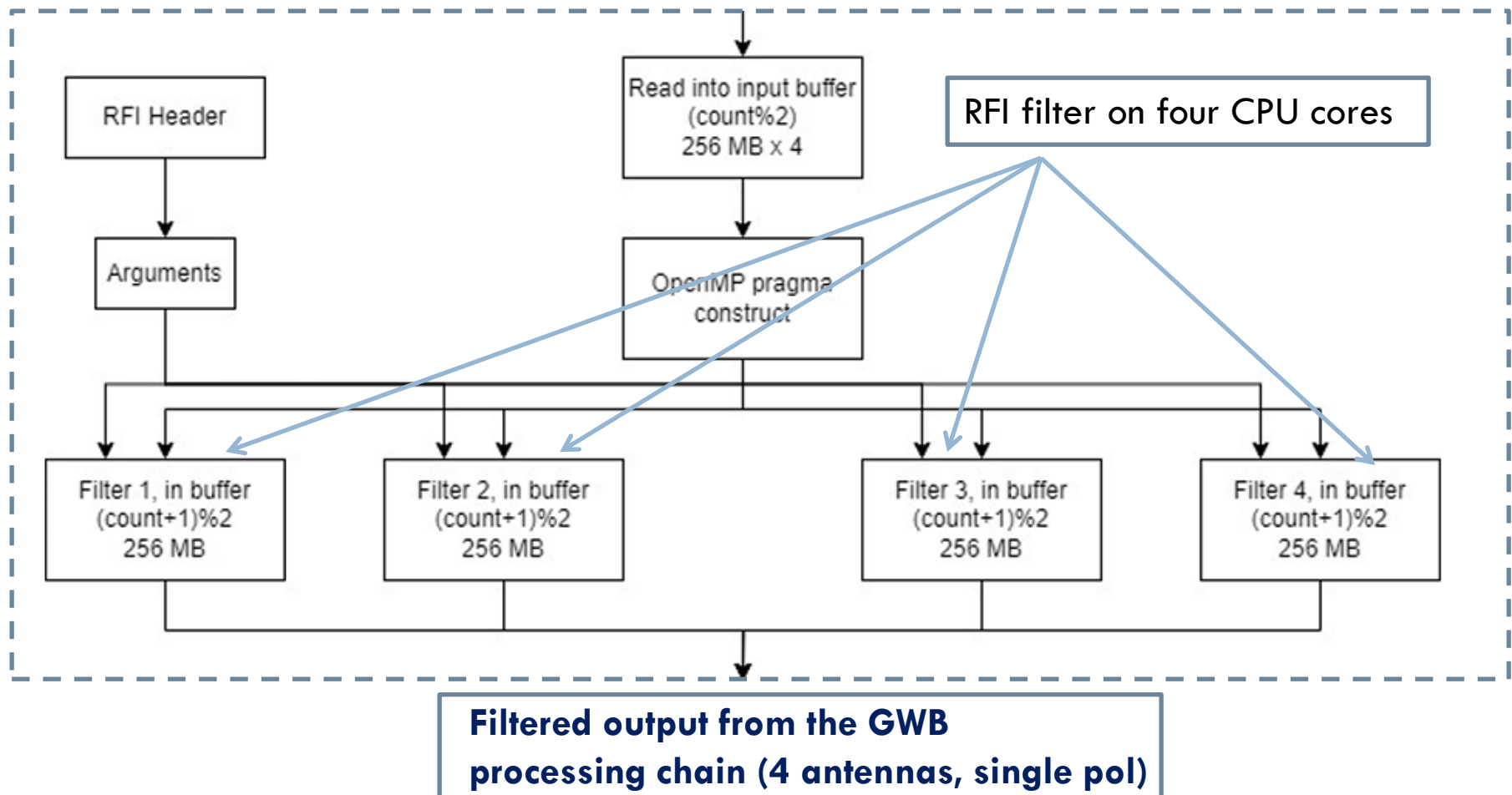
**Optimization done
using SSE/AVX
instructions**



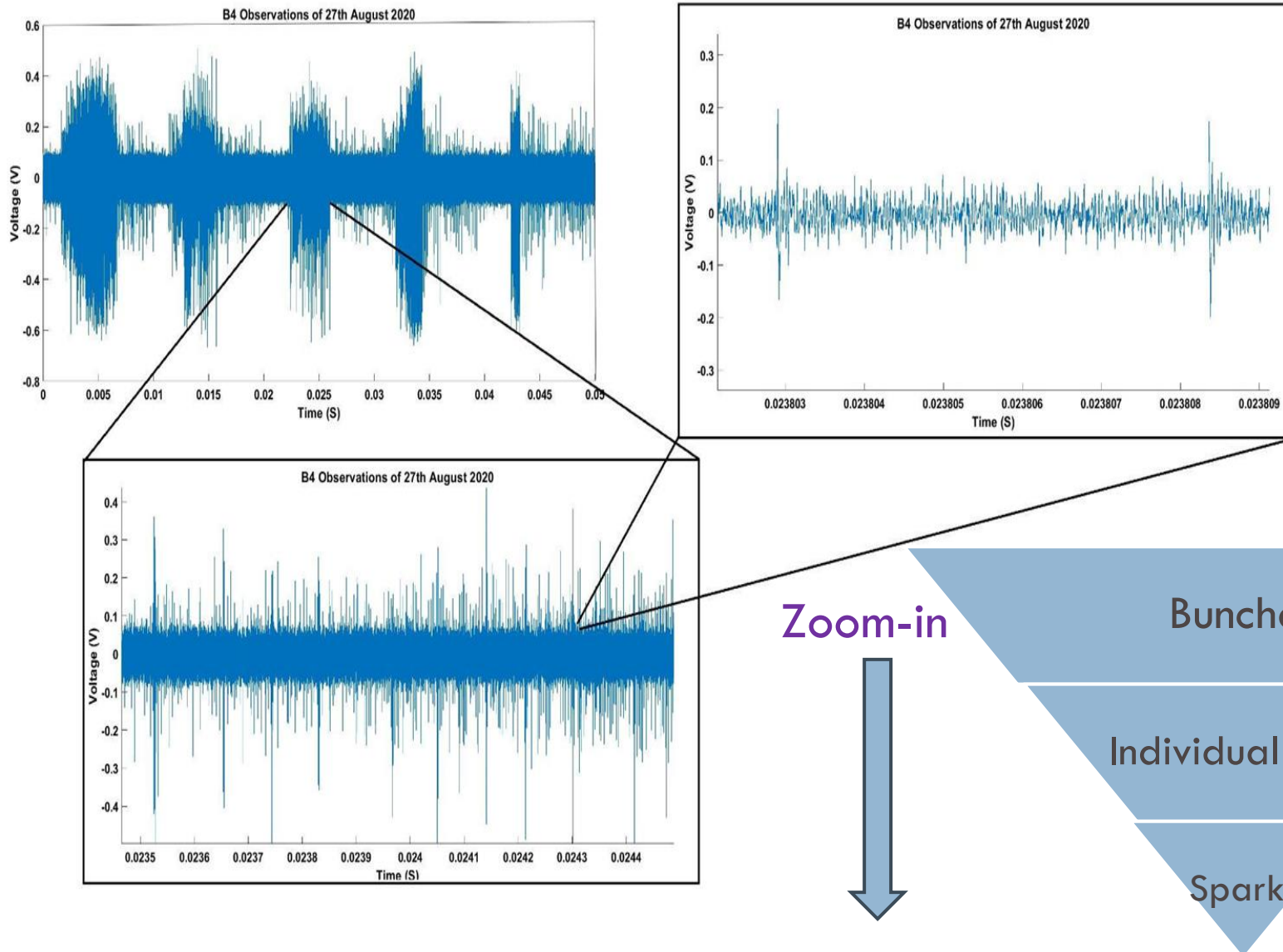
Four antennas processed on one server on CPU, each on one core

CPU Implementation: Towards Release

**Input from the GWB processing chain
(4 antennas, single pol)**



Powerline RFI: Composite Signal



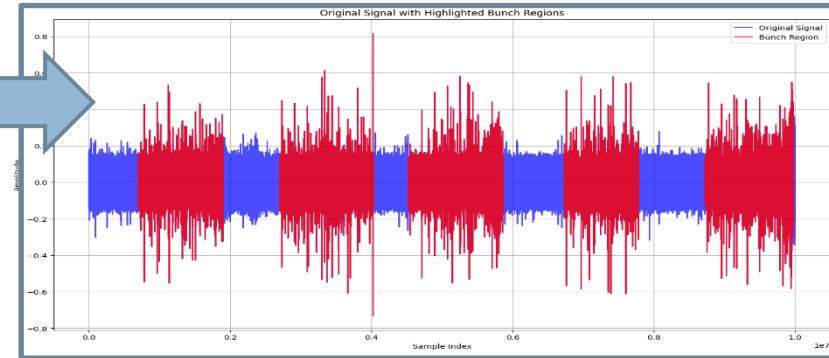
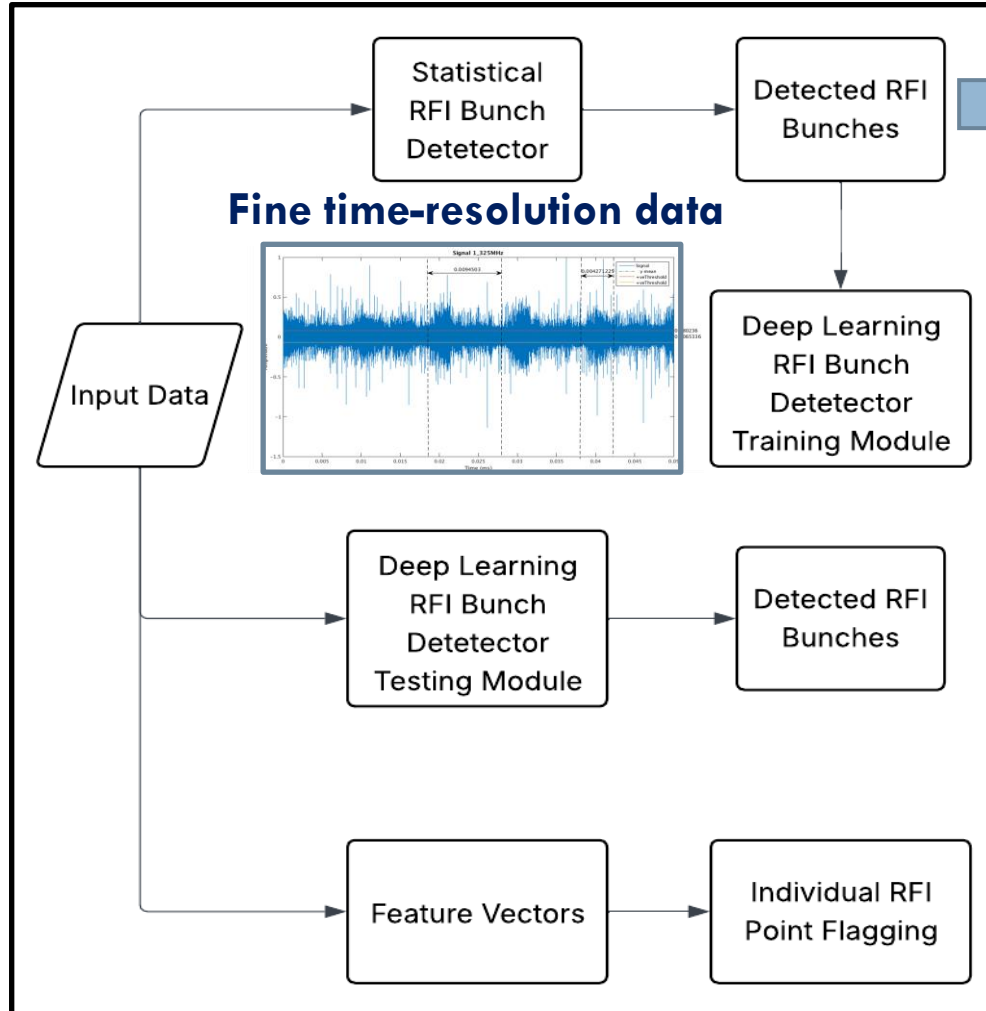
Zoom-in

Bunches

Individual Bunch

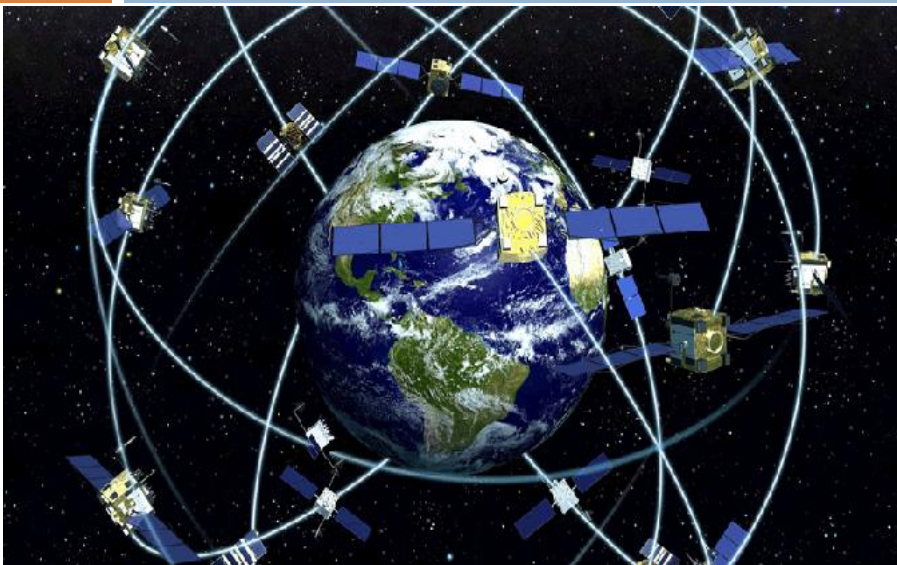
Sparks

Towards Statistical Learning Approaches



ENTIRE SIGNAL					
Percent RFI (%)	RFI_count (samples)	Not_RFI_count (samples)	Avg duration of RFI_on (seconds)	Avg duration of RFI_off (seconds)	Avg inter arrival time of bunch (seconds)
0.7923	79227	9920762	7.75E-06	0.0051	0.1048
0.4199	41988	9958001	9.16E-06	1.32E-02	1.55E-01
0.729	72895	9927094	1.14E-05	0.0054	0.0953
0.4348	43481	9956508	5.14E-06	0.044	0.1473
0.385	38495	9961494	6.96E-06	0.0223	0.1327
0.4166	41655	9958334	7.41E-06	0.0159	0.1436
0.4232	42317	9957672	6.50E-06	0.0307	0.0931
0.3824	38240	9961749	6.99E-06	0.0208	0.1476
1.0745	107452	9892550	8.30E-06	0.0037	0.0847
0.3714	37143	9962859	5.63E-06	0.0152	0.0989
1.9902	199019	9800975	6.06E-06	0.0017	0.2153
0.3057	30570	9969427	5.67E-06	0.0844	0.2076

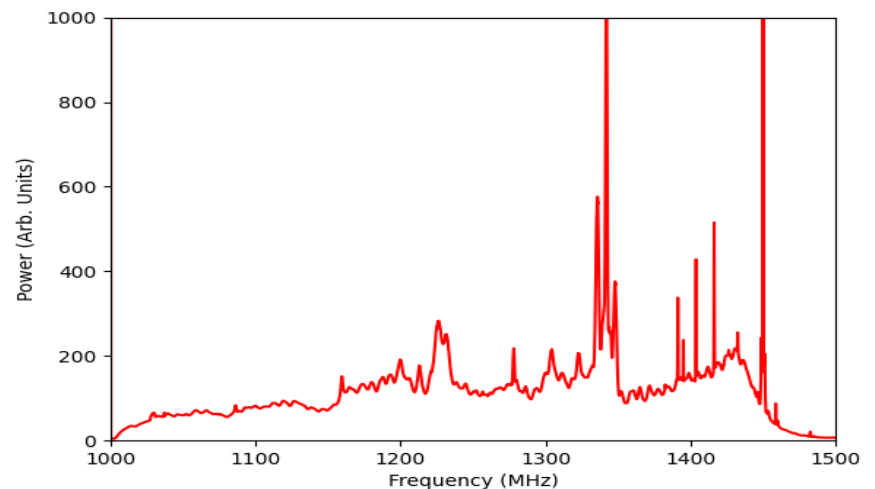
Narrowband RFI



- ☐ Spectrally (and at spatially) confined
- ☐ Communication transmitters – terrestrial and extra-terrestrial
- ☐ Stronger than the signal of interest (noise)

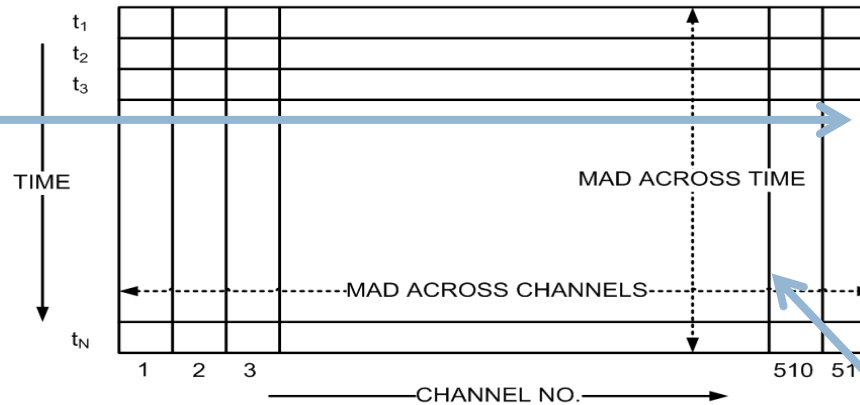


Typical uGMRT L-band



Time-Frequency Filtering

TIME-FREQUENCY DATA



Works for
intermittent RFI

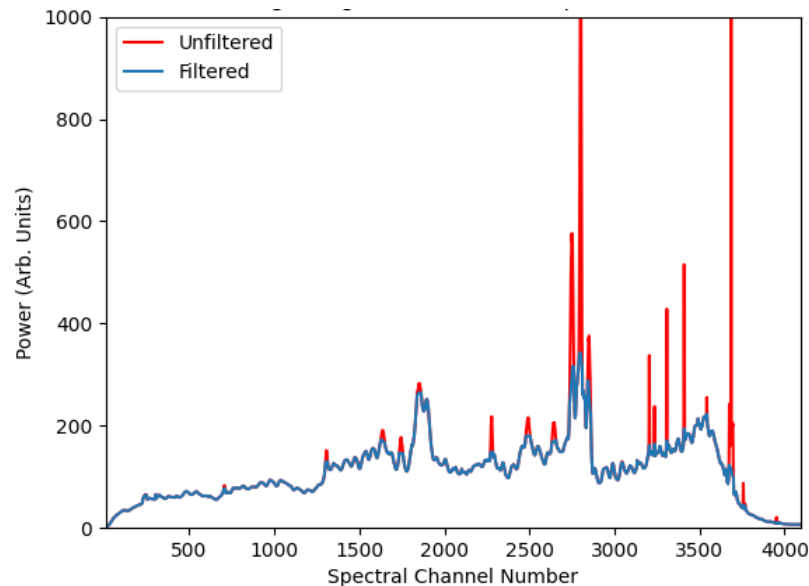
**Filtering across
frequency and
time is the best
solution**

Correlator/Beamformer
output

Narrowband RFI
filtering

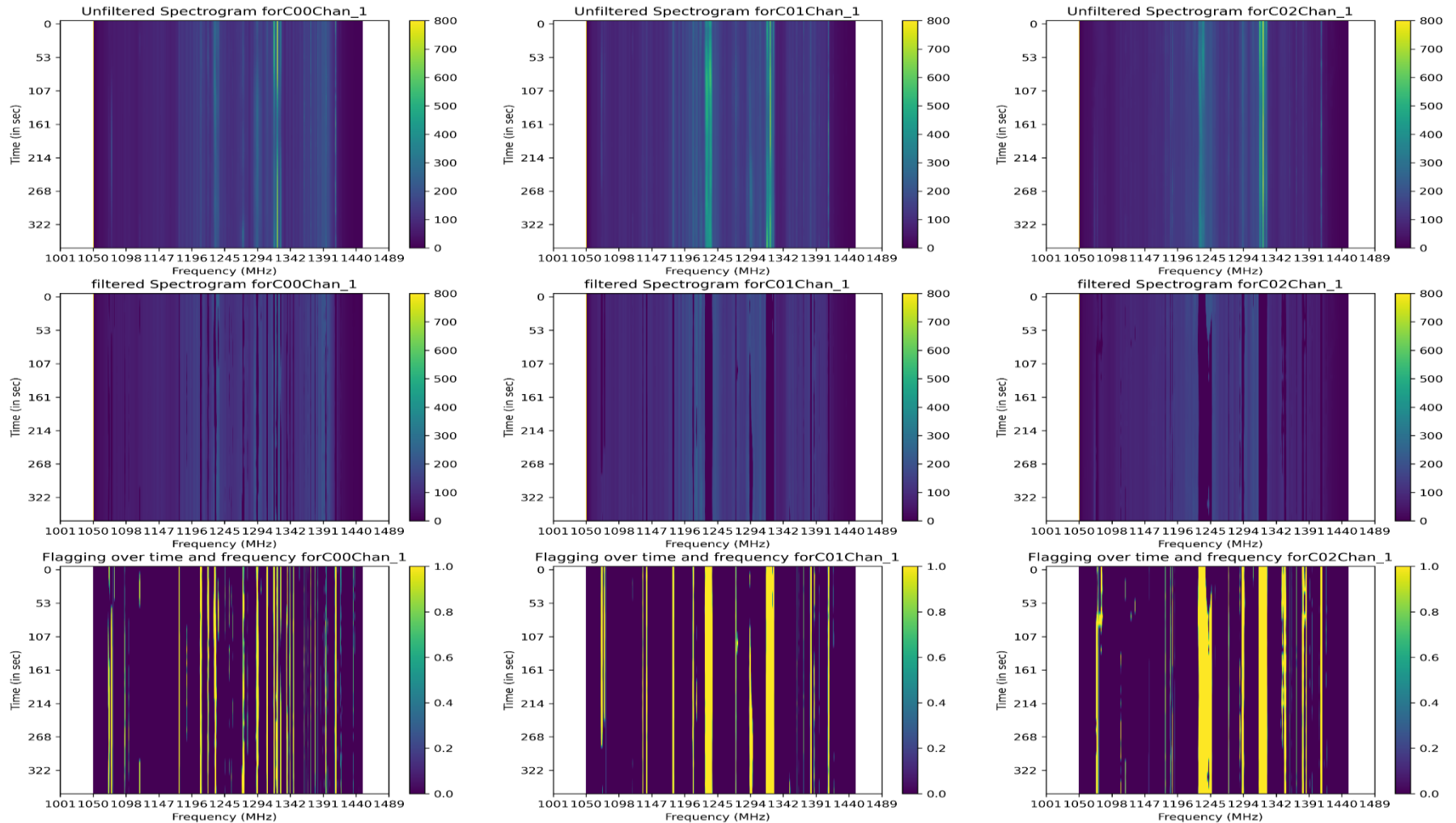
Post-integration and
Data Recording

Works for
continuous RFI



uGMRT Band-5 spectrum

Results from offline filtering on correlator output



Real-time implementation on correlator/beamformer output is underway