NC STATE UNIVERSITY

IMPRESS
INFORMATION PROCESSING AND SENSING

Cross-SDR Assessment for Spectrum Sensing

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Motivation

Spectrum sensing and detection

Reliable, cost-effective sensing supports wireless communication and other applications.

- Dynamic spectrum access
- Passive UAV detection

RF data for intelligent systems

Demand for RF training data continues to grow.

- Modulation recognition
- Cognitive radio
- Enhanced radar

Problem formulation

Five commercial software-defined radios

Different datasheet specifications require different parameter profiles.

Comparison within each profile

Live-band detections, scan time, and false-detections

Profiles vary sampling rate and frequency band. Receiver front-end configurations remain fixed.

Hardware: small-scale SDRs

Maximum stable sampling rate: 2.4 MS/s

Nooelec NESDR SMArt XTR

Tuning range to 55-2300 MHz

RTL-SDR Blog V3

Tuning range to 0.5-1766 MHz

Hardware: wideband SDRs

Tuning range up to 6 GHz

GSG HackRF One

Max. 20 MS/s

Ettus USRP B205mini

Max. 61.44 MS/s

Nuand bladeRF 2.0 Micro xA9

Max. 61.44 MS/s

Profile selection

RTL-SDR V3 and SMArt XTR	Limited frequency range and maximum sampling rate
HackRF One and bladeRF xA9	Lower sampling rates pose challenges due to analog-to-digital converter and bandpass filter limitations.
B205mini	Shared reference for the other four SDRs, with low and high sampling rates and a wide frequency range

Measurement profiles

Center-frequency range	Sampling rate	Subband bandwidth	Participating SDRs
902—928 MHz	2.4 MS/s	2 MHz	B205mini RTL-SDR V3 SMArt XTR
902—928 MHz	10 MS/s	5 MHz	B205mini HackRF One bladeRF xA9
2402—2480 MHz	10 MS/s	5 MHz	B205mini HackRF One bladeRF xA9

Sensing & detection framework

Wideband sensing through sequential scanning of subbands

Processing chain

Windowing, FFT, frequency response normalization,
energy detection, and subband stitching

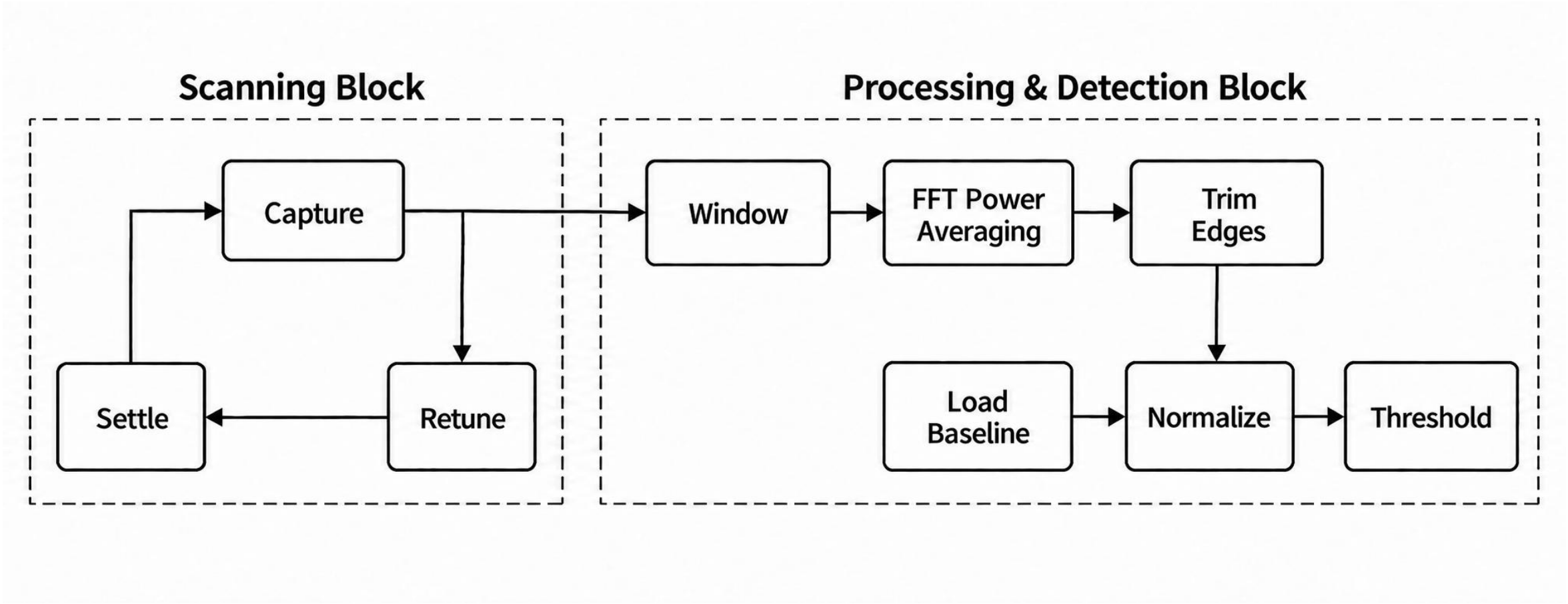
Detector settings

N = 1024 Pf = 10^{-5}

Settling after retune

0–30 ms between the five receivers

Scanning & processing workflow



Detection performance

Live-band observations

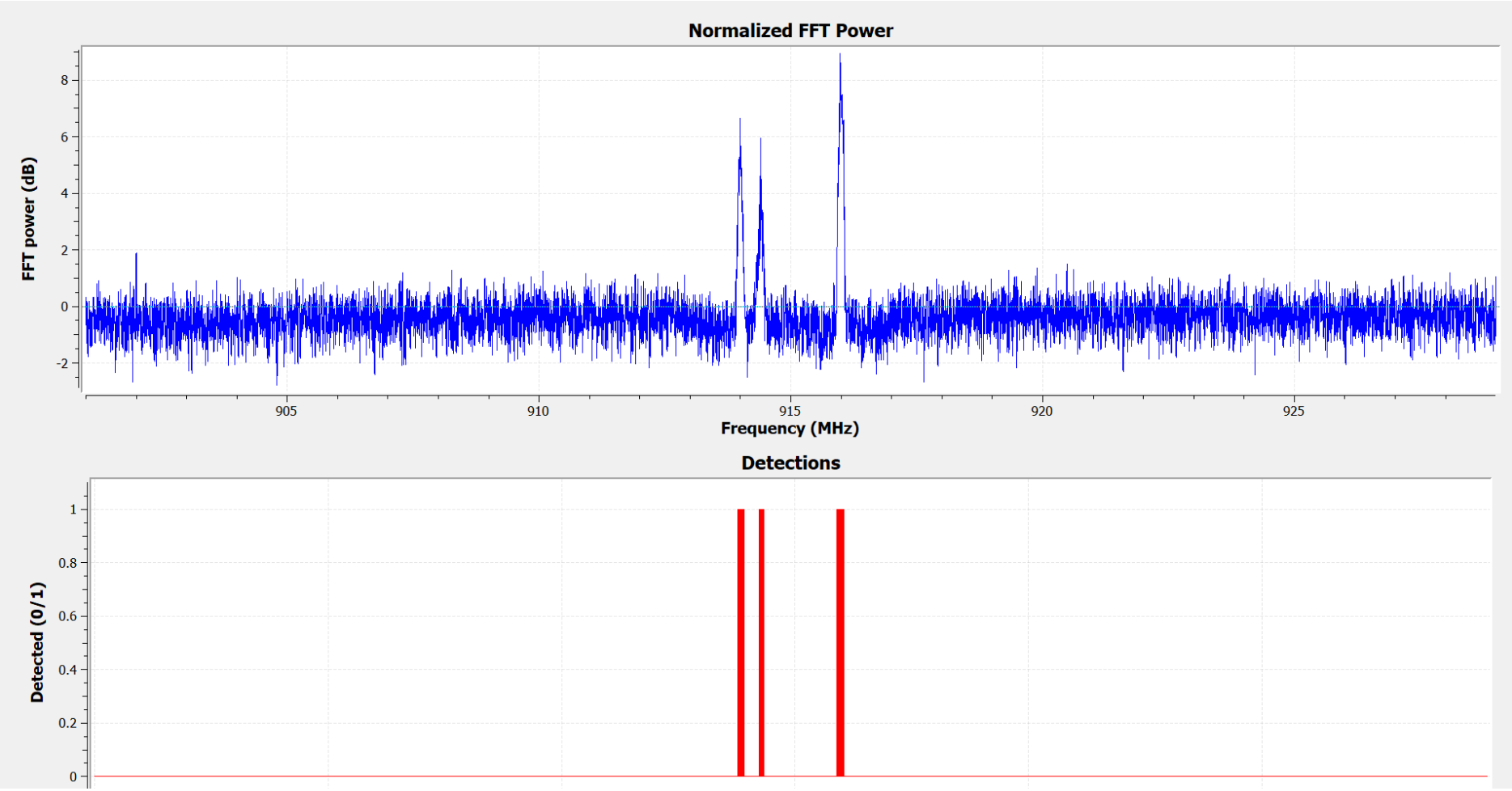
Across the trials, all SDRs detect nearly 100% of signals that can be visually distinguished from the noise floor.

Evaluation limits

No overall detection rule is yet implemented.
Detection probability is not numerically evaluated.

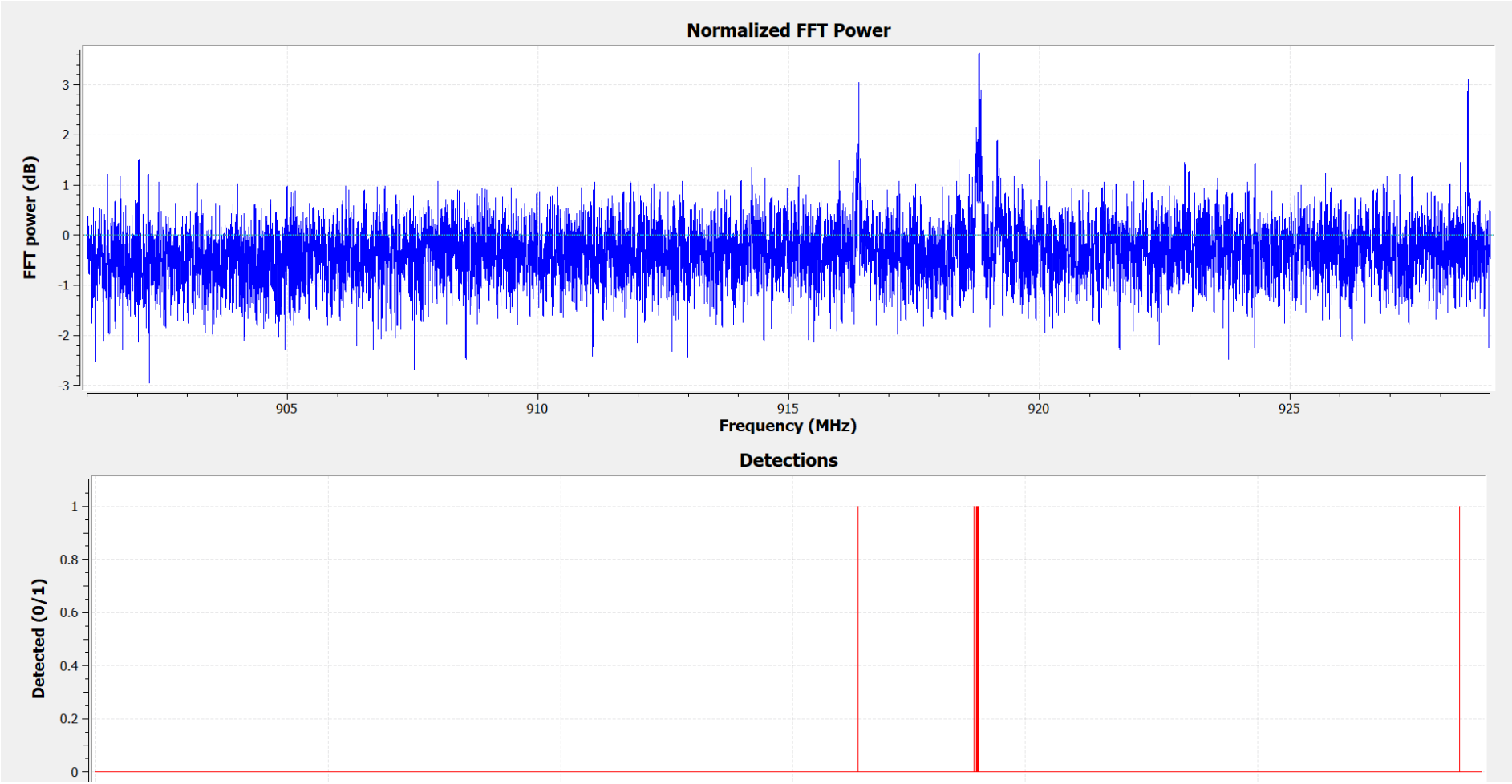
Detection in the 915 MHz ISM band

RTL-SDR V3 at 2.4 MS/s



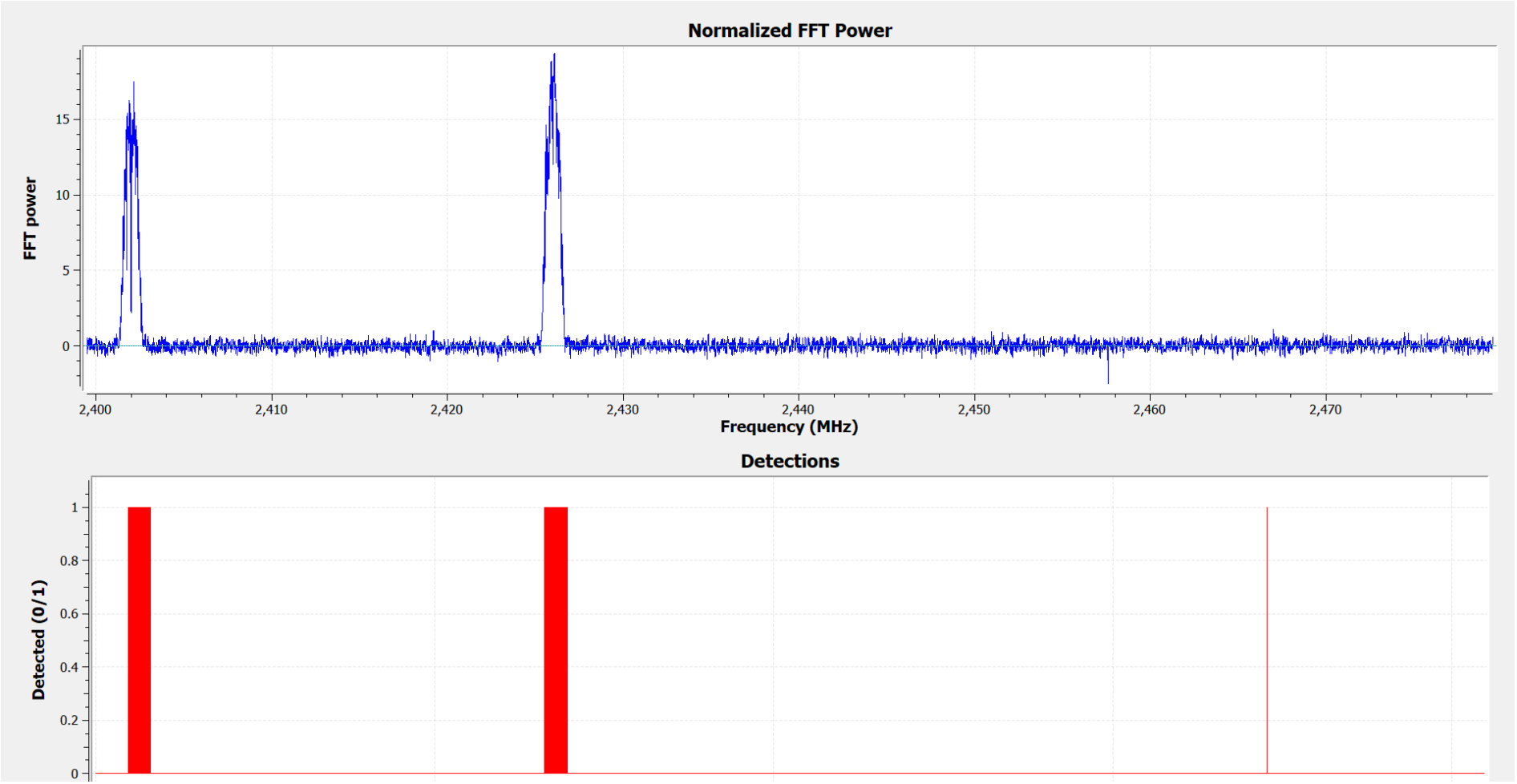
Detection near the noise floor

Robust to low-power spurs just 3 dB above baseline



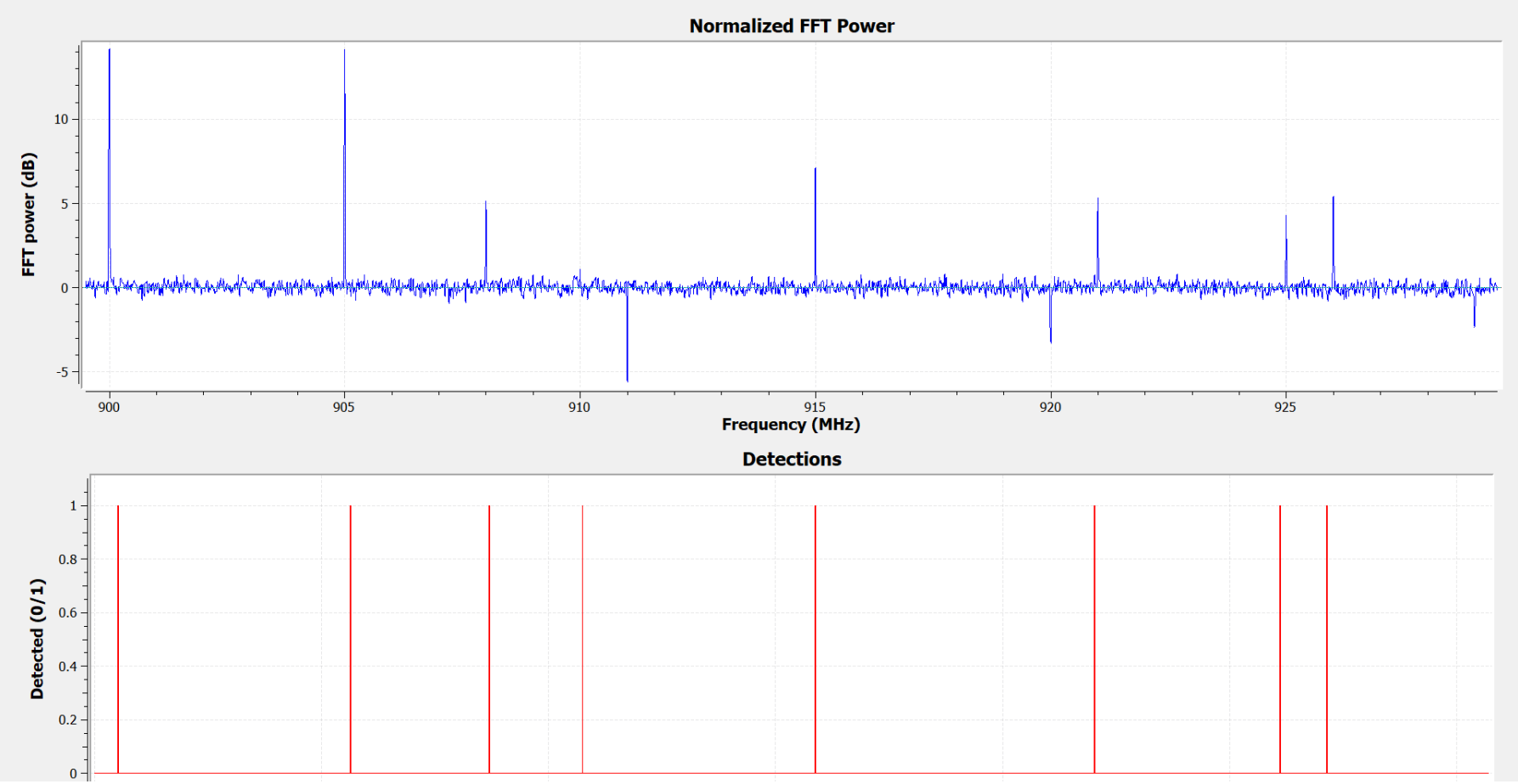
Detection in the 2.4 GHz Bluetooth band

bladeRF xA9 at 10 MS/s



Receiver artifacts

HackRF One and SMArt XTR show stochastic artifacts. A few frequencies consistently trigger false detections, attributed to the local oscillator and other device harmonics.



Timing analysis

Receiver	Frequency range	Sampling rate	Total time (s)	Scan time (ms)	Detection time (ms)
RTL-SDR V3	902—928 MHz	2.4 MS/s	0.707	45.3	8.3
SMArt XTR	902—928 MHz	2.4 MS/s	1.091	72.7	8.2
B205mini	902—928 MHz	2.4 MS/s	1.038	73.5	11.9
HackRF One	902—928 MHz	10 MS/s	0.480	77.5	16.3
bladeRF xA9	902—928 MHz	10 MS/s	0.522	82.7	16.9
B205mini	902—928 MHz	10 MS/s	0.931	153.9	17.1
HackRF One	2402—2480 MHz	10 MS/s	1.344	83.0	16.5
bladeRF xA9	2402—2480 MHz	10 MS/s	1.570	96.5	17.2
B205mini	2402—2480 MHz	10 MS/s	2.223	138.4	18.3

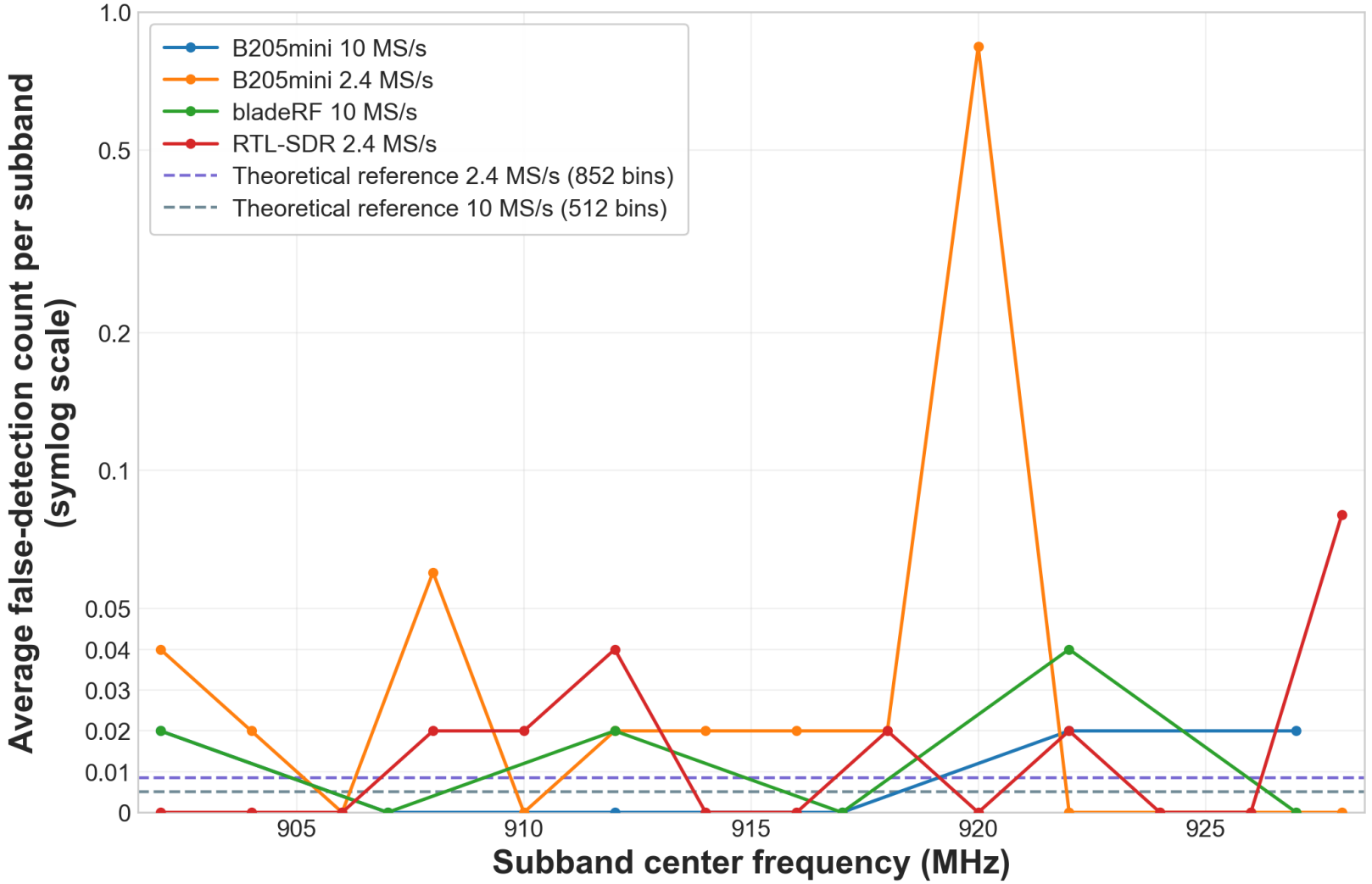
False detections

Mean number of false detections per subband at 30 ms and 10 ms dwell times

Receiver	Sampling rate	Expected false detections	False detections 30 ms	False detections 10 ms
RTL-SDR V3	2.4 MS/s	0.00852	0.0143	0.0143
SMArt XTR	2.4 MS/s	0.00852	6.7586	2.3329
B205mini	2.4 MS/s	0.00852	0.0743	0.0143
B205mini	10 MS/s	0.00512	0.0100	0.0100
HackRF One	10 MS/s	0.00512	1.9000	2.3100
bladeRF xA9	10 MS/s	0.00512	0.0133	0.0233

The 2.4 GHz band was excluded because high-power signals leaked through the terminating cap.

False detections by subband



Additional observations

RTL-SDR V3	Only receiver accurate with a 0 ms settling interval
HackRF One	Additional settling time observed only for the first subband after startup
NESDR SMArt XTR	Far less stable for detection, with many spurious tones and harmonics, despite sharing the RTL2832U demodulator with RTL-SDR V3
bladeRF	Relatively weak passband filtering prompted aggressive oversampling: 10 MS/s for 5 MHz windows

Concluding remarks

All five SDRs support simultaneous sensing and detection at resolutions as low as 10 ms with the tested sampling configurations.

B205mini, RTL-SDR, and bladeRF	Consistent baselines and clean scans
HackRF	Fastest scans of its bands, but robust detection requires correction for device artifacts
SMArt XTR	Greater instability from a highly stochastic receiver response

Further work

A robust overall detection rule for each subband

01 Group adjacent detected bins into one signal

02 Separate narrowband tones from random false detections

03 Recognize low-SNR signals with sparsely detected bins