A New RFI Filtering Technique for Weather Radar

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Motivation

The commercial sector has an insatiable appetite for RF spectrum…

that government wants to satisfy.

Obama Wants to Free up 500 MHz of Spectrum

June 28, 2010 - Today, President Obama signed a Presidential Memorandum to commit the Federal government to a sustained effort to make available 500 MHz of Federal and commercial spectrum over the next 10 years to foster investment, economic growth, and help create hundreds of thousands of jobs by meeting the burgeoning demand for mobile and fixed broadband, other high-value uses and benefits for other industries.

But the resource squeeze has led to problems for weather radars…

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

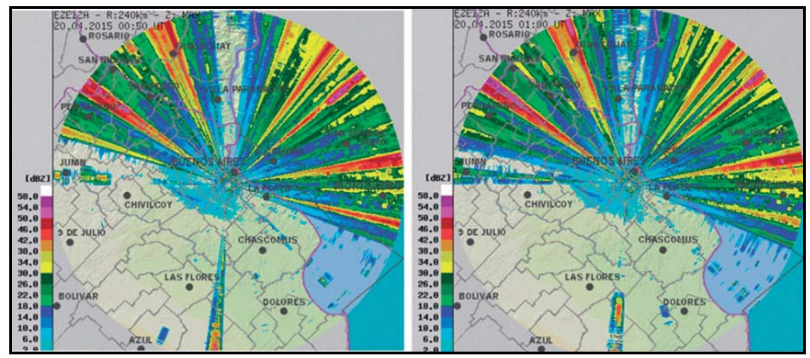
News: Climate, Technology

Wi-Fi threatens weather forecasts

Wireless technologies increasingly interfere with storm-monitoring radar, meteorologists warn

By Thomas Sumner 8:00am, October 26, 2015

especially in "shared spectrum" C band.

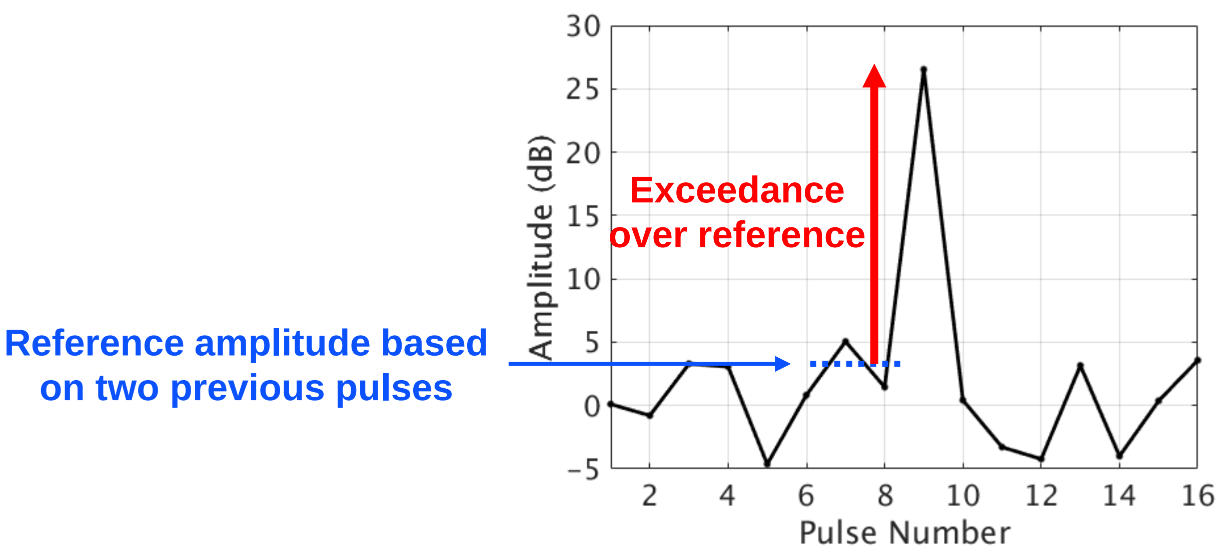


Improved interference filtering for weather radars is desired

RF = radio frequency

RF Interference (RFI) Detection

- **Before RFI can be filtered, it must be detected**
- **Detection based on time series amplitude statistics**
  - **Weather and receiver noise amplitudes are Rayleigh distributed**
  - **RFI pulses detected as threshold exceedance over reference level**
  - **Reference amplitude level typically based on a few previous pulses**



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- **Detection based on time series amplitude statistics**
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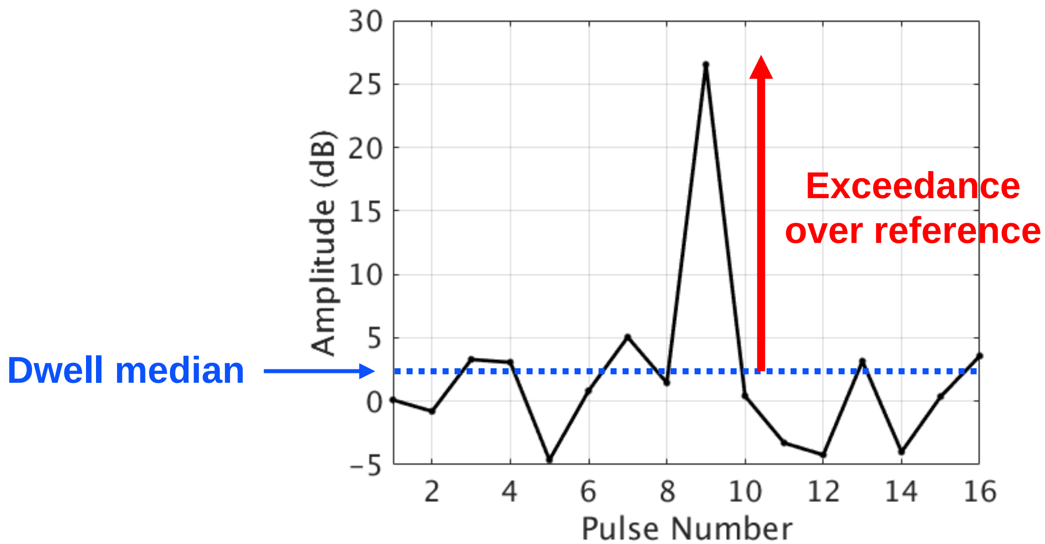
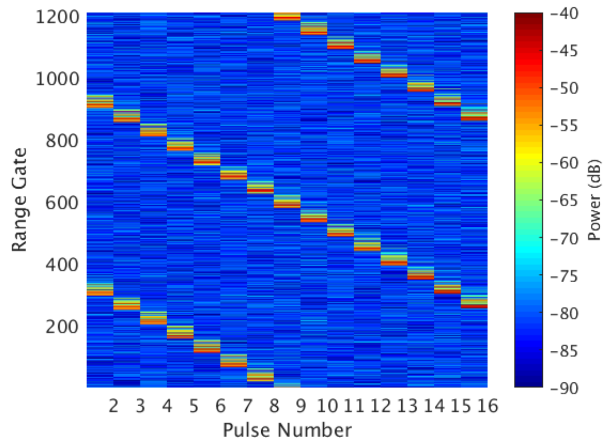
  - **RFI pulses detected as threshold exceedance over reference level**
  - **Reference amplitude level typically based on a few previous pulses or median of dwell**

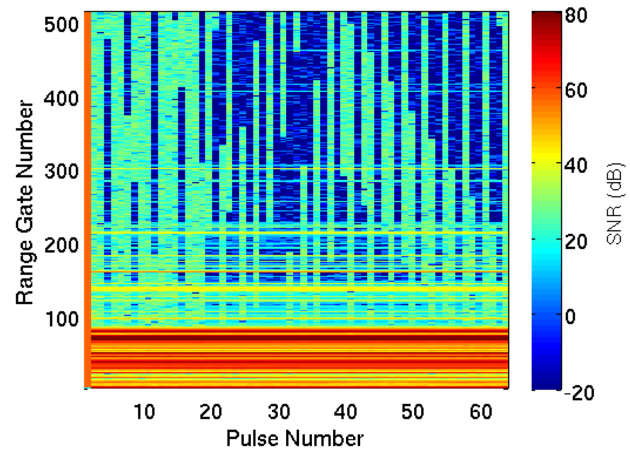


Emerging RFI Threats

RFI from a Traditional Radar



RFI from a Wi-Fi Device

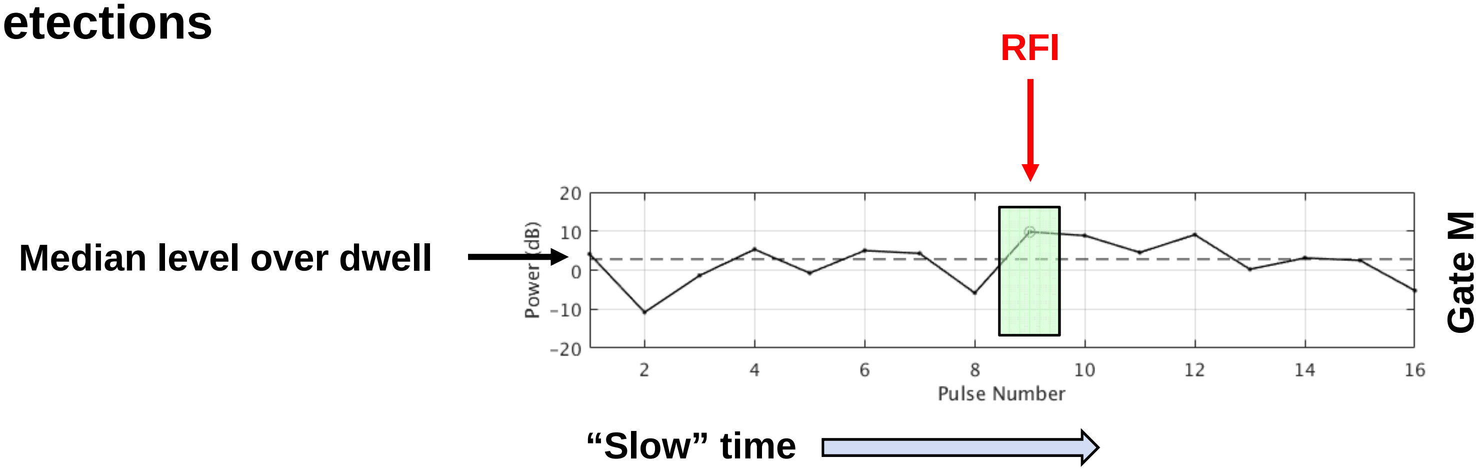


- **Traditional radars with tube-based amplifiers transmit short, high-power pulses with low duty cycles (< 1%)**
  - **Existing RFI detectors work reasonably well**
- **Newer radars with solid-state transmitters emit longer, lower-power pulses with higher duty cycles (~10%)**
- **Communication devices transmit at even higher duty cycles and lower power**

Alternative detection method needed for developing RFI environment

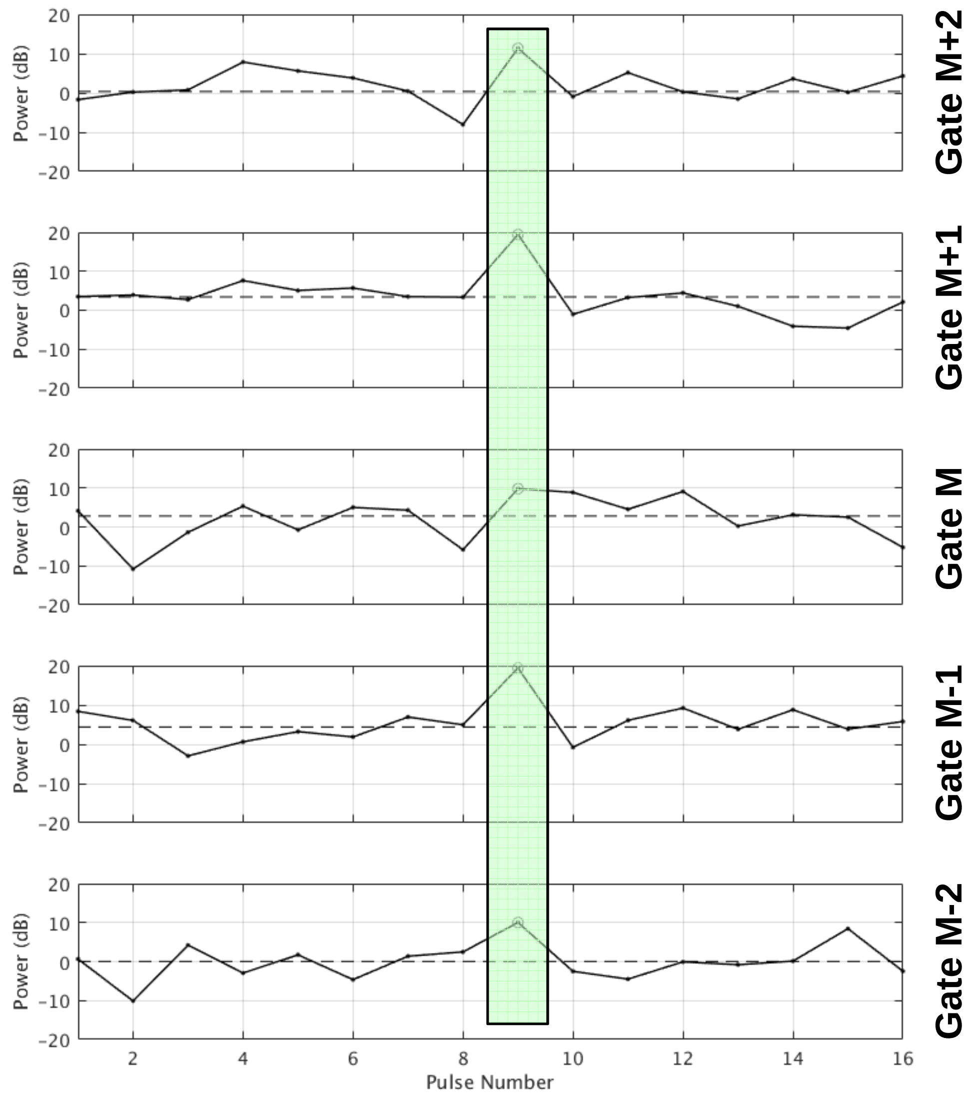
Utilizing the “Fast” Time Dimension

- **False alarm rate is too high if RFI detection threshold set too low**
  - **High thresholds result in missed detections**



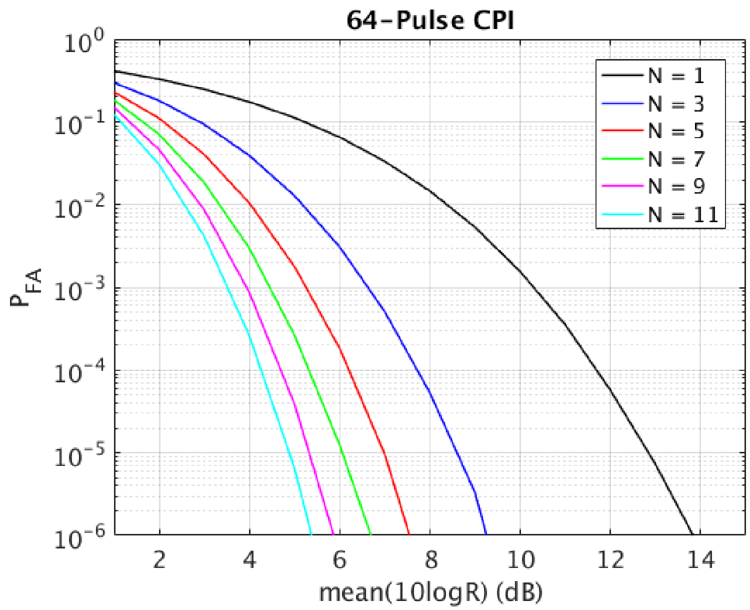
Utilizing the "Fast" Time Dimension

- **False alarm rate is too high if RFI detection threshold set too low**
  - **High thresholds result in missed detections**
- **Expand detection window into neighboring range gates ("fast" time dimension)**
  - **Detection threshold can be reduced while maintaining low false alarm rate**
  - **Use average threshold exceedance ratios over the window for robustness against noise-like RFI**



"2D" operation can improve detection/false alarm performance

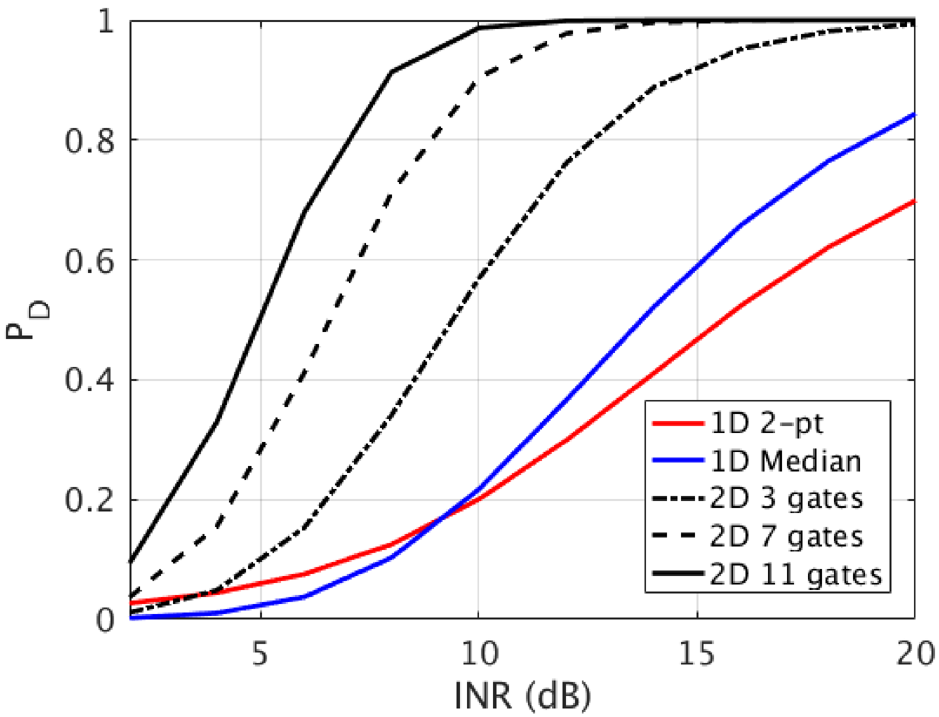
Detector Threshold vs. False Alarm Rate



- **Increasing the number of range gates in window reduces the detection threshold at constant false alarm rates**
  - **N = 1 corresponds to traditional 1D detector (median over dwell as reference)**
- **Theoretical results are for stationary beam (phased array radars)**
  - **Mechanically rotated antenna changes weather signal amplitude statistics during dwell**

CPI = coherent processing interval
P_{FA} = probability of false alarm
N = number of gates in window
R = power ratio of pulse to median

Simulated Detection Performance



Detector	Power Exceedance Threshold (dB)	P_{FA}
1D 2-pt reference	13.8	5×10^{-3}
1D median reference	13.8	1×10^{-6}
2D 3-gate window	9.2	1×10^{-6}
2D 7-gate window	6.6	1×10^{-6}
2D 11-gate window	5.3	1×10^{-6}

- **Assumes noise-like RFI present across range gates in single pulse position**
- **64-pulse CPI**
- **Monte Carlo simulation with 10^6 iterations**

2D algorithm yields detection of weaker RFI while maintaining constant low false alarm rate

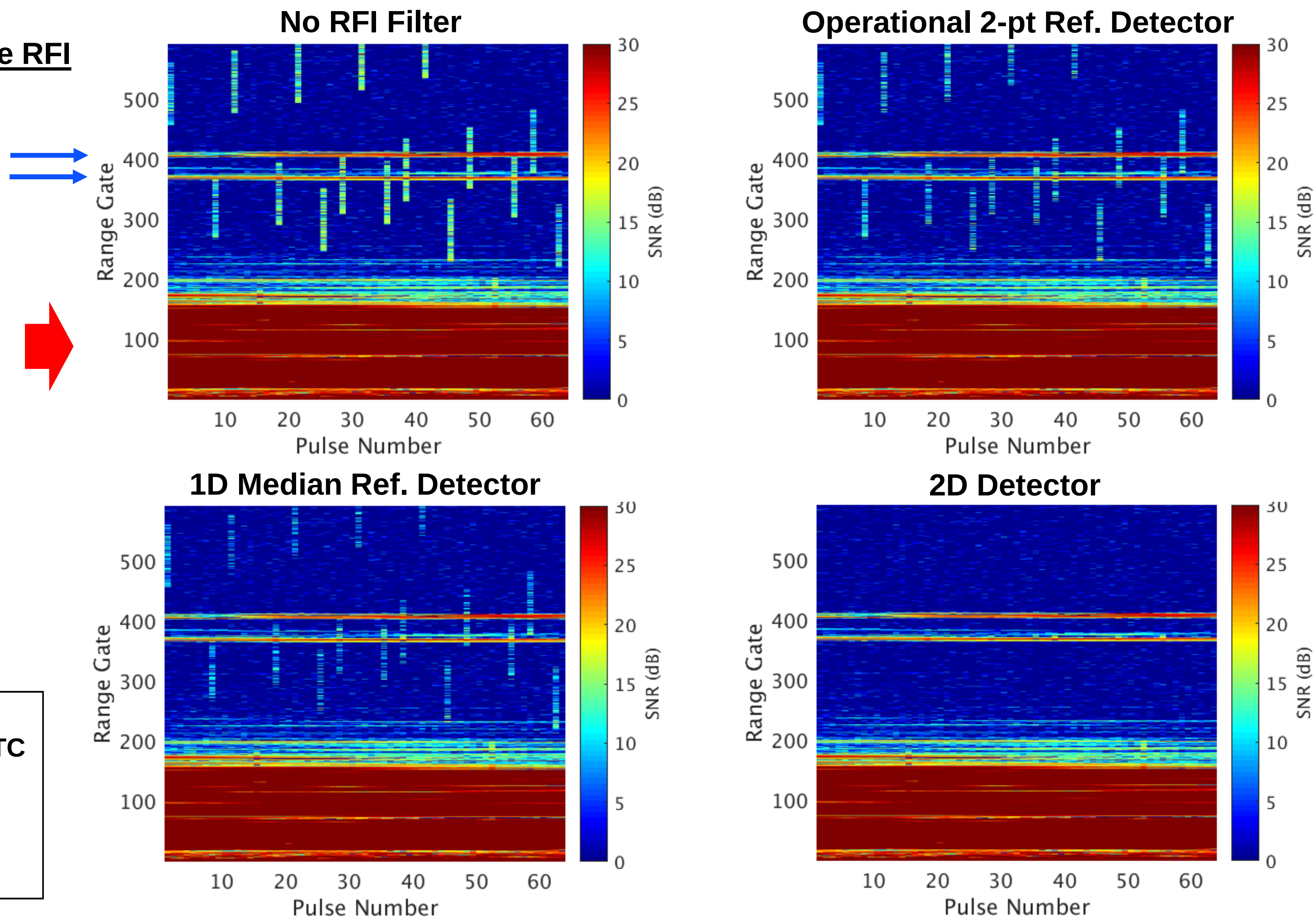
P_D = probability of detection　　**INR = interference-to-noise ratio**

RFI Filter Results: TDWR

U-NII Device RFI

Weather

Clutter +
Weather

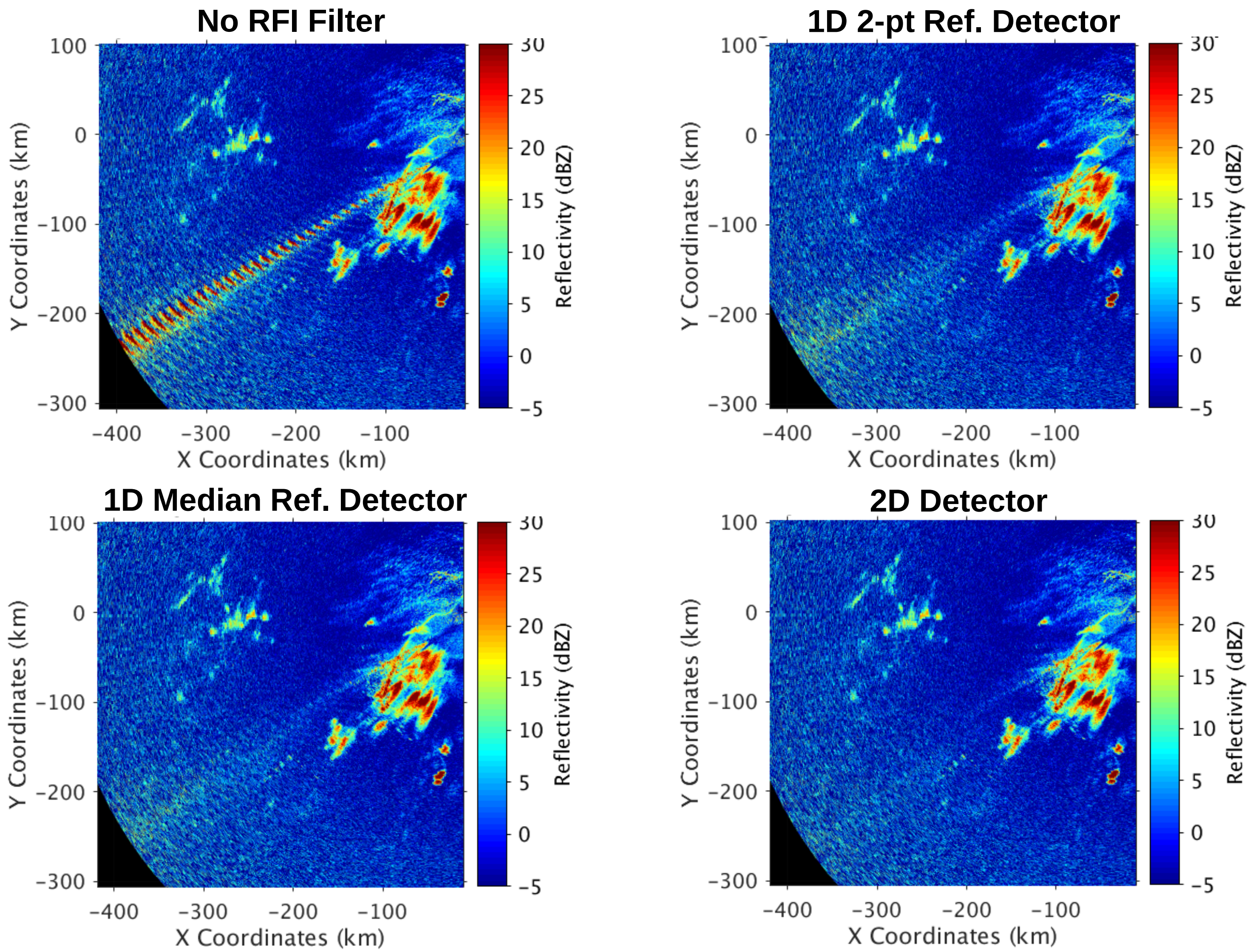


San Juan, PR
2015-4-5 4:24 UTC
151° azimuth
0.3° elevation
PRF = 1672 Hz
CPI = 88 pulses

U-NII = unlicensed national information infrastructure
PRF = pulse repetition frequency

RFI Filter Results (PPI): NEXRAD

<u>Short-pulse radar RFI</u>



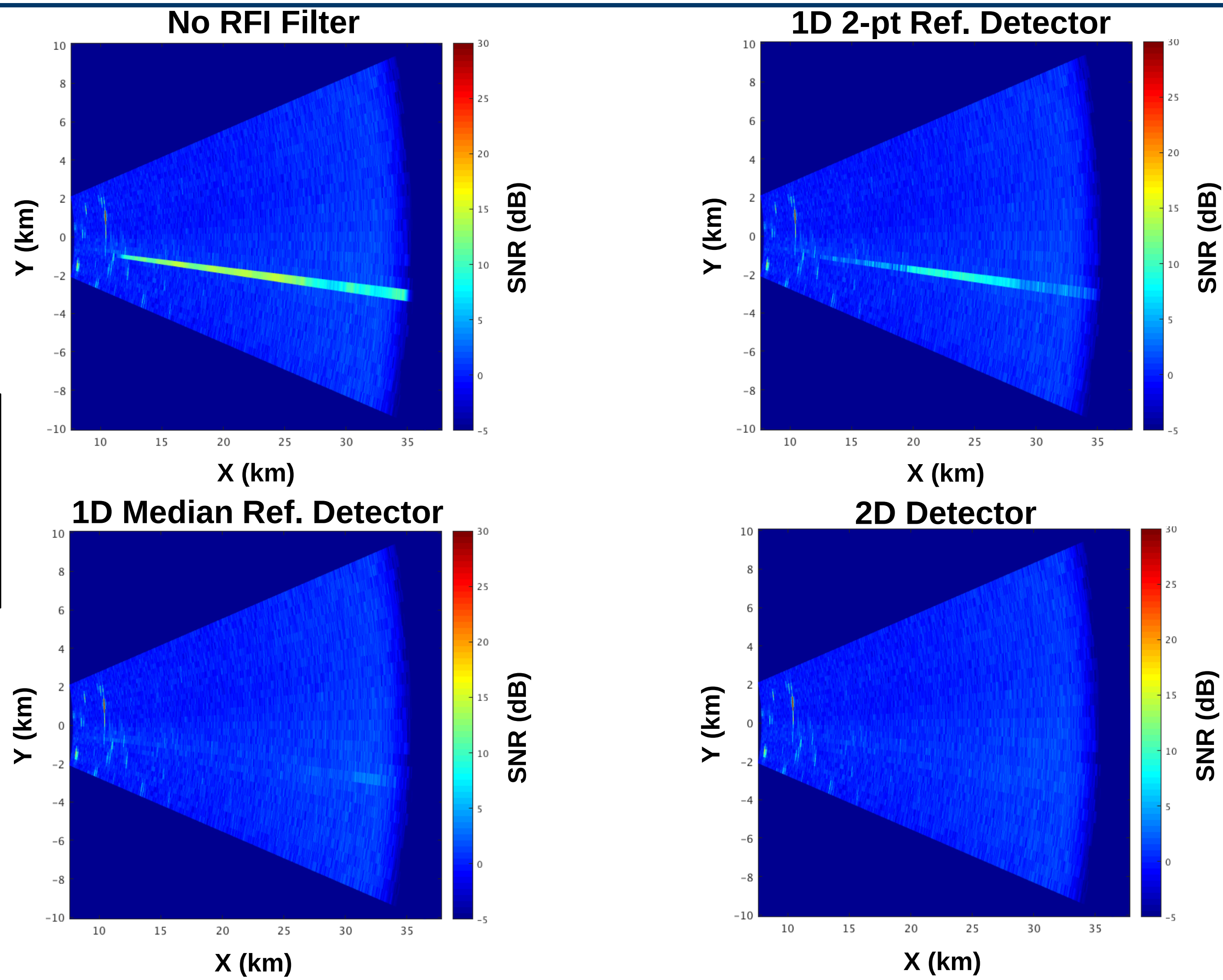
Morehead City, NC
2011-6-25 18:45 UTC
VCP 21
0.5° elevation
PRF = 318 Hz
CPI = 28 pulses

Operational NEXRAD does not have RFI filter

PPI = plan position indicator
VCP = volume coverage pattern

RFI Filter Results (PPI): Phased Array Radar

Unknown RFI



MPAR TPD
Norman, OK
2015-5-21 17:12 UTC
PRF = 500 Hz
CPI = 32 pulses

MPAR TPD = Multifunction Phased Array Radar 10-panel demonstrator

Discussion

- **Increased computational burden is only drawback to 2D RFI detection and filtering**
  - **Window lengths and number of windows (in “fast” time dimension) and reference level estimation span (in “slow” time dimension) can be varied to trade performance vs. speed**
- **In general, amplitude anomaly detection and filtering only works for RFI duty cycles < 50%**
  - **Could be complemented by spectral polarimetric detection and filtering (Rojas et al. 2012) for dual-polarization radars**

Summary

- **RFI is an increasing problem for weather radars**
  - **Opening 5.60-5.65 GHz to shared use with U-NII devices in 2003 has been especially problematic**
- **New 2D RFI detection and filtering algorithm performs better than traditional 1D algorithms**
  - **Extends mitigation to weaker, higher duty-cycle RFI signals characteristic of solid-state transmitter radars and U-NII devices**
- **Next step: Implementation in real-time radar processors**
  - **FY18 plans for support facility TDWR**

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