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PROTECTING PEOPLE AND ASSETS

# Mitigation of Radio Frequency Pulse Interference on Dual-Pol Weather Radar

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## Introduction

Radio frequency interference (RFI) has received growing attention across the weather radar community over the last decade. RFI can source from various radio devices (e.g. other radars, wireless internet devices, etc.) and display different interference characteristics on weather radar data. To date, there have not been well established methods to effectively mitigate all kinds of RFI signals.

In terms of waveform type, RFI can be recognized as both continuous interference and pulse interference. Continuous interference generally causes strong contamination in the whole radial path stemming from the interference source. The weaker contamination may appear in other directions, depending on the antenna sidelobe pattern. Normally, if the location of the RFI source is known, the radials of contamination can easily be identified. The pulse interference, however, is more complicated. Pulse RFI may appear in all the directions and contaminate variable range gates in every radar scan. The contamination is dynamic, sweep by sweep, and related to the pulse repetition frequency (PRF) of both the weather radar and the interference source.

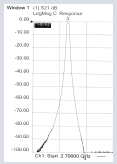
This study investigates the characteristics of pulse interference seen in dual-pol weather radar data, including interference patterns related to PRF and the dual-pol characteristics of interference signals. Based on the analysis results, a signal processing method is proposed for identifying and mitigating the pulse interference contamination in a dual-pol weather radar. Enterprise Electronics Corporation's (EEC) in-house C-Band radar, deployed in Enterprise, Alabama, is used for the experiments. The results well demonstrate the potential of proposed method for the RFI mitigation.

## Current EEC Techniques for Mitigating Interference

- **High-quality RF and IF band-pass filters: 80+ dB out-of-band rejection**

X-, C-, & S-band Tunable filters (RF)

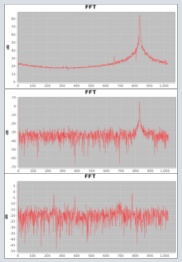
- Narrow passband
- Deep stopband
- Low loss



Out-of-band rejection testing (IF):

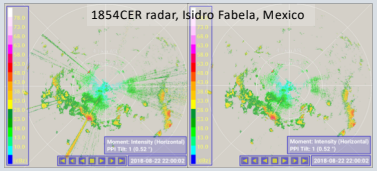
- Input -4dBm@60MHz: max > 85 dB
- Input: -84dBm@60MHz: max ≈ 5 dB
- Input: -4dBm@61MHz (out-of 0.5MHz band): max < 0 dB

The result shows the out-of-band signal rejection is 80+ dB.



- **Continuous Wave (CW) Interference Mitigation: Software Solution**

CW interference contaminates the radar data in radials. EEC has developed a signal processing module named "Strobe" to mitigate this CW interference. The module is integrated in EEC's radar software (EDGE®). It can remove the strobes caused by the CW interference. Its general concept is to identify the contaminated radials and interpolate the "bad" region with adjacent "good" radar observations.

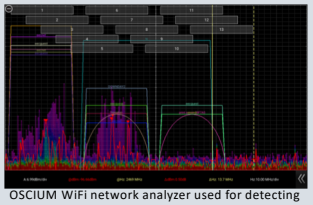



Before (left) and after (right) "Strobe" module data processing

- **Detection of Interference Source**

EEC provides professional instruments for the detection/analysis of RF interference so that customers can efficiently locate the source.

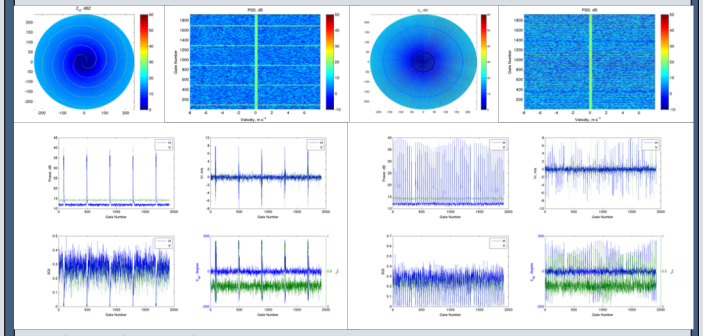
An example is shown in the figure (right). A WiFi network analyzer can easily identify the SSID, frequency/channel use, and signal amplitude for a WiFi interference. Connected to the antenna, the direction of interference source can be detected.



OSCIUM WiFi network analyzer used for detecting RF interference

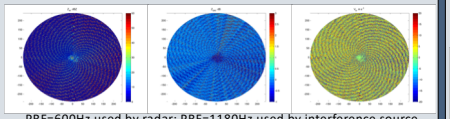
## Pulse Interference and Its Characteristics

Some interference devices might be a pulse system, such as pulse Doppler radars. Compared to the CW interference, the pulse interference has completely different effects on weather radar data. Therefore, the "Strobe" module is not capable of mitigating this type of interference. The typical features of pulse interference (e.g. on EEC's C-band in-house radar) are shown in the following figures.



Major features of pulse interference:
(1) Interference signals contaminate some range bins in each radial, showing a spiral pattern on the PPI images.
(2) Interference pattern is closely related to pulse repetition times (PRTs) of radar system and interfering source.
(3) Interference signals acts like strong noise where the whole power spectrum is contaminated.

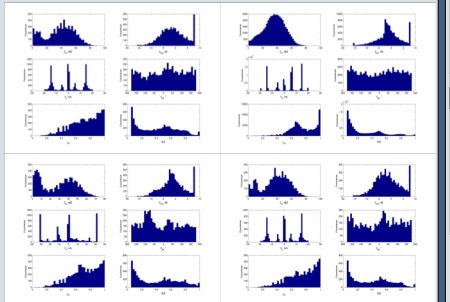
- The interference pattern is mainly determined by the ratio of two PRTs (interference vs. radar). Simple spiral pattern is common when two PRTs have a significant common factor. The pattern might be complex (see right) when two PRTs don't have a simple common factor.



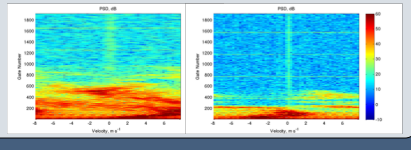
PRF=600Hz used by radar; PRF=1180Hz used by interference source

- The pulse width of interferences determines the width of spiral curves in the pattern, which is typically narrow as compared to wide coverage of weather echoes.
- Interference signals have a wide distribution of radar moments. Compared to weather echoes, the interference echoes mainly show:
  - Larger $Z_{DR}$ (positive or negative)
  - Smaller $\rho_{hv}$
  - Large variation of $\Phi_{dp}$
  - Lower SQI

  Right figures show the histograms of interference radar moments for different cases.



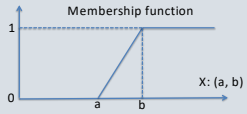
- The interference contaminates the whole power spectrum and may enlarge the spectrum width when mixed with weather signals. See figure (right) for the range-spectrum images of weather & interference.



- The texture information can be a good discriminator for interference.

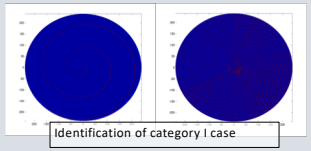
## Identification of Pulse Interference

- A fuzzy logic approach is proposed to identify the contamination of pulse interference in weather radar data. Two categories are treated differently in the signal processing. The membership functions used for these two categories are given as follows.

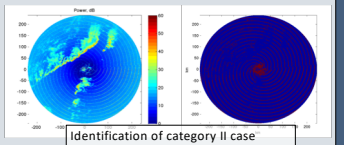



**Category I:** Clear air or weaker weather echoes (SNR≤10 dB or SNR≥10 dB & QC<0.4, where QC=SQI•$\rho_{hv}$)
- Texture of $Z_{DR}$: (1 dB, 1.5 dB)
- Texture of $\rho_{hv}$: (0.1, 0.15)
- Texture of SNR: (1.5 dB, 2 dB)

**Category II:** Stronger Weather Echoes (SNR≥10 dB & QC≥0.4)
- Texture of $Z_{DR}$: (0.6 dB, 1dB)
- Texture of $\rho_{hv}$: (0.04, 0.06)
- Texture of $\Phi_{dp}$: (20, 40)
- Texture of W: (0.5 m/s, 0.8 m/s)
- Texture of SQI: (0.2, 0.3)



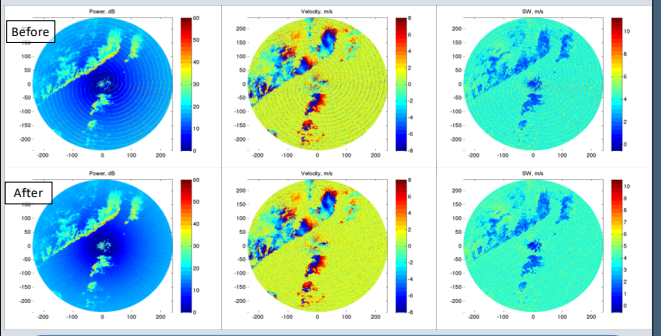
Identification of category I case



Identification of category II case

## Mitigation of Pulse Interference in Data

- A spatial filter is applied in order to replace the contaminated range bins with nearby un-contaminated bins within the influence range. The influence range might be adjusted depending on the pulse width of the interference. The default range is 2 km for this study. The results show good removal of pulse interference on moment data.




## Summary

- EEC has employed several useful techniques for mitigating the RF interference on weather radars.
- This study investigates the characteristics of pulse interference and proposes effective signal processing methods to mitigate the pulse interference on dual-pol weather radar.
- The pulse interference identification is based on a fuzzy logic approach and the interference removal is based on a spatial filter. Both functions are tested in this study and the preliminary results show the promising performance of the proposed methods.

### ACKNOWLEDGMENT

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