Radio Frequency Interferences (RFI) on Weather Radar Data Quality

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OUTLINE

- Canadian New Weather Radar Network Overview
- Ongoing challenges
- Radio Frequency Interferences (RFI) on Weather Radar Data Quality
- Mitigation Measures



"Generational" renewal

Once-in-a-generation event for the majority of people involved

Generational change of radar technology

- C-band to S-band wavelength
- Magnetron to klystron transmitter
- Conventional (Doppler) to polarimetry
- In-house integration to commercial off-the-shelf (COTS) hardware solution
- Change of industrial vendor
- New data representation (file formats)

Applications: from largely qualitative to qualitative <u>and</u> quantitative



Technology – Key Differences

	98A (Andrews)*	98E (Enterprise)	98R (Raytheon)	1700S (Selex)		
Operating Band	C-ba	nd (5.6-5.65GHz	z)	S-band (2.7-2.9GHz)		
Antenna Diameter	6.1 m	4.2 m	4.2 m	9.15 m		
Antenna Gain	49.2 dB	43.0 dB	42.9 dB	45.8 dB		
Beam Width	0.62°	1.1°	1.1°	0.88/0.86°		
Radome Diameter	9.1 m	5.5 m	5.5 m	11.8 m		
Polarization	Sir *King and	Single Pol, H-only *King and Exeter Radars are Dual Pol				
Transmitter (Tx)	Mag	Magnetron / 250k W				
Tx/Rx Location	Ground	Below Radome				
Reflectivity Range	~2	~250 km (CONVOL)				
Doppler Range (@48m/s)		240 km				
Receiver (Rx) Resolution		16 bit				
Min. Detectable Signal	-1	≤ -114dBm				
Signal Processor		GDRX				
Operating System			Linux			
Monitoring Software	BI	RAVIS				
Maintenance Interval		2 / year				



With completion of the final two radars this year...



Population Coverage: S-Band Radar	Population Count	% Total Population*
240 km (Doppler Range)	36,538,617	98.774%
330 km (Extended Range)	36,668,160	99.125%

* 2021 Census Population Count: 36,991,981

New/replacement sites – west to east

Halfmoon Peak, British Columbia Fort McMurray, Alberta Egbert, Ontario (offline, training/testing) Blainville, Québec

...more than 99% of the population will be within 330 km of a radar.

CHALLENGES

- Radio Frequency Interference
- Wind Farm Contaminations
- ZDR stability
- Hardware degradation and impacts on DQ
- Improvement to scan strategy and signal processing

Radio Frequency Interferences Contaminations



	SITE	King Radar	Franktown	Halfmoon Peak	Blainville	Cold Lake	Carvel	Aldergrove	Gore	Exeter	Marion Bridge	Strathmore	Dryden
2022	# Radials	16	16	9	5	3	7	5	7	2	2	2	2
	Intensity*	9	8	10	9	10	7	7	5	7	7	3	2
	Persistence*	10	10	10	10	10	10	10	10	10	5	5	2
2 1 or	Impact score	11.3	10.5	9.7	8.5	8.3	7.8	7.3	6.8	6.5	5.3	3.3	2.0

CARE

3

5

3.0

* Scale of 1-10 with 10 being most significant (values are subjectively assigned)



Impacts of RFI on Data Quality



RFI contamination along the path impacted by a tornado-producing supercell

Approximately when the tornado started developing; RFI contamination along the damage track

Radar covering Ottawa area

Radar covering Toronto area

Investigation of RFI Sources

- Unauthorized bandwidth
 usage
- Intermodulation at Transmitter
- Intermodulation at Receiver
- Spurious emission (out of band transmission)

A (MHz)	B (MHz)	C (MHz)	Products	Intermodulations (MHz)	
2665.00	751.00	716.00	A+2B-2C	2735.00	
2357.50	2151.25	1962.50	A+2B-2C	2735.00	
1948.75	2660.00	1870.00	A+B-C	2738.75	
1965.00	2670.00	1900.00	A+B-C	2735.00	
2660.00	1948.75	1870.00	A+B-C	2738.75	
2670.00	1965.00	1900.00	A+B-C	2735.00	
1948.75	751.00	2660.00	2A+2B-C	2739.50	

Cold Lako Alberta (2725MHz)

Mitigation Measures

Options	Pros	Cons
Hardware solutions: 1. Bandpass Filter 2. Band-reject (notch) Filter	 Immediate Signal Filtering Higher Signal Quality Simplicity Robustness 	 Limited Adaptability Frequency Specificity Cost and Complexity Insertion loss (reduced sensitivity)
Software solutions: Post processing using filters (clutter, Doppler and Dual-Pol data)	 Adaptability Wide Frequency Range Software-based Data Preservation 	 Data Integrity Complexity Processing Delay

A combination of both hardware filtering and post-processing techniques is often employed to strike a balance

Band-pass vs. Band-reject filters

Options	Pros	Cons	2700 – 2900 MHz 0 dI
Bandpas s Filter	 Pass frequencies between fL and fH Attenuate anything outside of the pass- band Protect RFI from future telecom expansion 	 Could have high insertion loss (~3dB with cable) 	2620-2690 MHz fr fn fH
Band- reject (notch) Filter	 Attenuate frequencies between fL and fH Passes anything outside of reject-band Help to determine what frequency causes RFI 	 Need to tune frequency at each site No protection from future telecom expansion 	Stopband (bandwidth = t ₂ - t ₁) 2620-2690 MHz f _L f _H

RFI INVESTIGATION WITH BAND-REJECT FILTERS AT THE KING RADAR SITE (F=2750MHZ)



a: PPI TX is OFF and EL angle is at 0.4°

- There are multiple strong RFI radials Strongest/Widest is at 66°
- b: A band reject (notch) filter was tuned to 2117 MHZ and added to the receiver chain
 - There was no improvement to RFI suppression
- c: The band reject filter was tuned to 2665MHZ and added to the receiver chain
 - · There was no improvement to RFI suppression
- d: The band reject filter was tuned to 2685MHZ and added to the receiver chain
 - · There was a significant improvement to the RFI level
 - The filter has a attenuation of 50 dB at 2685MHz
 - The attenuation at the receiver frequency (2.75 GHZ) was measured less than 0.1 dB
 - The cable/connectors attenuation were measured around 2.5 dB

RFI FILTER TESTING - BANDPASS FILTER CASFT, APRIL 2023

Without filter – Tx OFF

With filter – Tx Off

With filter – Tx ON



Customized filters and cables with low insertion loss ~ measured at 0.6dB

SENSITIVITY EVALUATION WITH BANDPASS FILTERS





Without **RFI** filters

With **RFI** Filters

DISTRIBUTION OF OBSERVED DBZ (BEFORE/DURING)



The minimum reported values increased during the test period as expected. The change appears to be larger than expected (1 to 1.5 dBZ). This is based on output data with 0.5 dBZ resolution so the perceived change may be a result of that coarse resolution.

NEXT STEPS

- One more experiment at a radar site with extreme RFI contamination
- User consultation to determine which and how many sites need mitigation measures
- Customize

Thank you Merci

