Mitigation of Wind Turbine Clutter on the WSR-88D Radars Using Spectral Processing and Non-Linear Filtering

Bob Palmer and Brad Isom

School of Meteorology / School of Electrical & Computer Engineering

http://arcc.ou.edu/
Outline

• Observed Effects of Wind Turbine Clutter (WTC) in Level-II Data

• Importance of the ORDA Revealed Through the *Doppler Spectrum*

• Preliminary Results from March, 2006 KDDC Experiment: Spotlight and VCP 21 Data
Gray County Wind Farm

- Located 25 miles SW of Dodge City, Kansas
- 170 towers
- Height of Tower: 217 feet (66m)
- Length of Blades: 77 feet (23.5m)
- RPM: 28.5
- Tip Velocity: 70.14 ms⁻¹
Level-II Radar Data Example
Dodge City, Kansas, June 17, 2006 (thunderstorms)
Outline

• Observed Effects of Wind Turbine Clutter (WTC) in Level-II Data

• Importance of the ORDA Revealed Through the Doppler Spectrum

• Preliminary Results from March, 2006 KDDC Experiment: Spotlight and VCP 21 Data
The Doppler spectrum is a power-weighted distribution of radial velocities within the resolution volume.

Examples of unique velocity distributions:
- Tornados
- Ground Clutter
- Sea Clutter
- Birds
- Wind Turbine Clutter (WTC)

Spectral Processing Possible With ORDA
Outline

• Observed Effects of Wind Turbine Clutter (WTC) in Level-II Data

• Importance of the ORDA Revealed Through the Doppler Spectrum

• Preliminary Results from March, 2006 KDDC Experiment: Spotlight and VCP 21 Data
Spotlight (stationary antenna)
- Oversampled to achieve 25 meter range gates
- Used the highest PRF: 1282 Hz (PRT = 0.78 ms)
- Selected azimuth angles to isolate turbines

VCP 21
- Approximately 16 hours of Level-I scanning
- Used for testing of mitigation algorithm under operational conditions

Range-Height Indicator (RHI)
- 10 elevation angles: 0.5-2.9°
- Shows negligible effect of WTC on sidelobes (88D only)
KDDC Spotlight
Single Isolated Turbine
Addition of Simulated Weather

Simulated time-series weather signal [Zrnic, 1969];
\( \sigma = 3 \text{ ms}^{-1} \), \( v_r \) varies with time, SNR = 20 dB
Non-Linear Filtering Methods

- Unwanted WTC signals are transient (0.1 sec)

- Wx echoes should be approximately stationary over seconds (temporal continuity)

- We will exploit this difference by using the continuity in the Wx signal

- Solution for Spotlight Data: Use a simple variation of a median filter to remove the artifacts
KDDC Spotlight: OUGMAP/Median Filter

Single Isolated Turbine

Spotlight Data

OUGMAP and Median Filtered Range=37.1045km

Time, s

Velocity, ms⁻¹
KDDC VCP 21 Scanning Data

WTC ONLY: Spatial Evolution of Doppler Spectra
Given Level-I data, it is possible combine the Wx and WTC signals.
KDDC VCP 21 Scanning Data

Wx/WTC Interaction

WTC Only

WTC and Wx
KDDC VCP 21 Scanning Data

WTC & Wx: Range/Azimuth Continuity in Doppler Spectra
• Problem: Turbine Clutter close to constant level in frequency dimension

• Possible Solution: 2-D FIR Notch Filter at DC with smoothing in range/azimuth
KDDC VCP 21 Scanning Data

Two-Dimensional Filtering: Preliminary Results

Unfiltered WTC/Wx

Filtered WTC/Wx
Summary and Future Work

- Explored advantages of Doppler spectral processing for mitigation of WTC

- Developed preliminary non-linear filtering scheme exploiting spatial/temporal continuity of weather signals

Future Development Work:
- Optimize processing scheme for exploiting three-dimensional continuity in Doppler spectra
- Possible simulation study of adverse effects of non-linear filter
- Future experiments may be needed for more difficult cases of multi-path scatter, multi-trip echoes, etc. KTFX Great Falls, Montana?
- Begin to explore challenges with real-time implementation

http://arrc.ou.edu/