Wind Turbine Impact on Radar

Overview of the Interagency Field Test and Evaluation Program

11 December 2012

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Outline

Background

• Flight Test
• Way Ahead
Wind Turbine Impacts

Turbines are growing in size and number:
- Tip speeds over 225 mph
- Blades more than 50 m long
- 30 – 40 dBsm
- Wind farms with 100s of turbines

Concern for:
- Flight Safety
- Homeland Air Security

- Decreased Sensitivity ($P_D$)
- False Targets ($P_{FA}$)
- Corrupted Track Quality

Decreased Sensitivity ($P_D$):
- False Targets ($P_{FA}$):
- Corrupted Track Quality:

Concern for:
- Flight Safety
- Homeland Air Security
Wind Turbine Are Impacting More Radars

Note: From OE/AAA filtered databases. Many of the older wind farms being filtered in database search.
Industry Proposed Mitigation Options

Reduced Signal Turbines

Replacement Radar

Radar Upgrades

Wind Farm Siting

Augmentation Radar

C2/Automation Upgrades
Radar Approaches to Improving Detection

Improve Range Resolution

Improve Doppler Resolution

Improve Altitude Resolution
Interagency Field Test & Evaluation

Evaluate wind turbine impact and industry mitigations

Steering Committee
DOE, DoD, DHS, FAA

Industry Mitigations
- Reduced RCS Turbines
- Replacement Radar
- Radar Upgrades
- Wind Farm Design
- Augmentation Radar
- C2/Automation Upgrades

Flight Tests & Analysis
- Targets of Opportunity
- Wind Turbines
- Instrumented Test Aircraft
- Radar
- ARAP
- Clutter environment (e.g., terrain, weather, birds, roads)

System Analysis

- 2-year, jointly funded program
- 3 flight campaigns
  - CARS (Tyler, MN)
  - ASR-11 (Abilene, TX)
  - ARSR-4 (King Mountain, TX)
- Invite selected mitigations
  - Selected 11 concepts to assess
- System analysis of mission impact

Interagency Field Test & Evaluation Products
- Characterize Current Impact
- Assess Proposed Mitigations
- Data for Future R&D

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Current IFT&E Scope

- Conduct 3 flight test campaigns to evaluate air surveillance
  - Existing high concentration wind farm areas
  - >100 flight hours with several different aircraft
  - 3 leading air surveillance radars (CARSR, ASR-11, and ARSR-4)
  - 11 industry-proposed mitigation systems

- Facilitate the acceptance of new COTS mitigation technologies

- Study the phenomenology to increase understanding of problem

- Develop a long-term roadmap to guide future government investment decisions in mitigation strategies

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• Field tests provide data
• Analysis provides context and meaning for the results
Outline

• Background

• Flight Test
  – Overview
  – Results

• Way Ahead
CARS R Test Area

Infill Radar (Type 1)

Infill Radars (Type 2)
2 Locations

CARS R with & without Upgrades
Field Test Overview

- **Targets of Opportunity**
  - I&Q RF data
  - Primary PLOTs
  - Tracks
  - Beacon PLOTs

- **Wind Turbines**
  - SCADA data

- **Test Aircraft**
  - GPS telemetry

- **Mitigation Systems**
  - PLOTs & Tracks

- **Radar Under Test**
  - I&Q RF data
  - Primary PLOTs
  - Tracks
  - Beacon PLOTs

- **ARAP**
## CARSR Flight Test Area & Turbines

**Red Box: Assigned Surveillance Area (22 x 22 nmi)**

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<th>Wind Turbines</th>
<th>with Telemetry</th>
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<tr>
<td><strong>Total</strong></td>
<td>2,104</td>
<td>430</td>
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<td><strong>In Line of Sight</strong></td>
<td>1,128</td>
<td>343</td>
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<td><strong>In Box</strong></td>
<td>459</td>
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CARSR
• Attach HW taps
  – At IF point, for RX and TX
  – Timing signal
  – ACP/ARP

• Record data on LAN
  – Read CD2, asterix data
  – Primary detections
  – Secondary detections
  – Merged PLOT data

• GPS for time tagging

• < 5 minute return to service

• Only tap redundant channel
  – Primary channel & all of secondary remain untouched
CARSR Fight Test Data Collection

- 9 days of testing with varied wind conditions
- 53 sorties for 138 flight hours
- 11 different aircraft

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Example Test Flight

*Cessna GA Aircraft*

![Wind Map](Image)

Data from Dry Run Apr 26—Not Included in Analysis
$P_D / P_{FA}$ Summary

- Primary Test Area
- All Aircraft Types
- CARSR Reference Frame

- Out of Wind Farm
- In Wind Farm
- CARSR (reference)
- Vendor 1
- Vendor 2

$P_D$ and $P_{FA}$ calculation method different than FAA method (see report for full description)
Broken Tracks Very Common in Wind Farms

- General Aviation aircraft
- Non-operational trackers (not fully optimized)

**Example 1**

- Successful Track
- Track Break

**Example 2**

- Track Break

Only 1 out of 3 aircraft tracked successfully over the wind farms using the baseline tracker (without mitigation)
Findings

• Wind farms significantly degrade CARSR performance
  – Significant degradation of detection over wind farms
  – Significant increase in false alarms over wind farms
  – Significant degradation of tracking over wind farms
  – Did not observe impact on transponders ("Secondary")

• Solutions are promising, but need additional work
  – High false alarm rates
  – Integration questions
  – Tracker performance
IFT&E Way Ahead (Research)

• Near-Term:
  – Complete IFT&E evaluations
  – GIS wind development planning tool
  – Integration and operational assessment of mitigations

• Mid- and Long-Term:
  – Advanced mitigations for CARSR
    • Data shows promising signal processing approaches
    • Extendable to other existing radars
  – Develop prototype next-generation radar (e.g., MPAR)
  – Airborne and maritime radars
  – Assist in planning future wind developments