X-Band Phased Array Radar: Current Radar Performance And Plans For Wake Vortex Experimentation

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Agenda

- Netted Low Power Radar (LPR) Overview
- Recent LPR Development & Assessment
- Upcoming LPR Demonstrations
- Overview of Upcoming Wake Vortex Evaluation
LPR Technical Summary

- **Novel, Low Cost, Mature, Dual-Pol X-band Radar Technology, Missions:**
  - Missions: Air Traffic Control (ATC) **AND** Weather Radar
  - Missions Being Researched:
    - Wave Vortex Detection
    - Winds Aloft Detection
    - Wake Vortex *Forecasting of Future Position*, possible with collection of dual pol weather radar data from LPR

- **Operating Frequency:** 9.0-9.2GHz or 9.3-9.5GHz

- **Output interfaces:** ASTERIX and NetCDF4 for merging with other air traffic radar data feeds

- **Size:** small size enables mounting on communication towers and rooftops, Height 46”, Width 74”, Depth 8”

- **Objective range for one LPR aperture:** > 18 nm

- **Netted LPR:** Can be implemented as single aperture or network of apertures for increased coverage

- **Mechanical:** Light-weight, air-cooled, weather-resistant enclosure

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Technology Demonstrations Completed

For export control, see cover page
LPR Building Blocks

Basic Building Blocks of LPR Shown Below
Details of RF CCA Array Face on Next Page

- X-Band RF CCA Array
  - Agile Pencil Beam
  - Dual Polarization
  - Electronically Scanned

- ETTUS Receiver
  - COTS Platform – Dual Channel
  - Digital Waveform Generator
  - Dual A/Ds
  - Configurable via software programmable waveform parameters

- I/Q Data

- Air and Weather Surveillance Superserver
  - SW largely derived from exportable ATC and Weather

- Application Specific Processing
  - Enhanced Target Tracking
  - Hydrology
  - Microburst
  - UAS
  - Target Classification

Array Face

Array Back End

ETTUS REX

Superserver

For export control, see cover page
LPR Hardware
Array Face: RF CCA

- Building Block Panel PWB consists of 128 identical unit cells
  - 18 layer board
  - Slot-fed single patch radiator

- Each unit cell contains: single SiGe flip chip, linear regulator, and associated caps / resistors

- 4 Power, 4 logic, and 1 RF connector
Netted LPR

- Netted LPR Includes
  - 4 LPRs (4 radar apertures) per Node
  - 1 Superserver / Radar Data Processor per Node
  - 1 Netted Surveillance and Weather Processor (NSWP) per Cluster
  - Interconnects: Communication Links to NSWP, Power Connections
- Network of apertures used to cover larger volumes → Currently project 9 nodes or 36 LPRs needed to cover 60 nmi range
Demonstrations Completed / OnGoing

- **LPR Performance Demonstrations**
  - 2 Demo Radars Set Up in Dallas, Texas since Oct 2013
  - LPRs track air traffic Targets of Opportunity (TOO) and local weather
    - Track Dallas Fort Worth and other local airport TOOs
    - Radars provide weather feeds to Dallas National Weather Service (NWS) via CASA network during storm season
  - Flight Trials
    - Tracked small metal and composite aircraft
    - Conducted flights to assess probability of detection, resolution

- **LPR Wind Farm Mitigation – InFill Radar**
  - Johnstown Pennsylvania Demo
    - LPR integrated with Air Surveillance Radar (ASR) to mitigate wind turbine effects in detecting 1m² targets > 1000ft above turbines
  - King Mountain Demo (Video next slide)
    - Assessment for potential InFill applications
    - Over 100 flights with aircraft of all sizes at wide range of altitudes
    - LPR tracking of aircraft over wind farms
**LPR 1m² Target Detection Performance**  
**Dallas, King Mtn, Johnstown**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Required</th>
<th>Objective 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>15nmi</td>
<td>18nmi†</td>
</tr>
<tr>
<td>Scan - Azimuth / Elevation (degs)</td>
<td>90 / 30</td>
<td>90 / 30</td>
</tr>
<tr>
<td>Range Accuracy (rms)</td>
<td>275 ft</td>
<td>109 ft</td>
</tr>
<tr>
<td>Azimuth Accuracy (rms)</td>
<td>0.16 deg</td>
<td>0.145†† deg</td>
</tr>
<tr>
<td>Height Accuracy (rms)</td>
<td>500 ft</td>
<td>231 ft</td>
</tr>
<tr>
<td>Range Resolution</td>
<td>760 ft</td>
<td>179 ft</td>
</tr>
<tr>
<td>Azimuth Resolution</td>
<td>2.6 deg</td>
<td>1.15††† deg</td>
</tr>
<tr>
<td>Detection Probability</td>
<td>0.90</td>
<td>0.91</td>
</tr>
</tbody>
</table>

†  Current value pending mitigation of RFCCA loss  
††  Projected value with agile beam active  
†††  This is the best case value based on limited data sample

*Track over wind farm*

*Azimuth Resolution Evaluation*
Agile Scanning: CASA Radar Network Example

- Each radar node does a low-elevation surveillance scan to determine where the weather is.

- Figure out where the weather is and focus the majority of the scanning effort on the volumes that contain weather.

- Each radar does a sectorized raster scan with width and pointing angle determined by optimization.

- LPR scanning strategies will meet the combined update rate requirements for both aircraft and weather detection and tracking.
RHI Weather Products for June 17, 2013 Event

Possible Updraft

Power Velocity

Single Pol LPR (X Band) Data Identifies Possible Updraft

For export control, see cover page
15:00 CST

NOAA NEXRAD data

LPR Compared to Nexrad Weather Level II Products
NSWP Weather Data Processing

- Level III Merged Products
  - Merged reflectivity
  - Vector winds
  - CASA/AWIPS II compatible NetCDF product files
    - Gridded (lat, lon, msl alt) coordinates
  - In an objective system, combines the outputs of the 50+ panels into a single product file

CASA WDSS-II Merged composite reflectivity

CASA Dual-Doppler Wind Vectors overlaid on Reflectivity
Further LPR Planned Demonstrations

- **Wake Vortex and Winds Aloft Evaluation, Oct ‘14**
  - LPR to be deployed in mobile configuration near airport sites in New England
  - Assess LPR performance in various weather conditions: fog, light rain, medium rain, varying winds
  - Determine recommended system configuration for WV detection, to be available end of 2014
  - Description of evaluation approach included on following pages

- **Precision Approach Radar (PAR) Assessment, May ‘14**
  - Assessment to be conducted in Johnstown, PA

- **Netted LPR integration and evaluation to be conducted in 2015**
LPR Wake Vortex Assessment - Sample Arrangement

- **Scenario 1**
  - Radar is ~1 km from aircraft approach
  - Radar is ~ 1 nmi from end of runway

- Radar Boresite is Tangential to Path of Aircraft Landing Approach

- Radar Performs Scans in Elevation on Boresite → Scans a Plane That is Tangential to the Approach Path

Possible Site Arrangement for WV Assessment on Boston Logan International Runway 33L
Geometry of Radar Scan Plane
Wrt Aircraft Approach, Wake Vortex

Radar Boresite Tangential to Approach Centerline

Aircraft $\frac{1}{4}^\circ$ Above Glideslope On Runway Centerline

For export control, see cover page
# Radar Parameters for Wake Vortex Evaluation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td>9.6 GHz</td>
</tr>
<tr>
<td><strong>Peak Power</strong></td>
<td>125W</td>
</tr>
<tr>
<td><strong>Polarization</strong></td>
<td>H/V alternating or per dwell</td>
</tr>
<tr>
<td><strong>Beamwidth</strong></td>
<td>1.85° Az</td>
</tr>
<tr>
<td></td>
<td>2.14° El</td>
</tr>
<tr>
<td><strong>Scan Coverage</strong></td>
<td>±45° Az (max)</td>
</tr>
<tr>
<td></td>
<td>0° to +30° El (max)</td>
</tr>
<tr>
<td><strong>Update Rate</strong></td>
<td></td>
</tr>
<tr>
<td>Search</td>
<td>4.8 seconds (max)</td>
</tr>
<tr>
<td><strong>Range Height Indicator (RHI)</strong></td>
<td>2.5 seconds (max)</td>
</tr>
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Summary

- Demonstrated Low Power Radar Technology
  - Dual pol, light weight, low cost
  - Provides high resolution air traffic and weather surveillance
  - Improved low level coverage
  - Adaptable scanning and waveform protocols

- Networked LPRs
  - To be demonstrated in 2015
  - Improved scanning protocols
  - Improved sensitivity, reliability
  - Configurable / adaptable to wide variations of requirements

- LPR Wake Vortex Assessment to be Performed in Fall ’14
  - Assessment to be performed in New England viewing vortex from heavy aircraft
  - Results and assessment to be available end of ‘14