Low Power X-Band Phased Radar
A High Resolution UAV and Weather Detection System

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FPAW/NBAA
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X-Band Phased Array Radars

### Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>9.0-9.6 GHz</td>
</tr>
<tr>
<td>Peak Power</td>
<td>125.4W</td>
</tr>
<tr>
<td>Average Power</td>
<td>23W</td>
</tr>
<tr>
<td>PRFs</td>
<td>3317Hz avg (Programmable)</td>
</tr>
<tr>
<td>Pulse Widths</td>
<td>6us (NLFM), 55us (LFM)</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>2.5/2MHz, 6MHz total</td>
</tr>
<tr>
<td>Horizontal Polarization BW</td>
<td>2.12° El; 1.85° Az</td>
</tr>
<tr>
<td>Vertical Polarization BW</td>
<td>2.14° El; 1.88° Az</td>
</tr>
<tr>
<td>Side Lobe Level</td>
<td>&lt;25dB typ</td>
</tr>
<tr>
<td>Antenna Gain</td>
<td>~37dB</td>
</tr>
<tr>
<td>Cross Polarization</td>
<td>~35dB Boresight</td>
</tr>
<tr>
<td>Instrumented Range</td>
<td>0.5 to 16+ nmi</td>
</tr>
<tr>
<td>Op. Angular Coverage</td>
<td>+/-45° Az by +/-15° El</td>
</tr>
<tr>
<td>Surveillance Update Rate</td>
<td>4.8sec</td>
</tr>
</tbody>
</table>

### Multi-Function X-band AESA Radar:
- Phase-phase array provides electronic control – no pedestal motors
- Horizontal search scanning provides surveillance across entire FoV
- Agile tracking beam focuses on detected targets
- Scheduler interleaves surveillance scanning with agile tracking
- Fast update rate and operating frequency provides high resolution
- Low SWaP allows for simple installation, standard network and power
- Low Cost provides versatility in designing coverage areas

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LPR Weather Data Processing

**Level II Moments**
- **Single-Pol**
  - Reflectivity (Z)
  - Velocity (V)
  - Spectral Width (W)
  - Signal-to-Noise Ratio (SNR)
- **Ground Clutter Filter**
  - Single-Delay line clutter canceller for volume surveillance scan data
  - Gaussian model spectral filter for the weather deep probe scan data

**Level II Polarimetric Variables**
- **Dual-Pol**
  - Differential Reflectivity (Zdr)
  - Correlation Coefficient (RhoHV)
  - Differential Phase (PhiDP)
- **Attenuation Correction**
  - Specific Differential Phase (Kdp) estimation
  - Kdp based attenuation correction of reflectivity and differential reflectivity
- **CASA/AWIPS II compatible NetCDF product files from each panel/node**
  - Radial (az, el, range) coordinates
Agile Beam Technology
Supports Surveillance and Weather

- Full azimuth coverage for both Surveillance and Weather
  - Single polarization weather collected during surveillance
    - 14.4s Surveillance revisit rate
    - Rescan of the full surveillance azimuth repeated
  - Weather deep probe interleaved after weather discovery in surveillance scan

- Track updates for 23 targets (objective 1sec)
  - Scheduler also supports 2s, 3s and 4s Track update for 45, 68 and 90 targets
  - Detection confirmation from surveillance reduces false alarms

System has an adaptable, software programmable multi function scheduler enabled by near instantaneous beam steering
Reflectivity Data Comparison (9/12/2014 Weather Event)

Radars location: LPR in Garland (XGAR) and WSR-88DP in Forth Worth (KFWS)
Grid Spacing of 100 m by 100 m
Weather event compared: September 9, 2014
Weather Demo (Sudbury) 3D Data – AWIPS
Overlapping, Netted Radars and Processing
Key System Benefits - Realized from CASA NWSP Prototype

- **Level II Data and III Products**
  - Alerting and model input data and products
  - Low level (<1000 ft) monitoring and 3-D windfields
  - CASA/AWIPS II compatible NetCDF product files
  - Objective system combines 50+ outputs into a single product files
  - High resolution and Probability of Detection airspace surveillance (cooperative/non-cooperative targets, weather, birds, windfarms, etc.)

- **“Nowcasting” 0-6 hour microscale high resolution weather model input**
  - Turbulence, Icing, precipitation, clouds, etc.
  - Massive data processing may be required
  - Decision support tool inputs
  - Multiple community resource
    - Aviation and surface transportation
    - Energy and utilities
    - Agriculture and commodities
    - Water resource management
    - Financial and insurance markets

- **Raytheon Team**
  - Marlborough – Radar Development and ATC systems
  - Omaha – Meteorological systems (AWIPS, FAA, DoD)
  - Aurora and Colorado Springs – Large data processing (JPSS, NASA, Government Systems)

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Merged Overlapped Radar Track Data

Overlayed Raw Track Data from both Radars Illustrates Overlapped Pd Improvement

Merged Pd 90% ave
- Mckinney Pd 0.78 nom
- Garland Pd 0.48 nom
STARS: GBSAA Support Services to UTM

**STARS = Aircraft Above 500 ft**

- Streamlined Departures
- Vector-Free Arrivals
- All-Weather Approaches

STARS is The FAA Critical Flight Safety Certified System of Record for Terminal Area Traffic Management

**Low Altitude Weather Services**

- **STARS AVOI Services for Weather Alerts**
  - NextGen Net-enabled Weather
  - Current Wx
    - >3000 ft
    - 6 min+ refresh
    - No collaborative scanning
  - LPR operational relevant Wx
    - Ground to 500+ ft
    - <1 min refresh rates
    - Adaptive / focus scanning
  - Future Wx Dynamic Protection Zone

- Draft rules say sUAS operators must assess (BLOS) weather & winds conditions
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**Performance Based Metrics = STARS: GBSAA**

- Area Volumes of Interest (AVOI)
- Dynamic Protection Zones (DPZ)
- UAS to other UAS & manned aircraft
- Other air navigation hazards: eg TFRs, No Fly Zones....

**STARS: GBSAA = UAS Below 500 ft**

(Assumes Surveillance Data Available)

- AVOIs can be:
  - Geographic Point of Interest
  - 3-D Polygon or cylinder with a minimum and maximum altitude
  - AVOIs can be statically displayed or can move with a track.

- Air Force chose STARS: GBSAA solution specifically to integrate with FAA
- STARS: GBSAA 3D Coordinate Based AVOIs can Support Autonomy
  (a future state M2M interface)

**Low Altitude Traffic Management Services**

- Air Force chose STARS: GBSAA solution specifically to integrate with FAA
- STARS: GBSAA 3D Coordinate Based AVOIs can Support Autonomy
  (a future state M2M interface)
LPR / STARS: GBSAA Enabled Commercial CONOPS

BVLOS Transit Flight Planning / Traffic Management
- LPR enabled low altitude STARS-GBSAA
- Unlikely to be a straight line flight
- Situational awareness for:
  - Commercial flight planning
    - DPZ’s, TFRs, Restricted Air Space,
    - Air Navigation Hazards, Advisory & No Fly Zones
  - BVLOS weather / winds
  - Non-cooperative / non-compliant aircraft
    - FAA – any sUAS that enters manned airspace
    - Birds / Wildlife / Insects
  - Standard FAA interface for exceptions when needed

Traffic Management
- Ground to Transit corridor flight planning
- Full situational awareness
  - Non-cooperatives, Ground traffic
  - Onboard SAA for collision avoidance

BVLOS Package Delivery
- Last “60 ft”
- Onboard SAA for collision avoidance
- Tree and other very low obstacles

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