Why X-band radar?

Søren Ræbild Nedergaard, Terma A/S
Agenda

1. Evolution – spectrum release, small targets & X-band radar advantages
2. Windturbine interference on Primary Radar
3. How to mitigate wind farm radar interference
3. Aerodrome Traffic awareness
4. Q&A
X-band vs S-band radar

Government focus:
- Spectrum auction – contribution to economy
- Broadband to support growth

“Spectrum is hugely valuable. In economic terms it is already worth over £50bn a year to the UK economy. We are confident that we can grow that value from spectrum’s direct use significantly and the indirect impact on businesses which rely on communications will multiply the effect on economic growth. In societal terms “....

The UK Spectrum Strategy
Delivering the best value from spectrum for the UK
10 March 2014
X-band vs S-band radar

Why is this a concern to S-band radar working in 2.7-3.1 Ghz range?

**Existing bands for mobile use**

<table>
<thead>
<tr>
<th>400 MHz</th>
<th>1000 MHz</th>
<th>1500 MHz</th>
<th>2000 MHz</th>
<th>2500 MHz</th>
<th>3000 MHz</th>
<th>3500 MHz</th>
<th>4000 MHz</th>
<th>4500 MHz</th>
<th>5000 MHz</th>
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</thead>
</table>

**Future bands for mobile use?**

| 400 MHz | 1000 MHz | 1500 MHz | 2000 MHz | 2500 MHz | 3000 MHz | 3500 MHz | 4000 MHz | 4500 MHz | 5000 MHz |
Benefits of X-band radar

- Higher Spatial Resolution
- Possible Range resolution 3-6 meter
- Small targets detection
Spatial resolution

- Narrow azimuth beam width
  - 0.4° with 18’ antenna (3dB)
- Fine range pulse width
  - 7m with 40NM inst. range (3dB)

-> fine target separation
-> very small clutter volume
RCS comparison S vs. X Band


Rain clutter at S- vs. X-band

Clutter parameters:

- **Delta:**
  - **Clutter volume:** $100\,\text{m} \times 2^\circ = 200^\circ\text{m}$
  - **Rain RCS (4\,\text{mm/h}):** $8 \times 10^{-9}\,\text{m}^2/\text{m}^3$
  - **Target RCS (~freq):** 1\,\text{sqm}

**S-band (typical):**

**X-band (SC4K):**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>S-band</th>
<th>X-band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clutter volume</td>
<td>$100,\text{m} \times 2^\circ = 200^\circ\text{m}$</td>
<td>$12,\text{m} \times 0.5^\circ = 6^\circ\text{m}$ $+15\text{dB}$</td>
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<tr>
<td>Rain RCS (4,\text{mm/h})</td>
<td>$8 \times 10^{-9},\text{m}^2/\text{m}^3$</td>
<td>$5 \times 10^{-7},\text{m}^2/\text{m}^3$ $-18\text{dB}$</td>
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<tr>
<td>Target RCS (~freq)</td>
<td>1,\text{sqm}</td>
<td>2-3,\text{sqm} $+3\text{dB}$</td>
</tr>
</tbody>
</table>

**Total:** $+0\text{dB}$
Small Target

Small targets like Unmanned Air Vehicle and birds

Typical RCS < 0.15 m² – Pd 90%
S-Band vs. X-band
S-Band vs. X-band

Raytheon PSR-11
Windfarm Radar issue

- **Large de-sensitive area:**
  - up to 25km before and after a wind farm *
  - up to \( \pm 5^\circ \) to the sides of the turbine
  - Multiple reflections and shadowing can extend the blind zone behind a windfarm

- The size and density of wind farms is exploding and makes the lack of coverage a security issue.

*Windfarm characteristics and their effect on radar systems, Clive Jackson IET 2007
The Effects of wind turbine farms on ATC radar, AWC/EAD/72/665/Trials May 2005*
Radar issue

No MTI suppression on turbine blades causes unwanted track initiation and track seduction

Figure 12: Recorded tracker time history [13], note the number of turbine plots (circled) and the seduction and loss of the (green) aircraft track in the windfarm with subsequent re-initialisation afterwards

*Windfarm characteristics and their effect on radar systems,*
Clive Jackson IET 2007
The technical challenge with S-band systems

De-sensitive area:
• PSLR of typical ATC radars is only -40dB
• Chirp length is typical 150us

This will extend the de-sensitive area 22.5km before and after the wind mills where only target above 100-1000 sqm can be detected

• Antenna beam-width and side-lobe level of typical ATC radar extend the de-sensitive area in azimuth up to 5°

Figure 6: Measured normalised antenna pattern (one-way) for a modern ATC antenna.

Typical range sidelobes and antenna pattern from WINDFARM CHARACTERISTICS AND THEIR EFFECT ON RADAR SYSTEMS by C A Jackson
### The technical challenge

#### Dynamic range:
- RCS of turbine tubular is up to 1,000,000sqm (60dBsqm)
- RCS of air planes can be 1 sqm with 10dB lower two way antenna gain

This calls for more than 80dB instantaneous dynamic range in receiver and processing to detect a 1sqm target

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<th>1.0</th>
<th>10</th>
<th>100</th>
<th>1,000</th>
<th>10,000</th>
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<tr>
<td>decibel sq. meters</td>
<td>(dBsm.)</td>
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<td>-20</td>
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<td>10</td>
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<td>Birds</td>
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</table>

**Figure 6:** RCS variation with rotation (Yaw = 0°)

**IMPACT MODELLING OF WIND FARMS ON MARINE NAVIGATIONAL RADAR** by L S Rashid and A K Brown
The technical challenge with S-band systems

Glint from blades:
- RCS glints of wind turbine blades are up to 30,000sqm (45dBsqm)
- The glints occur at different time for the different turbines
- The glints looks like a target that moves from scan to scan

Density of turbines:
- CFAR threshold will normally be on the top of the peak signals
- Normal resolution will merge signals together
- This will give "total" blindness in the whole area of windfarms

Resolving the Radar/Wind Farms Interaction, Geoff Butler BAE 2005
The Effects of wind turbine farms on ATC radar, AWC/EAD/72/665/Trials May 2005
The solution - requirements

1. Receiver instantaneous dynamic range > 70 dB.
2. Low elevation and azimuth antenna side lobes.
3. Low range side-lobes after pulse compression to minimize leakage of large discrete clutter returns into neighboring range bins.
4. Clutter sub-visibility after MTI/MTD: > 55 dB, preferably > 60 dB.
5. CFAR processor able to cope with clutter discrete of at least + 55 dBm2 and maintain threshold against a 1 m2 target...
6. High range and azimuth resolution to reduce likelihood of target and turbine falling in same range-azimuth cell. High center-frequency...
7. Small ground clutter map cell size, preferably << the inter-turbine separation distance.
8. Good resolution in Doppler frequency, to assist in discrimination between air target returns and turbine blade returns.
9. High update rate on target, so as to assist tracker in maintaining plot association.

Radar In-fill for Greater Wash Area Feasibility Study- Final Report, David J Bannister QinetiQ 2007
Wind farm mitigation strategy

1. High Spatial resolution
2. High Dynamic range
3. Inter-clutter visibility
4. Sub-clutter visibility
5. Adaptive clutter maps and CFAR
6. State of art tracking
Spatial resolution

- Narrow azimuth beam width
  - 0.4° with 18’ antenna (3dB)
- Fine range pulse width
  - 7m with 40NM inst. range (3dB)

-> fine target separation
-> very small clutter volume

Test target
Dynamic range

• 110dB dynamic range of receiver
• 138dB dynamic range of floating point processing

Large cylindrical “thermos bottle” at Strudstrup Power Plant
Inter-clutter and sub-clutter visibility

- Fast roll-off from -60dBp of large targets
- Clutter map/CFAR that is not seduced by wind turbines
- MTI attenuation better than 60dB
- MTI adaptivity to moving clutter

Normal and adapted MTI

Radial velocity [m/s]
Adaptive clutter maps and CFAR

- CFAR does not reduce sensitivity between turbines
knowledge based tracking

- Detect turbines and keep track of them.
- Use both normal and MTI video
- Use Interacting Multiple Model to handle manoeuvring targets
SCANTER 4002 SYSTEM

SCANTER 4002
Redundant Tx-Racks

15ft or 18 ft. HP or CP CSC2
with optional IFF
Why SCANTER 4002?

Coverage: SCANTER 4002 is the only radar for wind farm mitigation with a range up to 45 NM

Cost-effective: Mitigation of multiple wind farms with one sensor.

Scalability: Built-in scalability for additional turbines reduces risk as new wind farm is built

Accuracy: Co-location with existing radars eliminates slant range errors.

Deployment: Infill to existing PSR or PSR

Interference: No spectrum issues with existing PSR’s.

Support: Existing product with large customer base.
1½ year ago...

**Completed:**
- Inter-agency Field Test & Evaluation (US)
- MoD Technical Demonstration (UK)

**Further testing:**
- Integration with ANSP
- Extended range mitigation
- Scalability (multiple wind farms)
- NATS demo / endorsement
Wind Farm Trial Edinburgh:
• Co-location with Airport PSR
• Instrumented range 40 nm
• Multiple wind farms
• Integration with airport RDP
Performance (Flight Trials Edinburgh)

Results:

- Extended range mitigation
- Detection rate > 90%
- No turbine clutter
- Accurate positioning
- No interference

New airport radar to mitigate impact of wind turbines
08.10.2014

A single radar that can provide traditional airport surveillance functions and mitigate against the effects of wind turbines may be a step closer following trials conducted through 2014.

Air navigation services provider, NATS, and the radar manufacturer, TERMA, trialled the use of Terma’s SCANTER system to assess its performance as an extended range wind turbine mitigation system between January and March this year.

Initial results indicated that the system was not only capable of mitigating the effects of wind turbines, but could also detect aircraft through wind farm locations, even at ranges beyond 40nm.

Following this successful initial trial, the radar was evaluated during August by the Civil Aviation Authority as part of its Spectrum Release Programme. The results confirmed that the system is capable of detecting even small targets beyond 40nm and with good low level coverage. Based upon these initial positive results, further testing is expected to be undertaken with the CAA moving forward.

Iain Harris, NATS Director of Engineering, Services, said: “We’re committed to working with a range of developers and radar manufacturers to find the best way for airports to mitigate the impact of wind turbines. These latest trials with TERMA represent a breakthrough for airport
CAA Trial (Spectrum release program)

PSR Trial Newcastle Airport:
- Instrumented Range: 45 nm
- Antenna scan rate: 15 rpm
- Integration with test RDP
- Display at ATC Tower
CAA Trial (Spectrum release program)

Results:
• Small target detection range > 40 nm
• Small target coverage up to FL200
• Detection rate > 90 %
• Low False Alarm rate
• Accurate positioning
• No interference (X-band vs. S-band)
The X Factor: X Band radar and wind farm mitigation

28 October 2014

Earlier this month we issued a news release about our work with Terma to trial a new X Band radar system designed to mitigate the effects of wind turbines on airport radars.

“In addition, the trials so far have clearly shown that an X Band system has the performance capability to not only operate as an infill solution for wind farm mitigation, but also as a replacement primary radar with mitigation capability for airport applications.”
SCANTER 4002 Key Features

- High resolution, X-band radar
- 360° coverage
- 45 NM Instrumented Range
- Vertical coverage up to FL200/FL400
- ASTERIX data output
- In operation since 2007
- COTS: More than 25 systems delivered
- First Windfarm Mitigation Safety Case 2 approved
Aerodrome Traffic Awareness

Enhancing capabilities to our large portfolio of SMR installations world wide.

- Enhanced low level coverage, typical 400-600ft AGL
- Range up to 5NM
- Combined Surface & Air tracker
- 2-in-1 solution maintaining 60 RPM for SMR
- Detection of non transponder, low-level and small targets
- State of the art embedded knowledge based tracker

= SCANTER 5502 SMR