



# › WIND TURBINE ROBUST RADAR SYSTEMS

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## SUBJECTS

- › Phenomena
- › Radars being covered
- › Remedies
- › Conclusions

## PHENOMENA

- › There is an abundance of literature in which adverse effects of wind turbines to both primary and secondary radar are described.
- › There have been wind turbine clutter measurements, also well described in the open literature.

## PHENOMENA PRIMARY RADAR

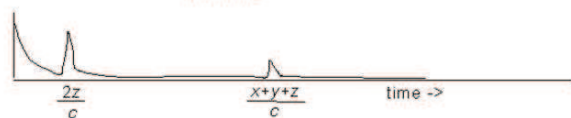
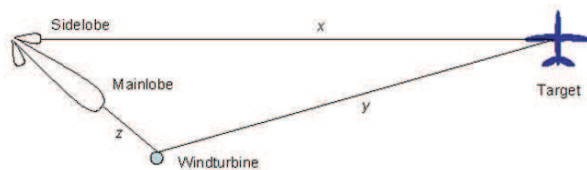
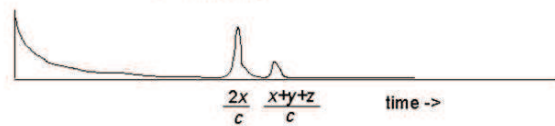
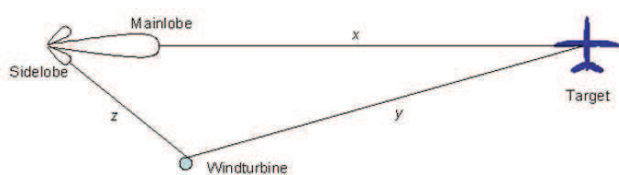
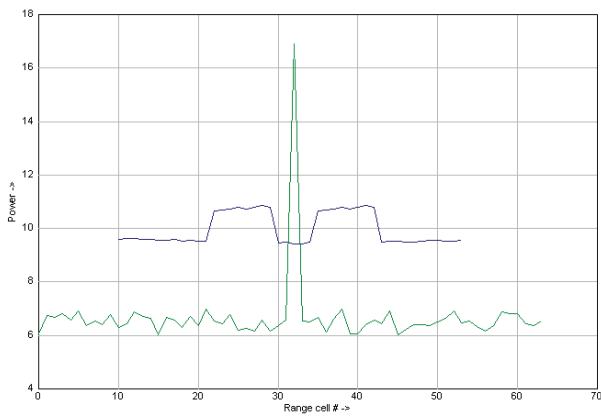
- › Desensitisation overhead: detection threshold increases due to the reception of wind turbine clutter.
- › Shadow: decreased sensitivity behind a wind turbine.
- › False tracks, initiated by wind turbines.
- › Track seduction: tracks get stuck in wind farms.
- › Ghost targets due to reflection against wind turbines.
- › Receiver saturation.
- › Processor overload.

# PHENOMENA SECONDARY RADAR

- › Erroneous bearing estimate.
- › Ghost targets due to reflection against wind turbines.
- › Shadow: decreased sensitivity behind a wind turbine.

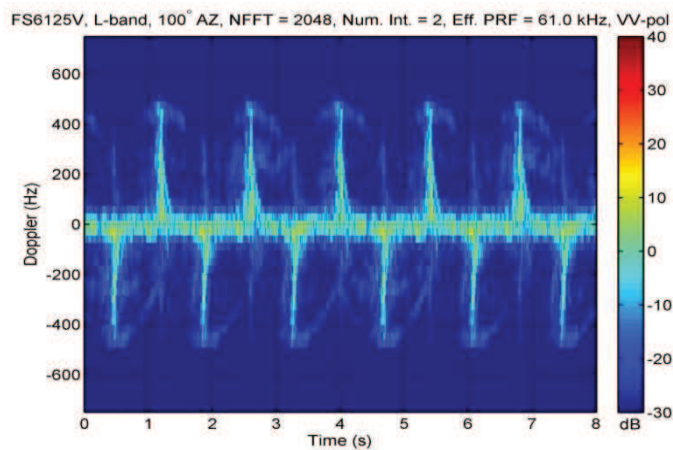
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# PHENOMENA

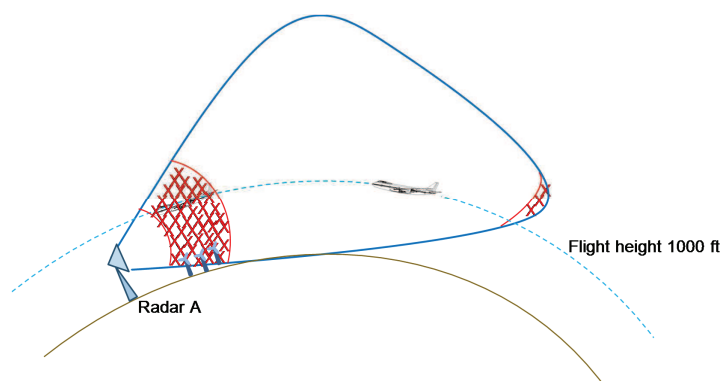


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## PHENOMENA BLADE FLASHES



Taken from QinetiQ



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## RADARS BEING COVERED

- › Radars for the air picture.
- › Primary 'civilian' ATC radars: approach / en route surveillance radars.
- › Monopulse mode-S SSR.

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## REMEDIES FOR PRIMARY RADARS

1. Desensitisation overhead: detection threshold increases due to the reception of wind turbine clutter.
  - More advanced CFAR filtering, *e.g.*, ordered statistics CFAR.
  - Cluttermap per Doppler filter.
  - Parallel receive beams rather than beamswitching on receive (2D → 3D).
  - Range dependent receive beam adaptation (*e.g.* 'nulling').
2. Shadow: decreased sensitivity behind a wind turbine.
  - Fill-in radar.
  - Sensor fusion.
3. False tracks, initiated by wind turbines.
  - Track Initiation Inhibit (TII).
4. Track seduction: tracks get stuck in wind farms.
  - Range azimuth gating (RAG), may require a wind turbine table.
  - Increased instantaneous bandwidth, *e.g.* 4 MHz rather than 1 MHz.
  - High range resolution fill-in radar (*e.g.* X-band)
5. Ghost targets due to reflection against wind turbines.
  - Sensor fusion.

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## REMEDIES SECONDARY RADARS

1. Erroneous bearing estimate.
  - Sensor fusion
2. Ghost targets due to reflection against wind turbines.
  - Sensor fusion, selective interrogation (mode-S)

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## CONCLUSIONS

- › State-of-the-art radars surveillance radars are significantly more robust than their ancestors.
- › Certain techniques are familiar in 'military' radar systems.
- › The process to modernize the systems took approximately 15 years.
- › Sensor fusion is a key component to mitigate adverse effects due to the reception of wind turbine clutter.
- › SEAs and DEAs are still necessary.

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ATTENTION**

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