Modelling the Potential Impact of Large Offshore Wind Farms on Radars

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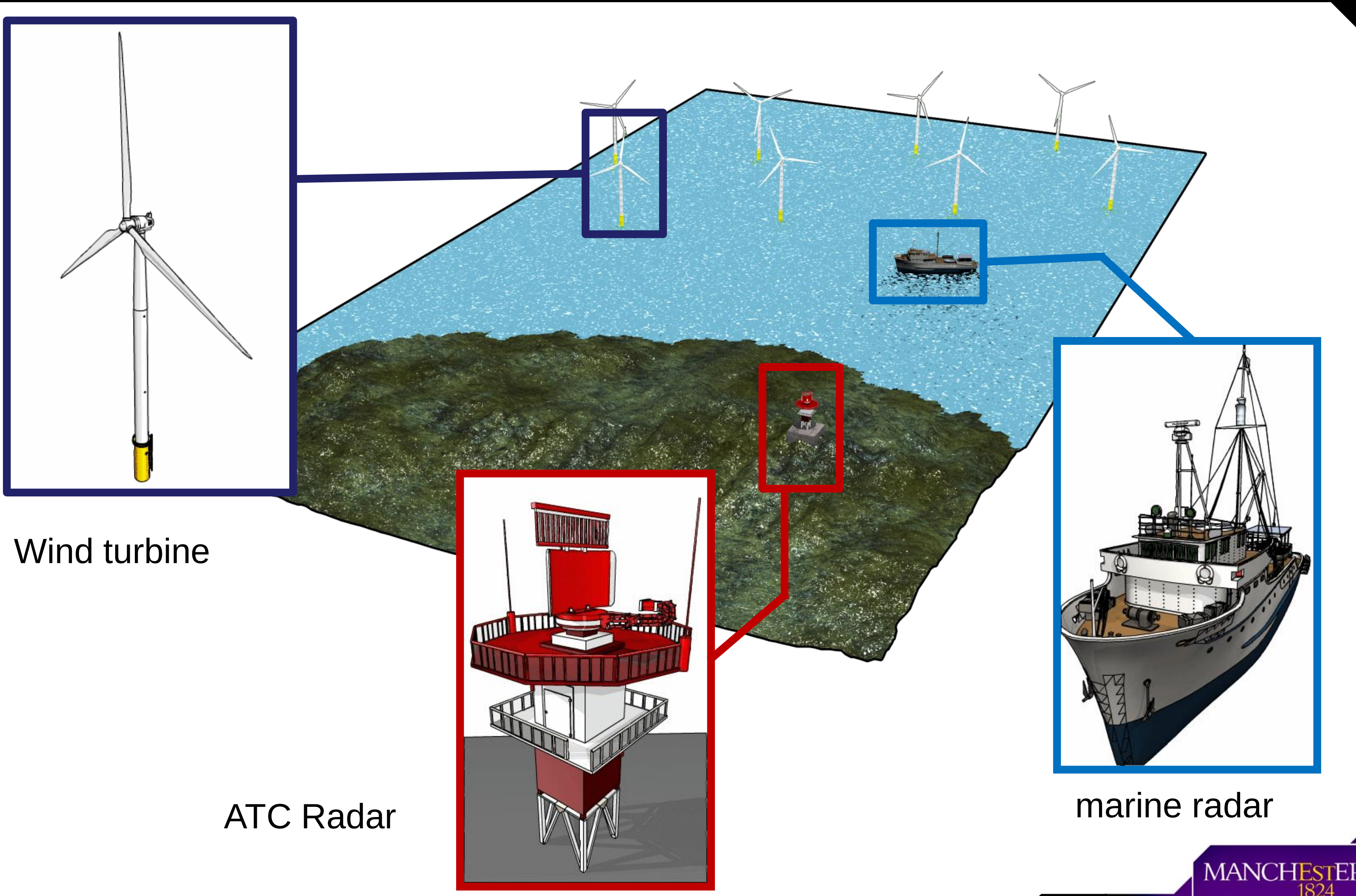
Overview

- Radar vs wind farms background
- Radar Early Warning Systems (REWS)
- REWS and Wind Farms - Key challenges
- Modelling methodology
- Modelling results
- Outlook and future work
- Q and A session

Wind Farms and Radars



The Need for modelling

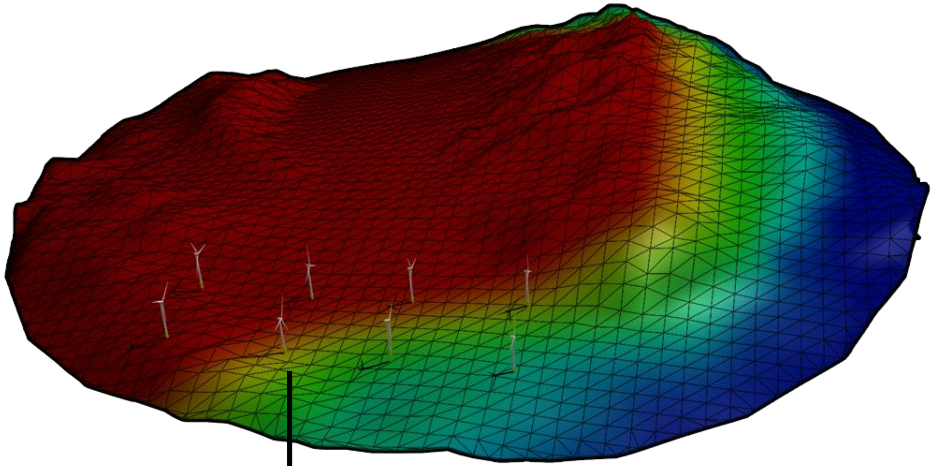
- Many planning applications for the development of new wind farms have been delayed or rejected due to the potential radar interference
- Objections are lifted once the concerns are proven not to affect the radar system
- To overcome the potential interference, good **understanding of the key parameters** affecting the impact of wind farms on a given radar system is needed.
- This can be gained through:
  - Experience from existing wind farm issues
  - Field trials and flight tests (expensive and difficult to coordinate)
  - Modelling and simulation (needed for understanding the issues and proving new technologies)

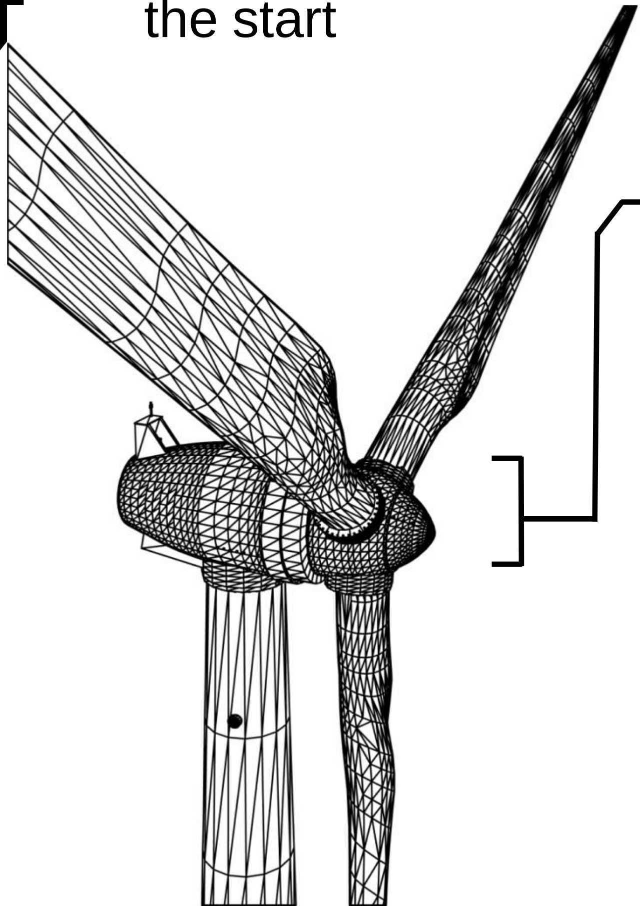
Modelling Challenges

- A simulator is needed to model the effect on radars before the construction of a wind-farm, such that the effects of different turbine design and farm layouts can be considered
- The model must provide accurate predictions of the scattering behaviour of turbines individually and the wind farm in totality
- HOWEVER:
  - Physical size is big, electrical size is huge!
  - The interaction might be different for every wind turbines, wind farms layout, radar and location
  - Pseudo random nature of the blade rotations in the wind farm makes it difficult to predict all possible outcomes
  - Various external parameters affecting the interaction
  - Interaction with local environment

Wind Farm and Radar Modelling

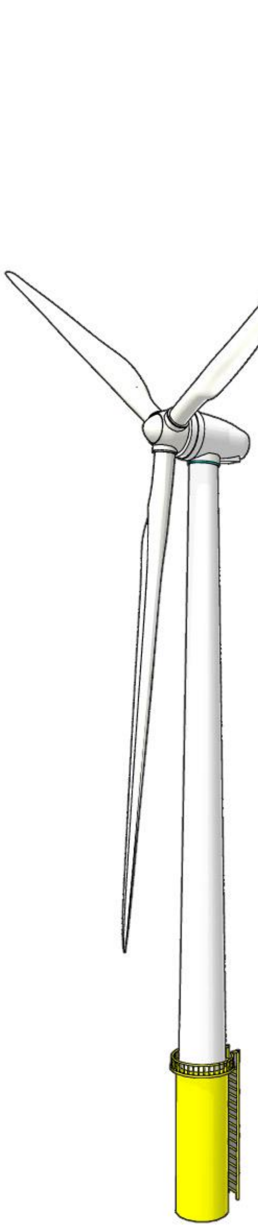
- Accurate turbine geometry for radar scattering modelling was used
- Turbine modelling is only the start

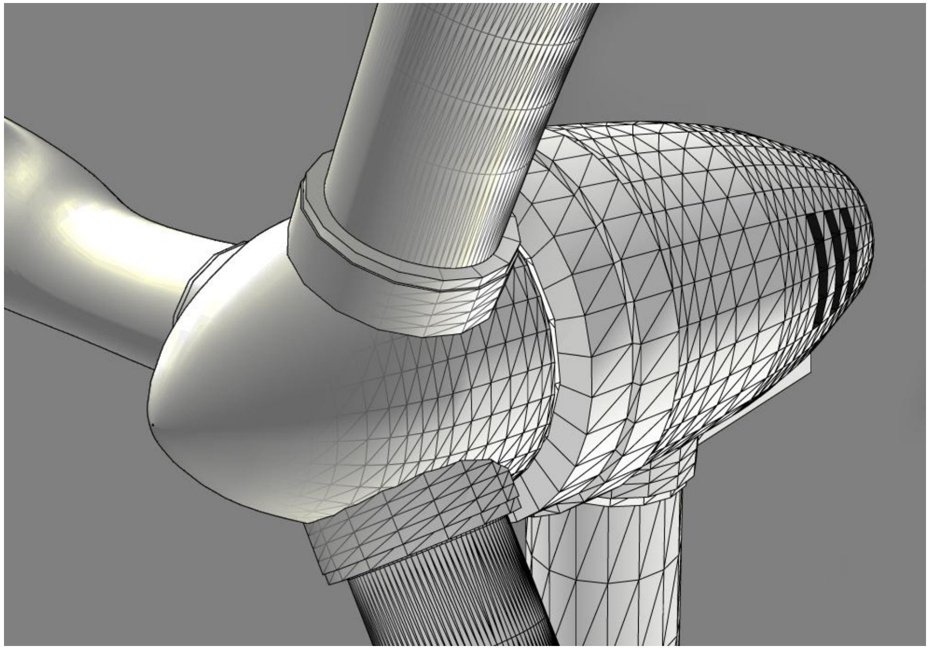




- The aim is to model a complete *wind farm* for site/radar specific assessment
- Environmental and inter-turbine interaction modelling
- Modelling the effects of local terrain
- Computational efficiency for rapid assessment of possible impact

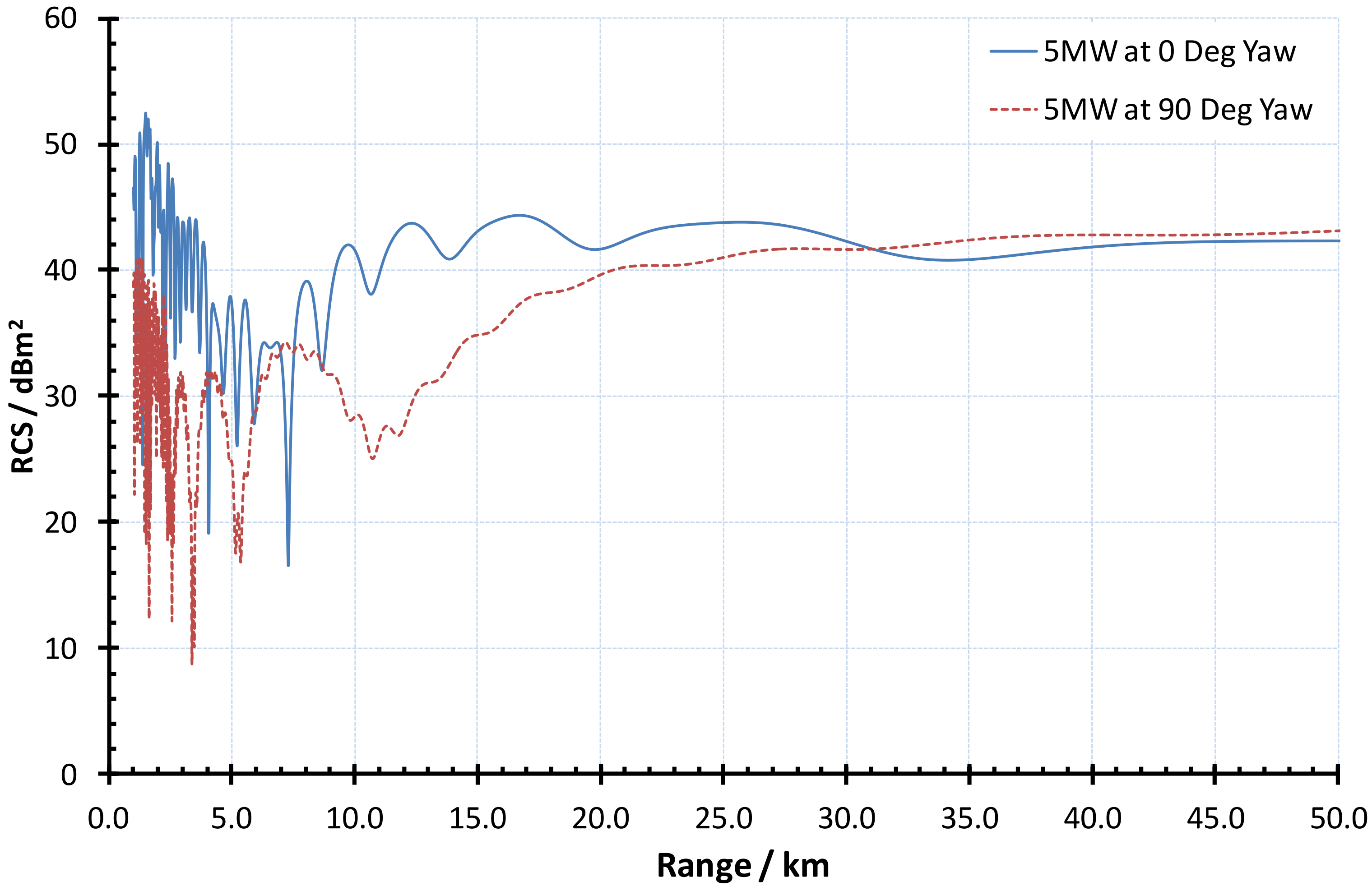
Generic Turbine CAD





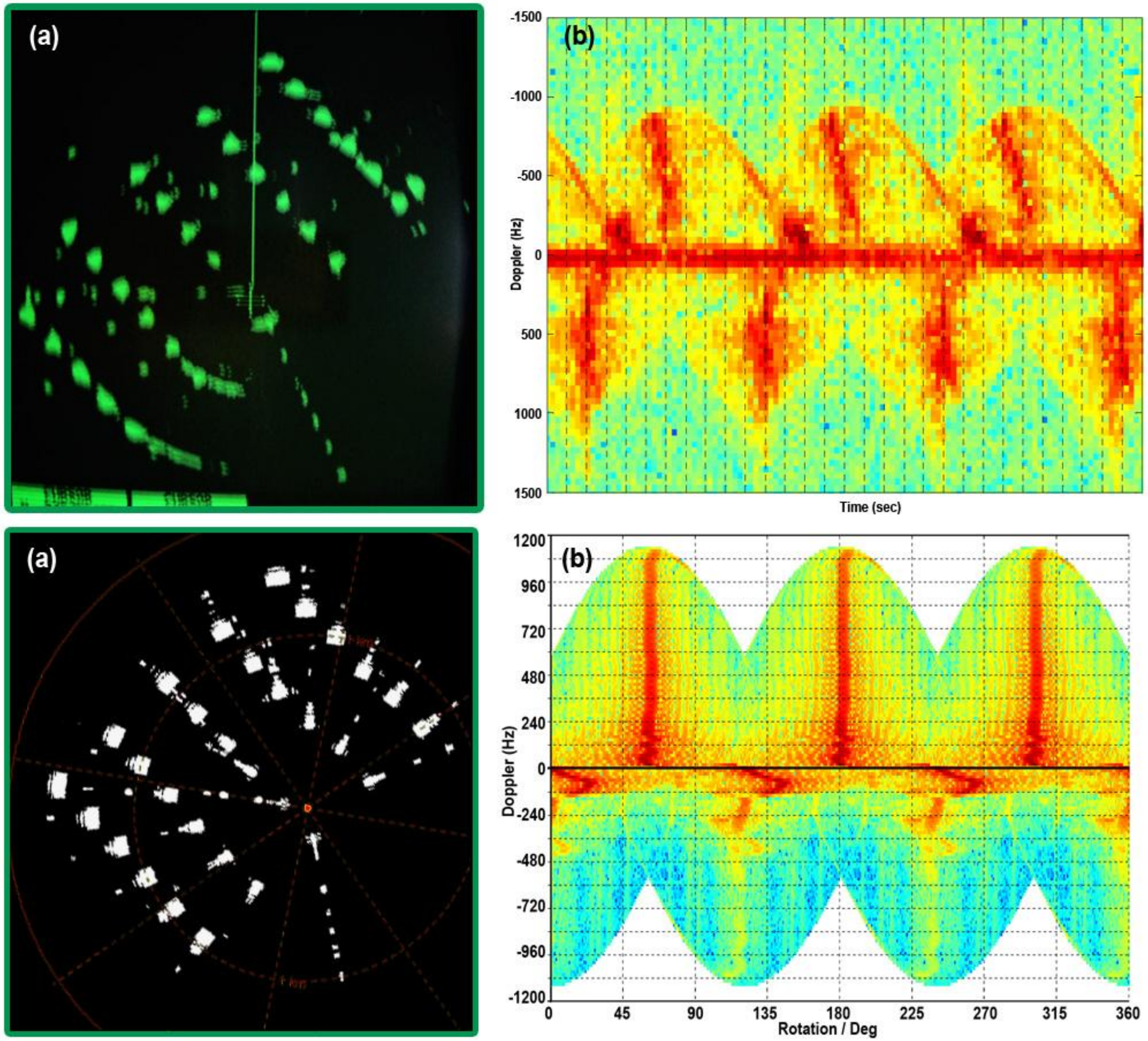
- The scattered energy from wind turbines is highly dependant on the geometry and size of the turbine.
- Within this modelling task, a detailed turbine geometry for a 5MW turbine was used (70m hub height 120m rotor diameter).
- When needed the dimensions were scaled up to represent larger turbines (eg 7MW turbines with 80m hub height and 140m rotor)

5MW Wind Turbine RCS Modelling Results



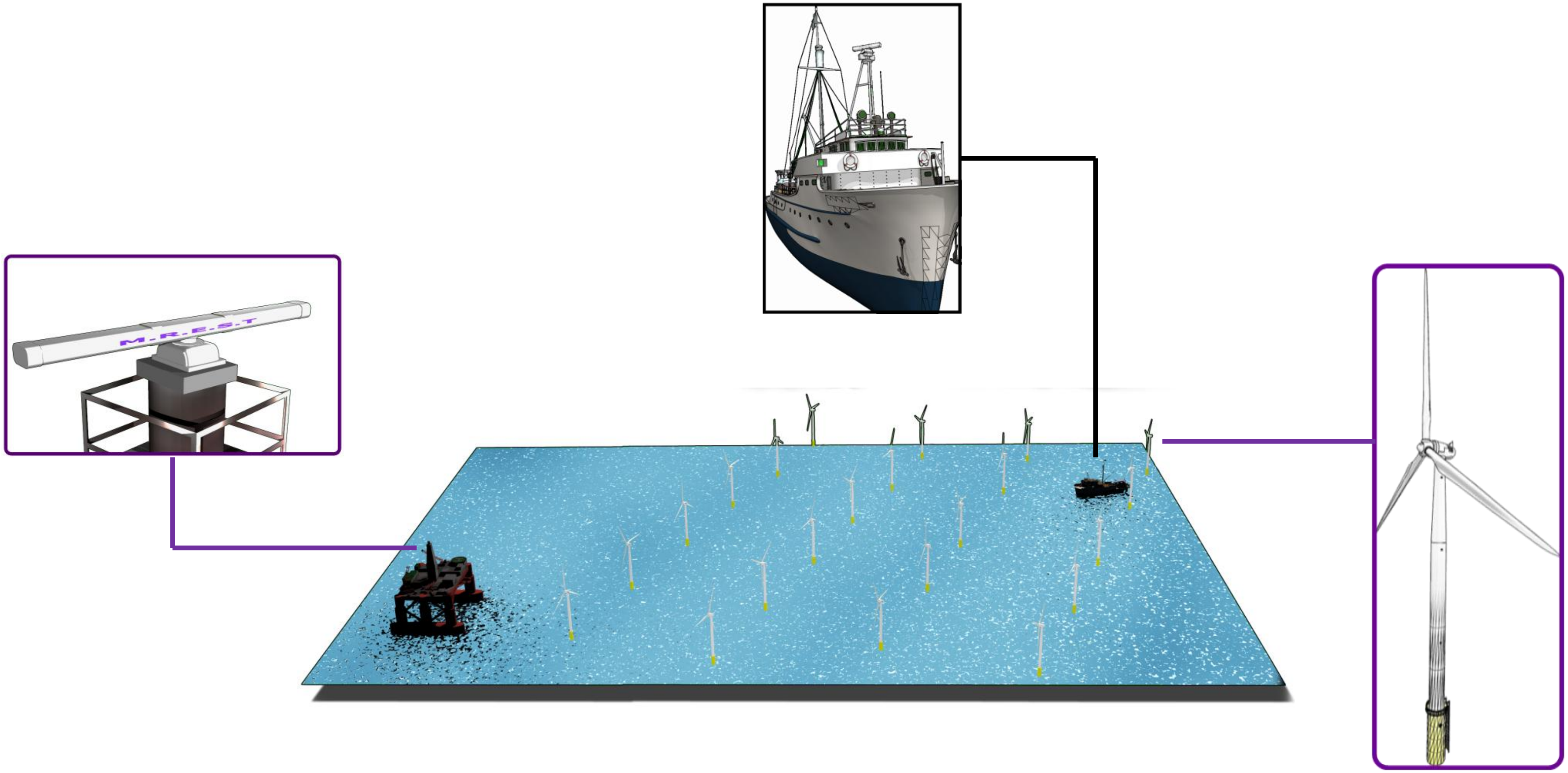
5MW Turbine nearfield RCS variation with range at yaw angles 0° and 90°

Wind Farm Modelling vs Measurements



*Doppler measurements were conducted by QinetiQ 2003

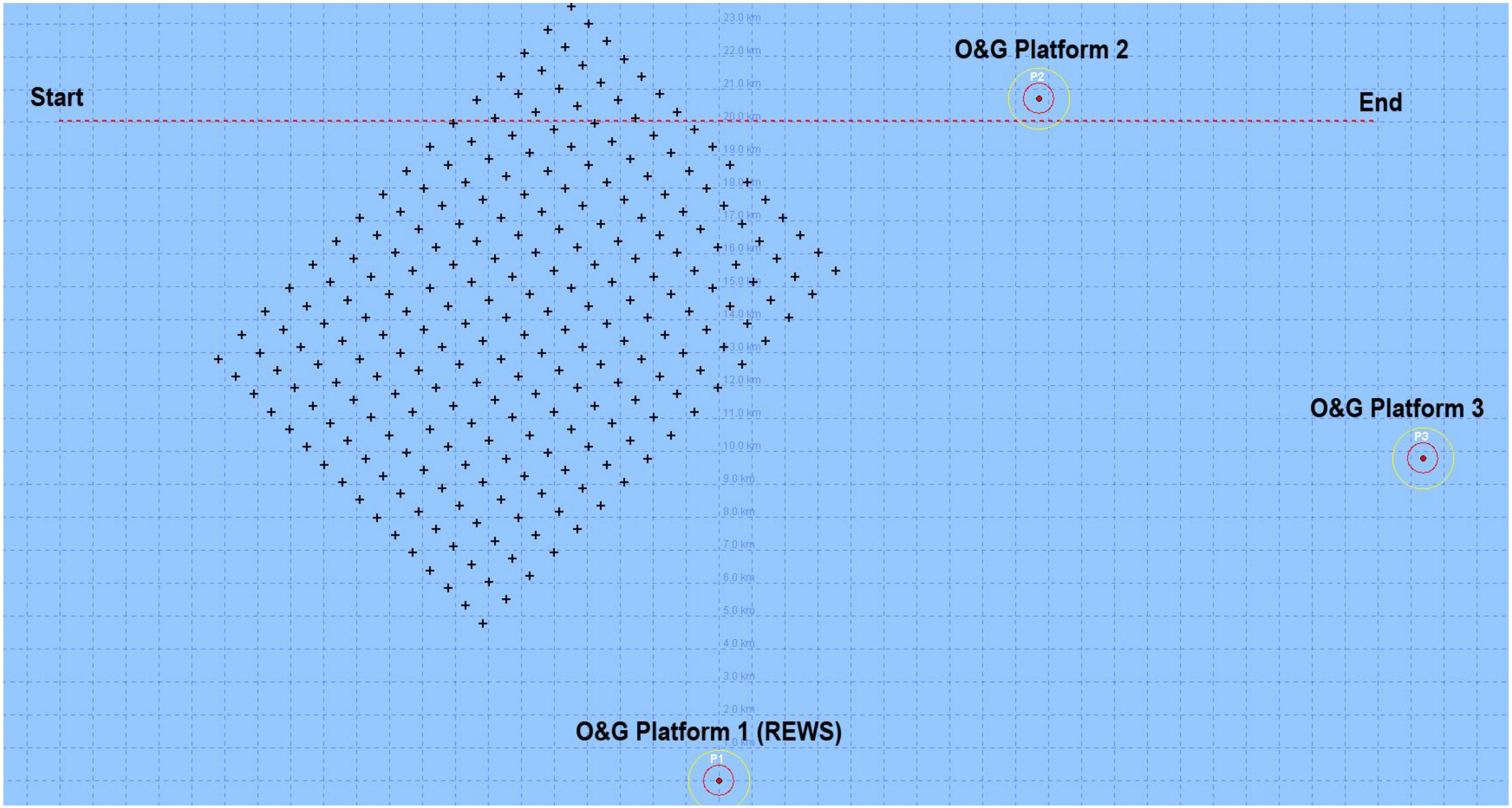
Radar Early Warning Systems (REWS)



Radar Early Warning Systems (REWS)

- REWS are highly complex and highly automated systems that relay on detection and tracking vessels near offshore oil and gas platforms
- REWS are mainly used monitor and protect offshore assets from collision with errant vessels
- REWS are used to detect and track all vessels on the radar horizon.
- REWS has preset collision alarm rules.
  - Typically, an Orange alarm is raised if a collision course is detected with Closest Point of Approach (CPA) of 0.5 NM or Time to Closest Point of Approach (TCPA) of 35 minutes
  - Red alarm is raised if the CPA is 0.27 NM or TCPA is 25 minutes.
- Should a vessel breach these rules an automatic alarm is raised to alert the operator.
- REWS uses complex filtering, thresholding and tracking techniques.
- REWS may also integrate AIS data to complement radar data

Modelling Scenario



REWS vs Wind Farms : Potential issues

- The list of detected targets are transmitted to other assets including nearby Emergency Response and Rescue Vessels (ERRVs) via ultra high frequency (UHF) radio links.
- UHF links use a low-bandwidth telemetry system and have a limit on the total number of tracks that can be transmitted. Overly large targets list may need extended time to be transmitted and may cause untimely update of the radar feed.
- Degradation of target detection due to:
  - Shadowing
  - Target masking
  - Increased threshold
- Degradation of tracking performance due to the above and also due to the varying turbine returns which may generate false tracks.

Shadowing

- The severity of the shadow depends on the distance of the target from the turbine.
- Radar diffraction around the turbine will reduce the effect of the shadow as the range between the shadowed target and the turbine is increased
- The diffraction effects is complex and requires extended runtime and detailed knowledge of the turbine geometry and environment.
- Optical shadowing is used

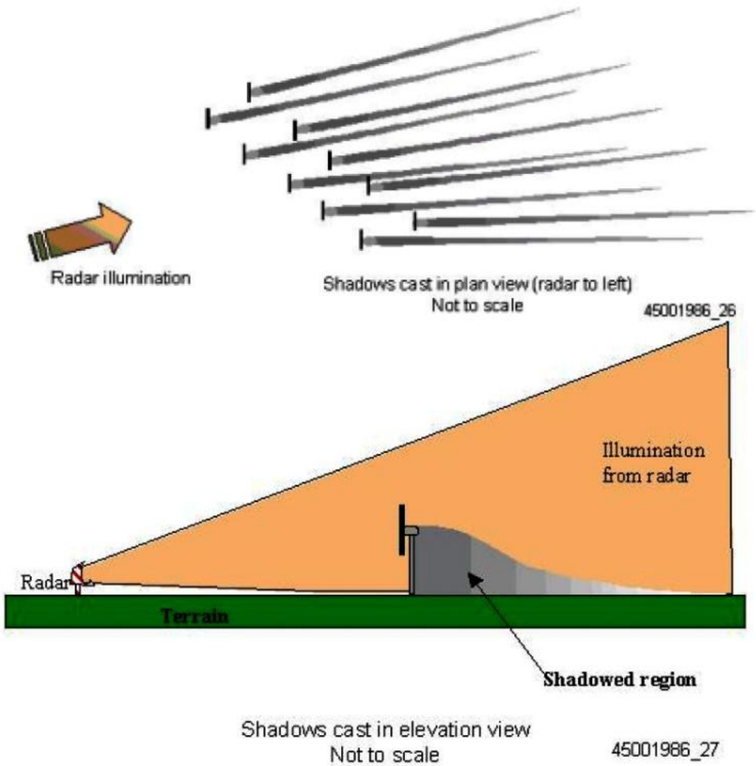
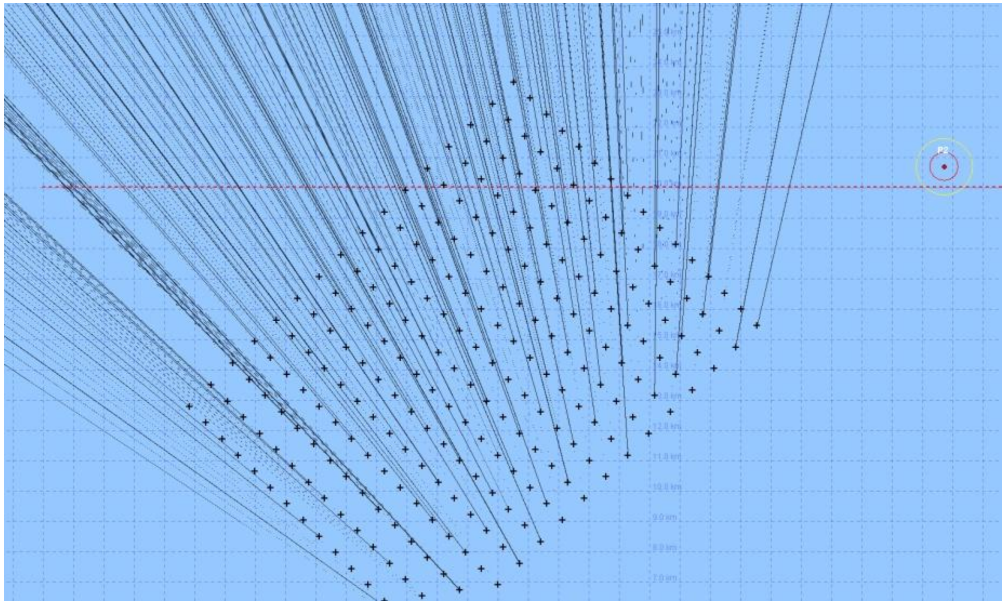


Illustration of radar shadowing with diffraction effects*

*source: M M Butler, D A Johnson “Feasibility of Mitigating the Effects of Wind farms on Primary Radar”,

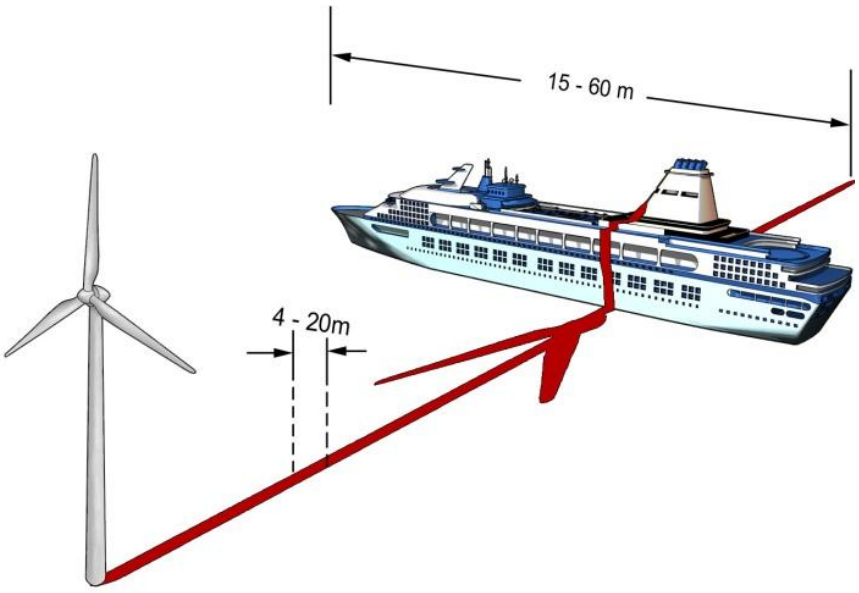
Turbine Optical Shadowing



- Point targets within the optical shadow will have no returns
- Optical shadowing is a conservative assumption and may produce pessimistic results
- It is also noted that optical shadowing may not be applicable to all scenarios and radar frequencies.
- However it is still very useful when assessing worst case scenarios and safety critical situations.
- This assumption may not be valid when assessing the effects of large vessels moving within narrow shadows.

Large Vessels and Turbine Shadowing

- Large vessels in excess of 1,000 Gross Tons (GT) are typically the main concern to the safety of the offshore platforms
- Vessels that are rated at 1,000GT and above can vary significantly in length (typically 15 – 60m).
- The length of the vessel is important to consider when assessing the effects of partial shadowing.
- A vessel with a length of 25m and RCS of 35 dBm^2 is considered.
- Partial shadowing may occur



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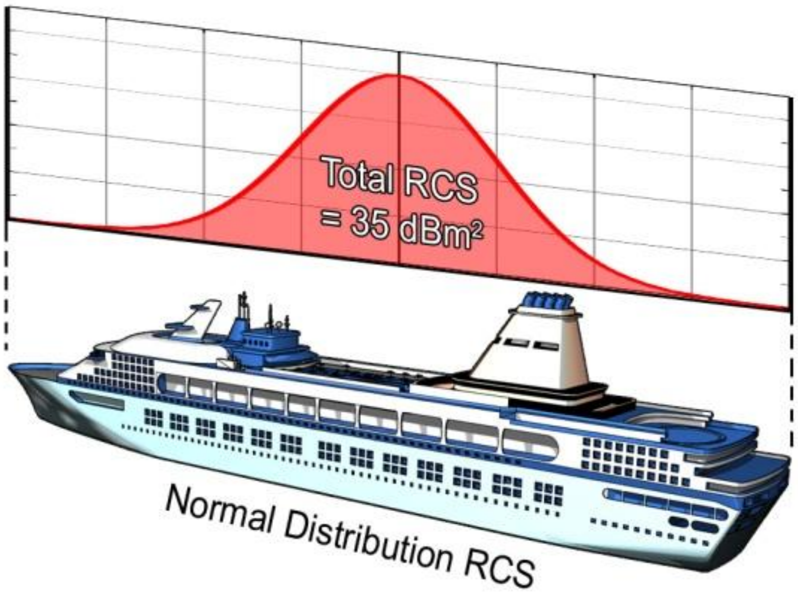
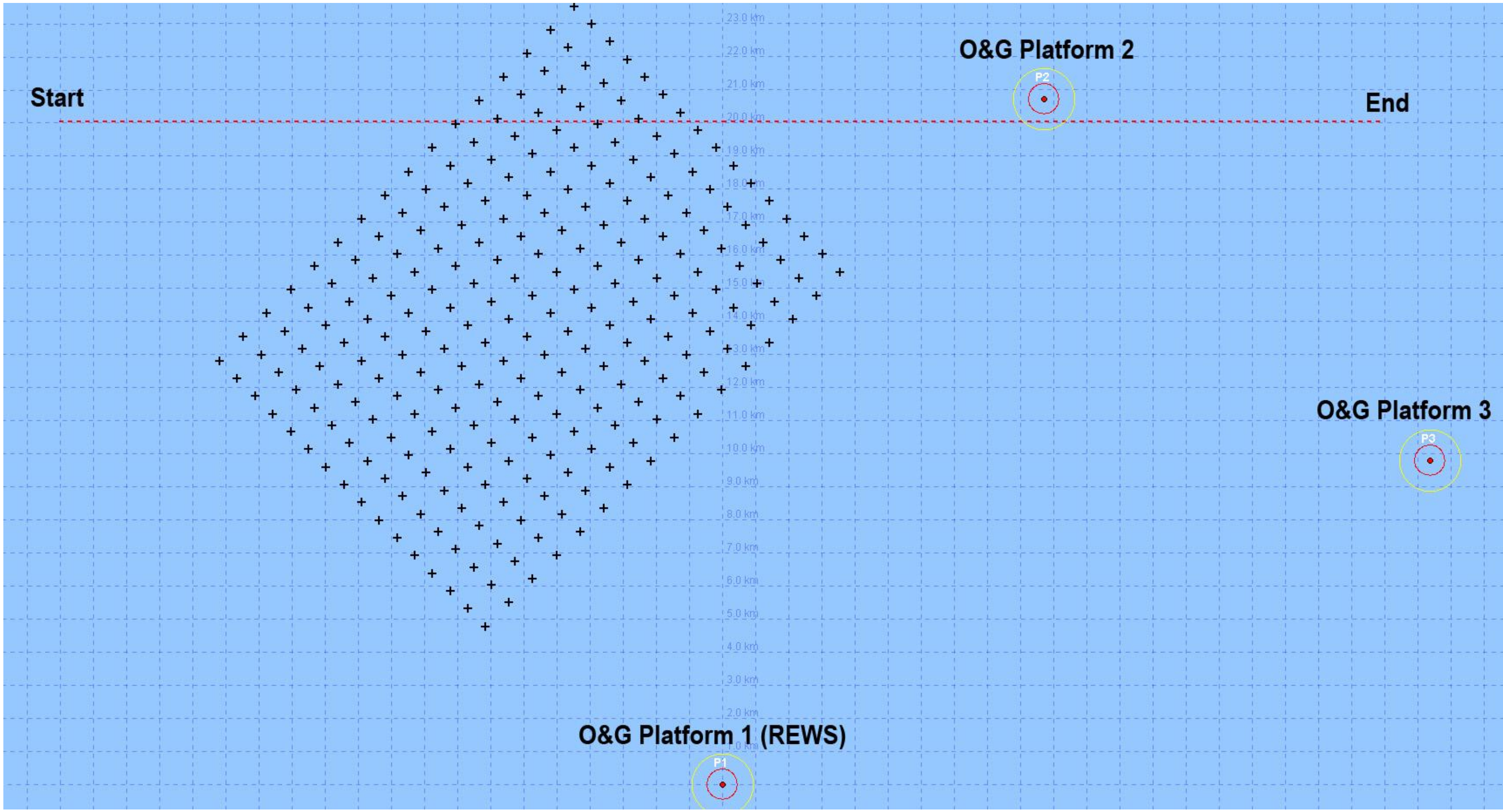
Modelling Vessel RCS for Partial Shadowing



- The vessel is assumed as a large number of scattering points that are equally spaced along the length of the vessel.
- The RCS of each scattering point is assumed to follow a normal distribution (bell-shape) centered at the midpoint of the vessel
- The total RCS of the modeled vessel was defined as 35dBm^2 (which is given by the area under the graph).
- The height of the scattering points was assumed to be 10m.

Modelling Scenario



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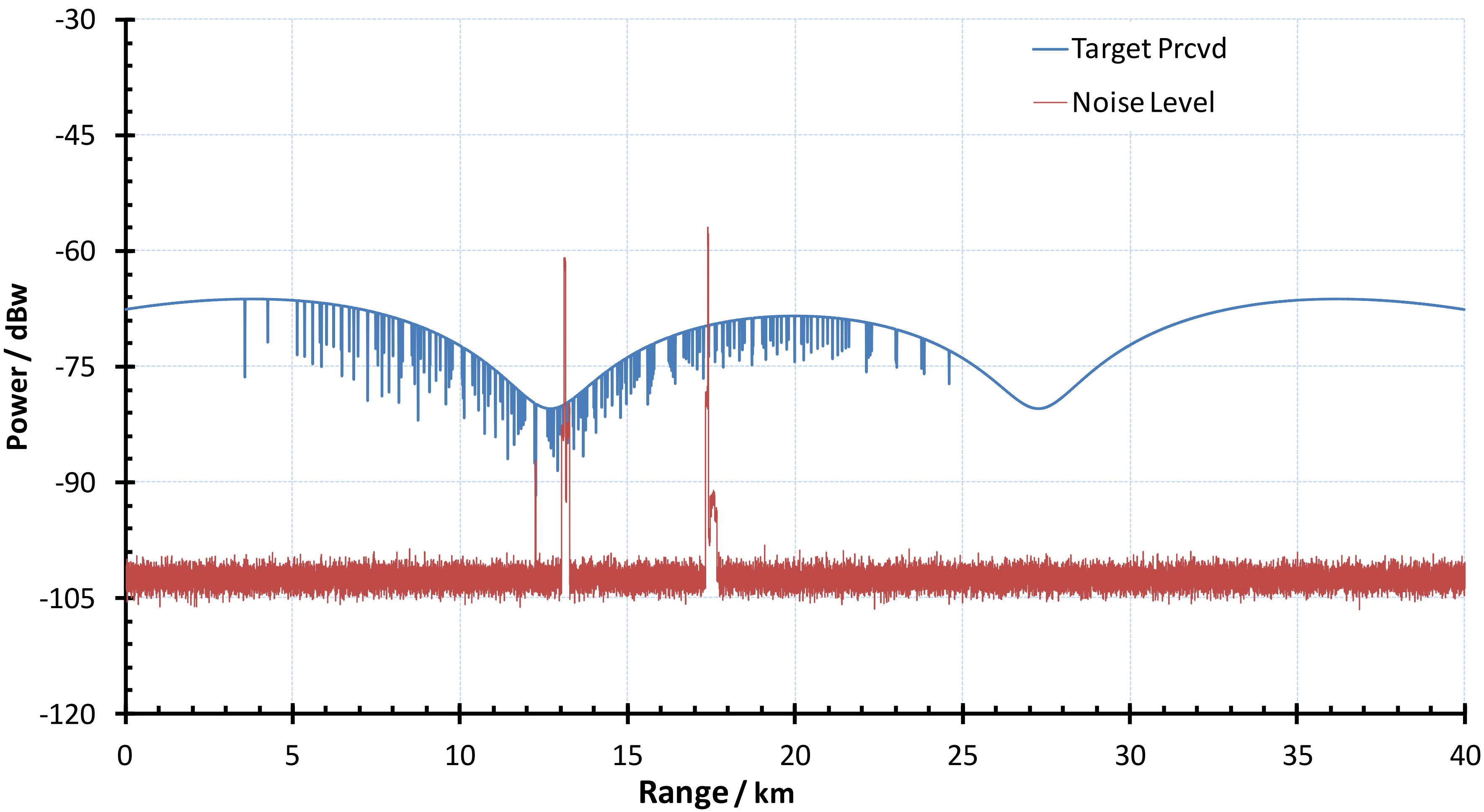
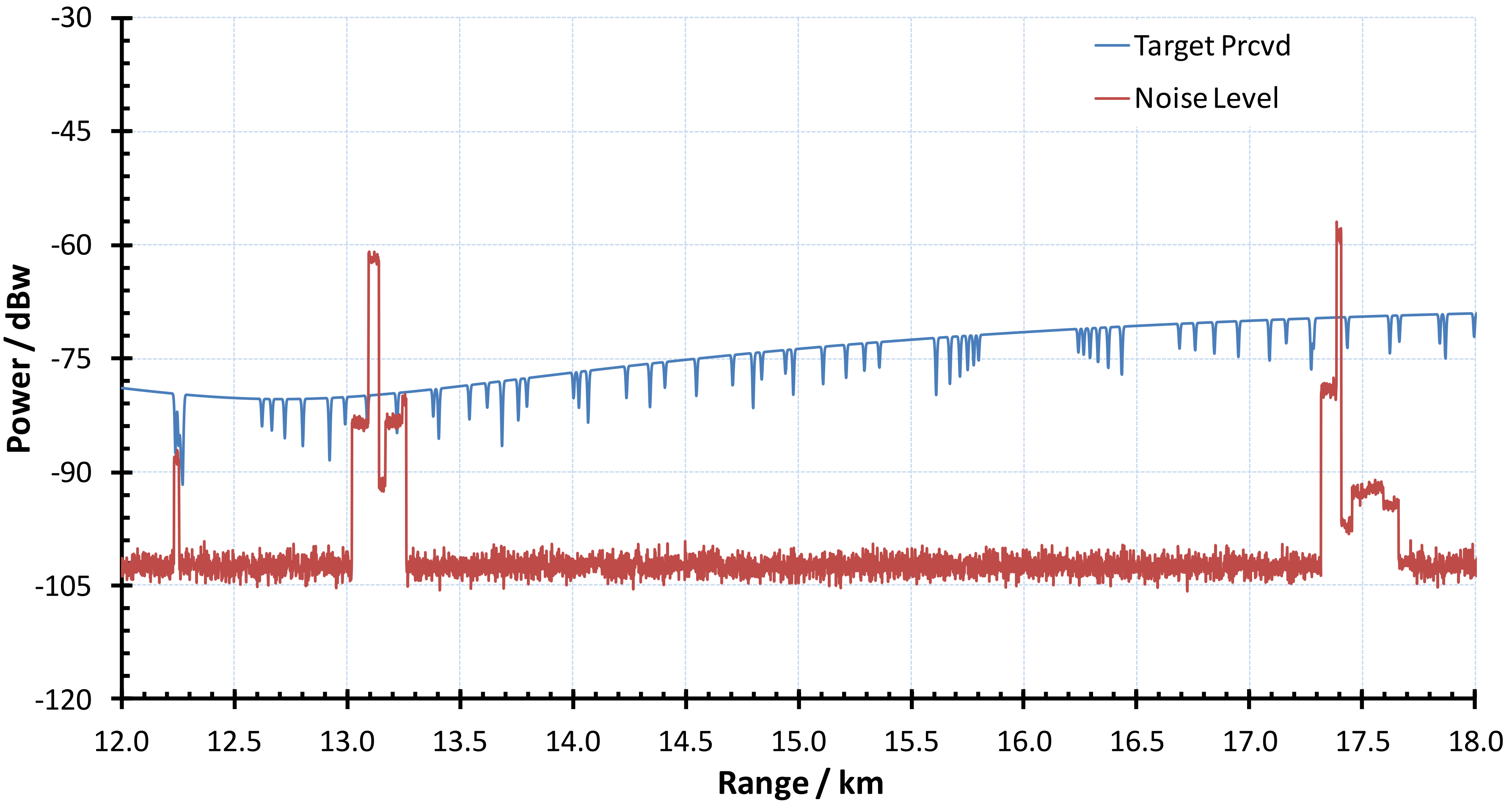
Vessel returns modelling



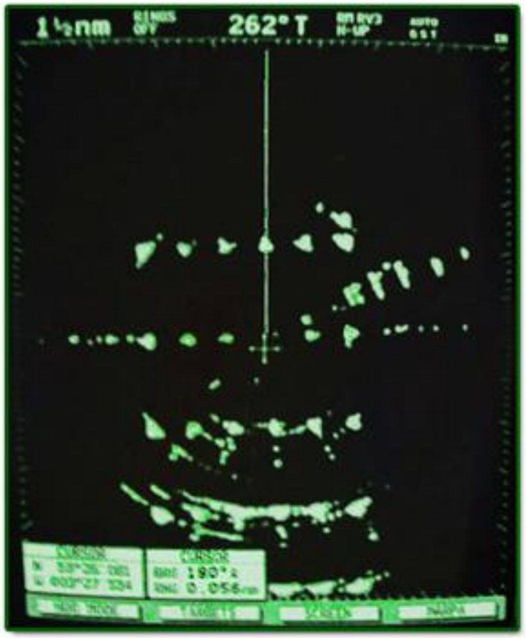
Vessel returns modelling

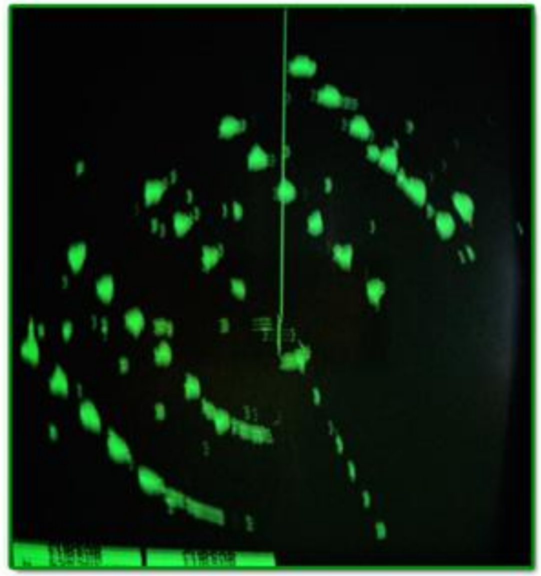


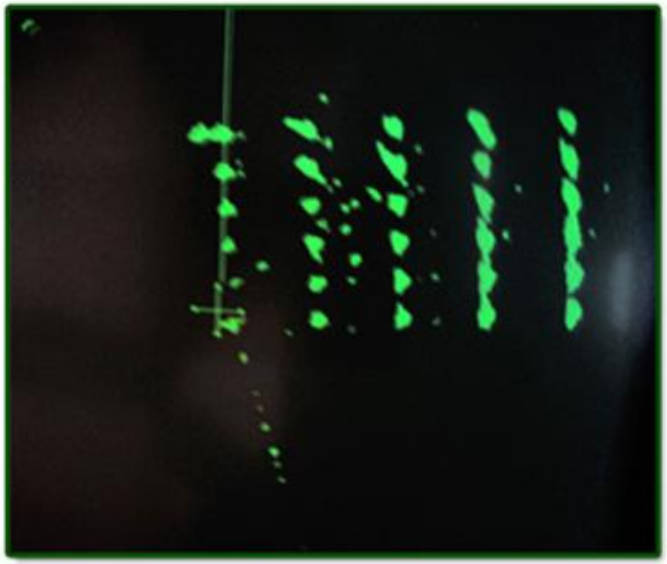
Possible Effects on Navigation and S&R Efforts

- It is common to have irregular arrays of turbines within the farm
- This may impact the mariner’s ability to visually navigate vessels from within the wind farm
- Vessels using onboard radars for navigational aids may experience adverse effects when operating near or within the wind farm

Multiple Reflections within Wind Farms

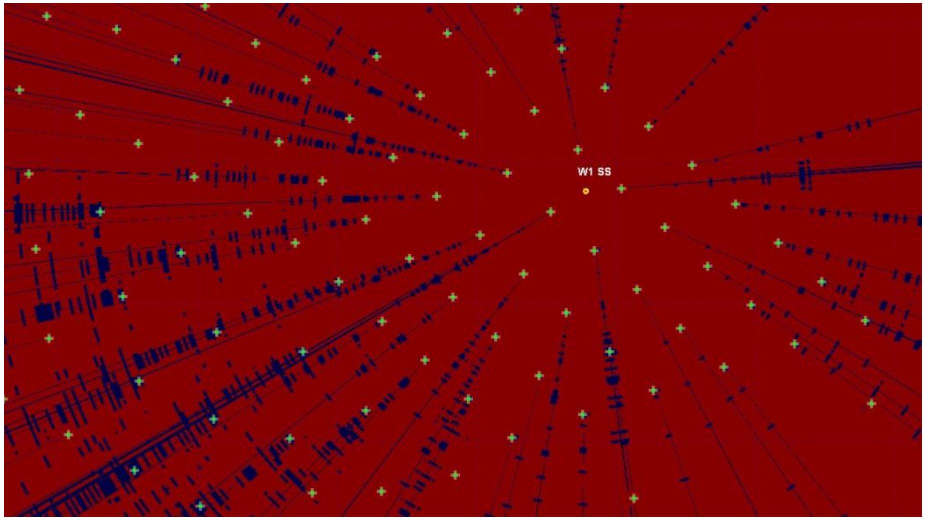






Radar Coverage within Wind Farms

- The MCA expressed some concerns regarding mariners ability to navigate through irregular wind farm arrays
- Also, radar interference may affect search and rescue efforts during low visibility conditions



- Study and analysis of radar siting onboard the offshore substations is needed
- Multiple radar installations with overlapping coverage might be needed.

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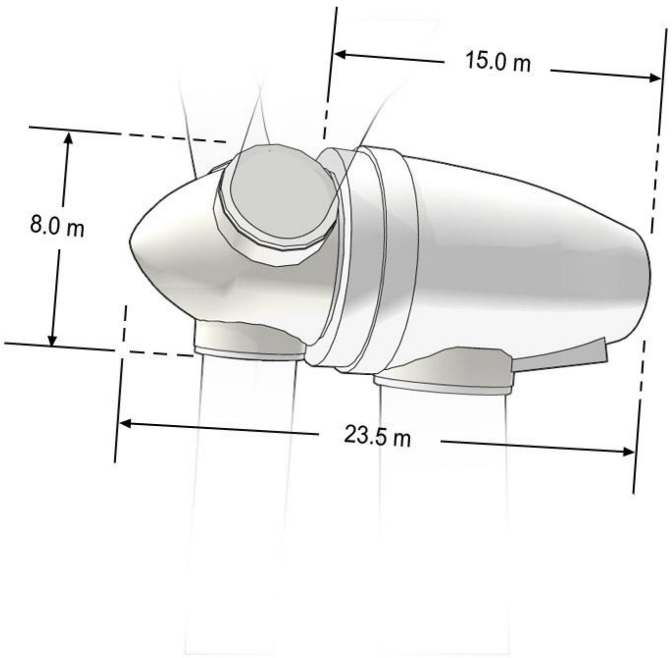
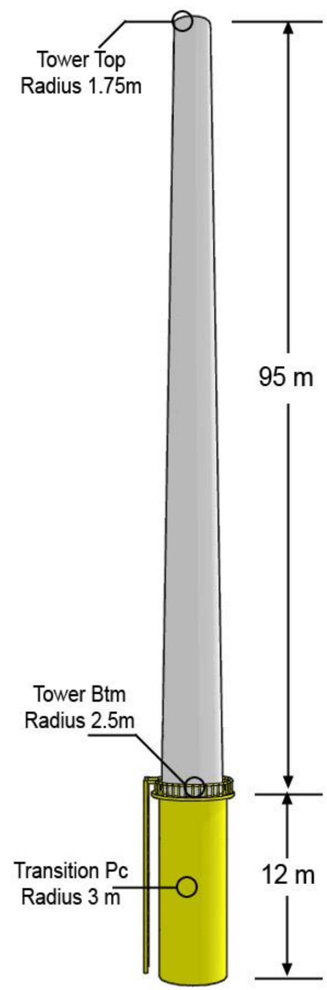
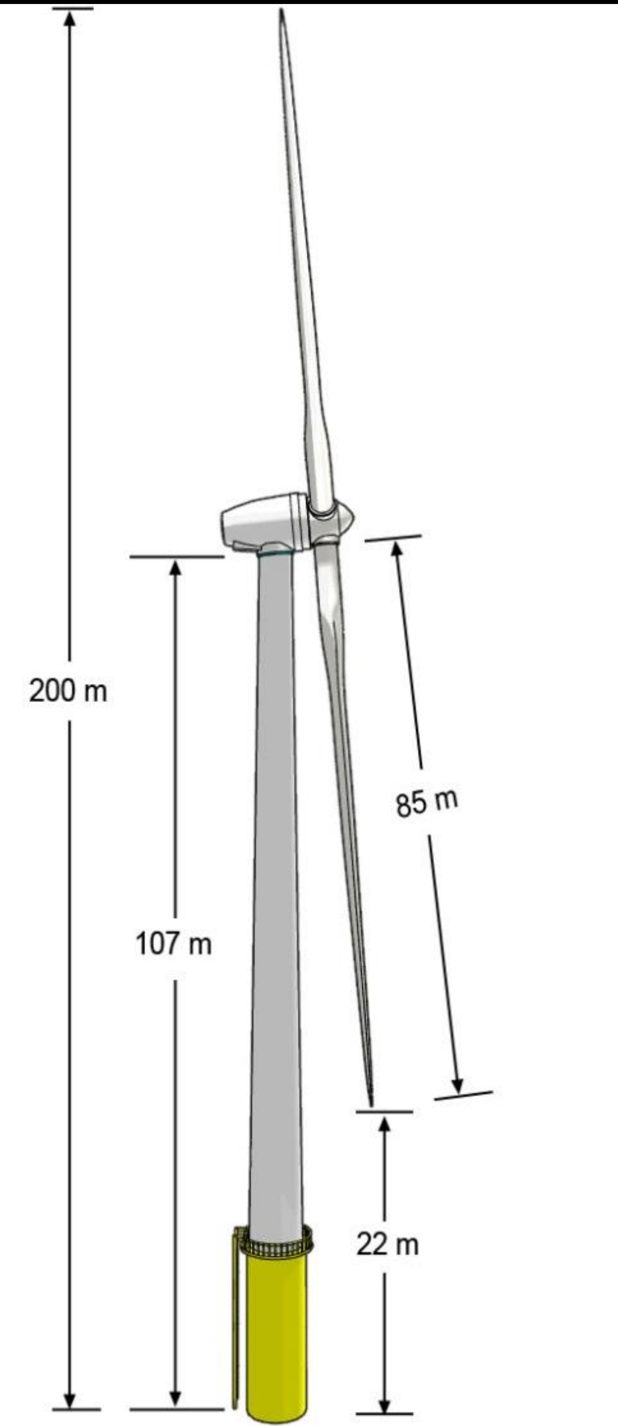
Future Work

- Modelling the impact of large off shore turbines on the tracking performance of navigational and safety radars
- Better modelling of the larger turbines geometries and materials (7 – 10MW)
- Modelling the impact of wind farms on new and emerging radar systems
- Analysis of measured data of the scattering characteristics of wind turbines and wind farms as a whole.
- Turbine EM Scattering and radiation effects on sensitive radio astronomy devices

Modelling Large 7MW Turbines



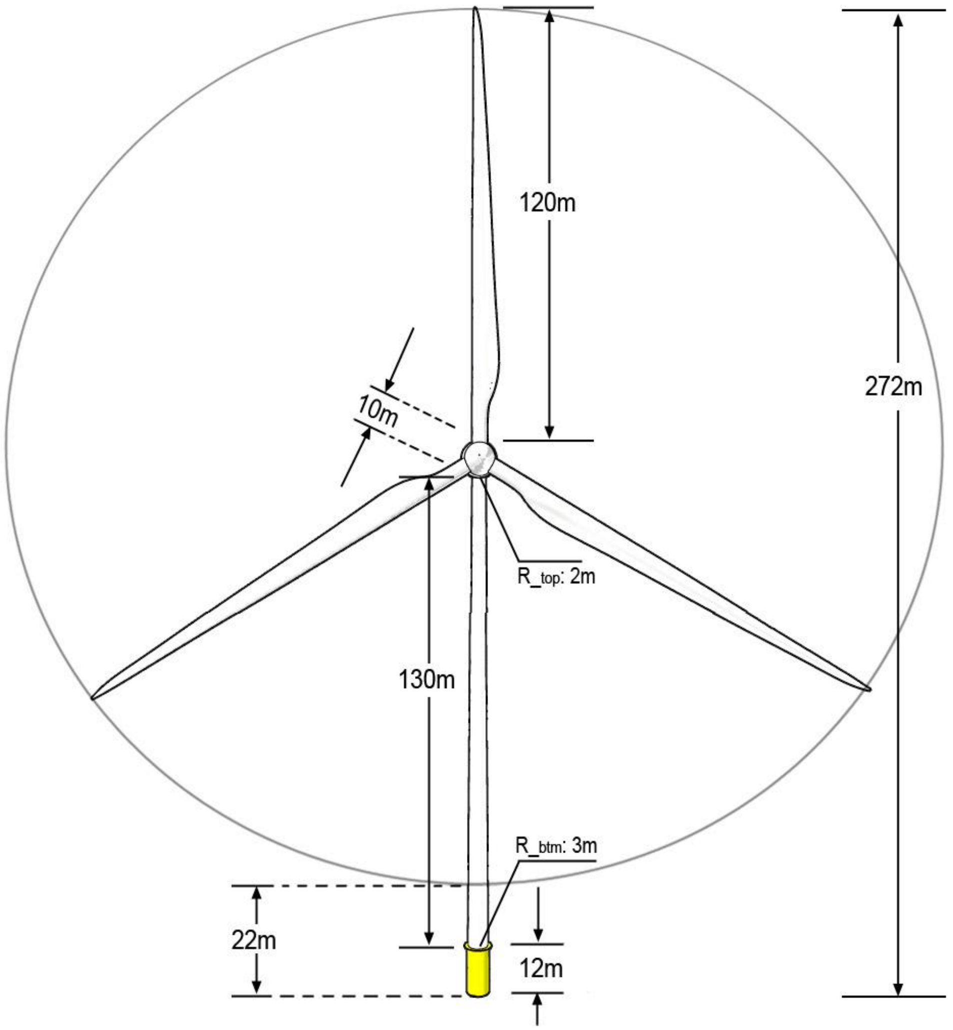




Examples such as the AREVA 180 and the Vestas V-164

Future Turbines 10MW

Examples such as the SeaTitan 10MW turbine and the Sway ST-10 Turbine



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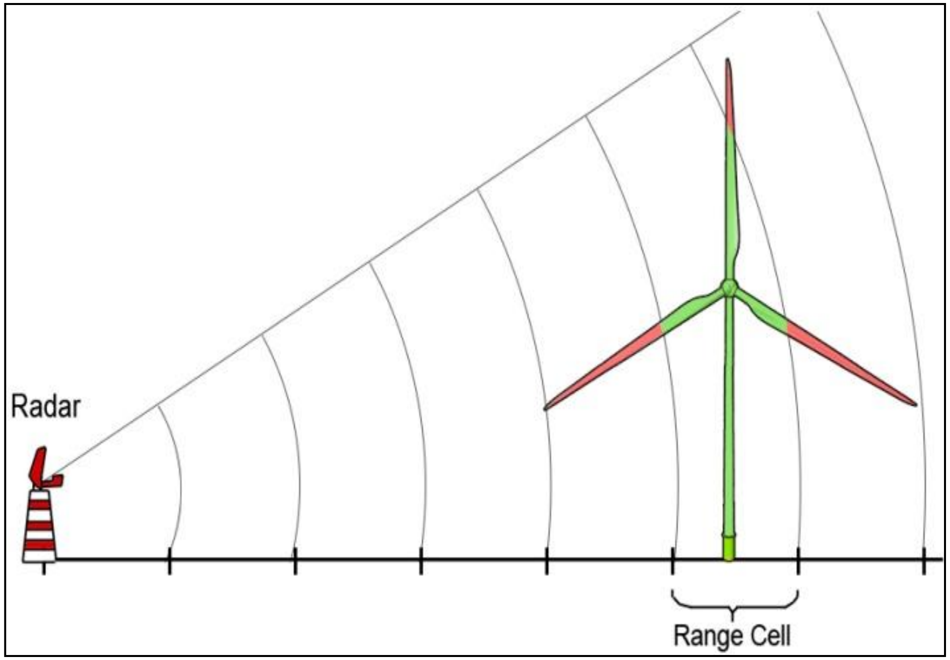
New radar issues associated with bigger turbines



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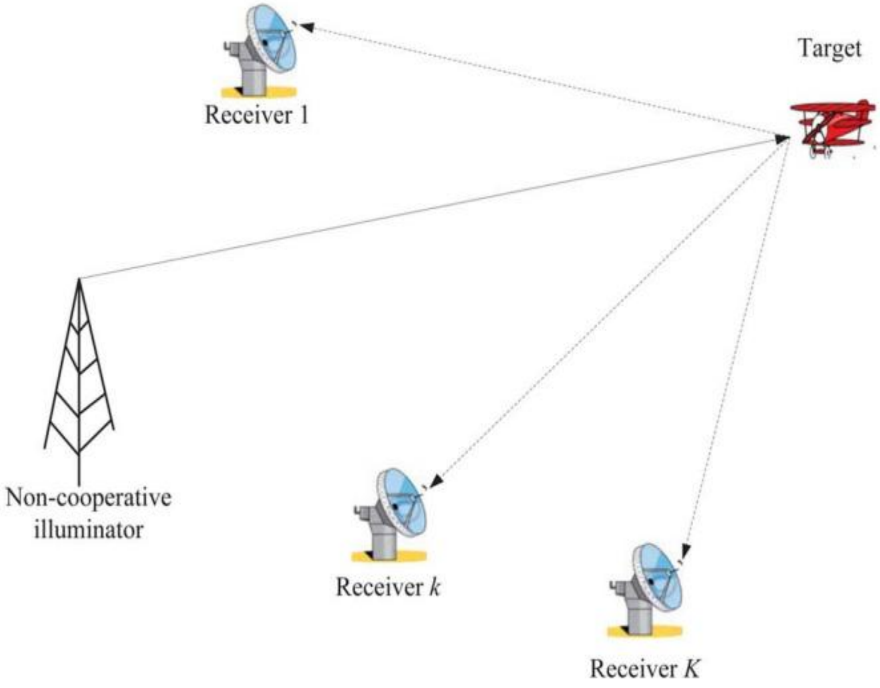
Multi-static Radar Systems



- Civil Aviation Authority and Ofcom are considering to update legacy equipment and move towards multistatic radar systems
- With the advancements of signal processing techniques, multistatic radars offer great potential in target detection and tracking as well as freeing some of the Electromagnetic spectrum
- Currently, multistatic radars work well detecting and tracking small number of targets
- This may be significantly affected when wind farms are considered

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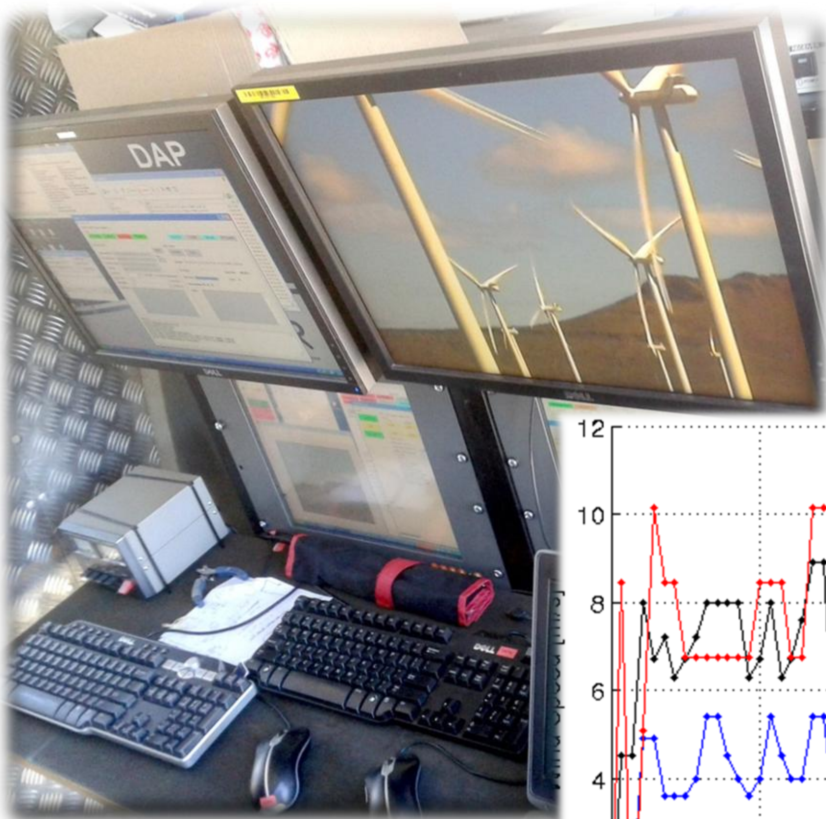
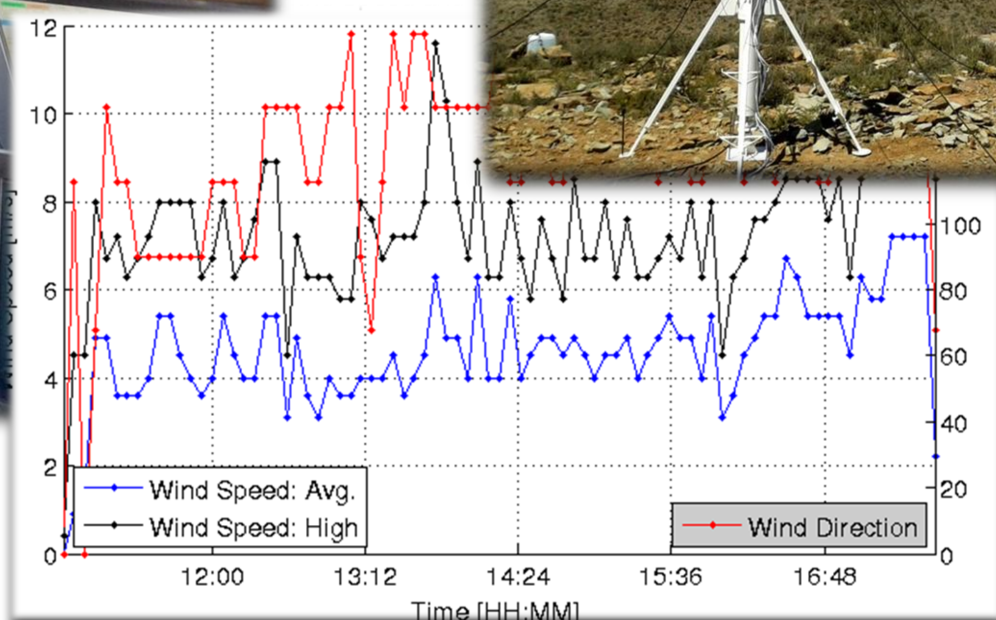
Wind Farm Scattering Measurements





Measurements were made and provided by CSIR – South Africa

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Questions

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