Assessment of wind turbines generators influence in aeronautical radars

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Outline

- Motivation.
- Basic concepts.
- Models.
- Result analysis.
- Exclusion regions.
- Conclusions.

Motivation

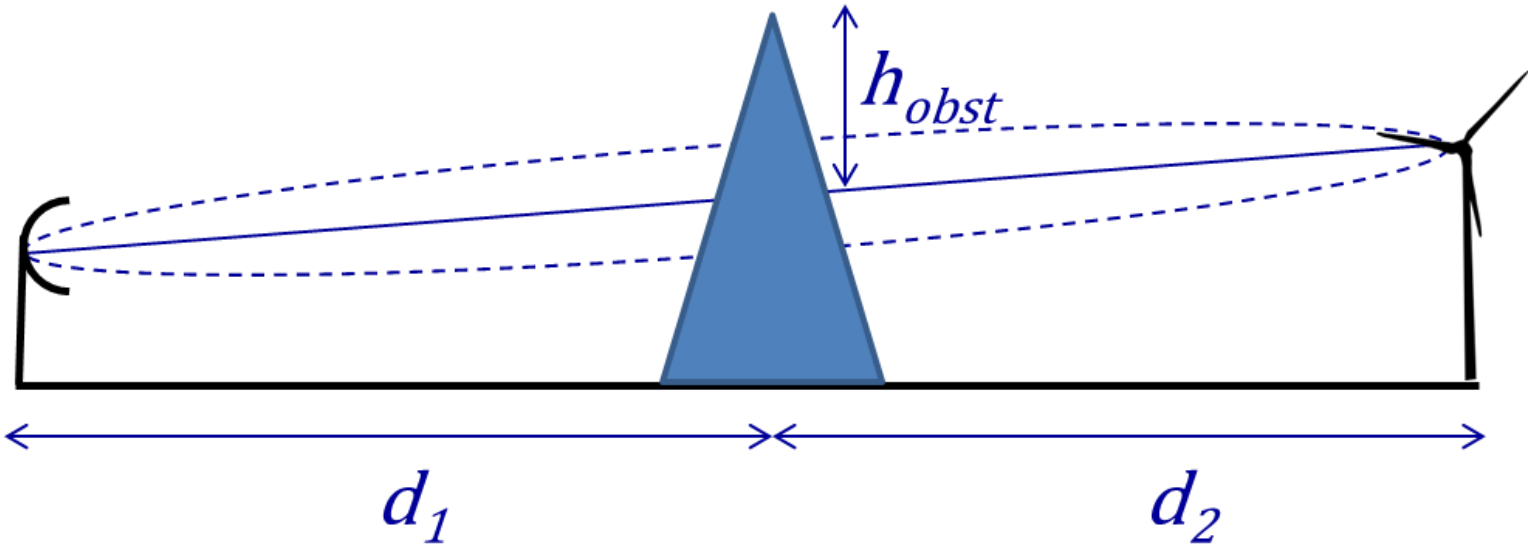
- Surveillance radars are very sensitive to interferences.
- The presence of wind turbines can create problems, because the movement of the metallic rotating blades may originate a significant disturbance in the propagation of the signals.
- A model to quantify the wind turbine impact on surveillance radars is required in order to define the exclusion regions around them.

Basic Aspects

- Two types of surveillance radars were analysed in this study:
  - Primary Surveillance Radar (PSR): one way communication, in 3 GHz band, and high transmitted powers;
  - Secondary Surveillance Radar (SSR): two way communication, in 1 GHz band.
- The wind turbine used in this study has:
  - Three blades with lengths up to 46 m, and tower heights up to 80 m.

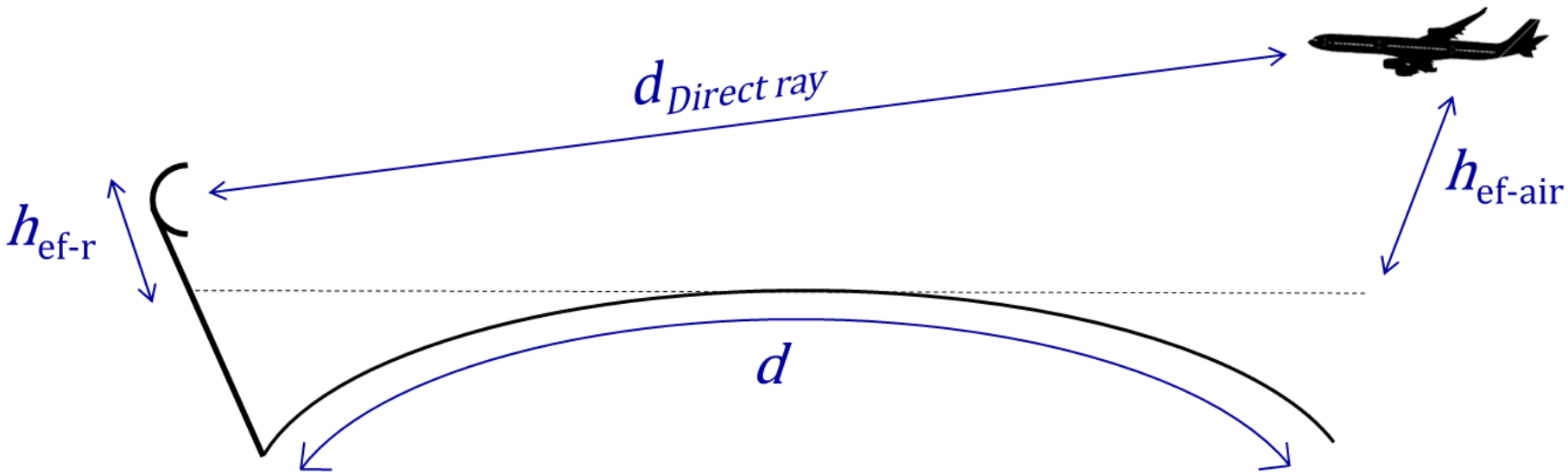
Propagation Models (1)

- For the radar-turbine link:
  - Flat Earth model is used.
  - Deygout model is used to account for terrain attenuation.



Propagation Models (2)

- For the turbine-airplane and radar-airplane links:
  - Spherical Earth Model is used, without terrain attenuation.



Wind Turbine Modelling


Source: 3dlt.com

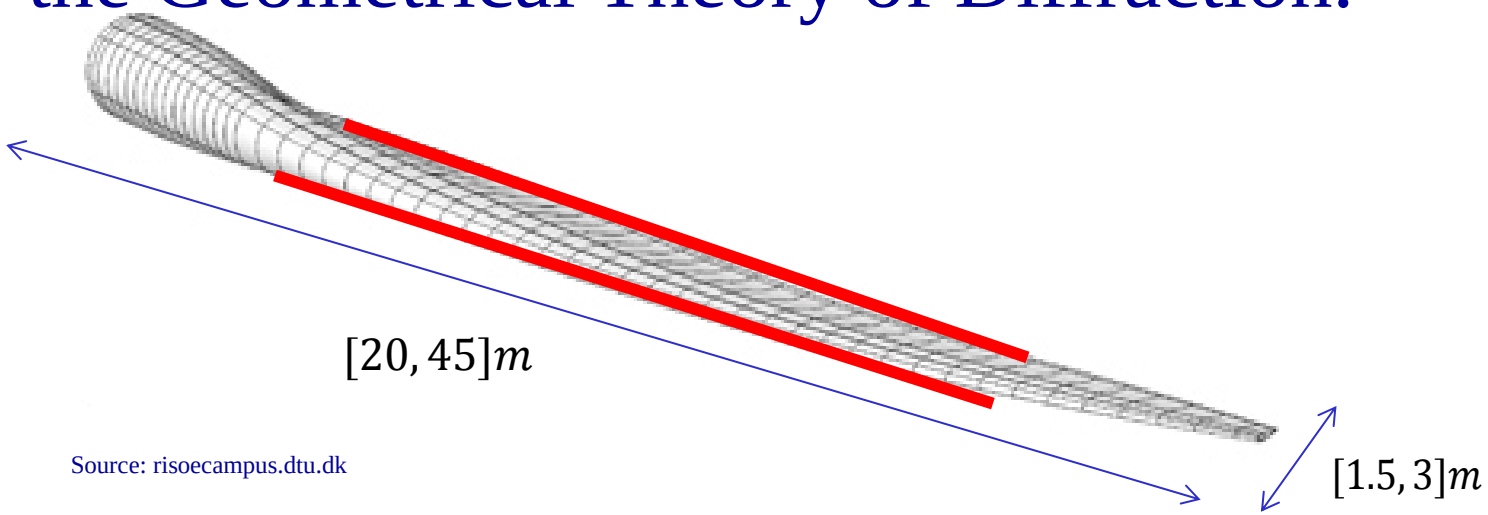
A highly conducting/dielectric thin cylinder assumption for mono-static blades RCS.

Cylinder simplified physical optics approximation for mono and bi-static tower RCS.

- Radar Cross Section (RCS) is a measure of how much energy is reflected from a wind turbine, being very sensitive to the turbine's configuration.

Diffraction on the blades

- The PSR and SSR wavelength is much smaller than both the wind turbine blade diameter and its length ($\lambda_{PSR} \approx 0.11\,m$, $\lambda_{SSR} \approx 0.3\,m$).
- Therefore, it is possible to consider the blade edges as infinite parallel edges, and then, apply the Geometrical Theory of Diffraction.



Source: risoecampus.dtu.dk

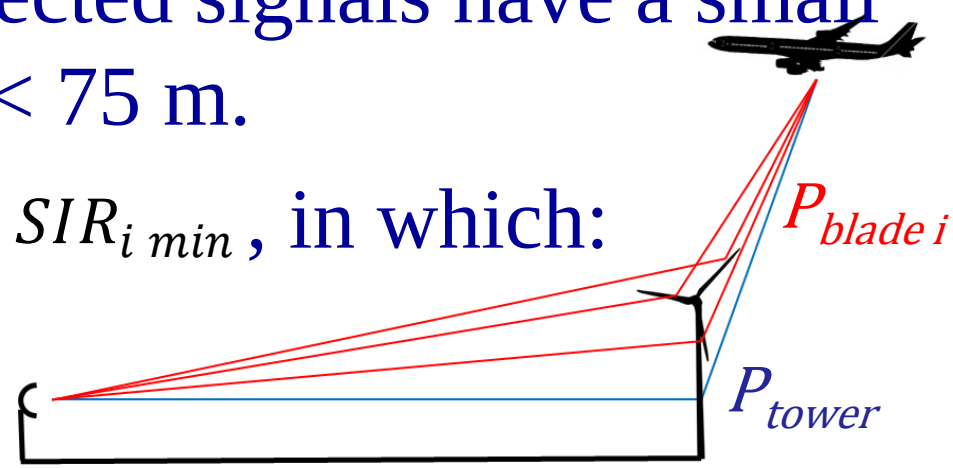
Impact on PSR Performance

- The criteria used to assess the impact created by a WT in the radar LoS are the following:
  - The power level of scattered energy that is less than -9 dB relative to the radar's noise floor will not cause adverse effects.
  - An interference-to-noise, *I/N*, level that is less than or equal to -6 dB will cause few effects.
  - Levels higher than -6 dB may cause measurable losses in desired targets and could cause the generation of some false targets.

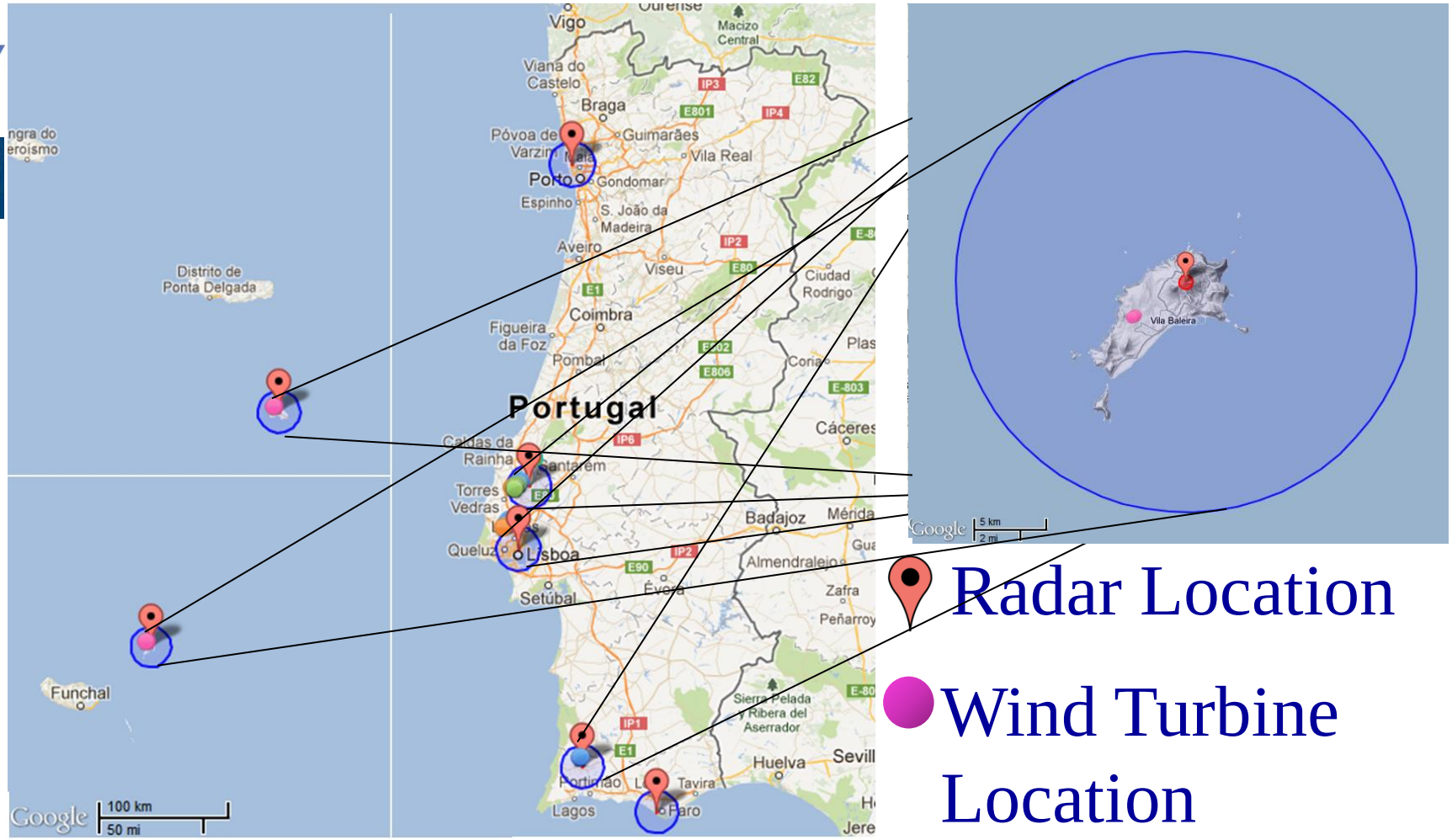
Impact on SSR Performance

- Position errors or false target reports may happen when the following two criteria are met:
  - The difference between direct, P_{direct}, and reflected, I_{WT}, signal strengths is less than the system requirement;
  - The direct and reflected signals have a small path difference of < 75 m.
- One must have $SIR_i \geq SIR_{i\,min}$, in which:

$$SIR_i = \frac{P_{direct}\ [\mathrm{W}]}{I_{WTn}\ [\mathrm{W}]}$$



Scenarios



There are 81 turbines in the interference zone (16 km).

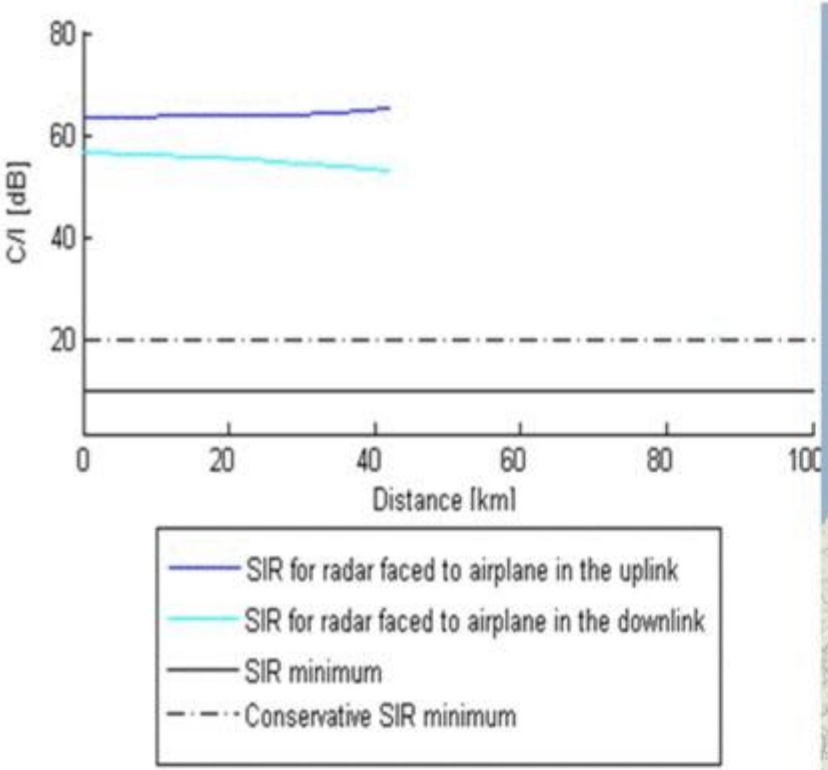
Impact on PSR

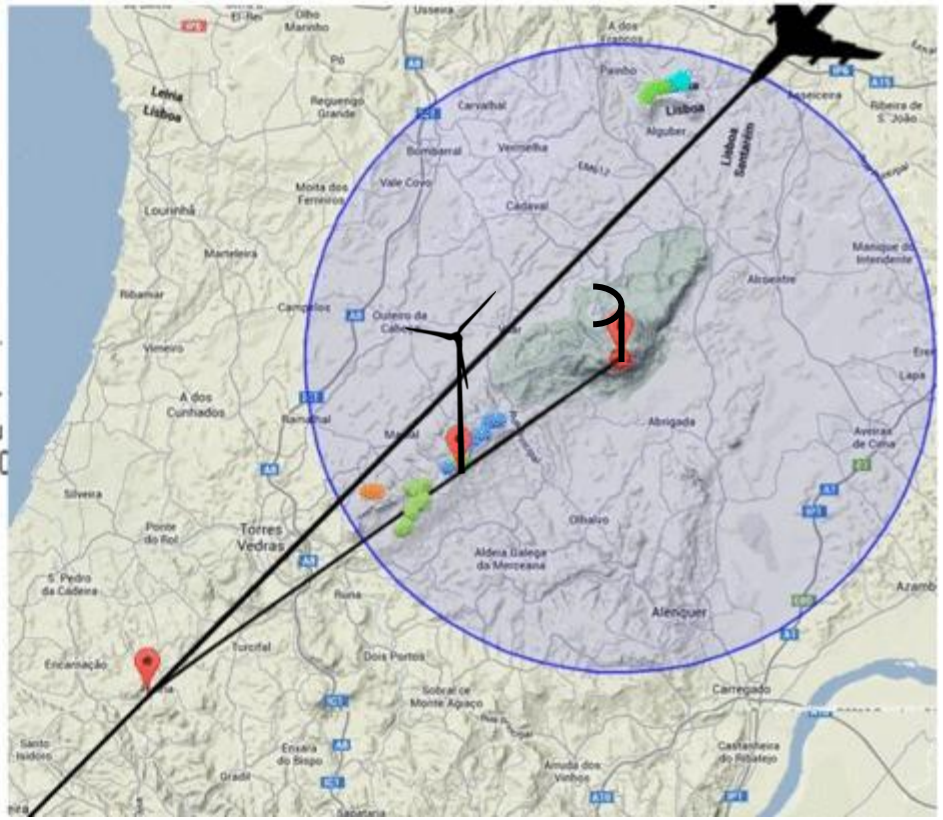
- The maximum radar received power is in [-37.95, -28.60] dBm, far above the threshold, due to the high wind turbine RCS, in [27.67, 36.05] dBsm.
- The values computed for the RCS comply with the maximum one set by Eurocontrol.
- Terrain attenuation has a major role in the impact created by wind turbines on the primary radar, because it affects the signal twice.

Impact on SSR (1)

- When the radar is pointing to:
  - the airplane, the SIR is always above the threshold;
  - the turbine, the SIR is always below the threshold, however, it does not create interference problems due to the Side Lobe Suppression (SLS) implementation.
- Higher Flight Levels (FLs) receive more interference, due to the high radar directivity.

Impact on SSR (2)





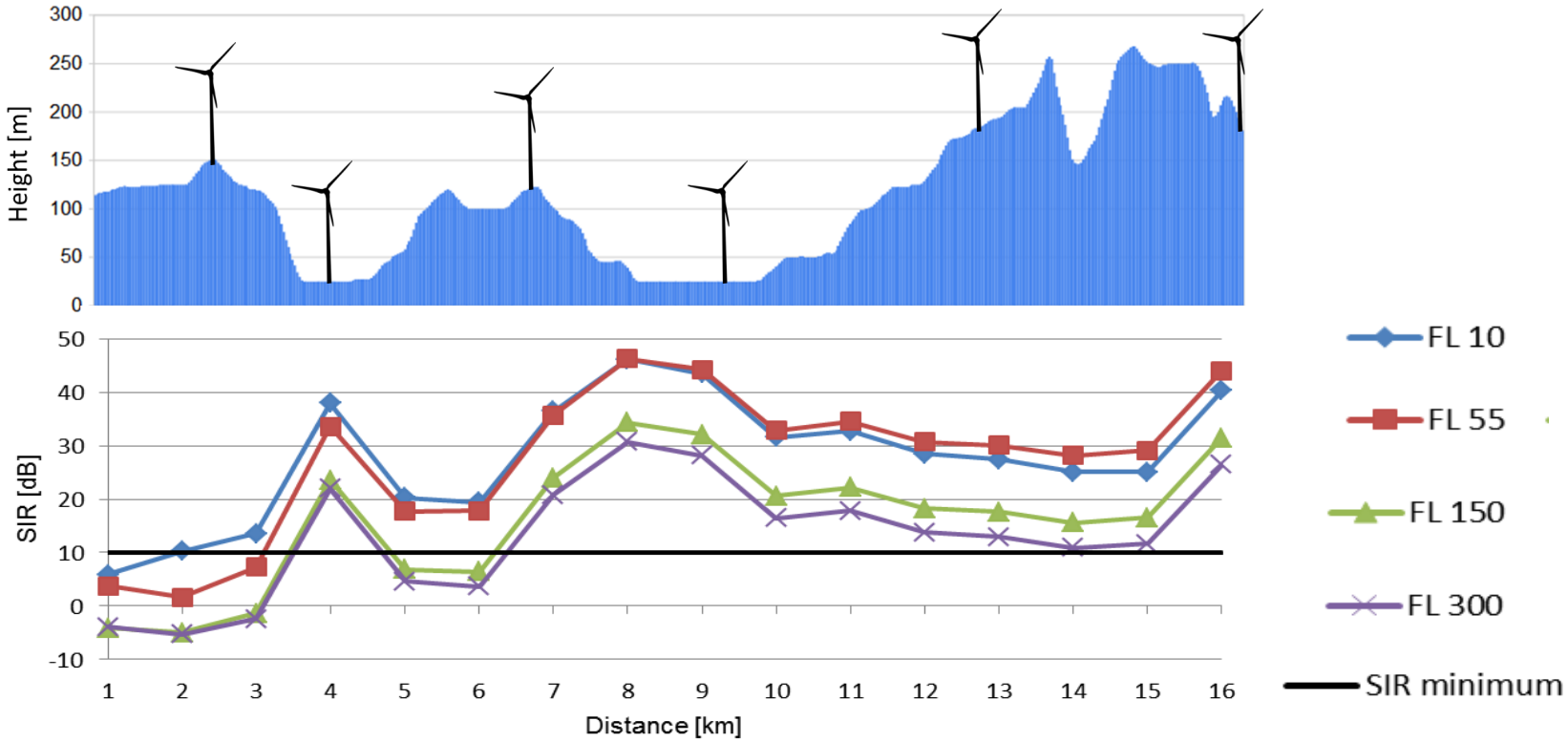
- When the airplane and the turbine lie in the same azimuth it could create measurable interference.

PSR Exclusion Region

- The exclusion region for the primary radar was defined using two different methods:
  - assuming flat terrain (200 km);
  - assuming terrain attenuation (38.5 dB).
- It is necessary to have a clutter rejection filter that can eliminate the clutter coming from wind turbines.
- CAA suggests the replacement of radars software, or to use Adaptive MTI techniques to filter the clutter from turbines.

SSR Exclusion Region (1)

- The surrounding terrain has a major role in SSR exclusion regions. So, they are different for each radar.



SSR Exclusion Region (2)

- An equally exclusion region around the radars was assumed.

Radar	Exclusion Regions [km]			
	FL 10	FL 55	FL 150	FL 300
Lisbon	2	3	7	7
Porto	1	3	6	10
Faro	1	4	7	8
S. Maria	2	2	8	12
P. Santo	2	3	9	13
Foia	1	1	6	9
Montejunto	1	3	6	8

Conclusions

- The objective of this work was to analyse wind turbines interference in surveillance radars, and to define exclusion regions around them.
- A model to quantify the impact on primary and secondary radar was developed, using the wind turbine RCS, and the diffraction on its blades.
- The presence of turbines in radars vicinity can harm the PSR. For the SSR, critical points were identified, and exclusion regions can go up to 13 km.

Thank you for your attention!