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Mitigating Radar Clutter Caused by Wind Turbines by Proper Siting

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Abstract

As wind energy develops quickly, more commercial-scale wind turbines with high tower and large rotor diameter are emerging. These large man-made structures present interference to nearby radars in the form of radar clutter. This newly recognized type of clutter has unique radar signatures, making it difficult to be identified and mitigated. Based on analysing the characteristics of wind turbine radar signatures, several wind turbine siting considerations will be discussed solely from the perspective of radar clutter mitigation.

Thrive of Wind Power

Wind power industry has grown rapidly around the world in the past decade. The total installed wind power capacity reached over 50,000 MW last year, over 10 times of 10 years ago. The development of this green and renewable energy solution not only helps diversify the energy portfolio, but also relieves the dependency on fossil fuel, thus further reduces the green house effect. Countries that demand large electricity consumption such as China, US, Germany, India, etc. are all on the top of the list of annual wind power installation in recent years.

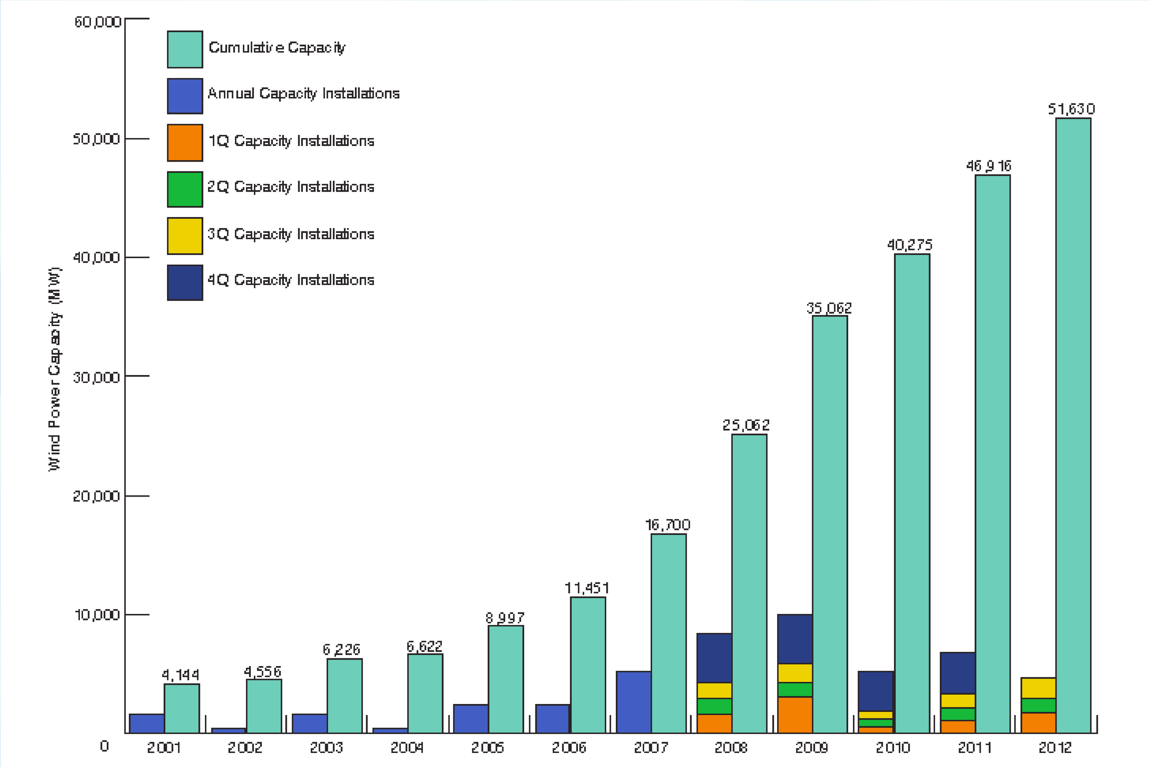


Fig.1 US Wind power accumulative capacity growth: picture from AWEA quarterly market report at www.awea.org

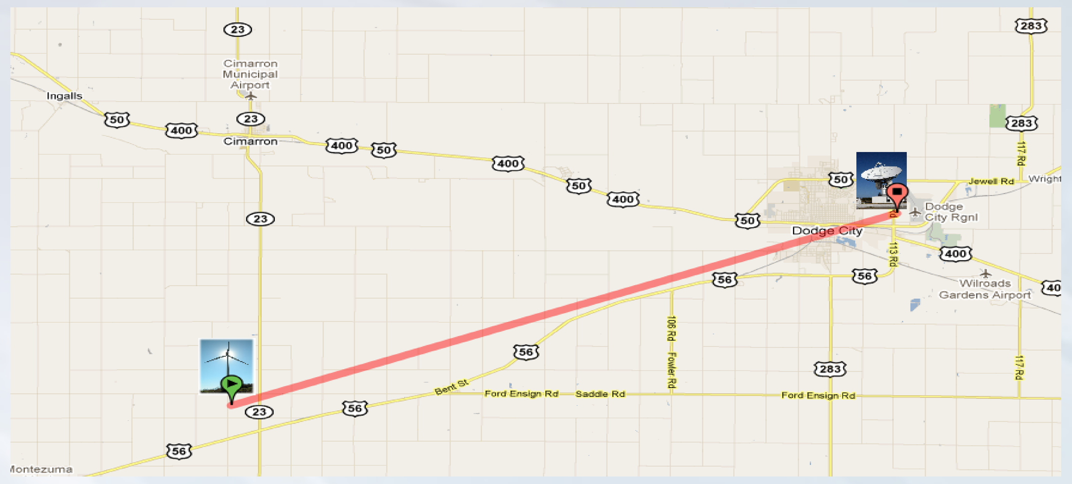
Wind Turbine Impacts on Radar

Radar is the acronym for Radio Detection and Ranging. It sends out microwave signal and captures waves scattered back to the receiver. Radar clutter is the return signal from undesired targets. Wind turbines have recently been recognized as a new type of radar clutter because of the following characteristics:

(1) Extremely large size results high Radar Cross Section

(2) Blade rotation leads to complex spectrum contamination,

(3) The increasing number of wind turbines (farms) creates more cluttered radar data.



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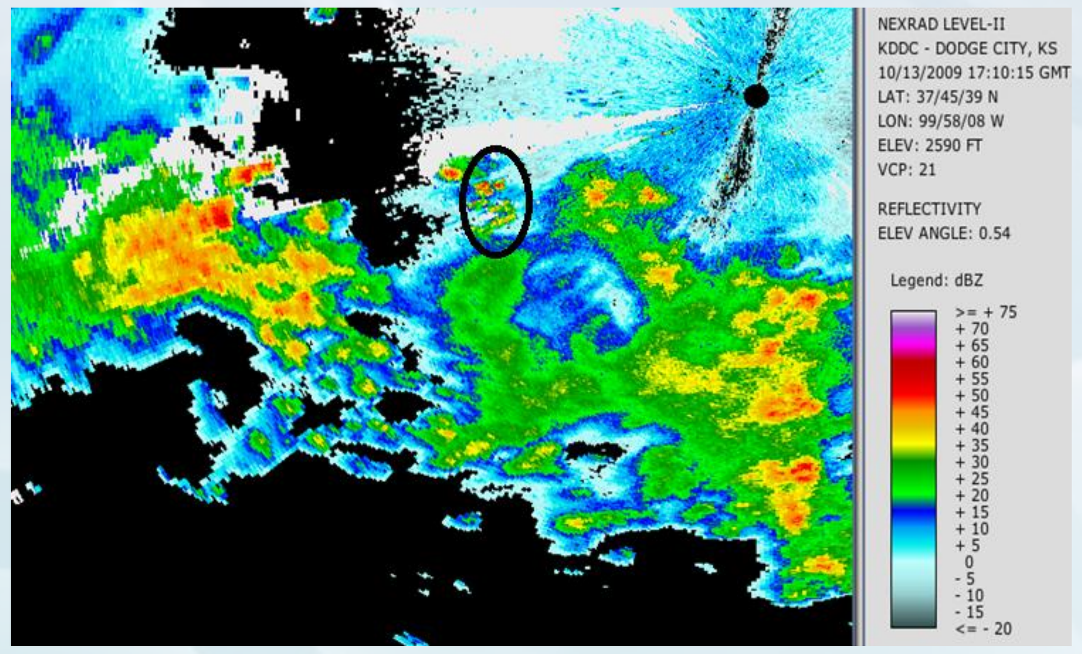


(b)

Fig.2 Example of radar clutter caused by wind turbines: (a) map showing the relative location of the wind farm to the radar; (b) Radar reflectivity estimates showing the wind farm (circled in black) and storm

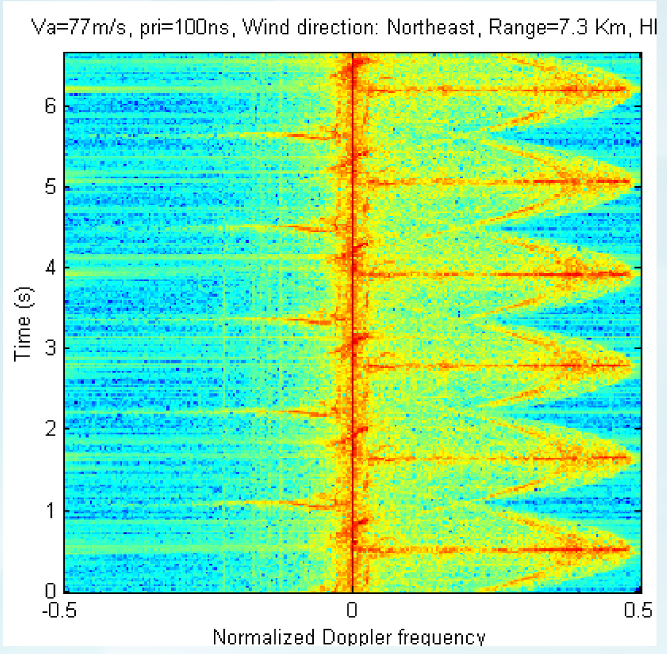


Fig.3 Time evolving Doppler spectrum of a wind turbine. Data collected with mobile radar operating in spotlight mode dwelling on the radial where there is a wind turbine

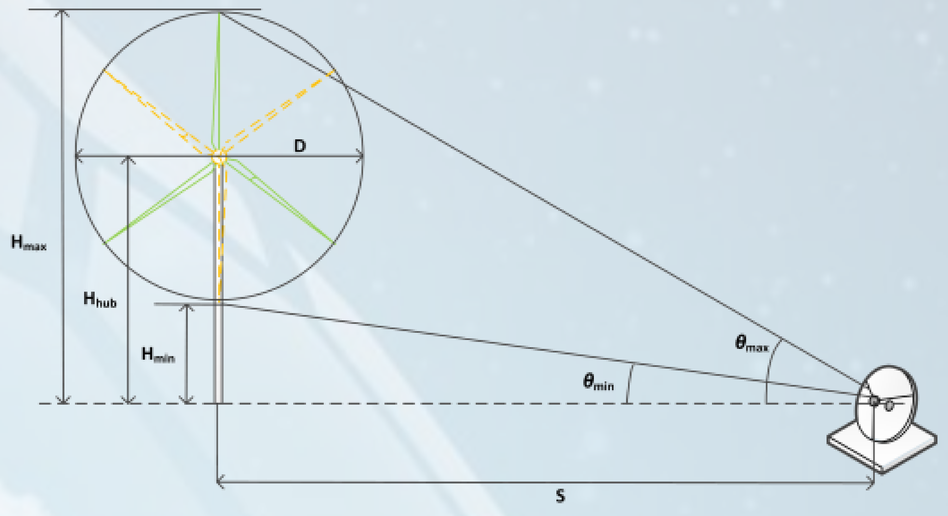
Conventional ground clutter filter techniques based on notch filter have failed in mitigating the Wind Turbine Clutter (WTC). Several mitigation solutions have been proposed, including but not limited to : gap-filler radar, stealth wind turbine, signal processing, etc.

Wind Farm/Turbine Siting Considerations

The siting of wind farm/turbine depends on many factors: wind resource, land cost, etc. However, it will only be discussed here how to proactively locate the wind farm/turbine to mitigate the WTC effect on radar.

A. LOS(Line of Sight) Avoidance

Radar beam propagates progressively higher above the ground due to earth curvature. If the visible elevation angle range of the wind turbine to the radar is outside the radar elevation scan, then the wind turbine is out of radar LOS and WTC will be avoided under normal atmospheric conditions.



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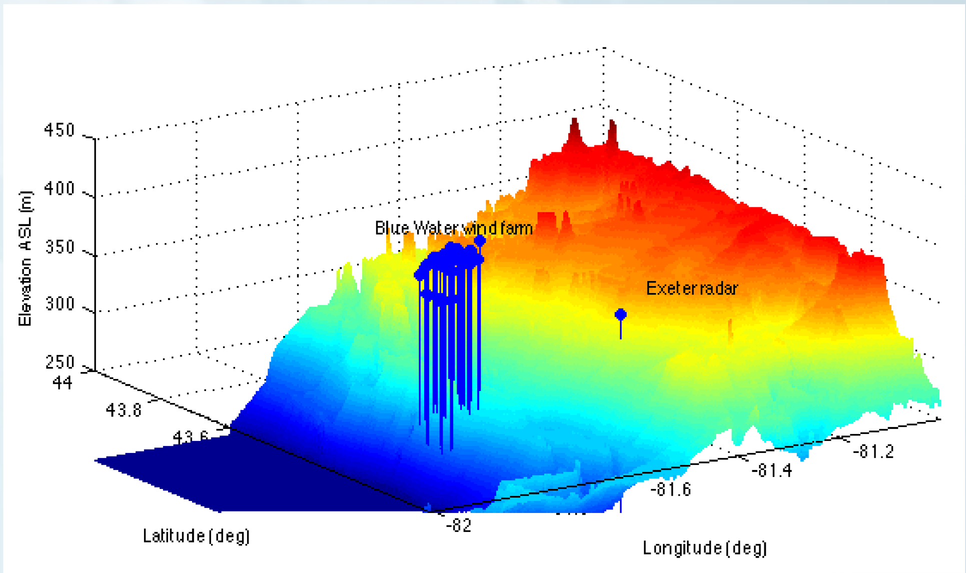

(b)

Fig.4 Example of LOS avoidance analysis: (a) the visible elevation angle range of a wind turbine to the radar, (b) 3D view of a proposed wind farm on top of DEM

B. Range Adjustment

The further away the wind farm is , the more possible it will be out of radar LOS. However, due to other constraints, it is now always feasible to build wind farms at far distance of radar . Because wind turbine is electrically large, its RCS varies with range as it falls in the Fresnel field of the radar. Thus, conventional definition based on far field assumption will mostly end up over-estimating. Using the range variation to properly choose the range close to the valley as in Fig.5, WTC can be suppressed by over 10 dB.

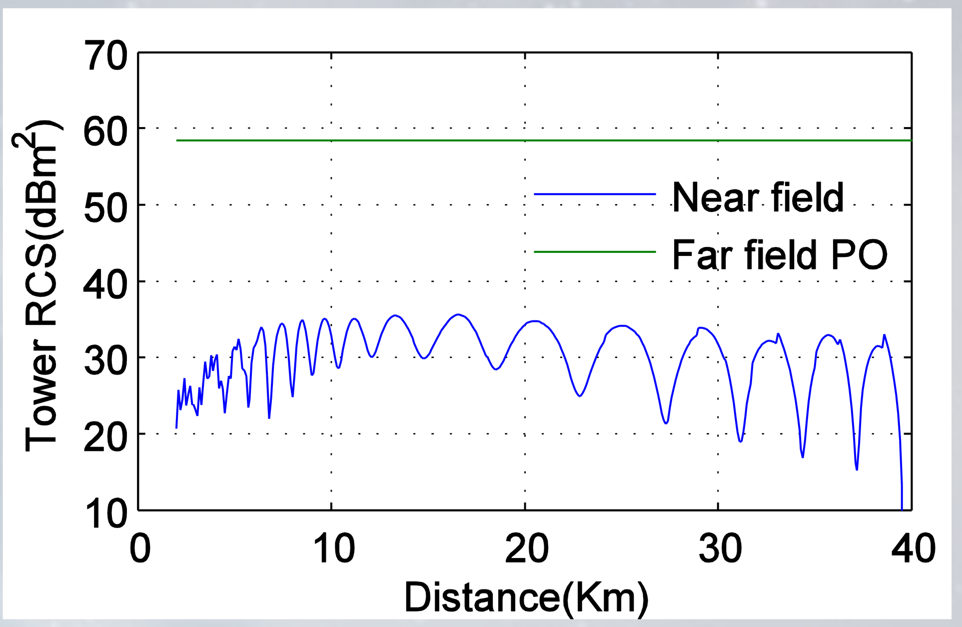

Fig.5 Broadside RCS of wind turbine tower versus distance

C. Azimuth Selection

Wind turbine slowly yaws to the wind direction to keep the blade facing into the wind for maximum efficiency. The RCS of wind turbine also changes as this yaw motion alters the aspect angle of the wind turbine w.r.t. the radar. Fig.6 shows the statistics of the RCS of wind turbines varying with the wind direction/ aspect angle. It is obvious that the RCS peaks at aspect angle of 0 and 180 degrees when the rotation plane is perpendicular to the radar beam. Referencing to the local wind rose, if the wind farm can be sited to mange a smaller averaged RCS, the clutter level will be lower.

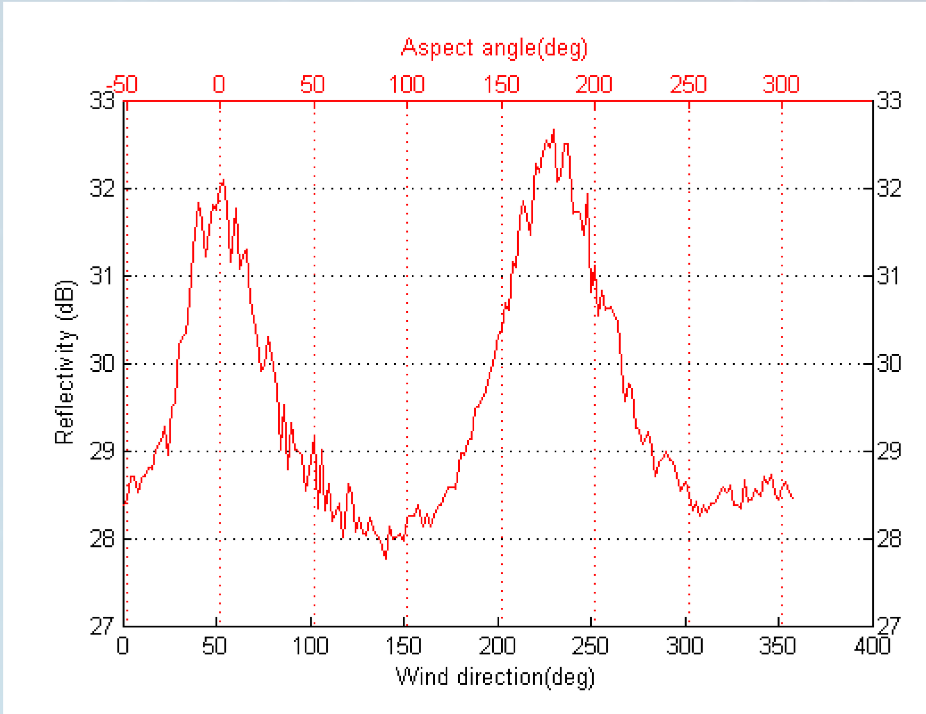

Fig.6 Wind turbine Reflectivity variation with wind direction /aspect angle

Conclusions

Wind turbines cause clutter effect to nearby radars. Several mitigation solutions regarding to siting have been discussed. It has been shown that by proper siting, wind turbine clutter can be reduced and the proposed siting considerations will actually give more freedom in areas close to radars.

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