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Overview of Remcom's Research Into the Impact of Wind Turbines on Radar Returns

Wind turbines located near a radar installation can significantly interfere with the ability of the radar to operate properly. Remcom has used our tools and expertise in radar scattering to perform a number of government-funded and internal research efforts into the impact that wind turbines and wind farms have on radar returns for Air Traffic Control (ATC) radar, early warning radar, weather radar, and instrumentation radar. We have also teamed with partners to investigate methods to mitigate this effect.

Our work and experience have included:

- Estimation of returns from wind turbines, including Doppler and RCS
- Collaborative work with partners to determine the impact of wind turbine scattering on radar signal processing, aircraft detection, and tracking
- Investigation of the effects of multipath between the tower and blades
- Investigation of the effects of blade shape, material properties, and construction on returns
- Prediction of the loss due to shadowing of aircraft from nearby turbines

Highlights of some of these effects and relevant samples and white papers are provided below.

The Effects of Wind Turbines on Radar Returns

Remcom has investigated methods for modeling the impact that wind turbines and wind farms have on radar returns. In 2010, Remcom used our XGtd electromagnetic analysis software along with novel post-processing techniques to simulate the magnitude and Doppler shift that would occur from radar pulses at various angles of incidence relative to the plane of rotation of the spinning blades. The rotation of the blades results in a Doppler shift that varies sinusoidally with time, as shown in Figure 1. A summary of some of this work was presented at MILCOM 2010.

(See Remcom's MILCOM 2010 whitepaper, *Modeling the Effects of Wind Turbines on Radar Returns* for complete details)

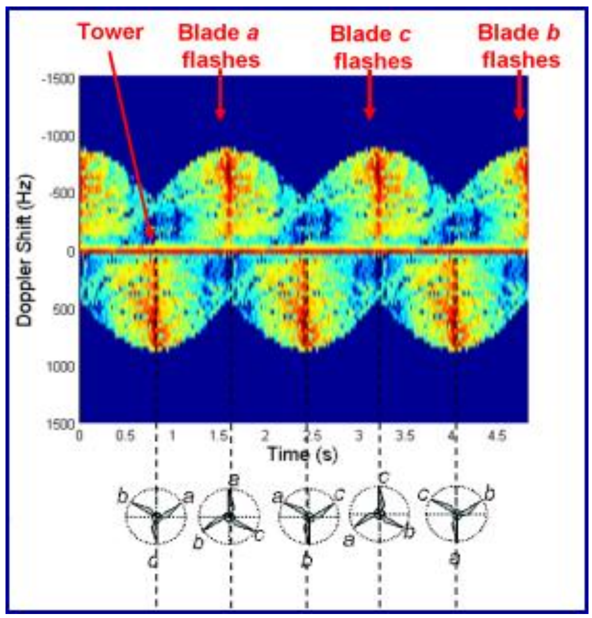


Figure 1: What a radar sees: RCS & Doppler vs. Time

Wind Turbines and Aircraft in the Presence of Ground Clutter

Remcom has teamed with partners on multiple different research efforts to investigate the impacts of wind turbines on radar scans. Because wind turbine blades are large and move at a speed similar to slower aircraft, as aircraft fly over a wind farm, the aircraft tracks can be lost, and false tracks can be generated from wind turbines that are incorrectly interpreted by the radar as aircraft.

The images in Figure 2 are from an animation showing predicted RCS from an air traffic control radar with an aircraft flying over a wind farm, before and after the static ground clutter (returns from terrain) are filtered out. The animation is the result of a large number of simulations using Remcom's tools and prototypes that combine the following:

(a) Propagation to aircraft and wind turbines over terrain

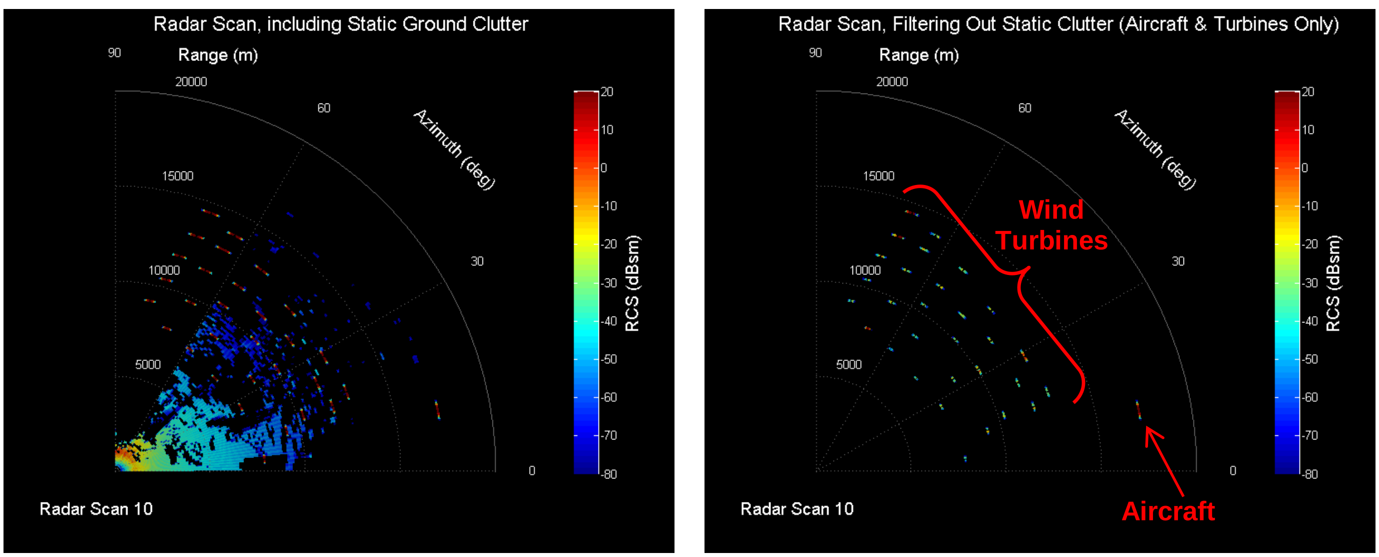
(b) Calculation of clutter backscatter from terrain based on materials and angles of incidence

(c) Calculation of backscatter from wind turbines and blades according to their blade rotation angles at the time of each radar scan, using XGtd

(d) Inclusion of aircraft Doppler as it flies across the scene

A basic filter has then been applied to remove the portions of returns with 0-Doppler (static clutter from the ground and wind turbine towers) to approximate what a radar might see after attempting to filter out objects not in motion. Although actual radars have much more sophisticated signal processing, this basic before/after animation of RCS from subsequent scans shows the problem that standard Doppler filtering would encounter when processing returns from a wind farm.

(see Remcom's video *Wind Turbines and Aircraft in the Presence of Ground Clutter* to watch the full animation)



(a) Including static clutter

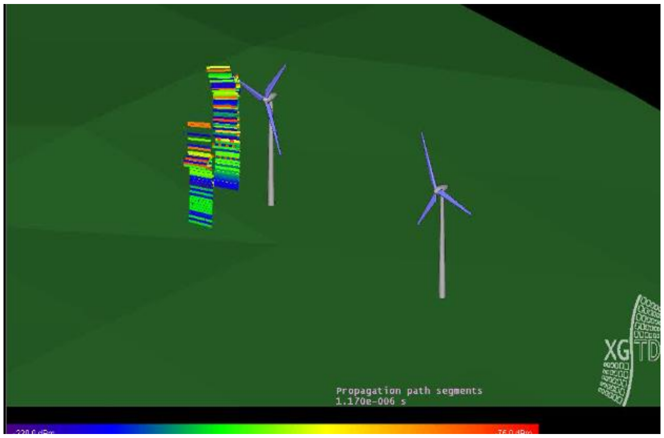
(b) After 0-Doppler filtering (aircraft and wind farm only)

Figure 2: Radar returns from aircraft, wind turbines, and static ground clutter

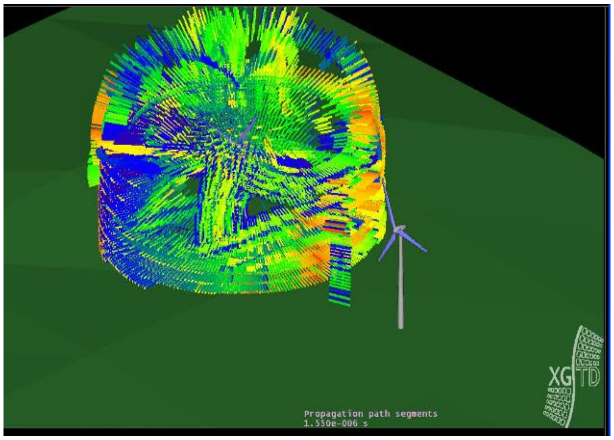
Simulating Multipath Between Wind Turbines

Using XGtd, Remcom engineers can simulate the propagation paths of fields interacting with two wind turbines in close proximity. XGtd then generates an animation that shows the directions and magnitudes of the strongest propagation paths, including multipath occurring between the turbines. The images in Figure 3 are from an animation showing the directions and magnitudes of the strongest propagation paths from scattering between two wind turbines.

(see Remcom's video *Simulating Multipath between Wind Turbines* for the full animation)



(a) Approaching radar signal



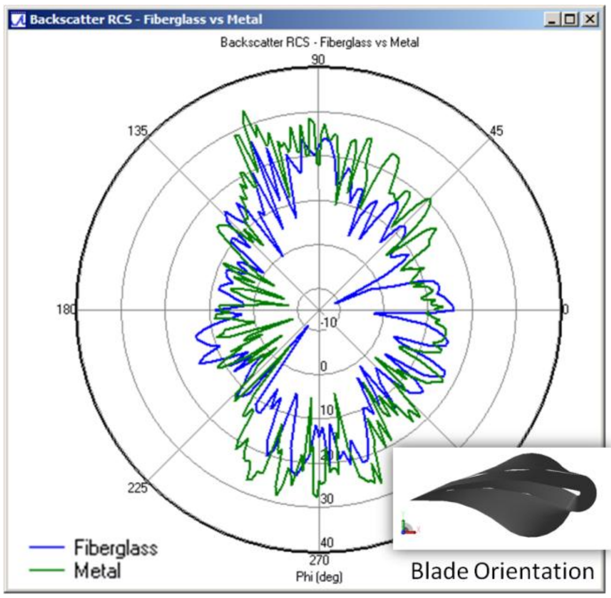
(b) Scattering from first wind turbine

Figure 3: Fields scattering from wind turbines

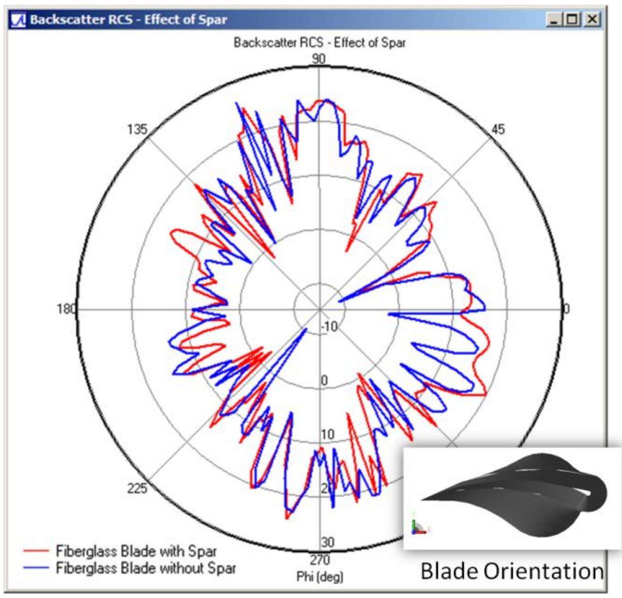
Modeling of Wind Turbine Scattering and Structural Effects in High Fidelity

On multiple projects, Remcom has used our XFdtd full-wave EM solver and XGtd high-frequency solver to predict the scattering from wind turbines and wind turbine components, to include towers, nacelles, and blades. Some recent research has included investigation of blade materials. Some sample comparisons of backscatter from a wind turbine blade for different structural materials are provided in Figure 4.

(see Remcom's presentation *High-Fidelity RCS Simulation of a Turbine Blade* for more details)



(a) Metal vs. Fiberglass



(b) Fiberglass blade, with and without a spar

Figure 4: Comparing backscatter RCS from wind turbine blades for different materials

Shadowing from Nearby Wind Turbines

For wind turbines very close to a radar, wind turbine shadowing can also reduce the returns from aircraft that fly behind the wind turbine, where shadows of several dB may hamper the probability of detection of the aircraft, perhaps causing tracks to be lost and adding to the impact caused by the interference from wind turbine returns described above. Figure 5 shows an example of shadowing behind the tower and blades of a wind turbine.

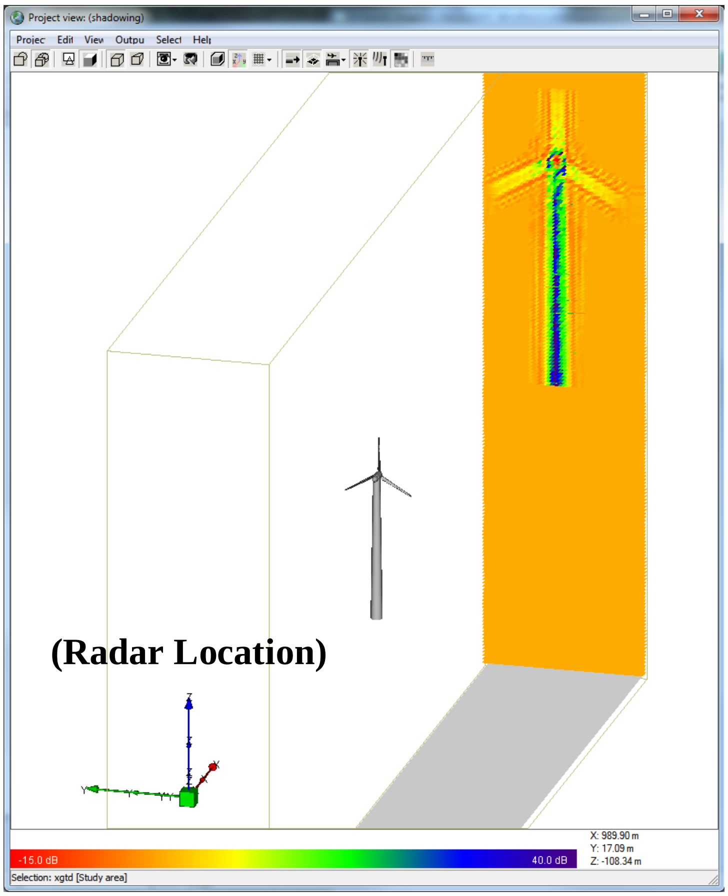


Figure 5: Plot of forward scatter from a wind turbine close to a radar, resulting in shadowing loss

For more information on Remcom's wind energy capabilities and research, contact us at sales@remcom.com or 814-861-1299.

Additional information can also be found on our website at www.remcom.com.