

■ **Wind Farm Analysis:
Potential Interference
Effects to Primary
Surveillance Radar**

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Objective

According to the American Wind Energy Association [1], wind energy accounted for 35,000 megawatts of generated power in the United States as of the end of 2009, accounting for roughly 2% of total power generated in that year. Of the current 35,000 megawatts of capacity, 10,000 megawatts were brought online in 2009 alone. This substantial increase mirrors that of the near 32% worldwide growth rate for wind farm electricity output.

As wind turbines continue to increase in size and wind farms further populate the landscape, radio communications interference analysis become imperative. Due to the large size and metallic construction of the wind turbines, they potentially create interference for radar installations in the form of shadowing, target loss, false target generation, multipath, general noise level elevation, and multiple scatterings.

Automatic Import of Wind Turbines

Wind turbines have highly variable RCS (Radar Cross Sections). That is, how ‘large’ a wind turbine appears to radar depends on wind speed, wind direction, and turbine blade orientation, among other factors. The RCS size of a wind turbine has a direct effect on the amount of interference it causes to radar systems. Local terrain elevations, radar antenna patterns, and any clutter that may be in the area—factors that are analyzed in HTZ Warfare—further determine potential interference effects.

A list of candidate wind turbine sites is entered for automatic placement in HTZ Warfare with parameters including RCS, location by latitude and longitude, and other information.

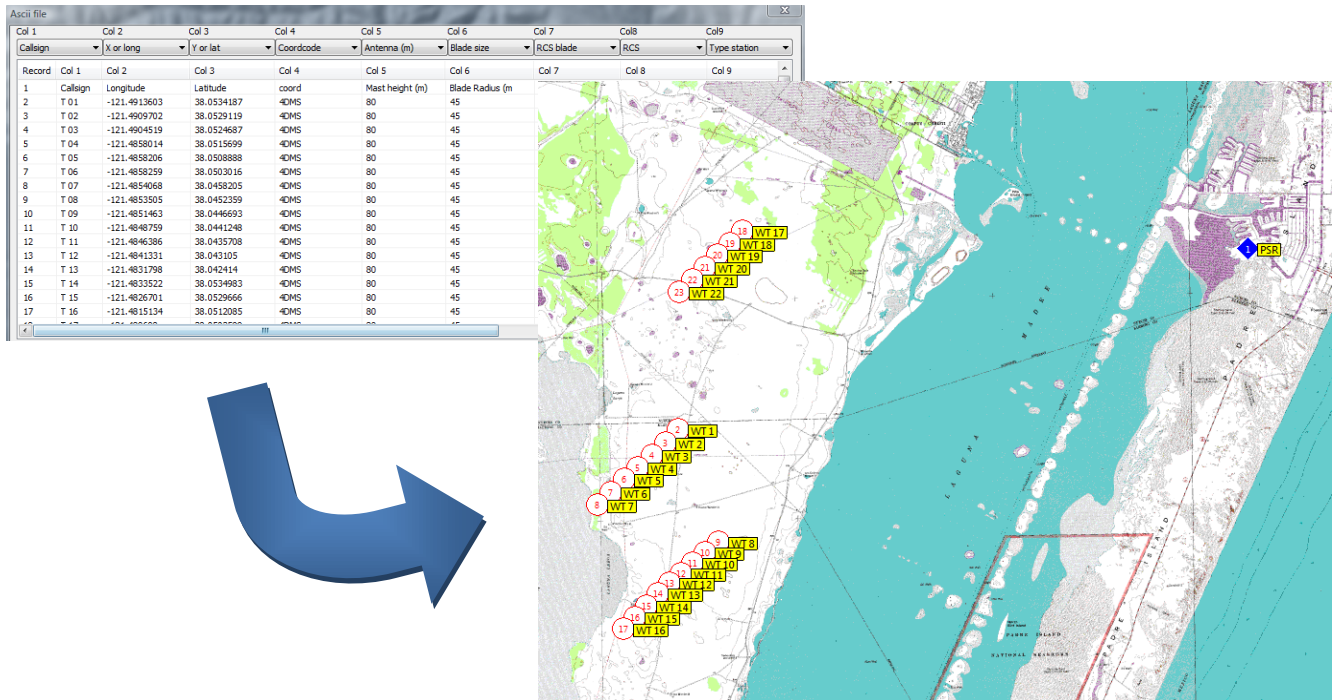


Figure 1: Importing Wind turbines to HTZ Warfare



Once wind turbines are entered, their parameters may be edited using the Wind turbine parameters window. A radar is then set up and its parameters are entered as well. Screenshots of both windows are below.

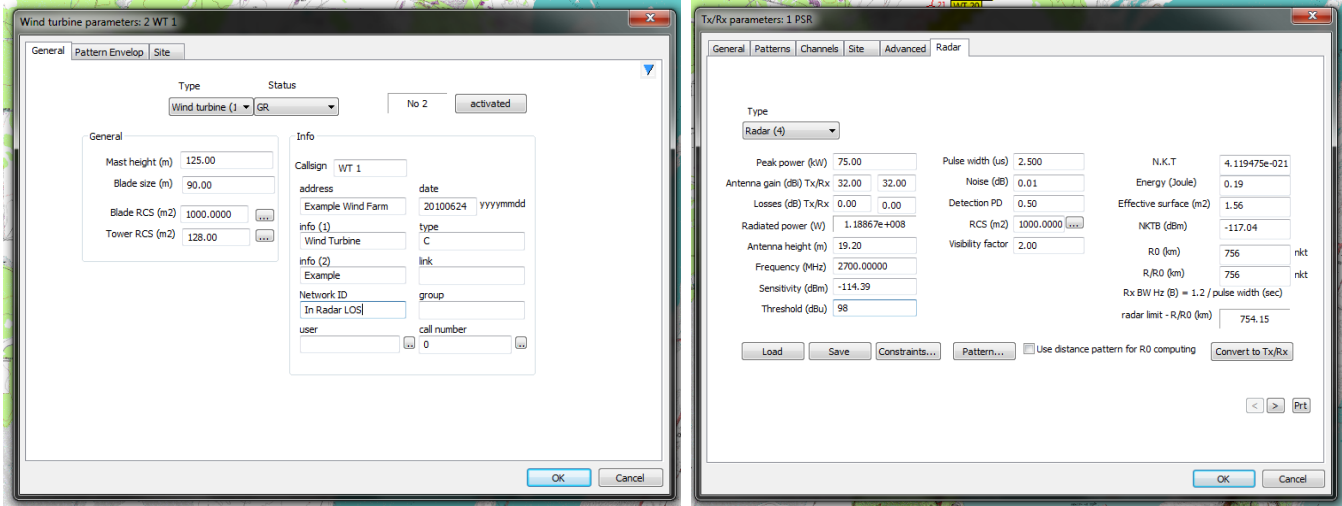


Figure 2: Wind turbine parameters window & Tx/Rx parameters window

Wind Turbine Interference Effects & Calculation Methodologies

There are three interference effects of main interest: shadowing, target loss, and false target creation. In shadowing, a wind turbine appears within radar line-of-sight and casts a shadow region behind it of lesser electromagnetic energy when it is illuminated by the radar signal. When airborne targets are located within this area of decreased electromagnetic signal, they are much less likely to be detected. HTZ Warfare allows for the graphical display of the widths and heights of the shadow regions.

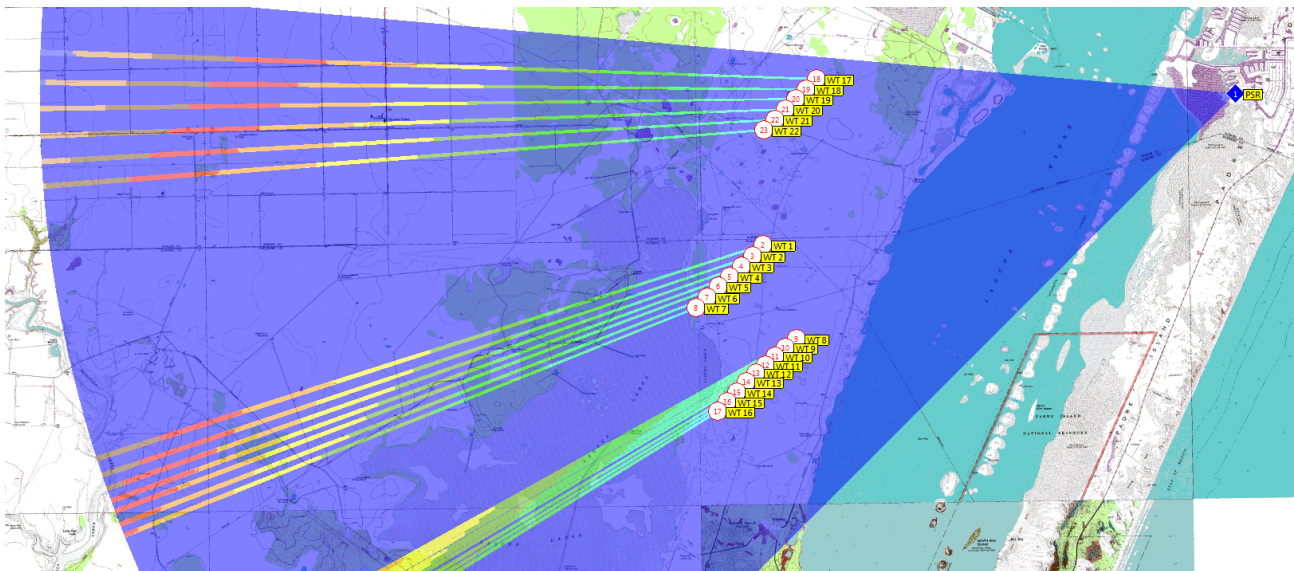


Figure 3: Wind turbine shadow analysis



In the figure above, the varying colors of the shadows represent the height of the region at that point. The heights obtained can be compared to aircraft flight altitudes within the region to determine whether aircraft can be lost within them. Point-to-point analysis is also possible. In the figure below, direct radar line-of-sight is displayed between radar and the top of a wind turbine. The ovalar region around the line-of-sight path represents the first Fresnel zone.

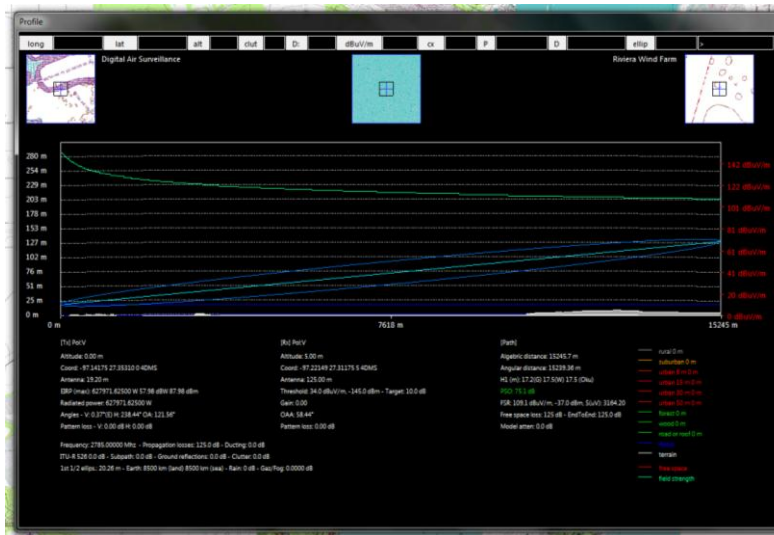


Figure 4: Line-of-sight analysis in HTZ Warfare

Target loss is a direct result of strong clutter returns. When an airborne target is within close azimuth and range proximity to a wind turbine and both are illuminated by radar, the wind turbine tends to reflect a much greater amount of electromagnetic energy back to the radar receiver. The strong clutter return from the wind turbine may then overwhelm the receiver to the point that the return from the target aircraft is not detected. The amount of clutter return to radar by each individual turbine is calculated using the Wind turbine interference report in HTZ Warfare, as seen below.

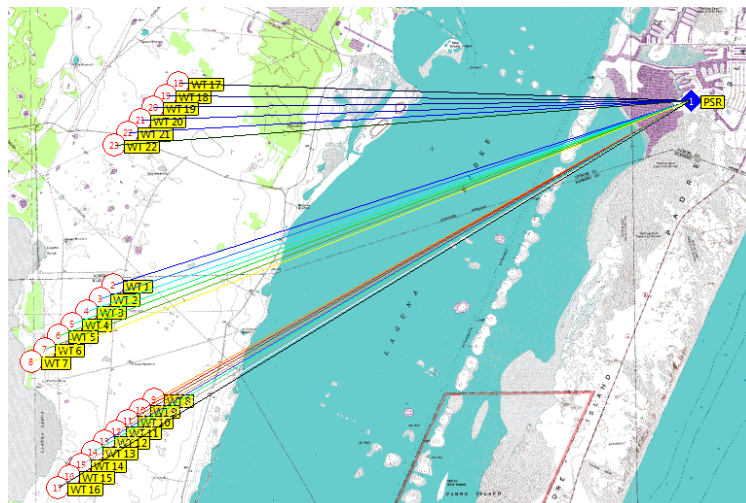


Figure 5: Wind farm clutter return analysis



The Wind turbine interference report yields a spreadsheet that lists the amount of power returned from each wind turbine for both the turbine’s stationary element (the tower) and the turbine’s moving elements (the blades and nacelle). Comparing these values with the radar performance threshold and power returns from airborne targets then reveals the severity of the possibility for target loss.

False target generation is the last of the main interference effects caused by wind turbines to primary surveillance radar. Even though modern radar has the ability to eliminate stationary clutter returns from objects that do not change their position, such as buildings and vegetation, it is the moving element of the turbines—their blades—that potentially trick the radar into interpreting the turbines as moving targets. The issue is further complicated by the varying RCS of the wind turbines. Two neighbouring turbines may be individually illuminated by radar during consecutive sweeps of the detection area. Due to the Doppler frequency shift the moving blades impart on the reflected energy and the spatial difference between the locations of the two turbines, a false target may appear on the radar operator’s screen. Since the effect is temporary and the number of turbines is limited, the turbines appear to ‘twinkle’ on the radar screen. If the turbines are close to the radar and the radar antenna has high enough gain at all points of its antenna pattern, ‘twinkling’ may occur at any radar azimuth at a distance equal to that between the turbine and the radar installation.

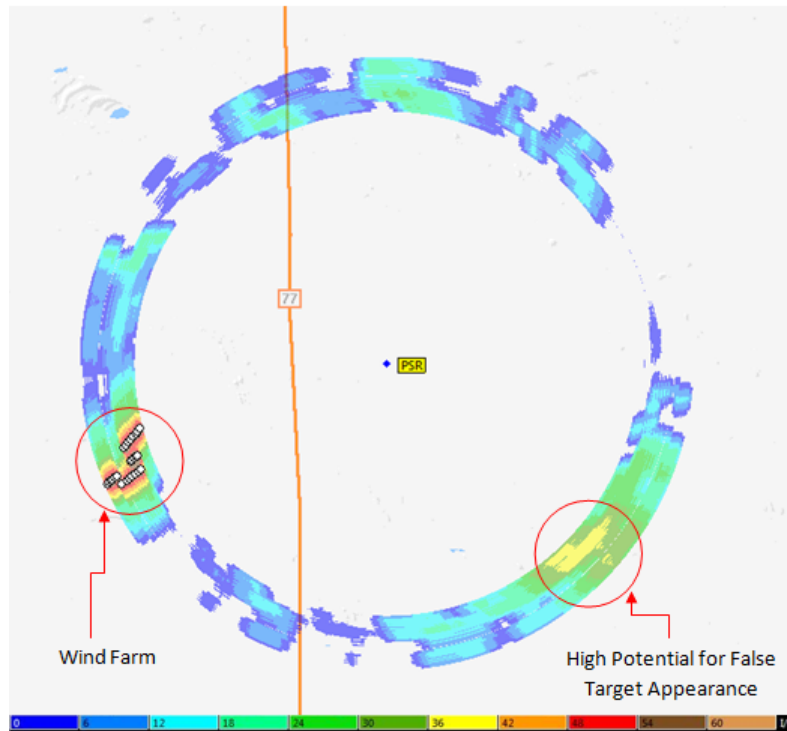


Figure 6: Areas of potential false target appearances

The above figure displays the areas where false targets are likely, taking into account the radar antenna pattern and variations in the local terrain. This feature—unique to HTZ Warfare—offers high-resolution analysis of potential false target generation. Areas of brown/red/yellow are more likely to see the creation of false targets than areas of blue and green. The appearance of false targets may hinder the radar operator’s ability to



distinguish between real and fake targets and may ultimately lead to general radar performance degradation in the form of increased noise levels.

Conclusion

As wind turbines become commonplace all over the world, the distances between turbines and radar installations shrink. The closer turbines get to radar, the greater is the intensity of interference effects experienced by the radar. In addition to general noise level elevation and complicated multiple scatterings possible within wind farms, turbines cause the formation of shadow regions, the loss of airborne targets, and the creation of false target plots. Thus degraded, the performance of radar may not be satisfactory to guarantee safe air space operation.

References

- [1] American Wind Energy Association, "AWEA Year End 2009 Market Report," January 2009.

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