OPTIONS FOR MITIGATION OF THE EFFECTS OF WINDFARMS ON RADAR SYTEMS

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Abstract

This paper follows on from a previous paper 'Windfarm characteristics and their effect on radar systems' [1] and considers various options for the mitigation of these previously described windfarm effects. Options include physical barriers to radio propagation, modifications/upgrades to existing radar, new radar designs and data fusion schemes utilising data from multiple sensors.

1 Introduction

In general, the effect of windfarms within radio line of sight of a radar (without any mitigation measures) is to reduce the performance of the radar in the following ways:

- Increased numbers of unwanted turbine returns (false alarms)
- Reduced detection performance against wanted targets such as aircraft
- A consequent reduction in the wanted target track integrity

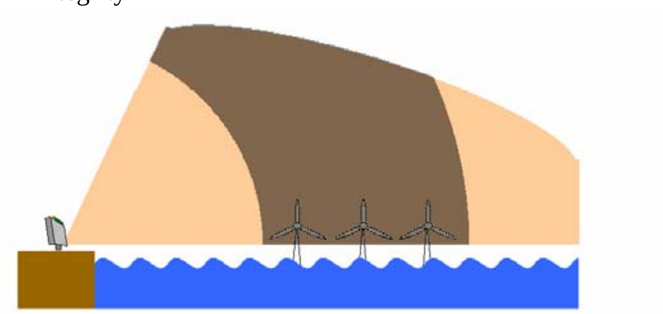

Figure 1 Windfarm affected zone

Although these are the result of various physical and radar systems effects, as described in [1], they are generally limited to the locale of windfarms or the immediate vicinity within a few kilometers. Depending on the detailed design of the radar, some effects may also be expected at extended ranges or azimuths either side the windfarm.

2 Single sensor mitigation options

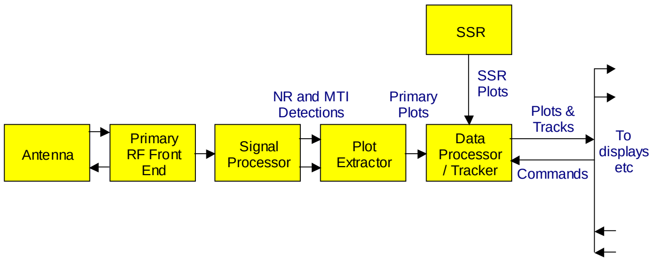

Figure 2 Radar system block diagram

2.1 Antenna design for low sidelobes (AZ&EL)

The advent of digital antenna design has lead to improvements in modern antenna sidelobe patterns. Figure 3 illustrates the sensitivity pattern for a modern ATC radar antenna.

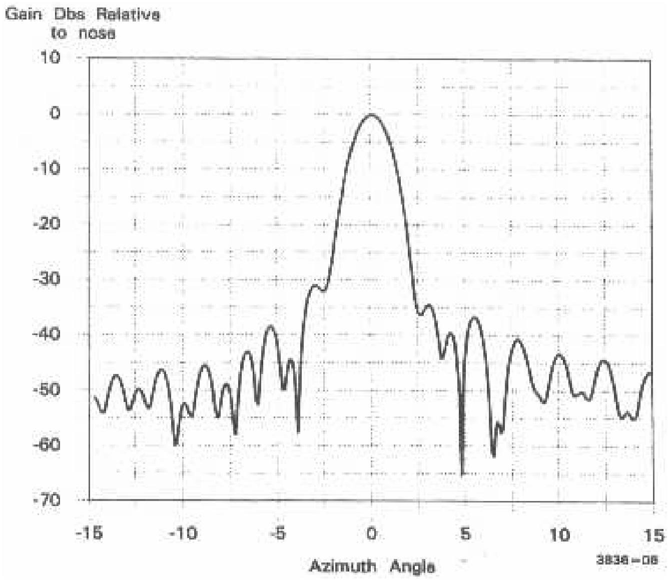

Figure 3 Typical one-way antenna sensitivity pattern for a modern carbon fibre composite antenna

{Will include an analysis of elevation sidelobes in 3D radar and methods of minimising them}

2.2 Antenna tilt

{Analysis of feasibility of using tilt to reduce windfarm effect on radar}

2.3 RF front end receiver dynamic range

Modern component typically have improved dynamic range over those used in older radar systems, the possibility of saturation and limiting is much reduced in modern systems but does still exist in the older radar systems. Receiver system upgrades would address this issue.

2.4 SPU

{Lots of detail here on alternative signal processing algorithms to minimise the extent of the windfarm affected zone}

- Short Pulses
- 12-14bit ADC - better dynamic range less likely to limit
- Nothing really possible for MTI/MTD due to low PRF of surveillance radar
- CFAR (edited BA, 2D&3DHRCM - some clever algos and modelling results to support the analysis) These algos will actually be built into the latest generation BAE Systems Insyte Air Defence radars.

2.5 Tracker/Data processor

{Lots of detail here on alternative plot and track filtering options}

- Non Auto Initiation (NAI) zone - ok but not great
- Plot / Track filtering - much better but still a bit limited
- More sophisticated algos…Advanced Digital Tracker - incorporates algos specifically to deal with WF

These plot and track filtering algorithms have been demonstrated in a number of radar / windfarm trials [Refs] to eliminate nearly all of the unwanted turbine clutter returns (false alarms). They do not improve the detection performance on small targets above windfarms. However, if some simple changes to SPU detection threshold control logic were made to allow improved target Pd (at the cost of increased Pfa) the extra false alarms could also be removed with by the plot/track filtering thus exposing genuine wanted target detections to be displayed and tracked.
The ADT plot/track filtering option could be an ‘add-on’ to any affected radar system with very few, if any, intrusive modifications.

3 Physical obstructions - terrain and/or clutter fences

3.1 Terrain

{Some results of terrain propagation studies}

3.2 Clutter fences

A number of studies have been carried out and published regarding the use of radar clutter fences [5][6][7] in addition to an internal unpublished Insyte study [8]. It has been shown that a clutter fence in the far field can be effective at reducing unwanted returns from low elevation clutter.
Some of the earliest clutter suppression fences were designed for the Nike-Zeus Acquisition Radar (ZAR) and the Multi Function Array Radar (MAR) at White Sands Missile Range in America, where several mountain ranges in the vicinity constituted a very severe clutter environment (particularly since some of the rocks have a high ferrous content). The MAR clutter fence, illustrated Figure 4, is also tilted outward to reduce the effect of coupling directly between transmitter and receiver via a fence reflection.
The suppression of low elevation clutter returns, using a clutter fence in the far field, is limited by diffraction effects over the top edge of the fence. The electromagnetic propagation losses (clutter suppression) over a diffracting knife-edge are a well understood phenomenon and methods for calculating them have been published. For the purposes of this study, the methods presented in ITU Recommendation ITU-R P.526-8 [9] have been used to estimate diffraction losses over such a knife-edge clutter fence.

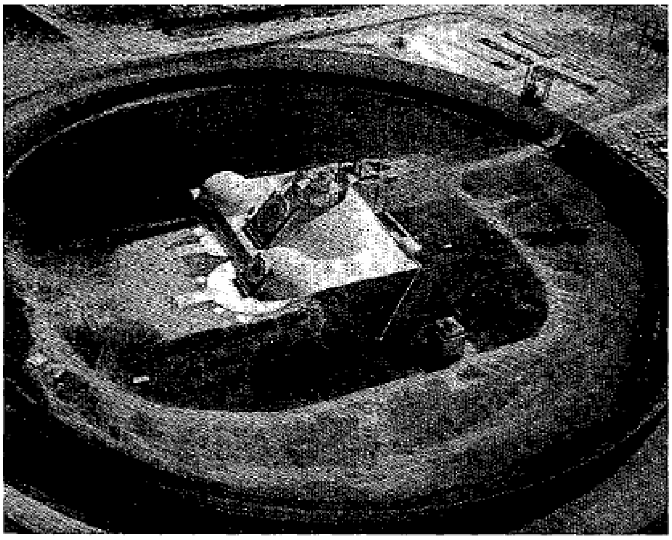

Figure 4 Clutter suppression fence for MAR installation at White Sands [5]

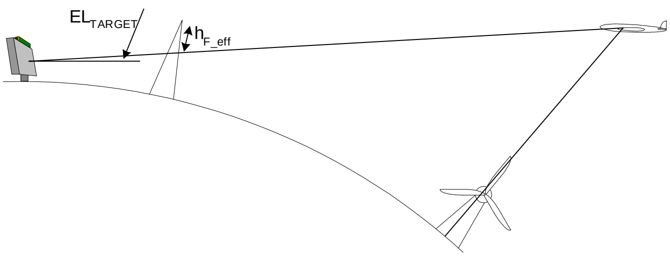

Figure 5 Curved earth clutter fence geometry

Objective is to reduce returns from wind turbines sufficiently to avoid windfarm effects while at same time maintaining

detection performance on air targets at altitude above windfarm.
This approach, combined with possible changes to the antenna height and tilt, can be explored to reduce the strength of wind turbine returns, however the impact of clutter fences on radar operations is a matter that would need discussion with the radar operator. If this option were followed up there are a number of factors to consider:

- Loss of low altitude air cover
    - At long ranges beyond the wind farm.
    - At short range.
- The suppression of low elevation clutter returns, using a clutter fence in the far field, is limited by diffraction effects over the top edge of the fence, which must be considered in any detailed analysis of this mitigation option.
- The wind farms under consideration will only occupy a limited angular extent when viewed from the radar site; therefore a clutter fence need only be wide enough to adequately obscure this extent. There is no necessity to protect directions where there are no windfarms planned.
- Planning issues concerning the construction of large clutter fence structures

4 Fill-in sensor & data fusion options

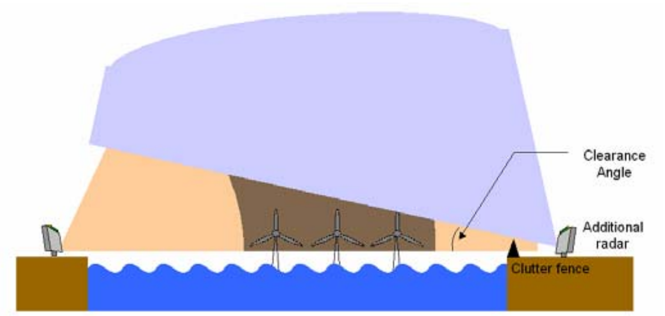

Figure 6 Fill in radar

{Will include a very detailed analysis of the requirements a multi sensor & data fusion system must meet and details of how this might be achieved in a real system. This option has been adopted to allow the removal of an objection on at least one case of possible windfarm / radar interaction (Whitelee windfarm and Glasgow International Airport airport) and is being explored in detail in a number of other cases.}

Candidate Fill-In sensors

{What type and capabilities required (may not be same as original sensor)}

Fill-in radar site location - geometrical considerations

{How to 'see' into airspace above WF without illuminating WF
Maybe use terrain and/or clutter fence}

Data fusion system requirements

{Simple mosaicing of video/plots }
{Or more sophisticated plot/track fusion solutions}

Reliability of combined system

{Is there more components / complexity in such a system - does this impact reliability?}

5 Windfarm / turbine options

5.1 Windfarm layout

The paper 'Windfarm characteristics and their effect on radar systems' [1] examined the aggregate effect of a number of turbines collected together into a windfarm in terms of the percentage range cell occupancy. It was seen that with the expected layout of a given windfarm using a triangular grid arrangement of turbines, the average range cell occupancy was optimistically ~50% while under certain conditions it could be as much as 100%.
With a turbine and a target in the same resolution cell it would be impossible to detect the wanted target and, depending on the sidelobe performance of the radar, there could be an effect on detection capability in other range cells. This is far from optimum as far as radar detection of wanted targets is concerned and it is clear that with these layouts, a considerable volume of space will have reduced or zero probability of detection of wanted targets.
Provided the radar site is fixed, without eliminating the windfarm completely, the optimum layout of turbines for a single radar system is with the turbines arranged on circular arcs centred on the radar. The spacing between arcs can be selected so that the miss / hit ratio on a wanted target in range is low enough to maintain track integrity.

{Insert figure with candidate layout having only 20% occupancy}

5.2 Stealthy turbines

- Proposed RCS-reducing treatment includes WT blades, nacelles and towers
- RCS reductions can be achieved without major redesign
- RCS reductions can be achieved within an acceptable cost budget
- Specific RCS-reducing hardware treatment proposed include;
    - thin light-weight coatings
    - no or minor structural design changes
    - limited use of new materials
    - limited use of shaping

Can reduce RCS of turbines by ~20dB. However, turbines are ~50-60dBm^2 RCS so reduction to 30-40dBm^2 is not sufficient to eliminate the problem because they would still be up to 10 000 x larger RCS than wanted 1m^2 targets.

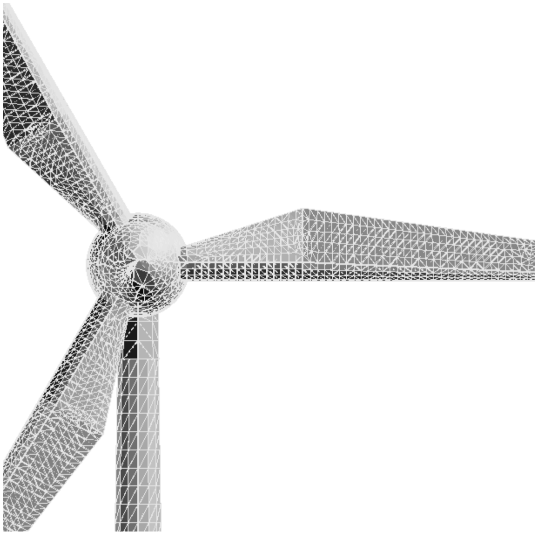

Figure 7 Candidate stealty turbine CAD model

Conclusions

It is clear that there are a number of options available to mitigate the effects of windfarm on radar - although none offer complete mitigation, there are some options and combinations of options which approach this ideal.
Some options can be applied to the single affected radar site. Apart from the plot/track filtering option, however, in many cases the single radar techniques would require significant modifications to an existing radar and might be more effectively achieved with the purchase of a new radar with the appropriate enhancements built into the design. This would have an added benefit of extended lifetime over upgrading an existing radar. Other options require the purchase of an additional radar to 'Fill-In' the areas 'lost' to an original radar and a data fusion system to combine the data from both radar into a single picture for presentation to an operator.

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Acknowledge input from BAE Systems ATC Towcester.

References

[1] C.A. Jackson, Windfarm characteristics and their effects on radar systems.
[2] Feasibility study on the use of additional sensors to mitigate the effect of windfarms in the Greater Wash area.
[3]….. Various windfarm / radar trials (Quixotic Zephyr, Swift Crofter, Mistral Crop, Celtic Storm etc….