Turbines and Anomalous Propagation in the Southern North Sea
NATS Safeguarding Office
24/06/20

Context

This note has been written to proactively provide a justification of what may appear to be NERL taking a more conservative stance in relation to offshore wind farm development.

During the planning process for offshore wind it is standard practice that theoretical models of the turbines, propagation environment and radar are used to determine if the turbines will be detected by one of NERL's costal radar. It is NERL'S position that the way these calculations are generally carried out does not fully account for variations in the propagation environment that can exist over large bodies of water.

NERL would therefore argue, based on practical experience and deeper theoretical consideration, that there will be a significant number of days where the detection volume is larger than identified and therefore any predicted impact and associated mitigation has to be scaled to account for this.

Background

In the most simplistic terms, the probability of a turbine being detected by a radar is dependent on the amount of power arriving at the radar's receiver which is itself a function of:

1. Power initially radiated by the radar
2. Percentage of this incident on the turbine
3. Amount reflected back by the turbine in the direction of the radar
4. Percentage of this which makes it to the radar's receiver

The first of these is fixed and well understood.

The third is dependent on the design and instantaneous state of the turbine. There has been significant domain specific analysis into different turbines and their propensity to reflect radar signals, a characteristic known as radar cross section or "RCS". There remains debate as to how this is scaled for turbines that have not been specifically measured, how its non-static nature and the fact it varies over the extent of the turbine are factored into calculations however for the purposes of this paper this is assumed to be settled.

The second and fourth can be bundled together as "propagation losses" and these have not received much attention in the published literature specific to radars and turbines. It is industry standard practice to derive them using one of the variants of the International Telecommunication Union ("ITU") 525/526 recommendations which cover 'Free Space Attenuation' and 'Propagation by Diffraction' respectively.

NERL employed the above methodology when assessing the first phase of the Hornsea windfarm, predicting it would not be visible and subsequently lodging no objection to the proposal. It was not long, however, after turbines started being erected, in early 2019, that Aberdeen Air Traffic Controllers began to report the impact of radar clutter on their operations. Since then, multiple formal occurrences have been recorded by both Aberdeen and Prestwick En-route ATC. This has caused NERL to re-examine how assessments of offshore wind farm proposals are undertaken.

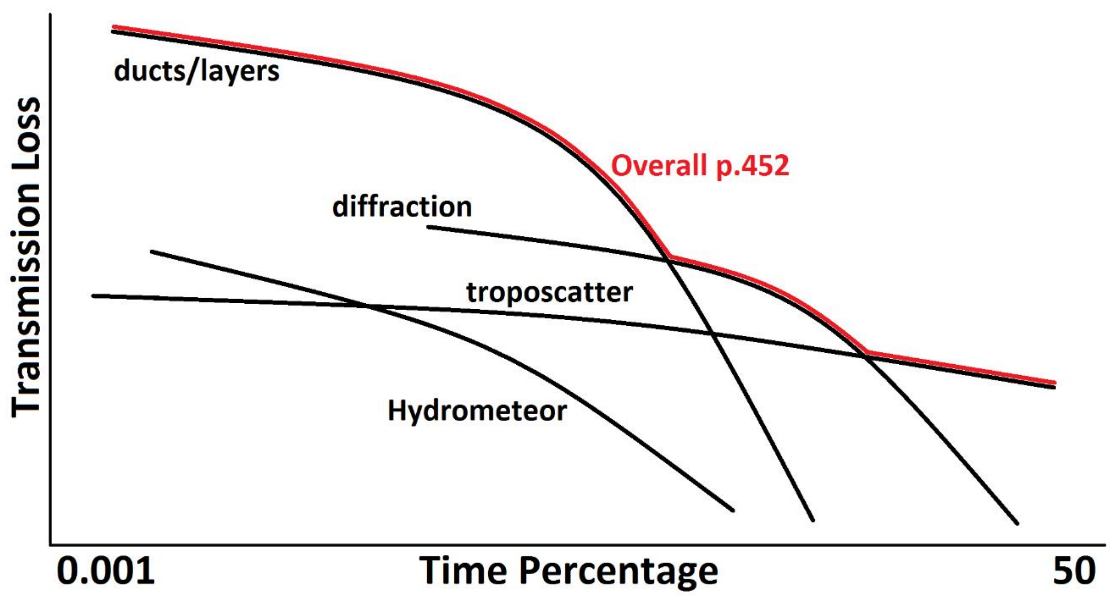
Literature Review

A paper published by the BBC research department in 1982 entitled "Computer Prediction of Field Strength" detailed how, at that time, variability in the offshore propagation environment was dealt with using a modified earth radius to simulate the effect of intermittent ducting. To simulate the median day, they used the standard k=1.33, whereas to simulate the most extreme 5% of days they used k=10 and for the final 1%, k=25.

The IEE compendium of papers published as the "Propagation of Radiowaves 2nd Edition" in 2003 details how this methodology was refined in the 1980s by a large European collaborative study known as COST210. This provided the empirical basis for the modelling techniques that would become ITU recommendation P.452 ("ITU P.452"), first published in 1992.

ITU P.452 has been revised numerous times, the latest incarnation being version 16 published in 2016, and is generally regarded as the most definitive guide to modelling surface effects and beyond-the-horizon propagation. The recommendation explicitly states that the models proposed are not applicable to "*aeronautical systems*". However, this is understood to mean that the modelling should not be applied to high altitude propagation paths and that ITU P.452 is appropriate for applications where both the radar and the interference source sit within the "surface layer" of the atmosphere.

ITU P.452 uses an envelope approach to determine how the losses on a point-to-point link vary over time by calculating the various sources of losses separately and then applying the dominant (lowest loss) mode of propagation for the time percentage of interest. This is shown in the figure below copied from the "Propagation of Radiowaves 2nd Edition".



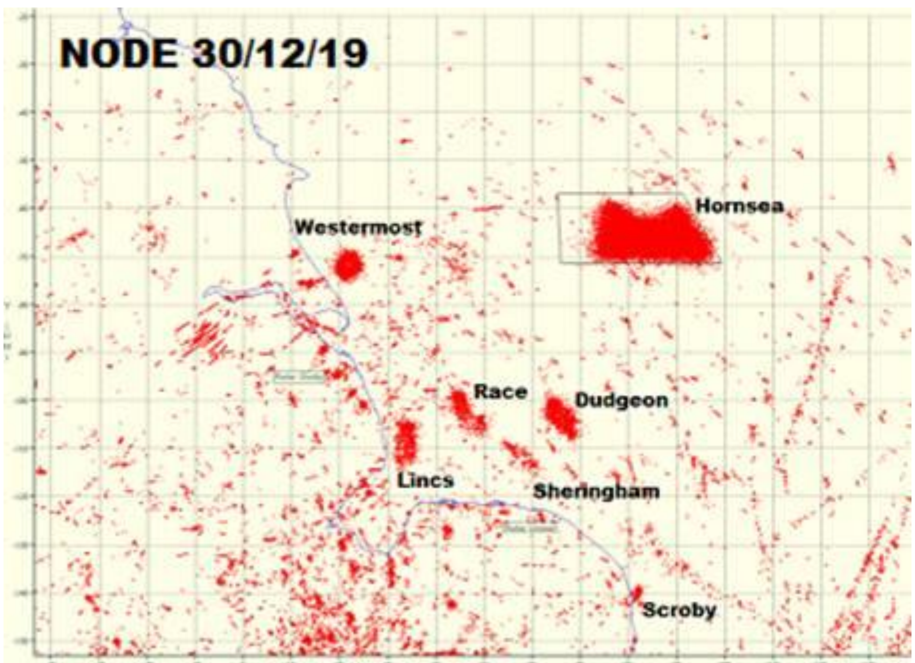
For radar-turbine assessments, troposcatter is not a significant factor. The current methodology, therefore, based solely on diffraction, aligns with the recommendation for the median day. For the proportion of time where ducts/layers become the dominant mode it is likely to significantly overestimate the losses and therefore underestimate the probability of detection.

Practical Evidence

Aberdeen ATC kept a log over 100 days early in the operation of the Hornsea windfarm and noted on 13 of those days that problematic clutter was visible. The days in question roughly correlated with the 18 days where radar recordings indicated the generation of significant false track activity within the windfarm volume.

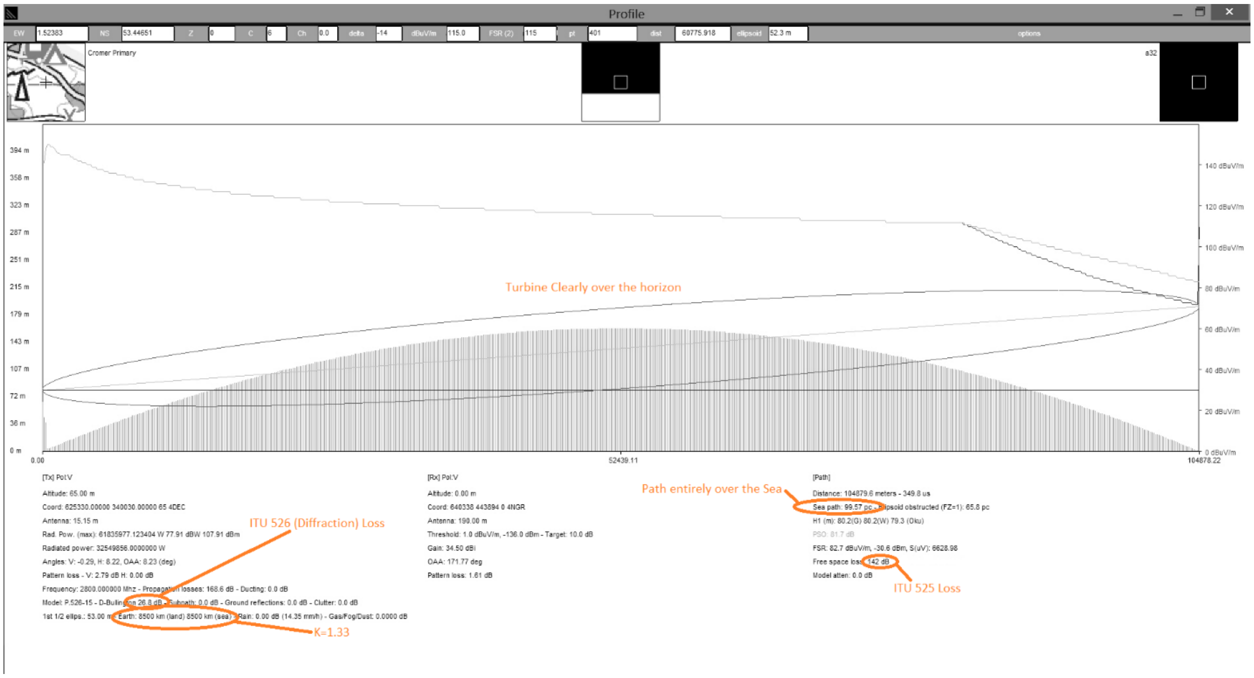
The numbers ranged from multiple days with no false track activity recorded to one particular day (18th April) where 8271 tracks were recorded. There did not appear to be a clear step-change in the false track numbers, inferring that it is a continuum rather than an obvious grouping into ducting/non-ducting days.

Detailed monitoring has not been in place since but investigations into a particularly bad day on the 30th of December indicated 24511 tracks within the Hornsea area. The diagram below shows the PSR-only returns displayed on the NODE multi-radar display over a three-hour period on the morning of 30th of December.

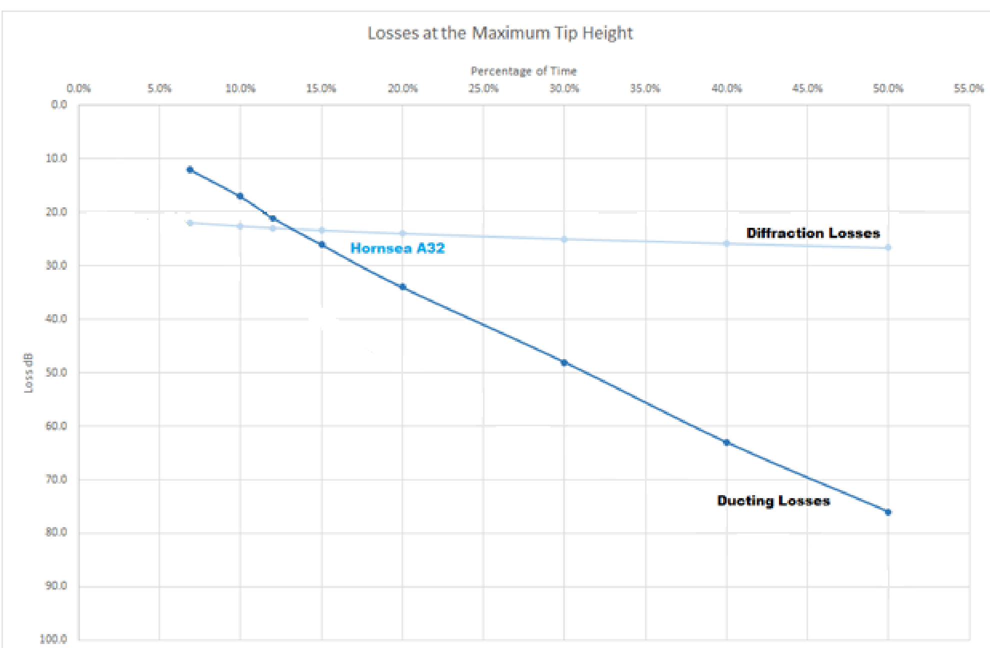


Modelling Results

ATDI's HTZ Communication propagation modelling tool was used to plot a path profile between the Cromer radar and the tip of Hornsea turbine A32. The results below are derived using the standard ITU 525/526 methodology and the profile visibly shows how far beyond the horizon the turbine sits.



The software was then used to simulate losses over the same path at various time percentages using an ITU 452 based methodology.



As expected, the 27dB figure for the median day (diffraction being the dominant mode at 50%) aligns with the predicted ITU 526 losses. As the time percentage parameter reduces this does not vary much initially as diffraction still dominates; for example, 25% of the time the losses are predicted to be 24.5dB or greater which should still be sufficient to avoid detection.

It is only when ducting becomes the dominant mode of propagation (cross over occurs at about 13% of the time) that the losses begin to fall rapidly reaching 12dB, 7% of the time. 12dB being equivalent to the signal at the radar being 63 times stronger than the median level based on a two-way propagation path.

This is a simple point-to-point example but could be incorporated into existing radar-turbine modelling to compute detection probabilities for differing time percentages.

Understanding of this issue is still evolving and will be informed by the examination of other windfarms and of times of the year with different prevalent weather conditions. However, it does appear that the time percentage where ducting is predicted to become the dominant mode of propagation aligns with both what the survey of Aberdeen ATC and the radar recordings tell us about Hornsea generating problematic clutter.

Conclusions

More work is required to fully understand the implications of the unexpected detection of the Hornsea windfarm by the Claxby and Cromer radars. However, it is clear that a windfarm assessment process that takes into account the variations in the propagation environment that can exist over large bodies of water is required.

Whilst this understanding matures NERL will assume that where ITU P.452 predicts that ducting is the dominant mode of propagation for a non-trivial percentage of the time, the turbines will be detected and that this clutter and its potential operational impact will need to be managed.

NERL'S stance on particular developments will still depend on the specific airspace and the air traffic operation's tolerance, either from an ATC or technical capacity perspective, for intermittent clutter in that area.

Overall, this is likely to lead to NERL objecting to more offshore windfarms and expanding our objection to greater volumes of those currently deemed partially visible. As always NERL will continue to work with developers in relation to those developments that are deemed unacceptable and it is worth noting that NERL has successfully identified mitigation options for every offshore objection raised to date.

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