dublin array

An Offshore Wind Farm on the Kish and Bray Banks

Environmental Impact Statement

January 2012 - Revision 1

Reviewed and Updated by

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SAORGUS | ENERGY LTD

Volume 3 of 5 - Appendix C
Marine Navigation Impact Assessment

Kish and Bray Banks Wind Farm Radar Impact Assessment

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1 Technical Memo: Kish and Bray Banks Wind Farm Radar Impact Assessment

1.1 Introduction

QinetiQ has been contracted to carry out a study on behalf of Saorgus Energy Limited to look at the radar visibility of a proposed offshore wind farm at Kish and Bray Banks, off the coast of Ireland. As part of the assessment, a number of ship based radar systems will be analysed, along with a vessel traffic services (VTS) system operated by Dublin Port.

The assessment represents the QinetiQ view formed from modelling evidence and expert opinion, based on information available at the time of writing. It would be infeasible for QinetiQ to assess every type of marine navigation radar and configuration that can be fitted to vessels at sea, so this study will assess an agreed number of representative radars.

It should be noted that both the collision regulation [1] and the Safety of Life at Sea (SOLAS) [2] International Maritime Organisation (IMO) documentation defines that any ship's navigation radar (and any similar navigational aids) are only aids to navigation. Hence, the Officer of the Watch always has ultimate responsibility to use all methods, including visual, to achieve safe navigation.

1.2 Kish and Bray Banks wind farm

One hundred and forty five wind turbines are proposed for the Kish and Bray Banks offshore wind farm, from here on known as Kish and Bray. The parameters used to model the turbines are given in Table 1.

Hub height (m)	100
Number of blades	3
Blade length (m)	60 (120 diameter)
Blade tip height (m)	160
Tower base radius (m)	3.0 (approximate)

Table 1 Details of the parameters used to model the turbines

Figure 1 shows the wind farm site plotted in Google Earth. Appendix A shows the layout of the Kish and Bray turbines, as provided by Saorgus [3], plotted in Google Earth, along with their identification (ID) numbers.

Figure 1 Kish and Bray wind farm plotted in Google Earth

It is expected that there will be no exclusion zones set around the wind farm once the turbines are operational [3].

1.3 Traffic assessment

A shipping collision risk assessment was undertaken for the area of the Kish and Bray wind farm, undertaken by Vectra Group Limited [4]. Figure 3 and Figure 3 show images from the risk assessment, with the turbine locations overlaid. The coloured arrows indicate the passage of various vessels around the Kish and Bray turbines, the majority of which are car and passenger type ferries and cargo vessels. This type of information will be used to identify areas of greatest impact in this radar impact assessment.

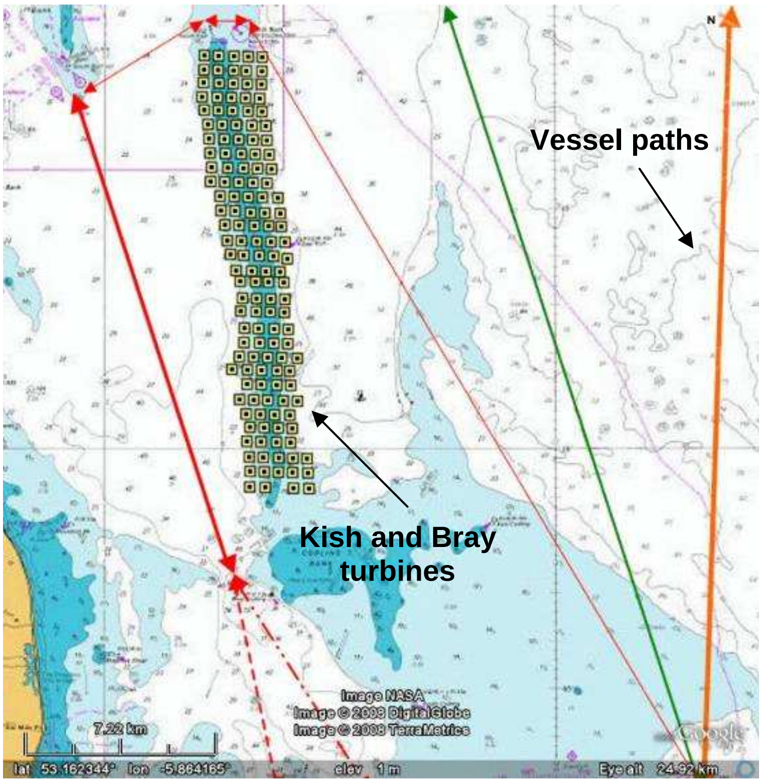

Figure 2 Passage of vessels around the Kish and Bray area in a north-south direction, as found by the collision risk assessment [4]

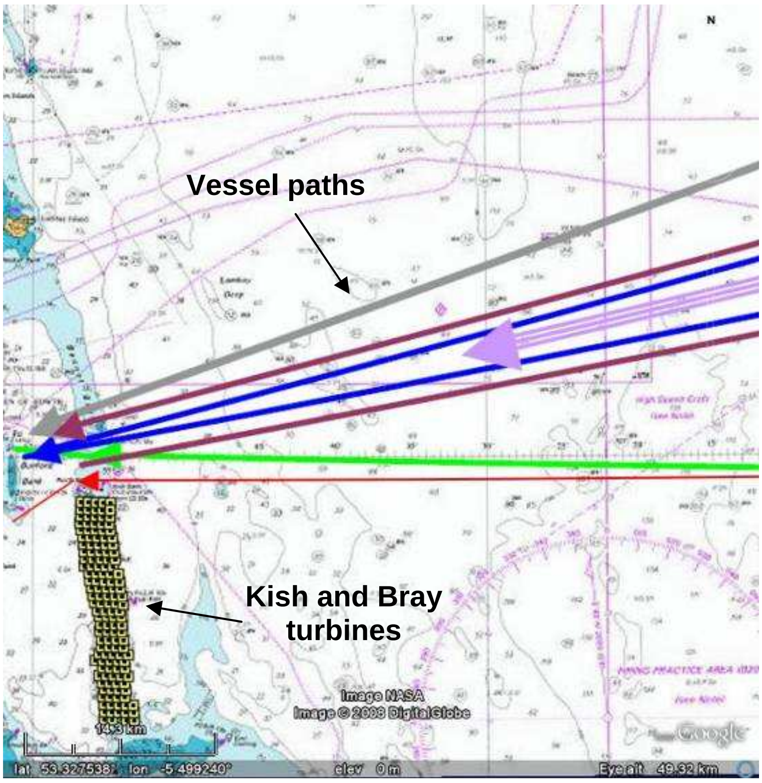

Figure 3 Passage of vessels around the Kish and Bray area in an east-west direction, as found by the collision risk assessment [4]

1.4 Radar setup

Based on the types of traffic identified in the collision risk assessment [4], two representative vessels for the area were used as the basis for this impact assessment, namely a cargo type vessel and a large ferry. A typical cargo type vessel or large ferry is likely to be greater than 3000 gross tonnes (GT), and thus according to the regulations [2], would be likely to have at least one 12 foot S-Band radar and one 8 foot X-Band radar. Using a sample of antenna heights determined from automatic identification system (AIS) data for the area, the S-Band radar has an average height of 22 metres above mean sea level (AMSL) for the medium sized vessel, and 47 metres AMSL for the large. The X-Band radar has an average height of 23 metres AMSL for the medium vessel, and 47 metres for the large.

Also located in the area is a VTS

X-Band radar operated by the Dublin Port, some 5 nautical miles (Nm), approximately 10km, north west of the proposed Kish and Bray wind farm. The following sub sections describe the S-Band and X-Band radars in more detail. The modelling did not take any automatic plotting or tracking aids into account, however, any of these systems are likely to reduce any potential effects of wind turbines on vessel based radar navigation systems.

1.4.1 S-Band ship radar

A generic S-Band radar was modelled in the study and Table 2 lists some of the parameters used to simulate the radar. Since the majority of navigation radars can be operated in various modes, the modelling assumed a medium pulse mode.

Frequency (GHz)	3.05
Peak power (kW)	30
Pulse duration (s)	0.25×10^{-6}
Horizontal beam width (^{o})	2.0
Main beam gain (dBi)	26
Dynamic range (dB)	80

Table 2 Details of the main parameters used to model the generic S-Band radar

1.4.2 X-Band ship radar

A generic X-Band radar was modelled in the study and Table 3 lists some of the parameters used to simulate the radar. Since the majority of navigation radars can be operated in various modes, the modelling assumed a medium pulse mode.

Frequency (GHz)	9.41
Peak power (kW)	25
Pulse duration (s)	0.25×10^{-6}
Horizontal beam width (°)	1.0
Main beam gain (dBi)	31
Dynamic range (dB)	80

Table 3 Details of the main parameters used to model the generic X-Band radar

1.4.3 X-Band VTS radar

The VTS radar, operated by Dublin Port, is there to monitor the flow of vessel traffic in the area. The radar is located at the Bailey Lighthouse at Howth, approximately 10km north west of the proposed Kish and Bray wind farm. Figure 4 shows the digital terrain[1], centred on the VTS radar (indicated with the blue cross), used in the modelling. The location of the proposed wind farm is also highlighted (with black dots). The height of the radar is assumed to be 35 metres AMSL based on information from various sources on the internet.

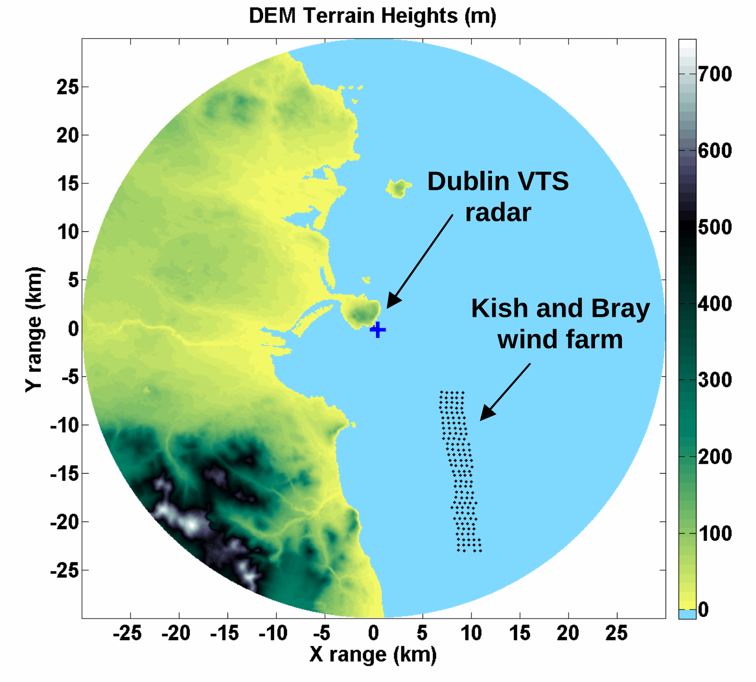

Figure 4 The digital terrain surrounding the Dublin VTS radar

A generic VTS type radar was modelled in the study and Table 4 lists some of the parameters used to simulate the radar. Since the majority of VTS radars can be operated in various modes, the modelling assumed a medium pulse mode.

[1] The digital terrain used provides heights on an approximately 90 metre spaced grid.

Frequency (GHz)	9.41
Peak power (kW)	25
Pulse duration (s)	250×10^{-9}
Horizontal beam width (^{o})	0.43
Main beam gain (dBi)	33
Dynamic range (dB)	80

Table 4 Details of the main parameters used to model the generic VTS radar

1.5 Radar cross section of wind turbines

In the maritime environment, a wind turbine tower is an important aspect to consider in a radar impact assessment. This is due to the constant source of high reflected energy received from the towers, and the navigational hazard they represent. However, reflections from the blades also need to be taken into account as they can appear as an intermittent source on a radar screen due to the rotation of the blades.

The radar cross section (RCS) is a measure of how reflective an object is at a particular frequency. Therefore, the larger the RCS, the more energy an object is likely to reflect making it easier to detect by a radar.

The turbine dimensions used in this study were given in Table 1, and defined the blade length as 60 metres. The RCS of a 60 metre wind turbine blade is approximately 41dBsm, and is based on real measurements and scaling factors. The decibel, or dB logarithmic scale, is often used by engineers to describe the signal levels in radar systems due to the large variations encountered.

The maximum RCS (σ) of a cylindrical turbine tower constructed from a perfect electrically conducting (PEC) material, such as steel, can be estimated by using Equation 1 [5].

$$\sigma_{\max} = \frac{2 \cdot \pi \cdot R \cdot H^2}{\lambda} \qquad 1$$

Where R = tower radius, H = tower height and λ = radar wavelength. Using the radar frequencies from section 1.4 of 3.05GHz (S-Band) and 9.41GHz (X-Band), as well as the turbine tower dimensions, in section 1.2, a maximum RCS of 62.8dBsm and 67.7dBsm respectively would be expected.

Figure 5 shows a comparison of a large wind turbine RCS to that of other objects.

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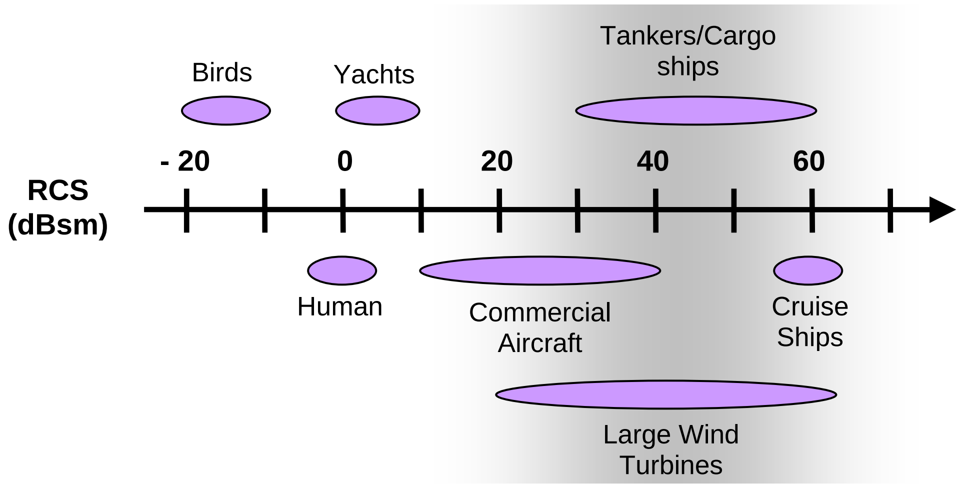

Figure 5 Comparison of a wind turbine RCS with other objects

Figure 5 shows that the largest wind turbines compare to large ships and cargo type vessels. Another point to note about the turbines is that they have quite a wide spread in RCS. This is, in part, due to the many different sizes and types of turbines. However, it is also due to the fact that wind turbine towers are usually tapered by some defined angle, usually only a degree or so, which means they have a larger diameter at the base than they do at the top. This has the effect of reflecting a radar's energy upwards, as opposed to directly back to the radar, thus reducing the tower's apparent RCS. This is represented simplistically in Figure 6. This effect is in contrast to reflections from other objects such as large shipping vessels, which tend to reflect the energy back in the direction of the radar.

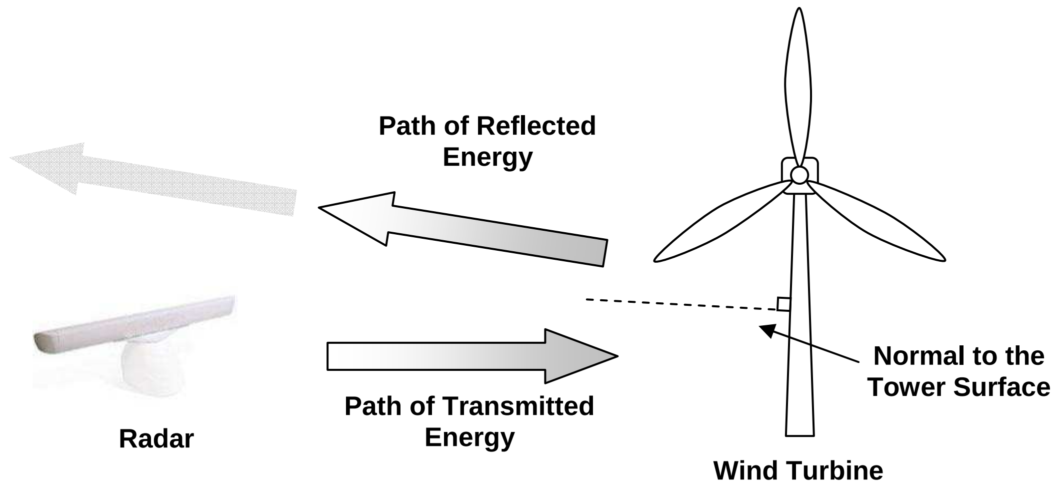

Figure 6 Simplistic representation of the radar's energy being reflected back above the radar due to the taper angle of the turbine tower, thus reducing the apparent RCS

A typical tower reflection pattern for the example turbine at 3.05GHz (S-Band) is given in Figure 7. This shows how the tower directs most of the reflected energy in the direction of the normal to the surface, i.e. at 90 degrees. Away from the normal, the reflection pattern is dominated by a series of peak and nulls.

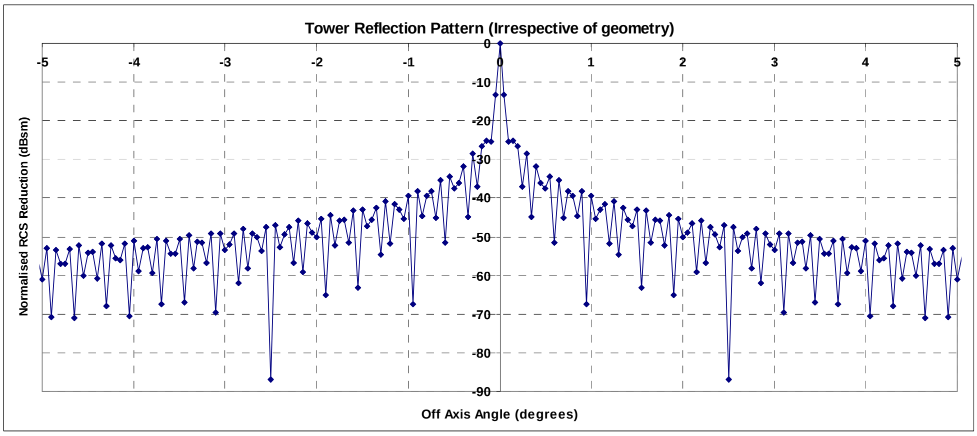

Figure 7 Tower reflection pattern from a PEC cylinder of similar dimensions to the turbine at S-Band

The complex reflection pattern means that the RCS of a wind turbine tower can vary dramatically depending on the elevation angle from the radar to the turbine tower. For example, as the distance from the radar to the turbine tower changes, so does the elevation angle, thus altering the apparent RCS. Given the height of the S-Band radars (22 metres and above), and the dimensions of the tower, Figure 8 shows how the apparent RCS of the tower can change with the distance to the turbine.

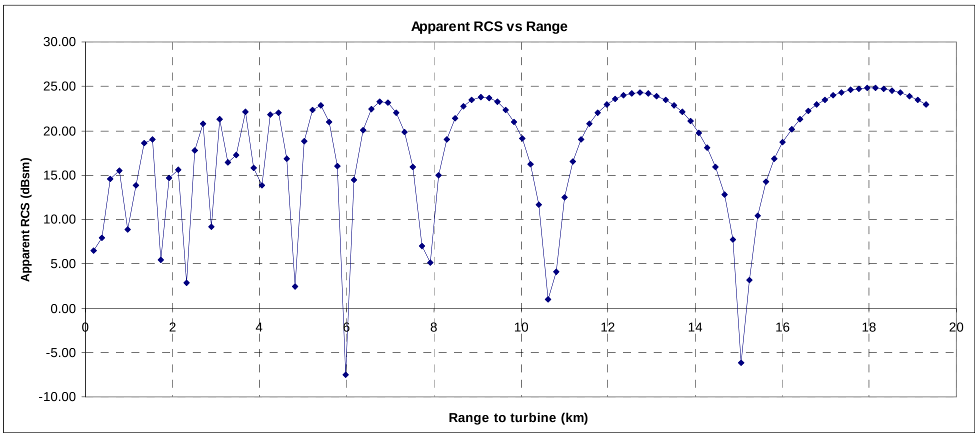

Figure 8 Apparent tower RCS as a function of range from the turbine for an S-Band radar

A typical tower reflection pattern for the example turbine at 9.41GHz (X-Band) is given in Figure 9.

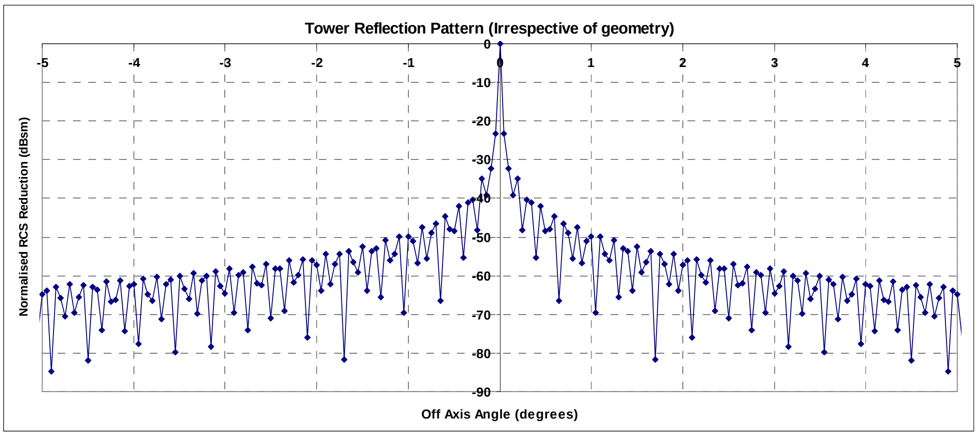

Figure 9 Tower reflection pattern from a PEC cylinder of similar dimensions to the turbine at X-Band

Given the height of the X-Band radar (23 metres and above), and the dimensions of the tower, Figure 10 shows how the apparent RCS of the tower can change with the distance to the turbine.

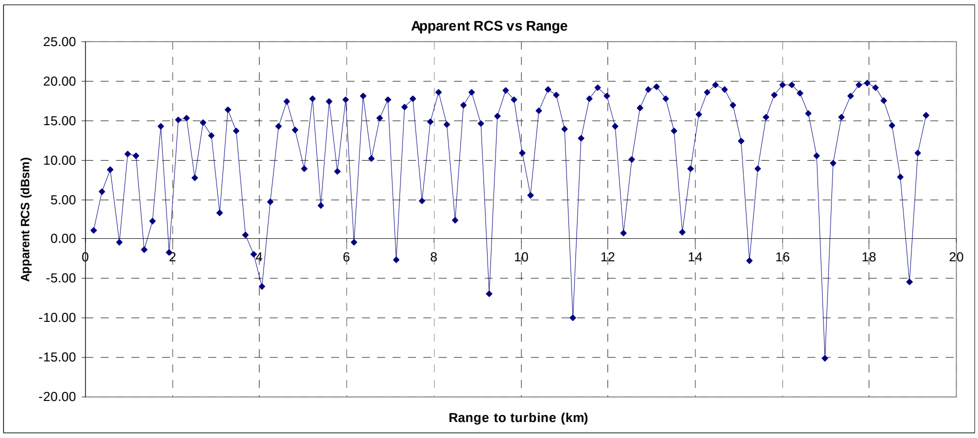

Figure 10 Apparent tower RCS as a function of range from the turbine for an X-Band radar

Given the large variation in apparent RCS of the wind turbine tower as a function of range, worst case RCS values were extracted for each of the radar frequencies at their respective heights, and are shown in Table 5.

Frequency (GHz)	Radar height (m)	Max tower RCS (dBsm)
3.05	22	24.3
	47	25.7
9.41	23	19.7
	35	20.9
	47	20.9

Table 5 Apparent RCS values for each of the different radars at their respective heights

Environmental conditions, such as sea states and temperature changes, can also affect the detectability of wind turbines, equivalent to altering the apparent RCS of the towers. Therefore, a worst case tower RCS of 25.7dBsm will be assumed for the rest of the study.

1.6 Physical shadowing

One of the main concerns for shipping, with regard to large physical structures, is the potential for objects to shadow other vessels from detection. This is the effect whereby the physical structure of an object blocks the propagating radar energy from reflecting off a vessel directly behind the object.

In the case of a wind turbine, it seems unlikely that a roughly six metre diameter object could obstruct any vessel considered in this assessment, which is likely to be many times the width of a turbine tower.

In fact, the phenomenon of diffraction (bending of the beam) means that any shadow cast behind an object, such as a tower, quickly fills back in. Figure 11 shows an example of how energy radiated out from a radar can interact with a tower, such as a wind turbine tower. As the energy passes around the tower, diffraction causes the beam to bend inwards forming a complex diffraction pattern, thus filling in most of the shadowed region behind the turbine.

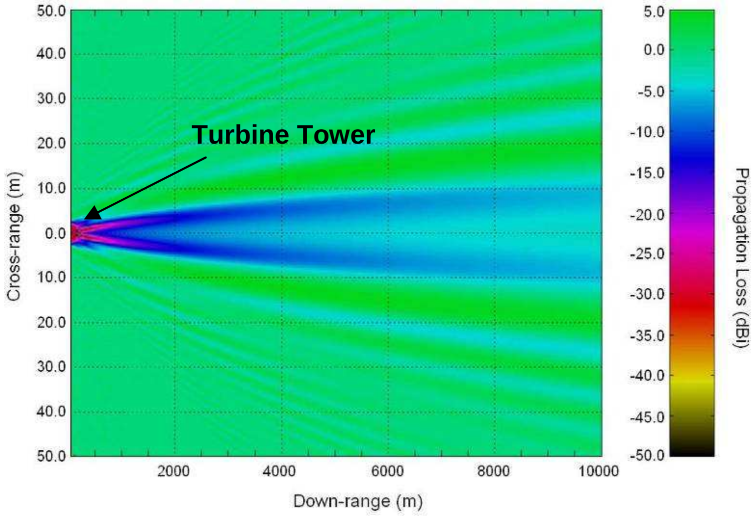

Figure 11 Example of propagation losses of an electromagnetic wave after diffracting around a turbine tower

Figure 12 plots slices through the above diffraction pattern, showing how the beam effectively fills in as the distance from the diffraction event, i.e. the tower, increases. At around 5km (2.7Nm) the beam has essentially filled back in and most of the radar's energy will get through to illuminate the vessel. Even in the worst case, where the shadowing is at its greatest, i.e. up to 100 metres behind the tower, the width of the shadowed region is only of the order of ten metres.

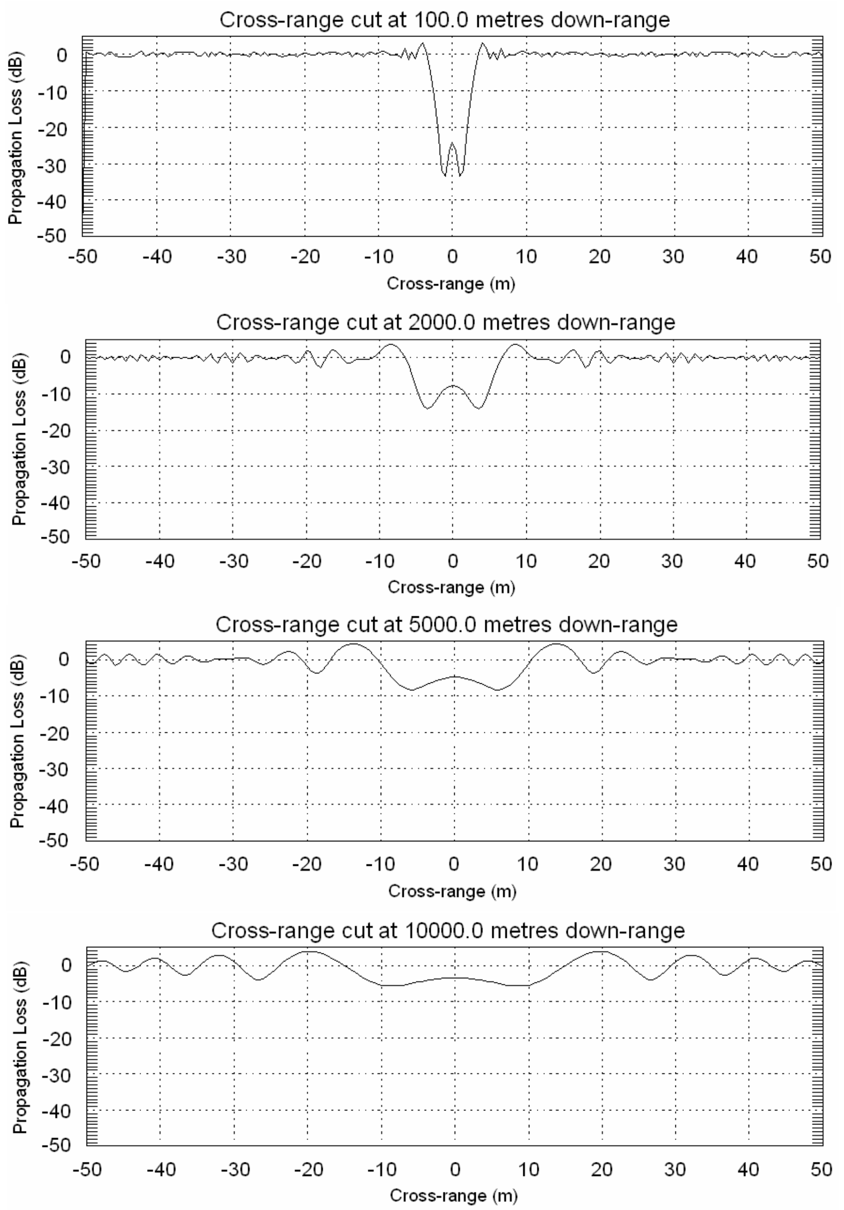

Figure 12 Slices through the diffraction pattern from a tower at various down-ranges

Figure 11 and Figure 12 effectively show that shadowing due to a single tower is unlikely to be a problem to anything more than the smallest of boats that are in close proximity to the rear of the tower, with respect to the viewing radar. The reduction in signal level due to shadowing of successive turbines can be determined via the same method, and is shown in Table 6.

No. of turbines causing shadowing	Signal loss (dB)
1	-30
2	-55
3	-80
4	-105

Table 6 Signal loss due to successive turbines shadowing

From Table 6, it is apparent that the signal loss due to the shadowing of two or more turbines could be enough to cause a loss of detection for larger vessels. However, the point to note from Figure 11 and Figure 12 is that the width of the signal loss was small (only 10-20 metres).

Figure 13 shows ship based views of the Kish and Bray turbines looking from the north, west and south of the turbines at a distance of approximately 1Nm.

The spacing between individual turbines ranges between 400 metres and 700 metres in most cases. It is apparent from the aspects shown in Figure 13, that in some cases the turbines align in such a way as to create gaps, where the detection of other vessels would be possible. However, much of the time turbines block most of the view of the opposite side of the wind farm. Therefore, a vessel on one side of the wind farm would most likely have difficulty in tracking another vessel on the other side, due to intermittent detection for the majority of the time.

The same would also be true for the Dublin VTS radar at Bailey Lighthouse. Figure 14 gives the aspect of the turbines from the point of view of the radar. This would result in a blind region to the east and south of the turbines, whereby the VTS radar would only get intermittent detection of any vessels travelling in that area.

It is, therefore, concluded that there will be a significant loss of detection for both ship based radars, and the VTS radar located at Bailey Lighthouse of vessels on the opposite side of the proposed Kish and Bray wind farm.

The importance of this loss of detection greatly depends on the operational significance of the region to the Dublin Port authorities. However, potential mitigation options to reduce the effects on ship based radars is to use radar absorbent materials on the turbines themselves, or set up exclusion zones around the wind farm where vessels would not be allowed to enter.

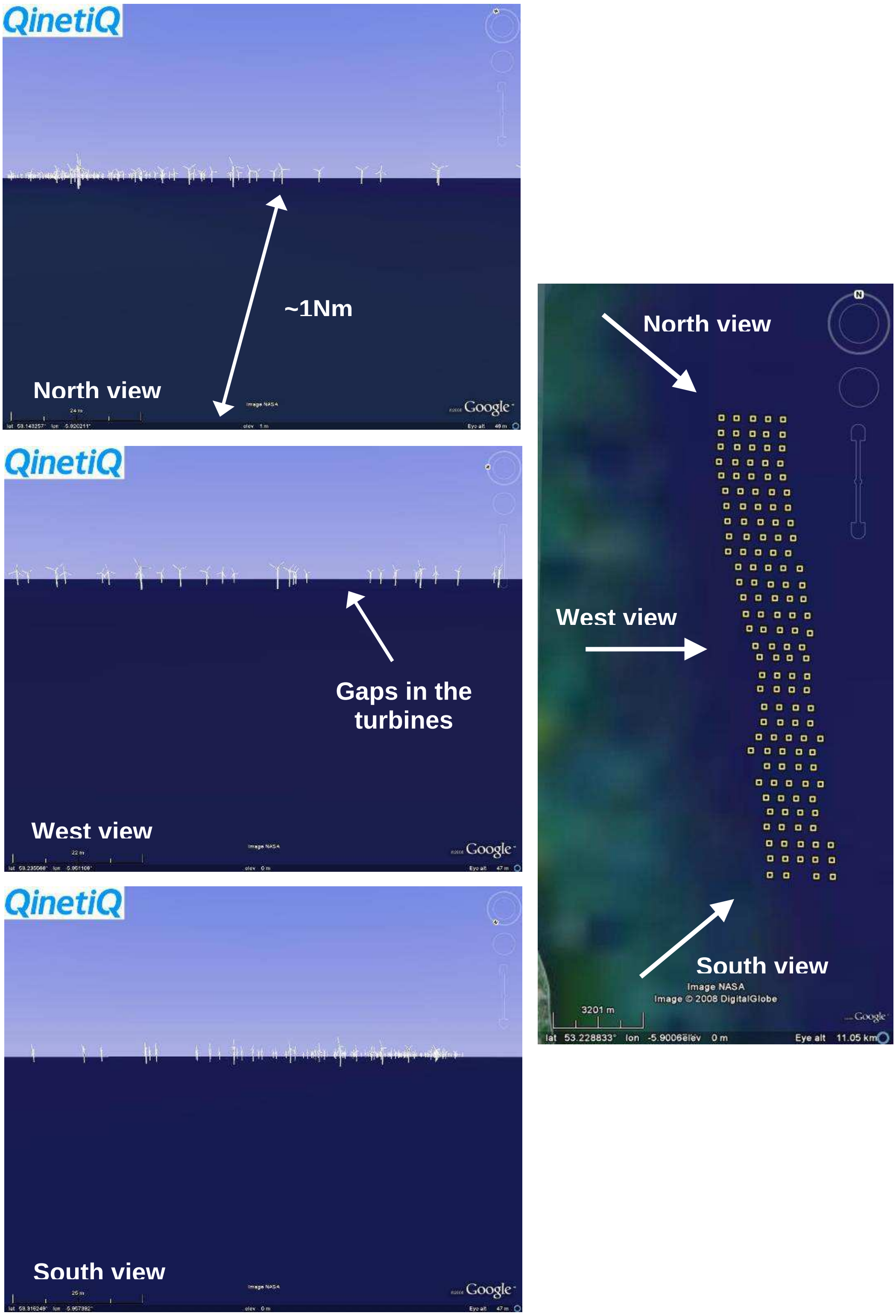

Figure 13 Various aspects of the Kish and Bray wind farm from the point of view of a large ship showing the spacing between turbines

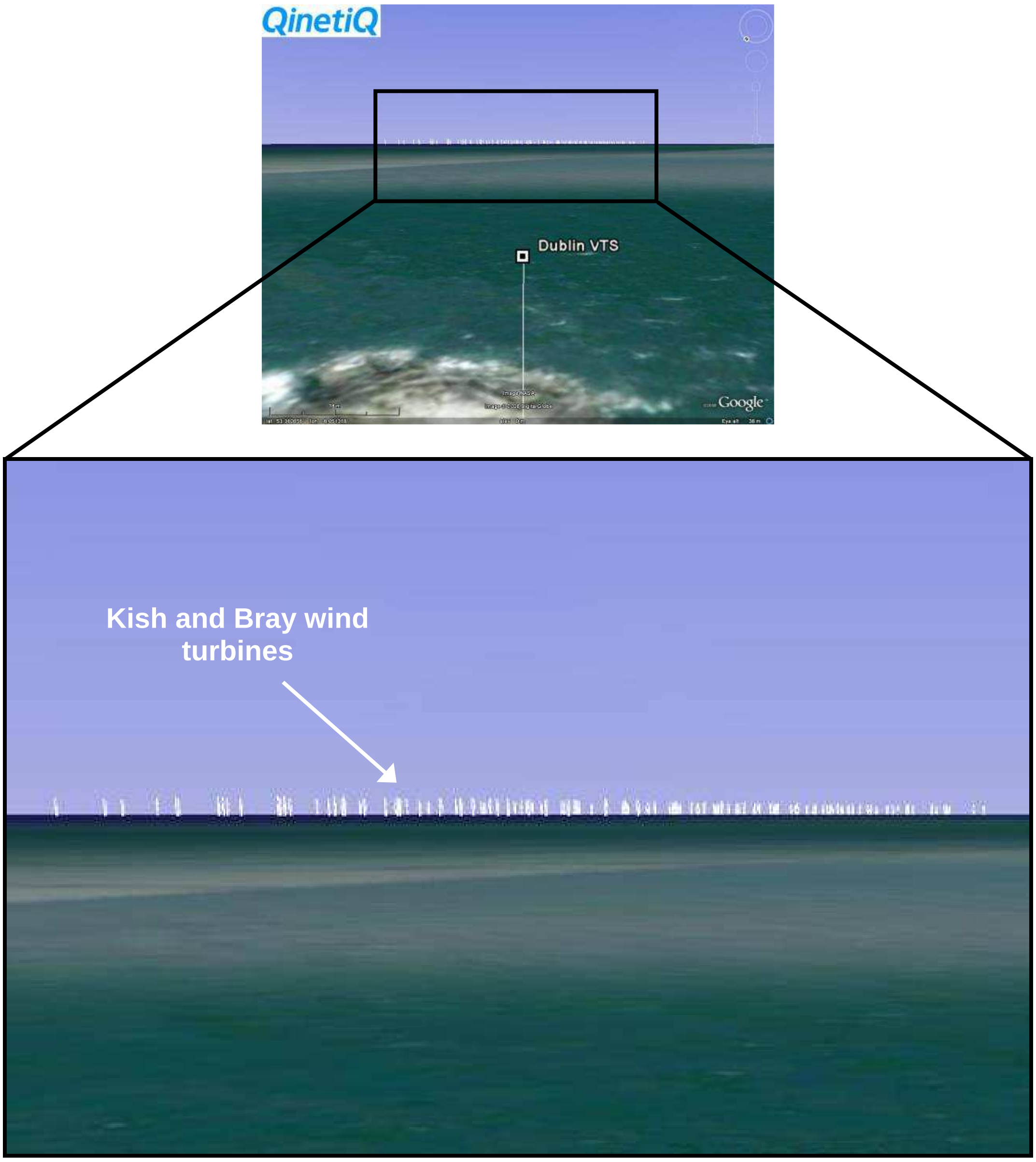

Figure 14 Kish and Bray wind turbines from the point of view of the Dublin VTS radar, showing the spacing between turbines

1.7 Probability of detection

A useful metric for assessing radar performance is *probability of detection* (Pd). Using a real radar plan position indicator (PPI) display, the human eye can often follow successive plots with a fairly low Pd (~0.5 or 50%) even in highly cluttered[2] conditions, however, automatic tracking systems require higher Pds (>0.9 or 90%) and much less clutter to track vessels successfully.

The naval electromagnetic environment simulation suite (NEMESiS) has been developed by QinetiQ over two decades to model the influence of the environment on military radar systems for the Ministry of Defence (MoD). At the heart of the

[2] Clutter is a radar term for unwanted returns such as radar reflections from rough seas, rain, or land. High clutter can lead to false plots.

model is an advanced propagation algorithm that simulates how microwave energy propagates through the atmosphere and reflects off the earth's surface. This can then be used to determine the Pd of an object.

The energy from a radar antenna radiates out in a narrow beam to capture as much detail as possible for every bearing. Antennas, however, are not perfect, and consequently, the main beam has several side beams (known as side lobes) associated with it, albeit at a much lower power level. Figure 15 shows an example azimuth antenna beam pattern used in the modelling for both generic S-Band and X-Band antennas, and illustrates their associated side lobes.

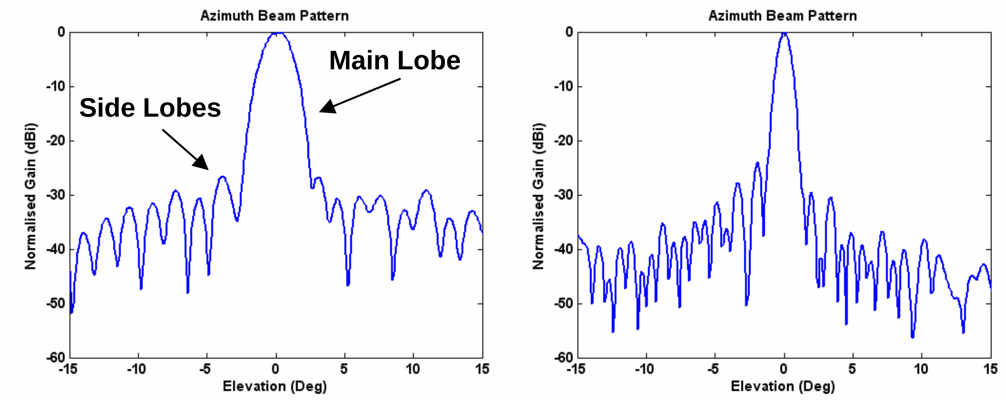

Figure 15 Example azimuth antenna patterns for an S-Band (left) and X-Band (right) radar showing the main lobe, along with the lower power side lobes

If the magnitude of reflected signals from an object is sufficiently high, it may be detected through the antenna's side lobes as well as through the main beam. This can cause an object to be detected on more than one bearing, producing false plots or even arcs of detection around the radar. In some cases, the signal strength may be large enough to form a complete ring around the radar, referred to as the *ring around effect*. More information on false plots is provided in section 1.9.

To model the Pd of the turbines, including side lobe effects, NEMESiS creates a three dimensional representation of the antenna patterns, which are given in Figure 16 for both the S-Band and X-Band antennas, to propagate into the marine environment.

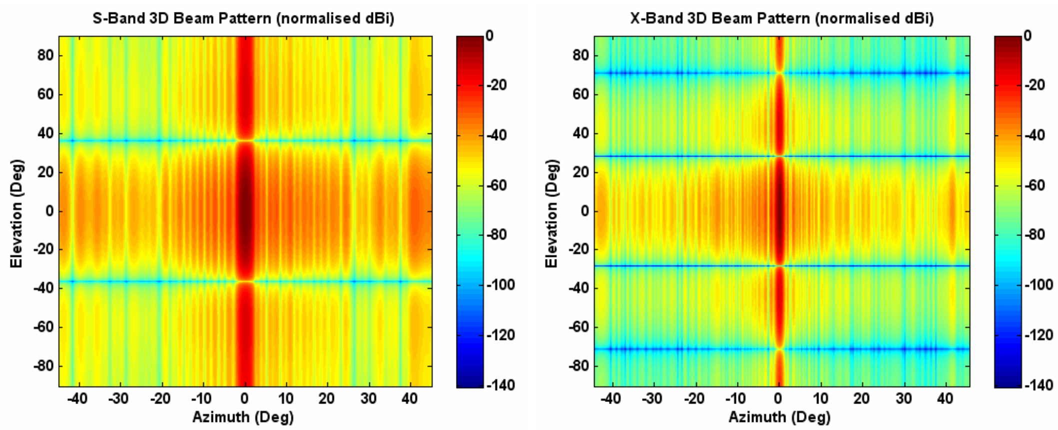

Figure 16 Example 3D antenna patterns for the S-Band (left) and X-Band (right) antennas

The following sub sections assess the Pd of a turbine for each of the radar. Conditions have been modelled using sea state 2, with a wind speed of 5.2 metres per second (10.1 knots), typical of the area.

1.7.1 S-Band radar (22 metre antenna height)

Figure 17 shows a Pd plot for the PEC tower using an S-Band radar mounted at a height of 22 metres AMSL. The red regions in Figure 17 indicate areas of high detection (Pd = 1), whereas the blue regions indicate little or no detection. It should be noted that the figure represents a snapshot of the radar detection probabilities in time, with the beam pointing on a bearing of 90 degrees, thus allowing the detection capabilities of the side lobes to be analysed along with the main lobe. The left hand image in Figure 17 shows the Pd for a PEC tower using the maximum theoretical RCS of 62.8dBsm, whereas the right hand image shows the Pd for the worst case apparent RCS of the PEC tower determined in section 1.5 (RCS of 25.7dBsm).

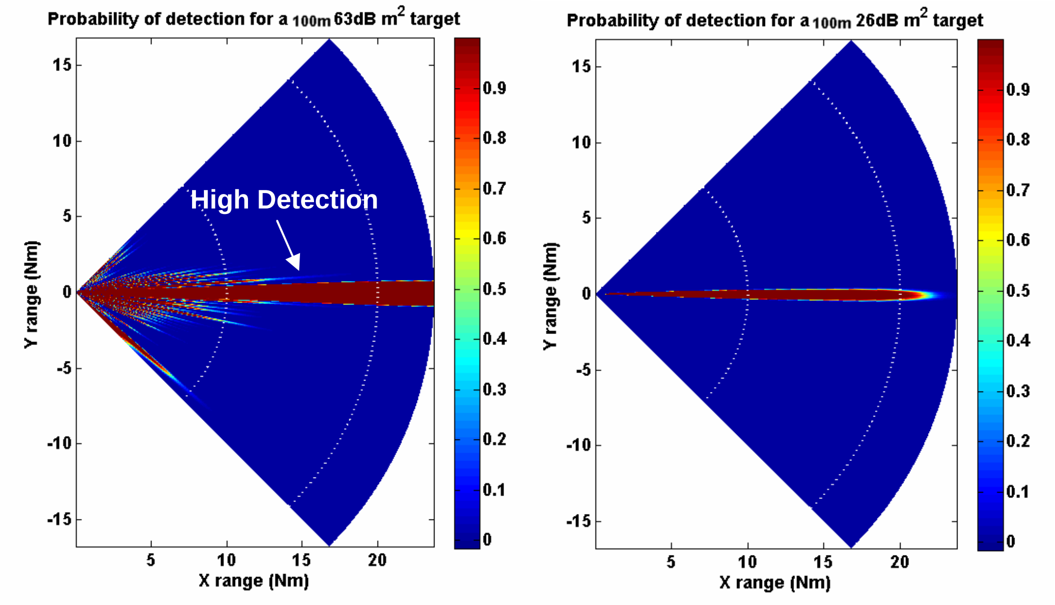

Figure 17 Pd for a PEC tower using the theoretical maximum RCS (left) and the apparent RCS (right) for the S-Band radar at a height of 22 metres AMSL

Figure 17 shows that using the maximum RCS, the tower would be detectable out to the full range of the radar (24Nm, or 44km). Significant side lobe effects would also be encountered, with the tower possibly being detected as much as 45 degrees off the main beam. With the apparent RCS used, the tower Pd is reduced, and is detectable out to a distance of approximately 22Nm (approximately 40km). There are no significant side lobe effects visible using the apparent RCS, although the area of high detection extends, in parts, over a region greater than the beamwidth of the antenna (2 degrees), up to as much as 5 degrees.

Figure 18 shows the Pd for the blade of the wind turbine, with an RCS of 41dBsm. In all instances, it is assumed that the blade is in the vertical position above the hub of the tower.

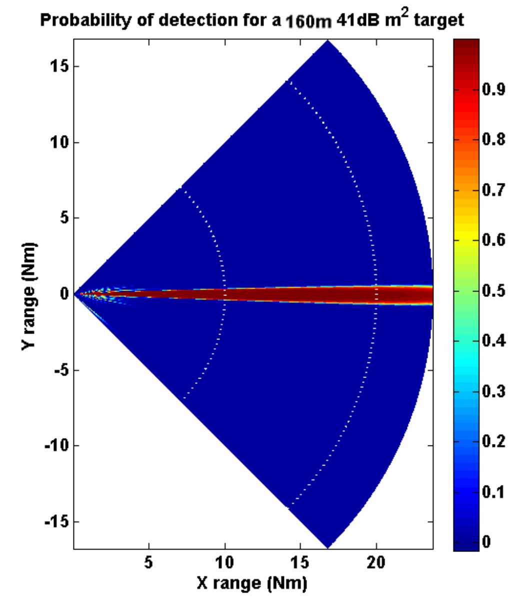

Figure 18 Pd for the wind turbine blade using the S-Band radar at a height of 22 metres AMSL

It is apparent from Figure 18 that the blade Pd is greater than that of the PEC tower case, and is detectable out to the full range of the radar. There are some minor side lobe effects at short ranges, and the area of high detection still extends, in parts, over a region greater than the beamwidth of the antenna, up to approximately 8 degrees.

This means that the appearance of the wind turbine on the radar's PPI display would be a constant source of clutter, spanning an area of approximately 5 degrees in bearing but possibly increasing up to 8 degrees intermittently as the blade flashes, with some minor side lobe effects at close ranges.

1.7.2 S-Band radar (47 metre antenna height)

Figure 19 shows a Pd plot for the PEC tower using an S-Band radar mounted at a height of 47 metres AMSL. The left hand image in Figure 19 shows the Pd for a PEC tower using the maximum theoretical RCS of 62.8dBsm, whereas the right hand image shows the Pd for the worst case apparent RCS of a PEC tower determined in section 1.5 (RCS of 25.7dBsm).

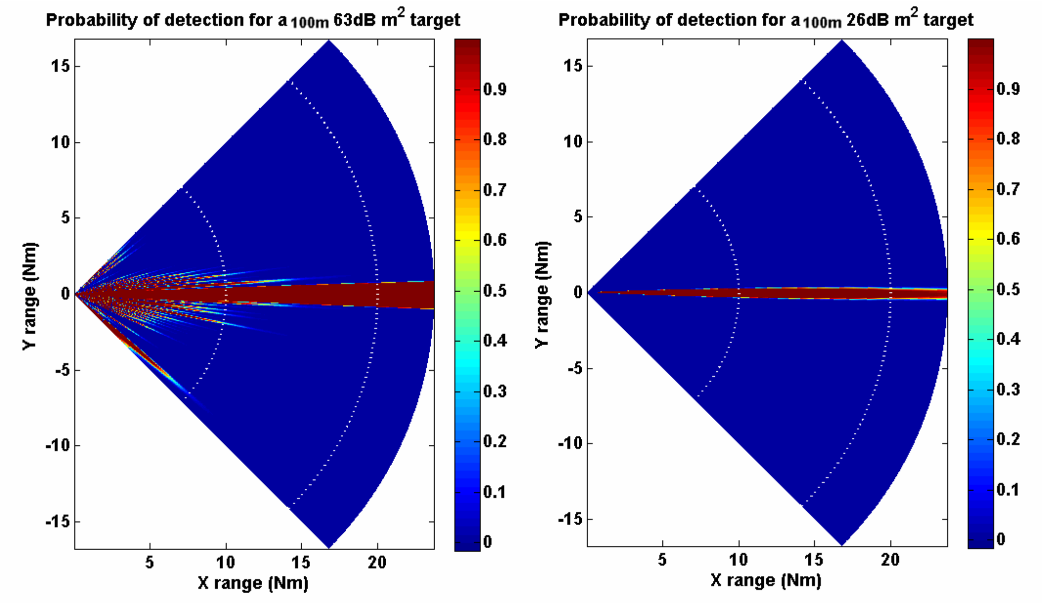

Figure 19 Pd for a PEC tower using the theoretical maximum RCS (left) and the apparent RCS (right) for the S-Band radar at a height of 47 metres AMSL

Figure 19 shows that using the maximum RCS, the tower would be detectable out to the full range of the radar. Significant side lobe effects would again be encountered, with the tower possibly being detected as much as 45 degrees off the main beam. With the apparent RCS used, the tower Pd is reduced but is still detectable out to the full range of the radar. There are no significant side lobe affects visible using the apparent RCS, although the area of high detection extends, in parts, over a region greater than the beamwidth of the antenna (2 degrees), up to approximately 5 degrees.

Figure 20 shows the Pd for the blade of the wind turbine, with an RCS of 41dBsm.

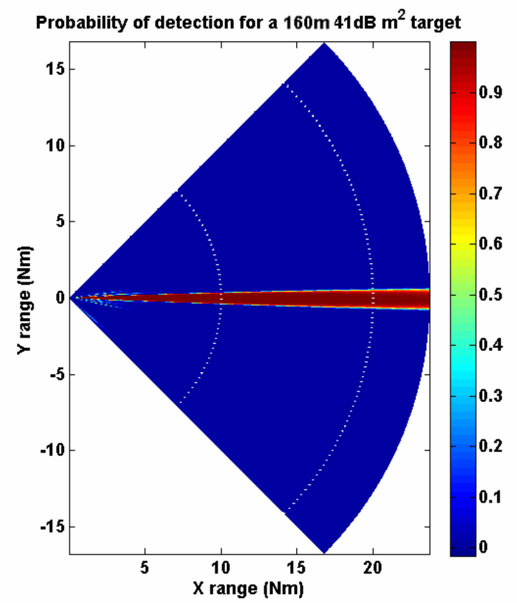

Figure 20 Pd for the wind turbine blade using the S-Band radar at a height of 47 metres AMSL

Figure 20 shows that the blade Pd is greater than that of the PEC tower case, and is detectable out to the full range of the radar. There are some minor side lobe effects at short ranges, and the area of high detection still extends, in parts, over a region greater than the beamwidth of the antenna, up to approximately 8 degrees.

This means that the appearance of the wind turbine on the radar's PPI display would be a constant source of clutter, spanning an area of approximately 5 degrees in bearing but possibly increasing up to 8 degrees intermittently as the blade flashes, with some minor side lobe effects at close ranges.

1.7.3 X-Band radar (23 metre antenna height)

Figure 21 shows a Pd plot for the PEC tower using an X-Band radar mounted at a height of 23 metres AMSL. The left hand image in Figure 21 shows the Pd for a PEC tower using the maximum theoretical RCS of 67.7dBsm, whereas the right hand image shows the Pd for the worst case apparent RCS of a PEC tower determined in section 1.5 (RCS of 25.7dBsm).

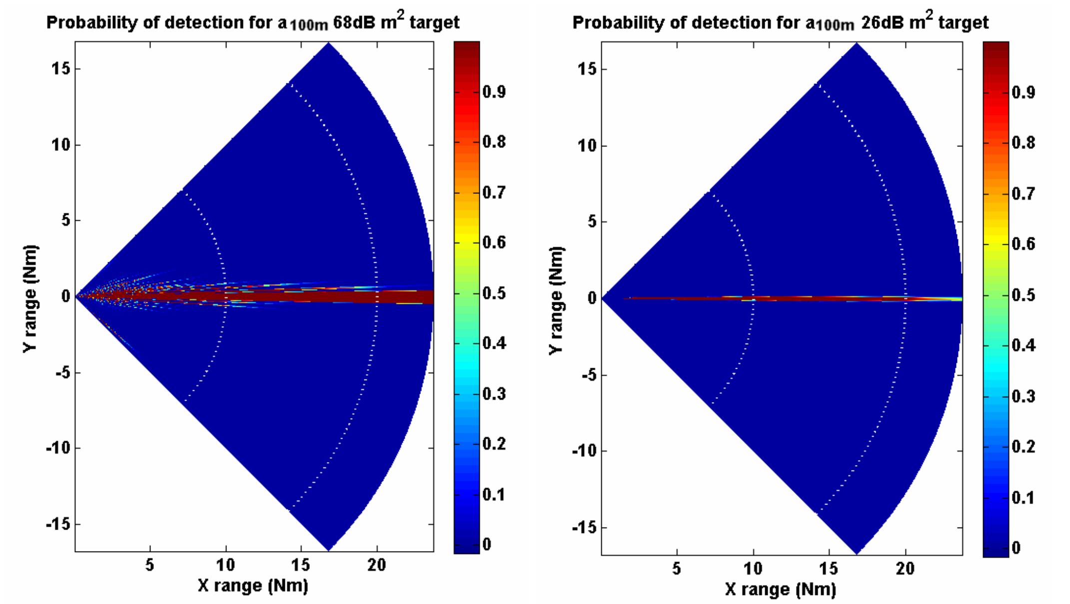

Figure 21 Pd for a PEC tower using the theoretical maximum RCS (left) and the apparent RCS (right) for the X-Band radar at a height of 23 metres AMSL

Figure 21 shows that using the maximum RCS, the tower would be detectable out to the full range of the radar. Side lobe effects are still apparent, with the tower possibly being detected as much as 10-15 degrees off the main beam. With the apparent RCS used, the tower Pd is reduced, although it is detectable out to the full range of the radar. There are no significant side lobe effects visible using the apparent RCS, although the area of high detection extends, in parts, over a region greater than the beamwidth of the antenna (1 degree), up to approximately 2 degrees.

Figure 22 shows the Pd for the blade of the wind turbine, with an RCS of 41dBsm.

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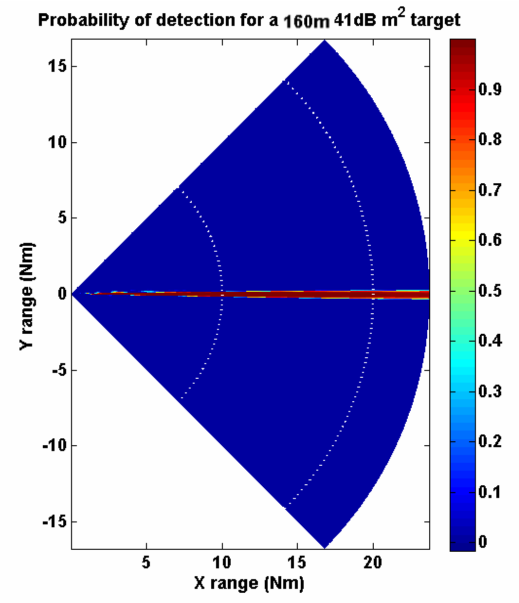

Figure 22 Pd for the wind turbine blade using the X-Band radar at a height of 23 metres AMSL

Figure 22 shows that the blade Pd is greater than that of the PEC tower case, and is detectable out to the full range of the radar. There are no side lobe effects at short ranges but the area of high detection still extends, in parts, over a region greater than the beamwidth of the antenna, up to approximately 2-3 degrees.

This means that the appearance of the wind turbine on the radar's PPI display would be a constant source of clutter, spanning an area of approximately 2 degrees in bearing but possibly increasing up to 3 degrees intermittently as the blade flashes but with no side lobe effects.

1.7.4 X-Band radar (47 metre antenna height)

Figure 23 shows a Pd plot for the PEC tower using an X-Band radar mounted at a height of 47 metres AMSL. The left hand image in Figure 23 shows the Pd for a PEC tower using the maximum theoretical RCS of 67.7dBsm, whereas the right hand image shows the Pd for the worst case apparent RCS of a PEC tower determined in section 1.5 (RCS of 25.7dBsm).

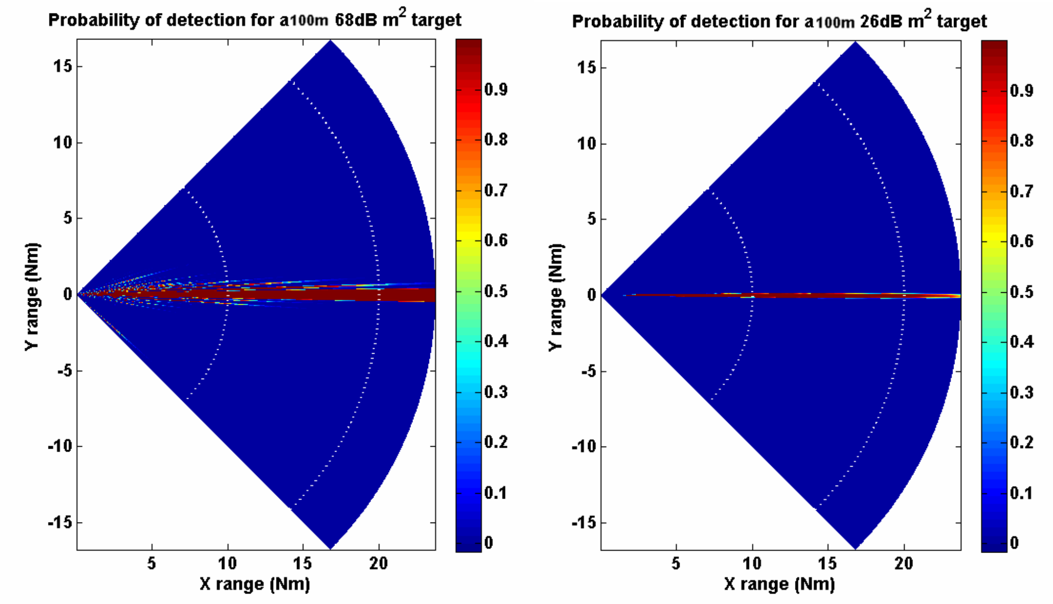

Figure 23 Pd for a PEC tower using the theoretical maximum RCS (left) and the apparent RCS (right) for the X-Band radar at a height of 47 metres AMSL

Figure 23 shows that using the maximum RCS, the tower would be detectable out to the full range of the radar. Side lobe effects are still apparent, with the tower possibly being detected as much as 10-15 degrees off the main beam. With the apparent RCS used, the tower Pd is reduced, and is still detectable out to the full range of the radar. There are no significant side lobe effects visible using the apparent RCS, although the area of high detection extends, in parts, over a region greater than the beamwidth of the antenna (1 degree), up to approximately 2 degrees.

Figure 24 shows the Pd for the blade of the wind turbine, with an RCS of 41dBsm.

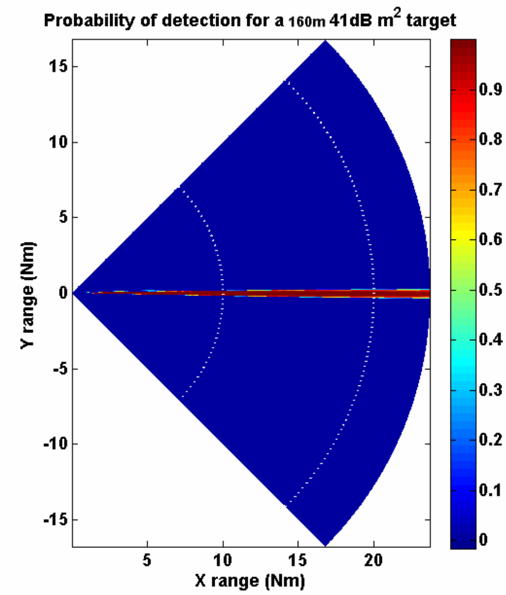

Figure 24 Pd for the wind turbine blade using the X-Band radar at a height of 47 metres AMSL

Figure 24 shows that the blade Pd is greater than that of the PEC tower case, and is detectable out to the full range of the radar. There are no side lobe effects at short ranges but the area of high detection still extends, in parts, over a region greater than the beamwidth of the antenna, up to approximately 2-3 degrees.

This means that the appearance of the wind turbine on the radar's PPI display would be a constant source of clutter, spanning an area of approximately 2 degrees in bearing but possibly increasing up to 3 degrees intermittently as the blade flashes but with no side lobe effects.

1.7.5 VTS radar (47 metre antenna height)

As the VTS radar is at a fixed location, NEMESiS can be used to simulate the appearance of the wind farm on the radar PPI display. Based on the previous X-Band results, which showed that there were unlikely to be any side lobe effects, it will be assumed that this will also be the same for VTS radar, reinforced more by the reduced antenna beamwidth. Figure 25 shows the clutter power for a sector of the VTS PPI display, showing the clutter associated with the simulated wind farm.

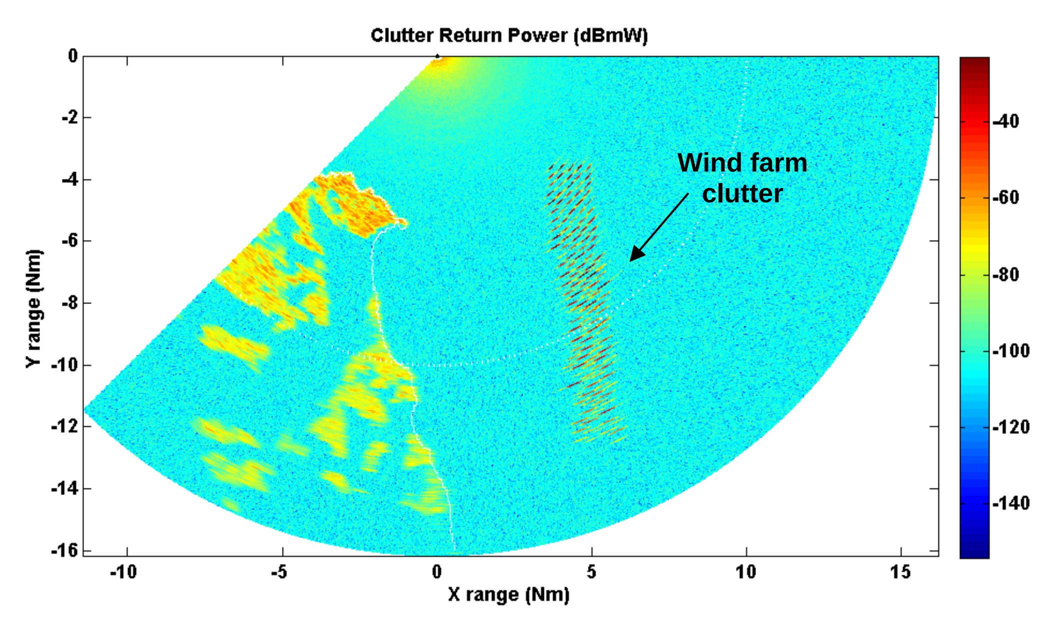

Figure 25 Clutter power for the Dublin VTS radar with the simulated Kish and Bray wind turbines

It should be noted that some of the turbines, especially towards the rear end of the wind farm, are unlikely to be visible on the display due to the physical shadowing effects discussed in section 1.6.

1.8 Receiver saturation

The variation in received signal strength for any radar system can be huge. This means that the dynamic range in a radar's receiver, which is the largest measurable signal divided by the smallest, must be very large. The smallest signal detectable by the radar receiver is defined by the noise that is inherent in any electrical system. The minimum detectable signal (MDS) for a radar system is set up to ensure that the probability of getting a false detection from this noise is low enough that it is not detrimental to radar performance, yet allowing maximum sensitivity in the receiver. A typical MDS for a navigation radar of the types considered in this study is approximately -100dBmW.

If signal levels exceed the dynamic range of the receiver, it can become saturated, leading to a possible loss of sensitivity behind the saturating object. This is depicted in Figure 26, which shows the radar beam intersecting the saturating object, and affecting the radar's sensitivity, or ability to detect objects. The sensitivity takes a defined amount of time to return to normal levels, dependent on the level of saturation and the RCS of the object that you're trying to detect, thus causing a blind zone behind the saturating object of up to 1km in some instances.

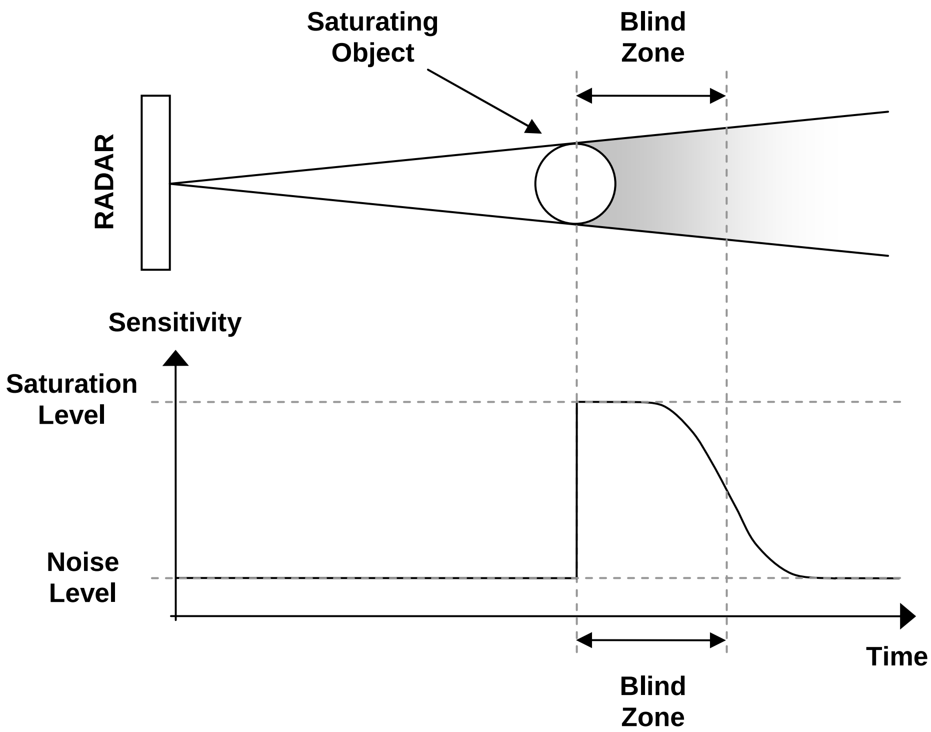

Figure 26 Plan view (top) of the radar beam intersecting the saturating object, and how that affects the radar's sensitivity to detect objects (bottom) causing a blind zone behind the object

To determine if the reflections from the turbines are likely to cause any receiver saturation, the power received can be calculated by the radar equation [6] (given in Equation 2), and compared against the instantaneous dynamic range for the radar.

$$P_r = \frac{P_t \cdot G^2 \cdot \sigma \cdot \lambda^2 \cdot F^4}{(4 \cdot \pi)^3 R^4} \qquad 2$$

P_r = power received at the antenna, P_t = power transmitted by the antenna, G = antenna gain, σ = RCS, λ = wavelength of transmitted energy, R = distance to the turbine and F^4 = pattern propagation factor (PPF), which is defined as the ratio of field strength to that of free space, created at a point by a propagating wave.

NEMESiS can be used to predict the PPF values from the propagation of the radar energy, and using the radar parameters from section 1.4, the potential for saturation can be deduced.

It should be noted that the following sub sections take into account sensitivity time control (STC), which decreases the sensitivity of the receiver as you get closer to the radar. Without STC applied, most reflections from objects close to the radar would send the receiver into saturation. A typical R^{-4} law has been used.

1.8.1 S-Band radar (22 metre antenna height)

Figure 27 shows the NEMESiS PPF values associated with the radar beam propagation for the S-Band radar mounted at a height of 22 metres AMSL.

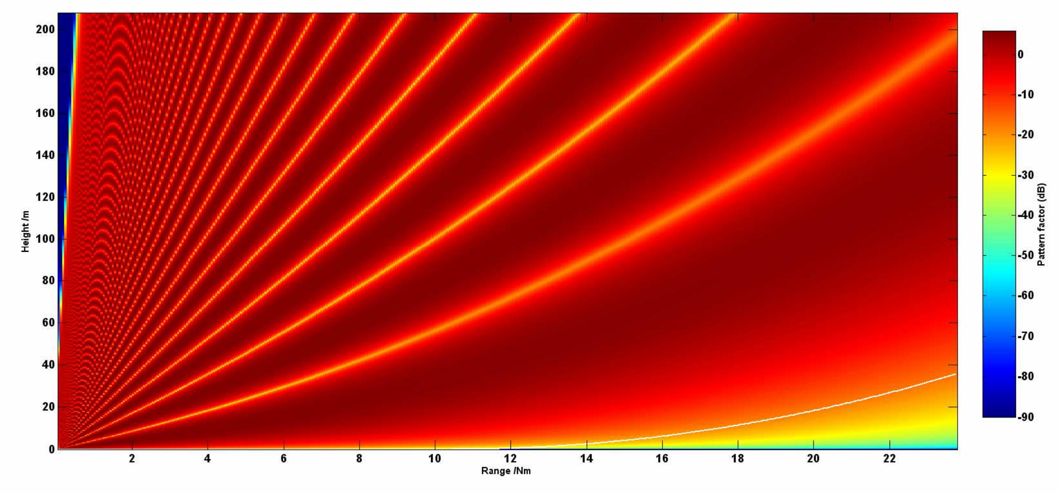

Figure 27 Side-on view of the actual PPF values associated with the S-Band radar antenna at 22 metres AMSL

Using the typical MDS value of -100dBmW, and combining this with the radar's dynamic range of 80dB gives a saturation level of approximately -20dBmW. If a signal greater than this is received, the radar is likely to go into saturation, and hence a loss of sensitivity is likely to be incurred. The higher the signal above the saturation level, the larger the loss of sensitivity may be.

Using the radar equation, the radar parameters from Table 2, the NEMESiS PPF values and the blade RCS (41dBsm), the predicted signal level received from the turbine as a function of range is shown in Figure 28.

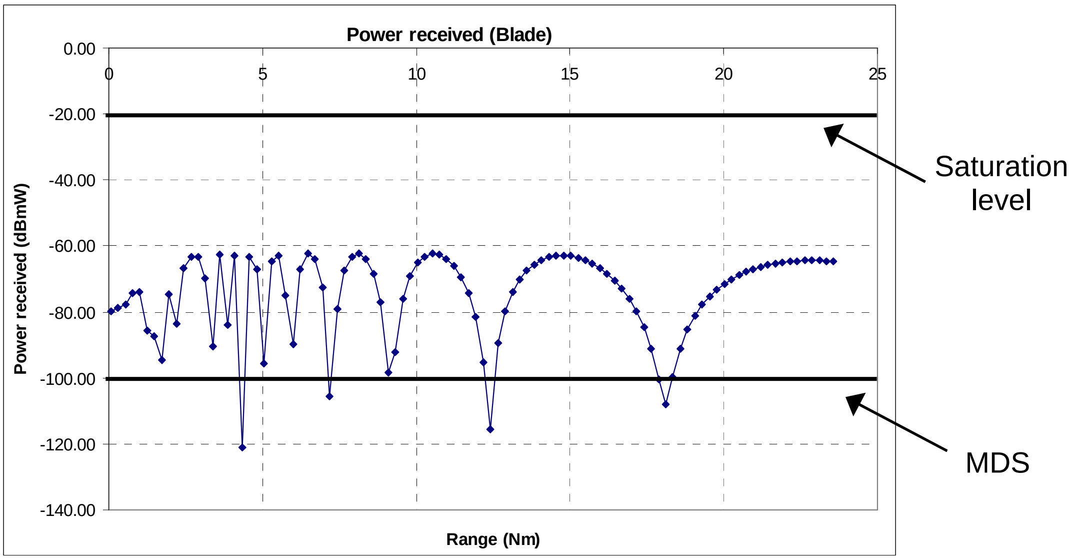

Figure 28 Predicted signal level from a blade as a function of range for the S-Band radar at a height of 22 metres AMSL, with STC applied

It is apparent from Figure 28 that the signal level received is greater than the MDS but is well below the level of saturation for the radar, with the application of STC. Therefore, it can be concluded that the tower signal will also not saturate the radar, and thus, no saturation effects are likely to be encountered with the S-Band radar in this configuration, and using STC.

1.8.2 S-Band radar (47 metre antenna height)

Figure 29 shows the NEMESiS PPF values associated with the radar beam propagation for the S-Band radar mounted at a height of 47 metres AMSL.

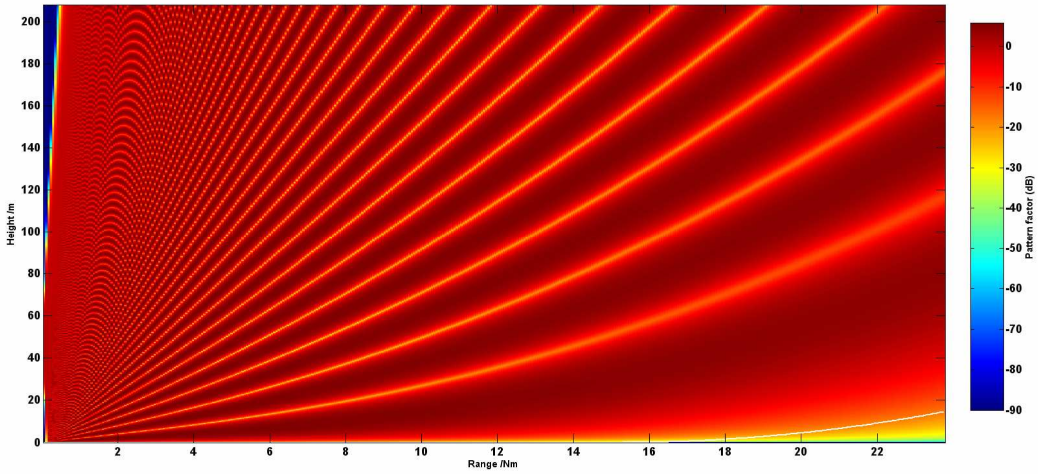

Figure 29 Side-on view of the actual PPF values associated with the S-Band radar antenna at 47 metres AMSL

Again using a typical saturation level of -20dBmW, along with the radar equation, radar parameters from Table 2, the NEMESiS PPF values and the blade RCS (41dBsm), the predicted signal level received from a turbine as a function of range is shown in Figure 30.

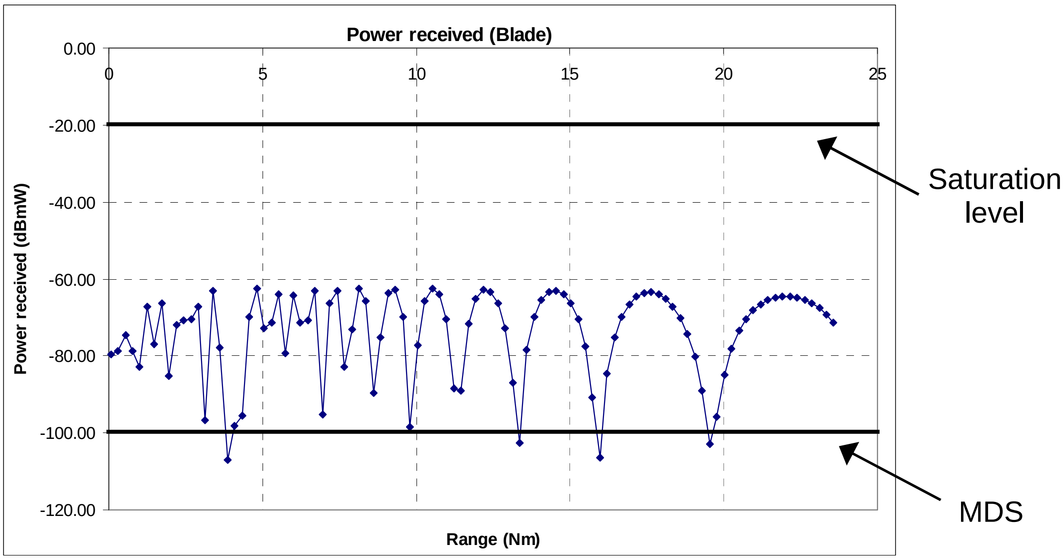

Figure 30 Predicted signal level from a blade as a function of range for the S-Band radar at a height of 47 metres AMSL, with STC applied

It is apparent from Figure 30 that the signal level received is greater than the MDS but is well below the level of saturation for the radar, with the application of STC. Therefore, it can be concluded that the tower signal will also not saturate the radar, and thus, no saturation effects are likely to be encountered with the S-Band radar in this configuration, and using STC.

1.8.3 X-Band radar (23 metre antenna height)

Figure 31 shows the NEMESiS PPF values associated with the radar beam propagation for the X-Band radar mounted at a height of 23 metres AMSL.

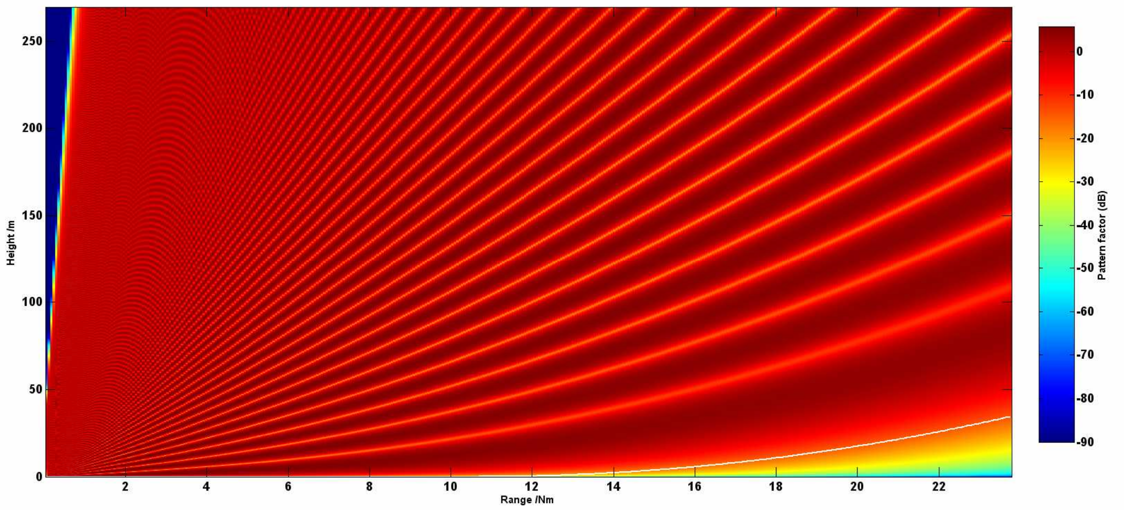

Figure 31 Side-on view of the actual PPF values associated with the X-Band radar antenna at 23 metres AMSL

Again using a typical saturation level of -20dBmW, along with the radar equation, radar parameters from Table 3, the NEMESiS PPF values and the blade RCS

(41dBsm), the predicted signal level received from a turbine as a function of range is shown in Figure 32.

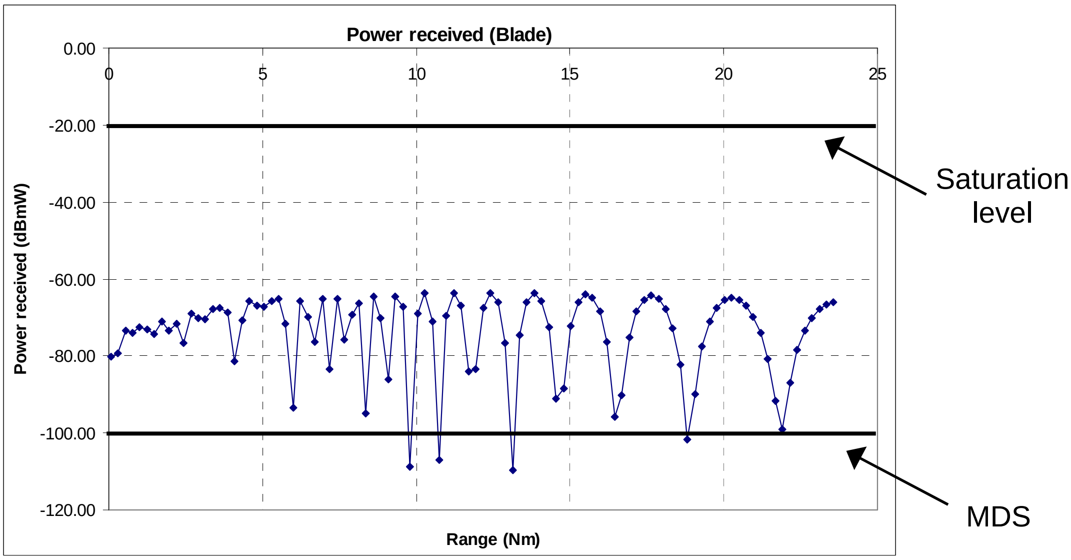

Figure 32 Predicted signal level from a blade as a function of range for the X-Band radar at a height of 23 metres AMSL, with STC applied

It is apparent from Figure 32 that the signal level received is greater than the MDS but is well below the level of saturation for the radar, with the application of STC. Therefore, it can be concluded that the tower signal will also not saturate the radar, and thus, no saturation effects are likely to be encountered with the X-Band radar in this configuration, and using STC.

1.8.4 X-Band radar (47 metre antenna height)

Figure 33 shows the NEMESiS PPF values associated with the radar beam propagation for the X-Band radar mounted at a height of 47 metres AMSL.

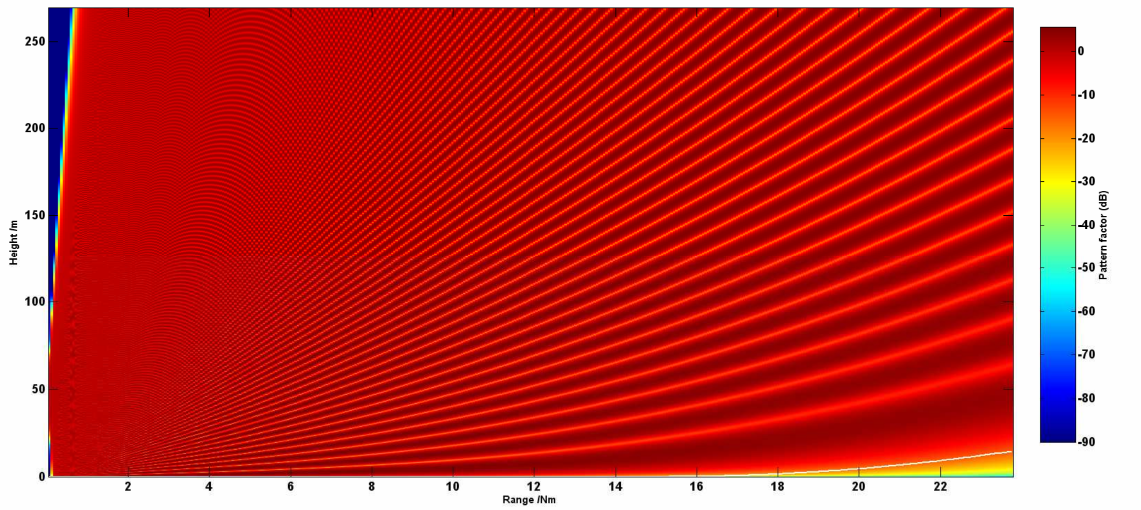

Figure 33 Side-on view of the actual PPF values associated with the X-Band radar antenna at 47 metres AMSL

Again using a typical saturation level of -20dBmW, along with the radar equation, radar parameters from Table 3, the NEMESiS PPF values and the blade RCS (41dBsm), the predicted signal level received from a turbine as a function of range is shown in Figure 34.

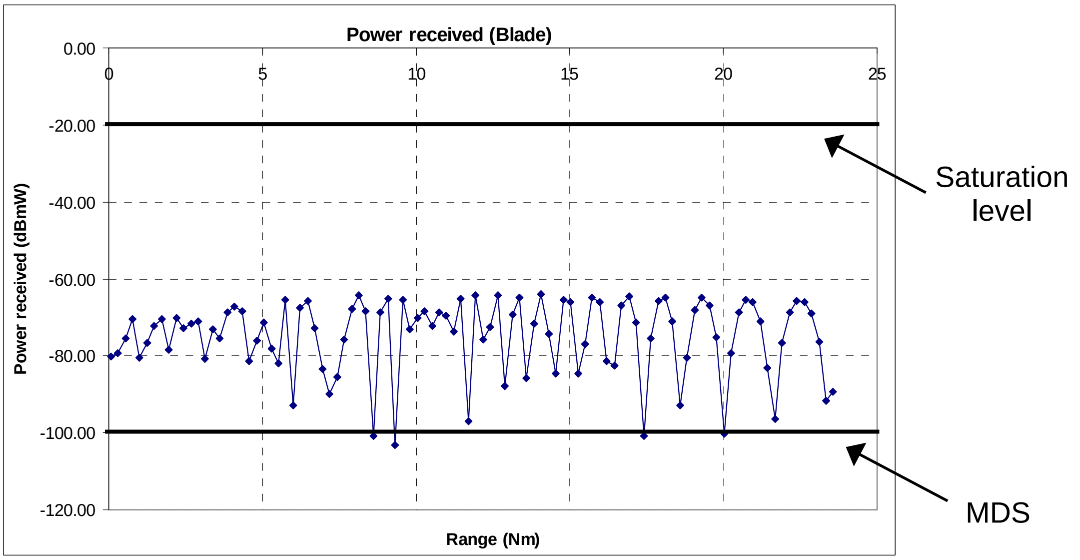

Figure 34 Predicted signal level from a blade as a function of range for the X-Band radar at a height of 47 metres AMSL, with STC applied

It is apparent from Figure 34 that the signal level received is greater than the MDS but is well below the level of saturation for the radar, with the application of STC. Therefore, it can be concluded that the tower signal will also not saturate the radar, and thus, no saturation effects are likely to be encountered with the X-Band radar in this configuration, and using STC.

1.8.5 VTS radar (35 metre antenna height)

Figure 35 shows the NEMESiS PPF values associated with the radar beam propagation for the X-Band radar mounted at a height of 35 metres AMSL.

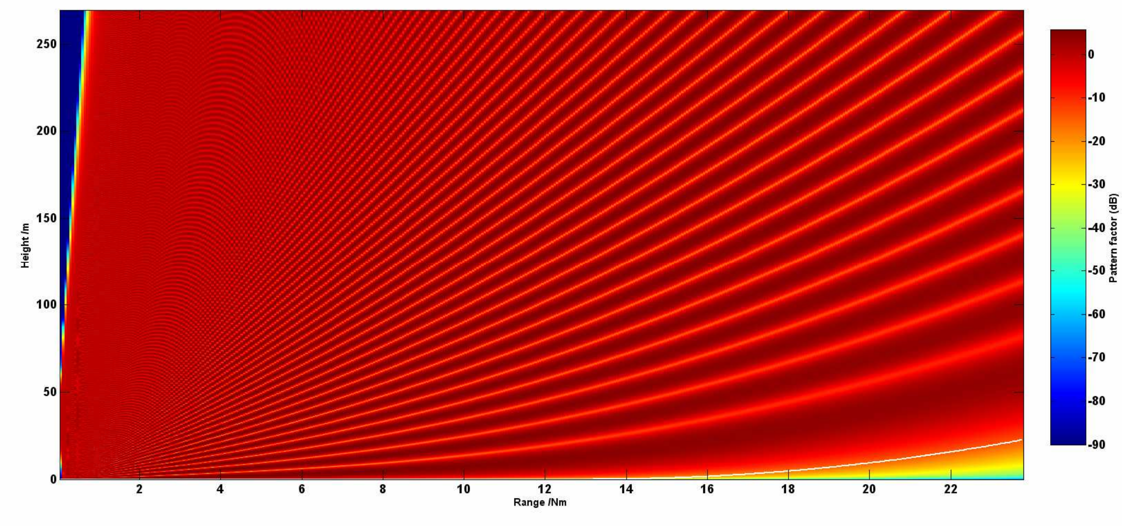

Figure 35 Side-on view of the actual PPF values associated with the VTS X-Band radar antenna at 35 metres AMSL

Again using a typical saturation level of -20dBmW, along with the radar equation, radar parameters from Table 3, the NEMESiS PPF values and the blade RCS (41dBsm), the predicted signal level received from a turbine as a function of range is shown in Figure 36.

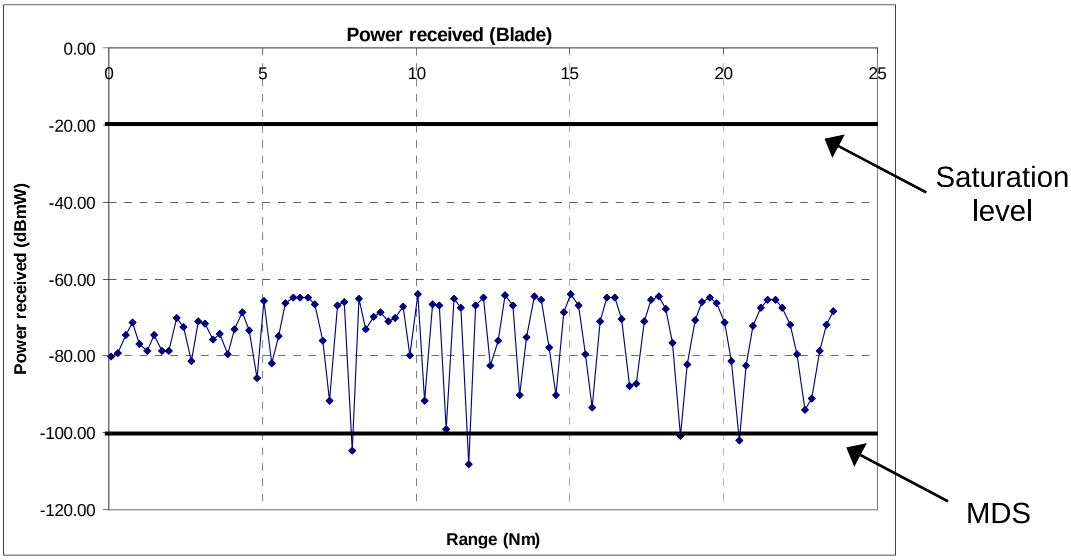

Figure 36 Predicted signal level from a blade as a function of range for the X-Band radar at a height of 35 metres AMSL, with STC applied

It is apparent from Figure 36 that the signal level received is greater than the MDS but is well below the level of saturation for the radar, with the application of STC. Therefore, it can be concluded that the tower signal will also not saturate the radar, and thus, no saturation effects are likely to be encountered with the VTS radar in this configuration, and using STC.

1.9 False plots

As with any case where there are multiple, highly reflective objects in close proximity to each other, there is always the chance that reflections between objects can cause false plots, or *ghost images*. This phenomenon is often seen when a vessel is coming into port or near a group of large RCS objects such as cargo ships and tankers. The main cause of this is the ships radars signals being reflected off the surfaces of other vessels, or even off the ships own masts.

With the almost limitless combinations of ship locations, and number of ships with respect to a group of turbines, it has to be accepted that the turbines may cause false plots, just as any other large vessel or large RCS object would.

One example that can realistically be assessed is the effect of the turbine layout on a single ship's radar. Figure 37 shows the process whereby transmitted radar energy can be reflected off one tower, onto a secondary tower, which then retro-reflects the energy back along the same path. If this retro-reflected energy is large enough to be detected, then it will appear as a false plot along the bearing of the first tower.

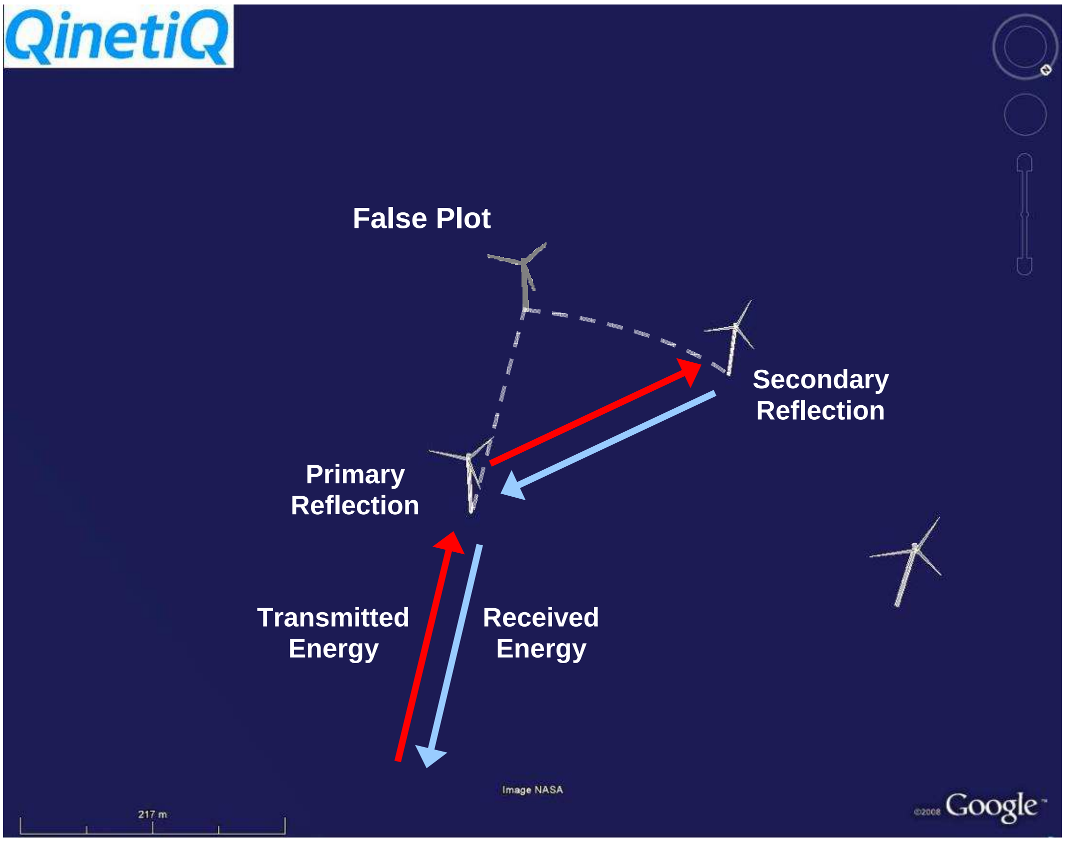

Figure 37 The path of reflected energy causing false plots

The spacing of the turbines means that the closest ones are approximately 500 metres apart. Subsequent turbines are then located roughly in additional 500 metre steps. Table 7 shows the reduction in signal strength to that of the strength you would expect from the primary reflector, at the various turbine range steps.

Range (km)	Signal Reduction (dBmW)
0.5	-49
1.0	-61
1.5	-67
2.0	-72

Table 7 Signal reduction from the received power of a secondary object with increasing range

From Table 7, it quickly becomes apparent that the power received from reflected signals quickly falls off as the separation distance increases. By applying these signal reductions to the signal level plots given in section 1.8, none of the radars are likely to detect reflected signals off multiple turbines.

Although unlikely, if false plots were to occur, it would be expected that only the most immediate turbines (approximately 500 metres) could cause false plots. However, these false plots are only likely to appear within the vicinity of the wind farm. The consequence of this event is that there may appear to be more turbines on a vessels radar display than actually exist, which would only be a problem trying to navigate through the wind farm itself.

1.10 Summary

This study has analysed the impact of a proposed wind farm at Kish and Bray Banks on a number of ship based S-Band and X-Band radars, as well as a land based VTS radar.

It was estimated that the worst case apparent RCS for the turbine towers, with the parameters used in this study, was likely to be in the order of 25.7dBsm. The RCS of the blades was estimated to be of the order of 41dBsm.

A number of effects were investigated as part of the impact assessment; these included shadowing, probability of detection, receiver saturation and false plots.

It was found that, due to the number of turbines and their layout, the effects of physical shadowing were likely to significantly degrade the detection performance of other vessels on the opposite side of the wind farm. However, with relatively large gaps between the turbines, where no shadowing would exist, intermittent detection would be expected. The Dublin Port VTS radar, would, therefore, experience a loss of detection for vessels to the south and east of the proposed wind farm.

The propagation modelling for both S-Band and X-Band radars showed that the turbines were likely to be detectable out to the full range of the radars (24Nm). Due to the large amounts of reflected energy from the turbines, detection would be over an area a few degrees wider than the radar's beamwidth, although no significant side lobe effects would be expected. Intermittent flashes from the blades would cause this wider area of detection to increase by a few more degrees. This widening effect could potentially mask detection of small craft in close proximity to the turbines.

It was found that there is unlikely to be any chance of saturation in the radar receivers as long as the use of STC is employed.

It was also determined that turbines in close proximity to each other are unlikely to cause false plots on a radar display. However, if any false plots were to occur, they would be contained in the region of the wind farm, but may cause the appearance of more turbines on a vessels radar display than would actually exist. This effect would be independent of the direction that ships are travelling but would vary depending on the proximity of the vessel to the turbines. Ghost images of the wind farm are also likely to be produced caused by reflections off other vessels, and also a ship's own masts, although this has not been investigated in this study.

It is, therefore, concluded that based on this study, any radars operating in the area will detect the turbines out to the full range of the radar but this is unlikely to be detrimental to the performance of the radar. However, detection of other vessels on the opposite side of the wind farm, as well as any smaller vessels within the wind farm, is likely to be significantly degraded.

Possible mitigation options, to reduce the effects of the turbines on various radar systems, would be to use radar absorbent materials in the construction of the turbines, or set up an exclusion zone around the wind farm itself, where vessels would not be allowed to enter.

Ultimately, as defined by the international regulations [1] [2], radar is purely an aid to navigation, and is one of many navigational tools used for the safe passage of vessel traffic.

1.11 References

[1] International Maritime Organisation, *International Regulations for Preventing Collisions at Sea*, 1972

[2] International Maritime Organisation, *Safety of Life at Sea (SOLAS)*, 1974

[3] Courtney, D. Saorgus Energy Ltd, *FW: UC RE: Kish and Bray Banks - Radar Assessment*, e-mail to Dearman, S. QinetiQ IS Division. Available e-mail: damien.courtney@saorgus.com, 16th October 2008

[4] Vectra Group Ltd, *Kish Offshore Wind Farm Shipping Collision Risk Study*, 961-3401, 17th September 2004

[5] Aerospaceweb.org, URL: http://www.aerospaceweb.org/question/electronics/q0168.shtml, June 2008

[6] Radar Basics, URL: http://www.radartutorial.eu/01.basics/rb13.en.html, July 2008

A Appendix A – Kish and Bray Wind Farm Layout

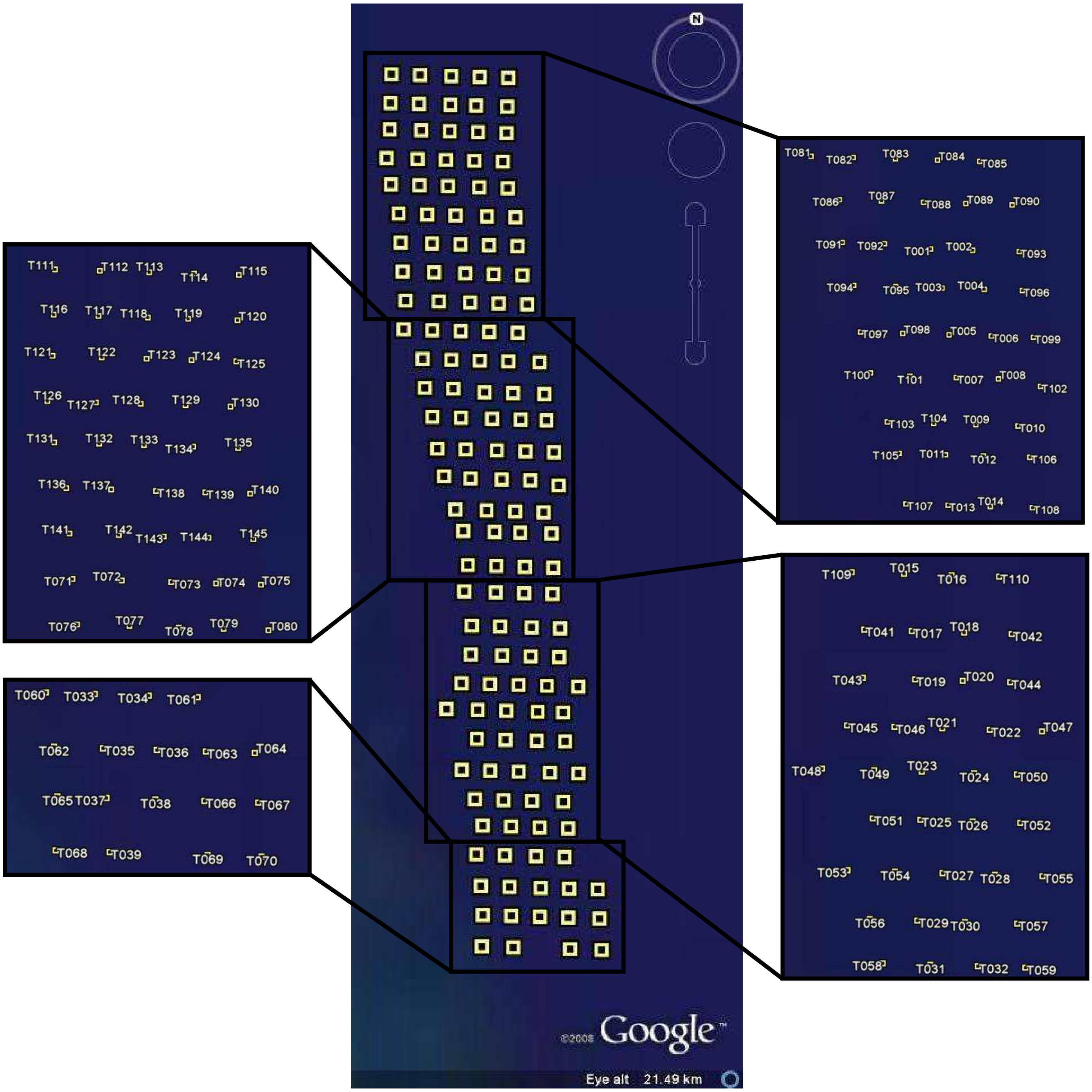

Figure 38 Kish and Bray turbine locations plotted on Google Earth showing their ID numbers

Saorgus Energy Ltd

Dublin Array Offshore Wind Farm Marine Navigation Impact Assessment

Prepared for:	Saorgus Energy Ltd Enterprise House Kerry Technology Park Listowel Road, Tralee, Co. Kerry
Prepared by:	Arcadis UK Limited Portland Tower Portland Street Manchester M1 3AH
Report No:	961-3401
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Rev	Date	Issue	Prepared	Reviewed	Approved
0	17th September 2004	1	Capt. Thomas J. Proctor	Capt. Thomas J. Proctor	Dr. Martyn Ramsden
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2	25th November 2008	1	Capt. Thomas J. Proctor	Capt. Thomas J. Proctor	Dr S. Booth
3	03rd February 2009	1	Capt. Thomas J. Proctor	Capt. Thomas J. Proctor	Dr. G. Bamford
4	18th November 2011	1	Capt. Thomas J. Proctor	Capt. Thomas J. Proctor	Dr S. Booth

Table of Contents

Executive Summary

The traffic operating to the Western sector of the Irish Sea is well established with approximately 42,000 ship movements per annum shared by ports on the East coast of Ireland. The ports of Dublin and Dun Laoghaire handle approximately 7825 vessels per annum, 7579 to Dublin alone (15645 ship movements per annum – 43 per day) which equate to 37% of the total. The majority of the trade is monopolised by the 'regular users', namely ferry operators, RoRo operators and Container Feeder vessels. It is worth noting here that the traffic to Dun Laoghaire from Holyhead has all but ceased throughout the winter season. However, the assessment has allowed for its return for four months in the summer.

Routeing decisions are invariably influenced by commercial needs and, in this respect a section on routeing rationale illustrates the saving gained by the use of various routes which mariners find attractive in sheltering from weather, tidal influence and distance saved or, a combination of each.

Analysis of commercial traffic in the various sectors around the Kish/Bray Banks reveal a well ordered systematic flow to the North of Kish Bank Lighthouse.

Distribution of traffic to the East and West of Kish/Bray Bank is similar in numbers although traffic in the Eastern arm is well dispersed.

Traffic to the West of Kish operates in closer proximity to the unmarked South and West of the Kish/Bray Banks. Traffic negotiating the Southern extremity of Kish/Bray Banks will do so via the West Codling Buoy some 2 nautical miles South.

Recreational traffic in the form of pleasure craft is not considered a hazard and the numbers, which cross Kish/Bray Bank, are few. Fishing is mostly confined to inshore but reference to bottom trawling is made due to their mode of operation.

The project extends into the Dublin Port approaches and into the area of coverage of the Dublin Port VTS. The VTS Radar is located at the Bailey Lighthouse at Howth**.**
A study on the potential impacts from radar was undertaken by Qinetic entitled 'Kish and Bray Banks Wind Farm Radar Impact Assessment' in February 2009. This study forms an integral part of the assessment of potential impacts on marine navigation. Dublin Port Company was consulted after the Qinetic study was completed, and confirmation provided that potential radar screening identified in the study did not pose a problem to Dublin Port Company (see copy of attached letter in Appendix VI of this report).

It is considered possible, but unlikely, that wind generators and cables may cause propagation problems and electro magnetic interference in onboard navigation equipment.

1.0 Introduction

Arcadis UK Limited (formerly Vectra Group Limited) has been contracted by Saorgus Energy Ltd to undertake an assessment of the potential impact of the proposed Dublin Array Offshore Wind Farm on shipping and marine navigation. This report documents the findings of that study undertaken between August and September 2004 and updated in February 2009 and further updated in November 2011. The UK DTI document "Guidance on the Assessment of the Impact of Offshore Wind Farms – ' Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms' was used as a reference in compiling this assessment.
Recommendations of the Marine Survey Office officials was also taken into account in its preparation.

1.1 Aim

The aim of the study was to establish the potential impact of the proposed wind farm on the safety of shipping and marine navigation in the area.

1.2 Scope

The scope of the study incorporates both the construction and operational period: The report will identify:

- The existing shipping Traffic in the area.
- Assess the impact of the proposed development on shipping collision.
- Identify any mitigation measures that may be deemed necessary.

1.3 References

- Guidance on the Assessment of the impact of Offshore Wind Farms.(UK-DTI)-("Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms")
- The Merchant Shipping (High Speed Craft) Regulations 2004. SI 302/2004
- Seabed Mapping and Seafloor Process in the Kish, Burford, Bray and Fraser Banks area, South Western Irish Sea. (Wheeler, Walsh & Sutton)
- A study of the Leading Long Period Waves in Fast Ferry Wash (Whittaker, Doyle & Elsaesser)
- A Physical Study of Fast Ferry Wash Characteristics in Shallow Water (MCA Research Project 457)
- Fisheries Information – Cod, Whiting Plaice and Sole in the Irish Sea. CEFAS 04/01
- Port Marine Safety Code. Department of the Environment, Transport and the Regions (UK). March 2000
- A Guide to Good Practice on Port Marine Operations. Department for Transport, Local Government and the Regions. March 2002.
- Recommendation for the Marking of Offshore Wind Farms.
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- The Harbour Master, Wicklow Harbour

- The Harbour Master & Commercial Department, Port of Dublin
- The Harbour Master, Drogheda
- The Harbour Master, Dundalk
- The Harbour Master, Greenore
- The Harbour Master, Warrenpoint
- The Commercial Department, Port of Belfast
- The Harbour Master, Port of Larne
- The Irish Sailing Association
- The Secretary, Malahide Marina
- The Secretary, Howth Marina
- The Secretary, Dublin City Moorings
- The Seretary, Dun Laoghaire Marina
- The Secretary, Clontarf Yacht & Boat Club
- The Commissioners of Irish Lights.

2.0 Methodology

Information for this assessment has been compiled from the following sources:

- Irish/UK Sea Ports Import /Export Data.
- Irish Sea Ferry Services.
- Irish Sea Ship Numbers.

2.1 Abstract

The southern Irish Sea is characterised by a series of NNE-SSW trending bedforms that influence the principal tidal current directions.
In the Western part of the southern Irish Sea, just off the Wicklow coast at a distance of approx 5/6 miles are found a series of coast parallel offshore banks, which by definition, lie in a North/South direction. Standing in 20-30metres of water, these banks form a natural wave protection to the coast. Southernmost of these banks is the Arklow Bank and the northernmost being the Kish Bank. The largest of the banks in the afore mentioned range is the Kish and Bray. The Bray Bank being the southerly continuation of the Kish.

3.0 The Kish and Bray Banks

3.1 Location and Extent

The Kish and Bray Banks together extend for a distance of approximately 10 nautical miles having an average width of approx 0.5 nautical mile. Its northerly extent is marked by the North Kish (North Cardinal Mark) in position *53˚ 18.5'N 005˚ 56.4'W* having Very Quick Flashing (*VQ*) characteristic and painted Black and Yellow (BY).

The northerly extremity is further marked by the Kisk Bank Lighthouse [*53˚ 18.7'N 005˚ 55.3'W*] located some 5 cables (half a nautical mile) ENE of the North Kish (NCM) and some 3 cables ENE of the bank. The characteristics of the Kish Bank Lighthouse are *Fl.(2)20s29m22M Horn(2)30s* ***Racon(T)***

The southernmost extremity of the banks are found in position 53˚ 08.8'N 005˚ 54.5'W and are unmarked by navigation buoys.
The eastern extremity of the bank is marked by a Red Can Buoy (East Kish) in position *53˚ 14. 3'N 005˚ 53.6'W* having the characteristics *Fl.(2)R.10s*.

The Westerly edge of the bank is unmarked by any navigational buoys.

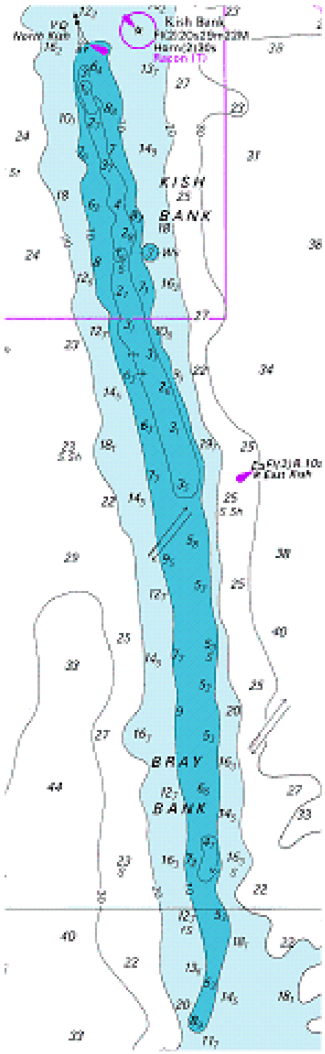

Fig.1

3.2 Depths on Bank[1]

The Kish and Bray Bank are depicted on Admiralty Charts by a 10 metre contour line. The Banks are further subdivided into two 5 metre patches North and South.

The northerly patch bordered by the 5 metre contour line extends south for 4.4 nautical miles and has an average depth of 3.5 metres with minimum depths of 1.8m[*53˚ 18'N 005˚ 56.2'W*] and 1.6m [*53˚ 16.5'N 005˚ 55.8'W*].

The southerly extent of the 5m contour approximates to the same latitude of the East Kish Buoy (Red can).

The southerly patch bordered by the 5m contour line is relatively small having a minimum depth of 4.7m [*53˚ 10.5'N 005˚ 54.2'W*] and extending for 0.5 nautical miles north/south. Apart from this outcrop the average depth over the Bray Bank is approx 6.5m.

There are two wrecks symbols, ⋕, which denote: *Wreck, depth unknown, which is not considered dangerous to surface navigation*.

There is also a 3m Wk outcrop external to the 10m contour at position *53˚ 16.5'N 005˚ 55.3'W* this denotes: *Wreck over which the depth has been obtained by sounding but not by wire sweep.*

3.3 Bank Composition

The seabed inway of the banks consist of Sand (S), Stones (St) and Shells (Sh). Grain size data and bedform interpretations suggest a northerly sediment transport system with gravel dominant in the south (Bray Bank) grading to sands in the north (Kish Bank). The regional seabed sedimentary map[2] includes coverage of the area under consideration. The map depicts the area as "covered by sand with a tongue of slightly gravely sand extending up from the western side of the Kish Bank.

3.4 Tidal Streams in way of the Banks

The tidal stream across the Kish and Bray banks follow a NE (flood) and SW (ebb) direction with known speeds of between 1-3kts. Tidal stream arrows are shown in positions *53˚ 13.7'N 005˚ 55.1'W* in way of South Kish Bank and *53˚ 11.8'N 005˚ 53.4'W* in way of Bray Bank. These streams are continuously active and do not have any appreciable standing time. Hence, the deflection from the general N/S direction.

The tidal stream table C refers to position midway between the Kish Bank Lighthouse and the more northerly Bennet Bank, South Cardinal Mark. Its importance will be explained later.

[1] All depths are reduced to Chart Datum [Lowest Astronomical Tide – LAT]
[2] British Geological Survey and Geological Survey of Ireland, 1990

C	Lat 53° 19.3'N		Long 005° 54.5'W
HOURS	DIRECTION°	SPRING RATE(kts)	NEAP RATE(kts)
-6	002	1.3	0.7
-5	002	2.1	1.1
-4	002	2.1	1.2
-3	002	1.5	0.9
-2	002	0.8	0.5
-1	182	0.1	0.0
HW	182	1.1	0.6
+1	182	2.0	1.1
+2	182	2.2	1.2
+3	182	1.8	1.0
+4	182	1.0	0.5
+5	182	0.1	0
+6	002	0.9	0.5

Table 1.

The table gives direction and rate for each hour before and after High Water (HW).
To the south of the Bray Bank the tidal stream follows a NE/SW direction with speeds of 2-4kts in way of the channel between Bray Bank and the Codling Bank.

4.0 General Traffic Flow within Irish Sea

The Irish Sea is a major hub of International Shipping and hence serves both continental and worldwide ports. The flow of traffic is in both the North/South and East/West direction.

4.1 North/South Traffic

4.1.1 Northbound Traffic

The Northbound traffic emanates from the St.Georges Channel through the main arteries known as Traffic Separation Schemes off 'The Smalls'[***Fl(3)15s25M***] in the East and 'Tusker Rock'[***Q(2)7.5s24M***] in the West. The ship sizes/types will vary from large tankers/bulk carriers to coastal tankers/bulk carriers. Northbound vessels rounding 'The Smalls' and destined for a port in the United Kingdom will generally stay to the East heading for the Traffic Separation Scheme off Anglesey and thence North West ports in the United Kingdom. Vessels destined for ports further North, such as Glasgow, Belfast and Larne will invariably pass to the West of the Isle of Man passing approx 2.5 miles East of The Codling Bank Lanby Buoy[***Fl.4s.12m.15M***], and thence approx 15 miles East of Kish Bank [***Fl.2(W).20s22M***].
Northbound vessels destined for ports on the East coast of the Irish Republic and North of Arklow and Wicklow will have the option of passing the Codling Bank Lanby Buoy approx 2.5 miles to the East and thence on to there various destinations or, if

proceeding to Dublin then via India North-NCM[3] (VQ) and India South - SCM[4] *[Q(6)=L.Fl.15s]* or West Codling *[Fl.G.10s]* and South Codling- SCM *[VQ(6)=L.Fl.10s].* See *Appendix I – North South Traffic Flow*.

4.1.2 Southbound Traffic

Southbound traffic entering the Irish Sea from the North Channel, North of Belfast Lough, will in general be considerably less than the numbers entering from the South.
The size and type will be similar to the Northbound traffic but their numbers probably in the region of 20%. By definition therefore, the Southbound flow will be greater as it will consist of both the Southbound entering from the North Channel and the returning Northbound. See Appendix II – South Bound Traffic Flow

4.2 East/West Traffic

The East/West traffic in the Irish Sea in monopolised by the established Ferry Services, the Container Feeder Services and Coastal Bulk (Liquid and Dry). The larger deep sea vessels do have a small Easterly ballast component invariably from the ports of Dublin, Cork and Belfast to Liverpool/Bristol Channel. See Appendix III – East/West Traffic Flow

East/West traffic outside the immediate area under consideration will not be addressed.

[3] North Cardinal Mark
[4] South Cardinal Mark

5.0 Routeing Rationale

Vessels destined for Dublin from the North will approach via the Traffic Separation scheme North of Burford Bank at reporting point '***Charlie***'. Similarly, those departing and destined North will do so via '***Delta***'. Their impact on our study will be negligible.

Vessels destined for Dublin from the South will, as already stated, emanate from the Traffic Separation Schemes (TSS) in the St.Georges Channel.
Vessels navigating the TSS off 'The Smalls' have the option of:

- Proceeding towards South Burford TSS (*Alpha*) via East of the Codling Lanby Buoy and East of Kish Bank Light and a distance of some 103 nm.

- Proceeding towards South Burford TSS (*Alpha*) via a route passing approx 1 nm West of the North Arklow Buoy (Q.Fl) and approx 6 cables West of India South (Q(6) +LFl.15s) thence approx 6 cables West of West Codling(Fl.G.10s) a distance of some 95 nm.

Vessels navigating the TSS off 'Tusker Rock' have the option of :

- Proceeding towards South Burford TSS (*Alpha*) via East of the Codling Lanby Buoy and East of Kish Bank Light and a distance of some 82 nm.

- Proceeding towards South Burford TSS (*Alpha*) via the Glassgorman Banks and passing between Arklow Bank and Seven Fathom Bank to North Arklow Buoy (Q.Fl) thence to approx 6 cables West of India South (Q(6) +LFl.15s) and 6 cables West of West Codling(Fl.G.10s) a distance of some 68 nm. This is locally referred to as the 'inside route'.

The above routes and approximate distances also apply vice versa i.e. southbound departing point ***'Bravo'*** at the South Burford TSS.

Dublin Port can accommodate vessels drawing up to 10.2m at high water. Vessels drawing 7.0m may enter at any state of the tide.
By definition ships destined for Dublin Port will not exceed this draft and in many cases will be of a lesser draft and therefore have little difficulty in navigating the shorter route available which has ample depth of water for vessels destined for the port. The aforementioned 'inside channel' from The Tusker to South Burford is primarily used by coastal vessel with local knowledge in vessel drawing approximately 4/5m.

6.0 Recreational Traffic

There are several Marinas in the immediate vicinity of Dublin Bay namely Dun Laoghaire, Clontarf Yacht & Boat Club, Malahide, Howth, Poolbeg and Dublin (City Moorings).

Dun Laoghaire is the main leisure and yacht port serving the surrounding area and situated on the Southside of Dublin Bay. The Marina currently has berths for approx 820 craft. Berths can accommodate craft from 6 metres to those in excess of 20 metres in length.
The type of craft presently moored at the marina are mix of power and sail. The smaller craft restrict their movement to areas where they are back at their mooring by nightfall and in this respect rarely venture south of Killiney Bay or North of Howth. There are however, many craft who undertake voyages farther a field.

Clontarf Yacht & Boat Club is located within the inner Harbour of Dublin Port (Northwest of North Bull Light and West of Bull Wall. The club has moorings for 150 boats and dinghies. The club also races in the outer harbour many times throughout the year, mainly of a weekends.

Malahide Marina is located some 5 miles North of Dublin Bay and can accommodate up to 350 pleasure craft with an upper loa of 75 metres and a draught alongside of 4 metres.

Howth Marina, located on the Northside of Howth Head, has berths for 250 craft the majority of which are sail. The sailing ground for the members is mainly of a local flavour with much interplay between other clubs in the area. From April through to September visitors arrive from many European countries. September through March is very quiet at Howth.

Dublin City Moorings are located at Custom House Quay close to Dublin City Centre but no longer exist as an entity.

Poolbeg Yacht Club is located on the South Bank of the River Liffey just East of the East Link Bridge. Moorings are available for 20/30 craft.

Angling is very popular along the Southeast coast but there is limited activity on Kish Bank itself due to distance offshore and the tidal current effect on small pleasure craft. What angling activity takes place is limited to inshore areas to the West of the bank in way of Dublin Bay (South), Scotsman's Bay, Dalkey Island, Killiney Bay and South along the Wicklow coast.

7.0 Commercial Fishing

Commercial fishing on and around the Kish Bank is much reduced in recent years due in the main to the depletion in fish stocks. It may be summarised as to say commercial fishing on the Kish/Bray Banks is negligible. A note will be registered later with respect to trawlers in general operating in vicinity of wind farms. There is however, a thriving inshore industry in the fishing for 'whelks' which does extend to a lesser degree to Kish/Bray Banks.

8.0 Port Statistics

8.1 East Coast of Ireland.

The statistics used below are from those ports, which will have most impact on the area under consideration.

NUMBER AND TYPE OF VESSEL ARRIVAL 2004						
PORT	**LIQUID BULK**	**DRY BULK**	**CONTAINER**	**SPECIALISED**	**GENERAL***	**TOTAL**
ARKLOW		5				**5**
WICKLOW		24			150	**174**
DUN LAOGHAIRE					**1074**	**1074**
DUBLIN	**463**	**398**	**1622**	**196**	**5351**	**8030**
DROGHEDA	119	43	97		384	**643**
DUNDALK	16	203				**219**
GREENORE	9	105			69	**183**
TOTAL						**10328**

Table 2

The above data was used on the initial study of 2004

NUMBER AND TYPE OF VESSEL ARRIVAL 2010						
PORT	**LIQUID BULK**	**DRY BULK**	**CONTAINER**	**SPECIALISED**	**GENERAL***	**TOTAL**
ARKLOW						**0**
WICKLOW		8			45	**53**
DUN LAOGHAIRE					**243**	**243**
DUBLIN	**437**	**375**	**1529**	**185**	**5053**	**7579**
DROGHEDA	34	12	27		107	**180**
DUNDALK	3	37				**40**
GREENORE	6	72			48	**126**
TOTAL						**8221**

* Includes Ferries

Table 3

Dublin Bay current traffic, including Dun Loaghaire traffic, is declared at some 43 vessel movements per day i.e 21.5 vessels per day which equates to 7822 for the present year which represents a decrease for the Dublin Port/Dun Loaghaire figures of approximately 14% on 2004.

Arklow traffic is presently engaged in the occasional servicing the Arklow Bank Wind Farm. In the past four years they have received one small commercial vessel and that was in the early part of 2011.

Wicklow traffic attributes 30% of its traffic being shared with Warrenpoint/Belfast Approx 3% is shared with Cork. The balance is from Scandinavia and Holland with a small proportion from UK. The majority enter the Irish Sea North about.

Dun Laoghaire commercial traffic is currently ceased. It is assumed that a seasonal service will be offered over a four month summer period. Two services a day are envisaged. A figure of 243 arrivals per annum has been attributed.

Dublin see separate Dublin Bay Traffic Analysis(8.2 & 8.3)

Drogheda shares none of it's traffic with Dublin. The greater proportion, 85% of its trade is with Scandinavia and therefore utilise the Northern route entering/departing the Irish sea through the North Channel. This accounts for approx 153 vessels the balance, 27, enter and depart through the South Irish Sea and it is estimated that no more than 10% will utilize the inside passage.

Dundalk share no traffic with Dublin and declares a 33/67 split with approx 13 vessels attributed as coming and going from North and 27 vessels from the South. No more than 10% are considered to use the inside passage and that is because of weather.

Greenore attributes approximately 10% of its traffic as being shared with Dublin. The vessels usually lighten in Dublin to facilitate entry into Greenore. A further 10% will be attributed to a Northerly influx giving 13 vesssels. The vast majority are attributed to a Southerly inflow/outflow due their South Continent/Biscay customer base with no more than 10% utilizing the inside passage. 126 vessels are attributed for 2010

Warrenpoint has declared ship numbers for 2010 of approx 845 per annum i.e. ship movements of some 2,400 of which there are 24 ferry movements per week to Heysham and 4 LoLo movements per week with Waterford/Zeebrugge. The balance, 502, consisting of coastal traffic. Their flow being 65% S 35%N.

Belfast has declared ship numbers for 2010 of approximately 5664 per annum i.e. ship movements of some 11328 of which approximately 10% are contributed to coastal movements (containers feeders etc which are shared with Dublin).
Belfast maintains ferry services with Stranraer, Birkenhead, Heysham and Troon, which comprise ship numbers of 4283. Approx 10% of the Southbound traffic may navigate to the West of Kish Bank for weather protection.

Larne has declared ship numbers for 2010 of approx 4,500 per annum i.e. ship movements of some 9,000 of which all are, in the main, ferries. There are some small cargo movements in the port. There are 22 ferry movements per days in the winter and 30 ferry movements per day in the Summer. The ferries service the ports of Fleetwood, Cairnryan and Troon. 50 NC.

This gives ship numbers for the East coast of Ireland as 19,230, which equates to approximately 38,460 ship movements per annum

8.2 Dublin Bay Traffic Analysis

Dublin Port / Dun Laoghaire Harbour ship movements amount to 15645 per annum which translates into 43 movements per day:

- *30 Ferry/RoRo movements per day (including seasonal adjustments).*
- *Approx 8 regular runners (Container Feeder Ships, Car Carriers etc).*
- *Approx 5 unscheduled.*

8.2.1 Ferry/RoRo Traffic

The trans Irish Sea Ferry/RoRos account for 71% of traffic entering and departing Dublin Bay.
Approximately 33% of this traffic, namely that traffic to Holyhead, enters /departs Dublin Bay through the Kish/Bennet channel i.e. that channel between Kish Bank Lighthouse and Bennet Bank Buoy. The remaining 37% entering/departing Dublin Bay some several miles North of Bennet Bank Buoy on a course from/to North Burford and positions north of the TSS off The Skerries *[Fl(2) 20M Iso.R.10M Horn (2) 60s (Racon(T)]* Northwest of Anglesey. See Appendix IV

8.2.2 Liner Services (Regular Runners)

This traffic amounts to approximately 4 vessels per day (1460pa).
Approximately 10% will arrive/depart through reporting points Charlie & Delta at the Bailey TSS. *The Northerly Element 146.*
Approximately 60% will arrive/depart via reporting points Alpha & Bravo at the South Burford TTS. *The Southerly Element 876.*
Approx 30.0% (the non regular and larger ships) enter through Kish/Bennet Channel. There is a 2:1 split between the Southerly and Easterly element. 438

8.2.3 Unscheduled Traffic

This traffic amounts to approximately 2,5 vessels per day (913pa)

Approximately 10% will arrive/depart through reporting points Charlie & Delta at the Bailey TSS. *The Northerly Element.91*
Approximately 60% will arrive/depart via reporting points Alpha & Bravo at the South Burford TTS. *The Southerly Element. 548*
Approx 30.0% (the non regular and larger ships) enter through Kish/Bennet Channel. There is a 2:1 split between the Southerly and Easterly element. 274

8.3 Directional Analysis

DIRECTION ANALYSIS						
Port	Ship Nos	North		South		East/ West
		IS[5]	OS[6]	IS[7]	OS[8]	
Arklow	0					
Wicklow	53	51		2		
Dun Laoghaire	243					243
Dublin	7579		275	1654	551[7]*	5099[8]
Drogheda	180		153	3	24	
Dundalk	40		13	3	24	
Greenore	126	12		12	102	
Warrenpoint	845		121	82	213	429
Belfast	5664	567		92	827	4178
Larne	4500		39		10	4451
	19,230	51		1848	1751	

Table 4

8.4 Annual Disposition

North Kish:
There are approximately 6935 vessels (13870 ship movements) navigating to the North of the Kish Bank on an Annual basis.
Approx 38 ship movements per day.

South Kish:
There are approximately 1848 vessels (3696 ship movements) navigating to the South of the Kish Bank on an Annual Basis.
Approx 10 ship movements per day.

East Kish:
There are approximately 1751 vessels (3502 ship movements) navigating to the East of the Kish Bank on an Annual Basis.
Approx 10 ship movements per day.

West Kish:
There are approximately 1899 (*1848 + 51*) vessels (3798 ship movements) navigating to the West of the Kish Bank on an Annual Basis.
Approx 10.5 ship movements per day.

[5] Inside Routeing
[6] Outside Routeing
[7] Unscheduled
[8] Scheduled + Easterly Ferries

9.0 Sector Analysis

9.1 North Kish

The area under consideration is the Ferry/RoRo corridor North of Kish L/H.

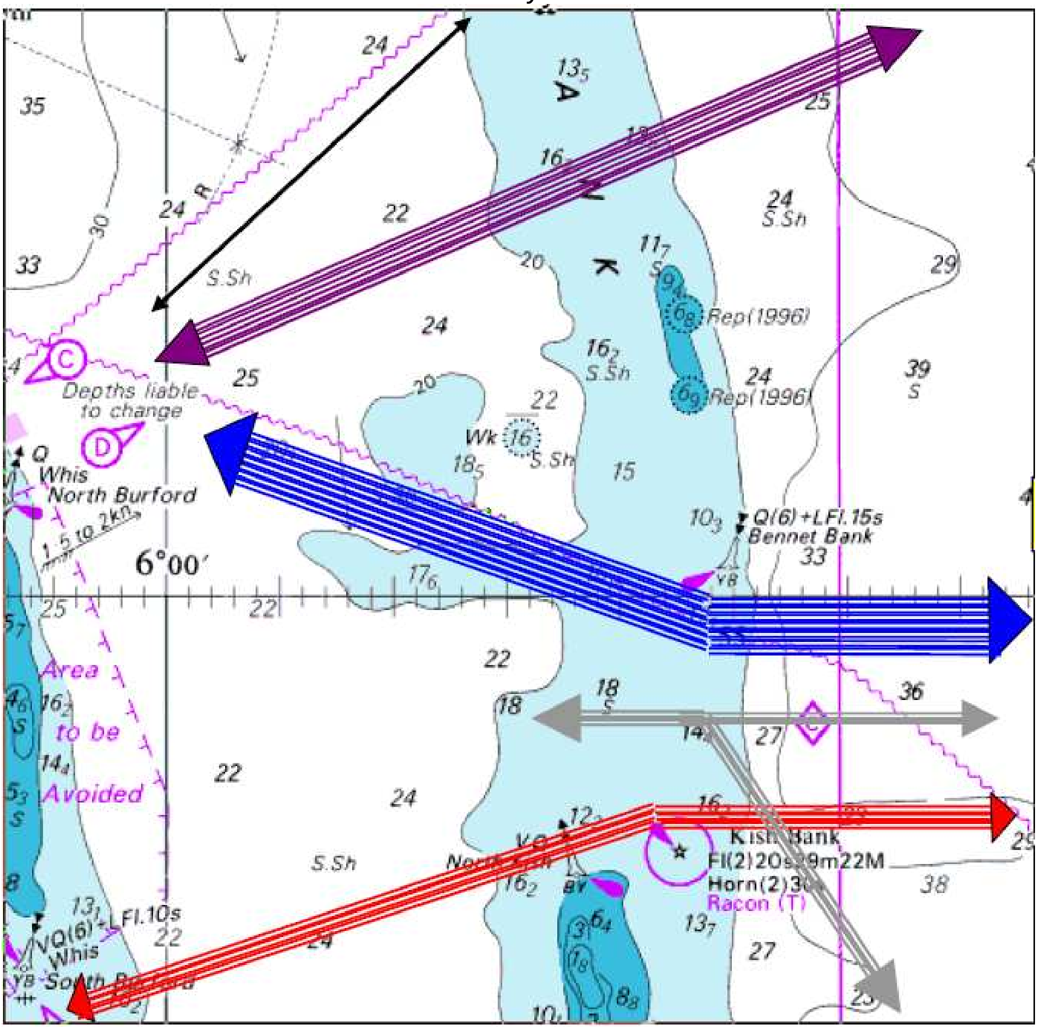

Fig. 2

1. **The Holyhead-Dun Laoghaire Service: Seasonal.**
2. **The Mersey - Dublin Service: 10 passages per day.**
3. **The Holyhead-Dublin Service: 16 passages per day.**
4. **Dublin - Heysham 2 passages per day…**
5. **Scheduled and Unscheduled Traffic: 5 passages per day (1.5 East/3.5South)**

Note: Although the HSC operate at speeds of approximately 40 knots the speed is much reduced on passing Kish and Bennet Bank.

9.2 South Kish

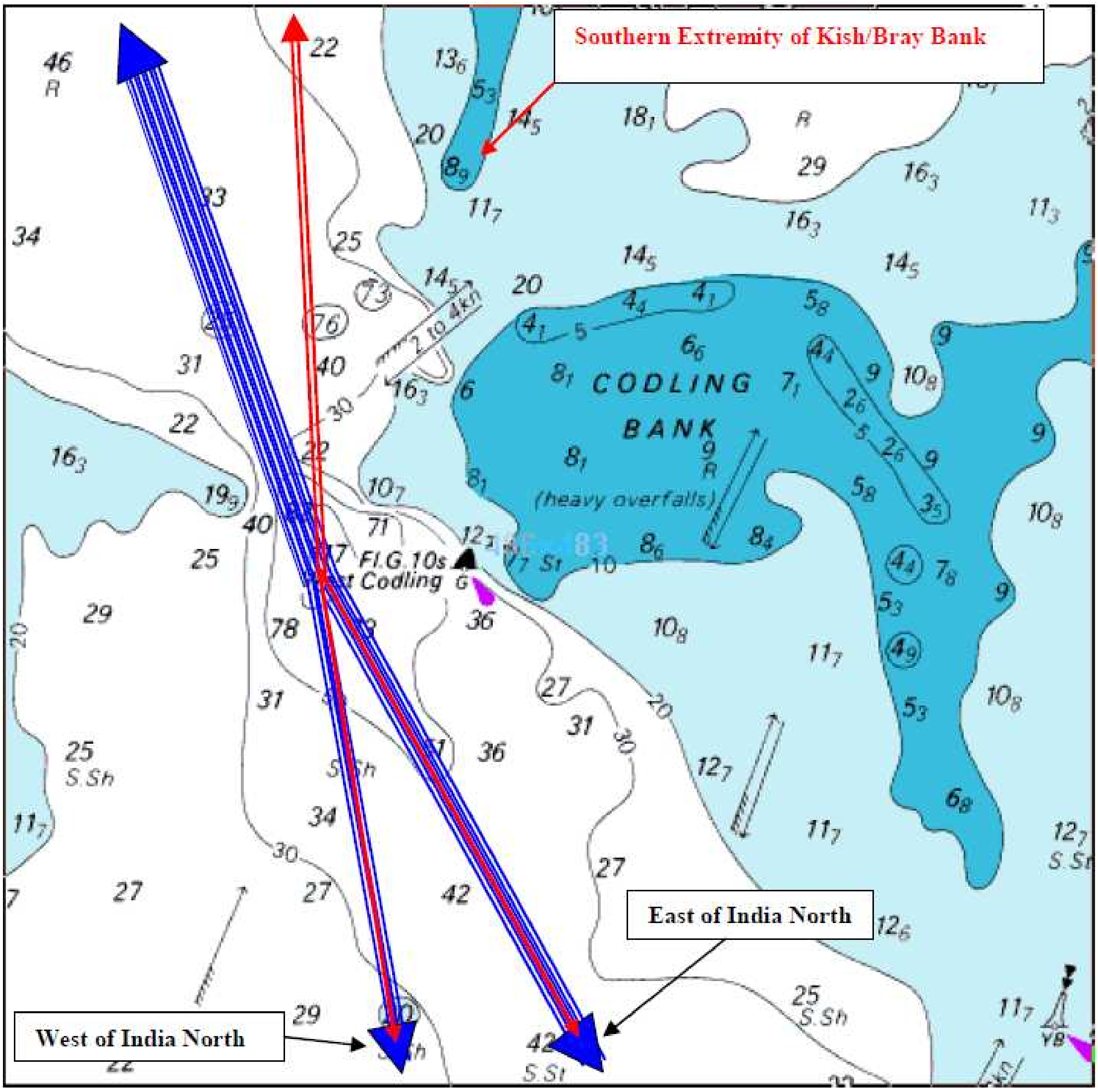

Fig. 3

1. **Dublin Traffic:** **9 passages per day**
2. **Drogheda, Dundalk, Greenore, Warrenpoint & Belfast Traffic:** **1 passages per day**

NB: ***Wicklow/Waterford traffic has not been shown as its impact is not considered important as it routing is biased further West.***

9.3 East Kish Analysis

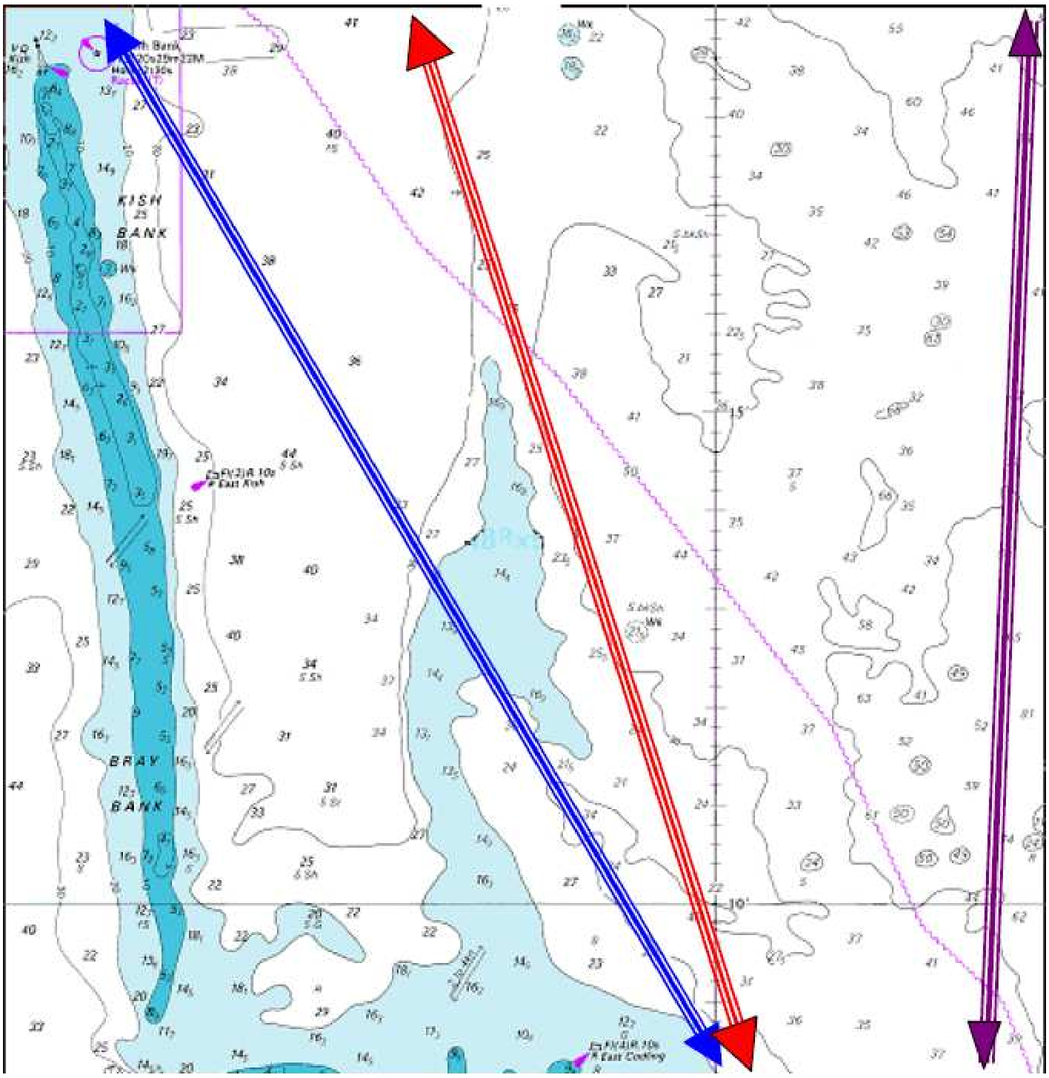

Fig. 4

1. **Dublin Traffic:** **2 passages per day.**
2. **Drogheda, Dundalk, Greenore, Warrenpoint & Belfast Traffic:** **3 passages per day**
3. **Belfast /Larne Traffic:** **5 passages per day**

9.4 West Kish Analysis

The area under consideration is West of Kish Bank referred to in text as the 'Inside passage'

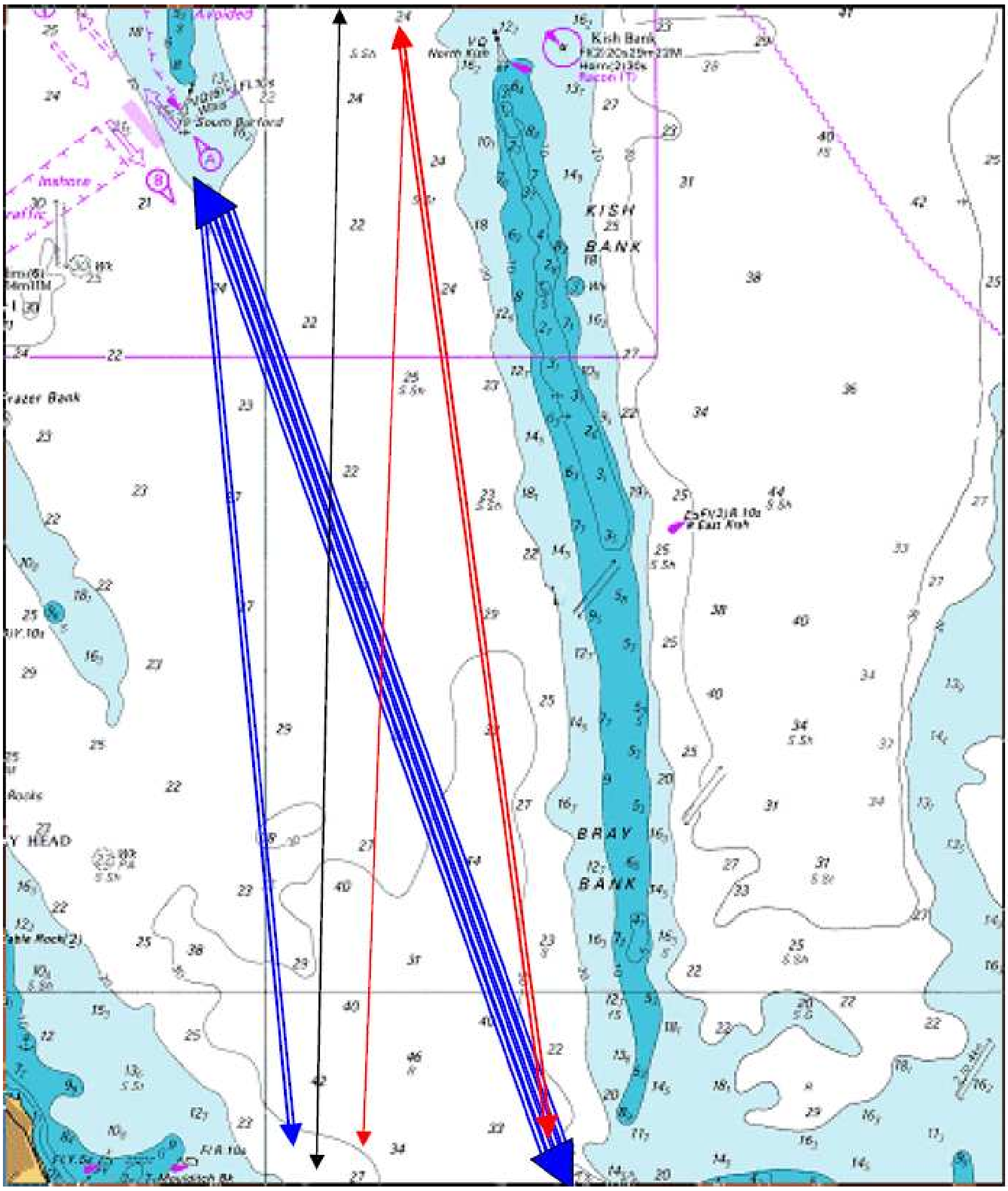

Fig. 5

1. **Wicklow Traffic:** **1 passage per day.**
2. **Dublin Traffic:** **8 passages per day**
3. **Drogheda, Dundalk, Greenore, Warrenpoint & Belfast Traffic:** **1.5 passages per day**

10.0 Impact of Proposed Development on Marine Navigation

10.1 Proposed Development

The proposed Dublin Array Offshore Wind Farm will comprise up to 145 turbines, with a minimum spacing of 500 mtrs, installed on the Kish and Bray banks.
The turbine dimensions are as follows;

- Hub height : Up to 100mtrs
- Rotor diameter : Up to 120mtrs

10.2 Preliminary Layout

The Marine Survey Office recommend moving the four corner turbines to elsewhere on the site to improve visibility at the corners. This, will be facilitated in the final design.
Construction will take place on a continuous basis over approximately two years.

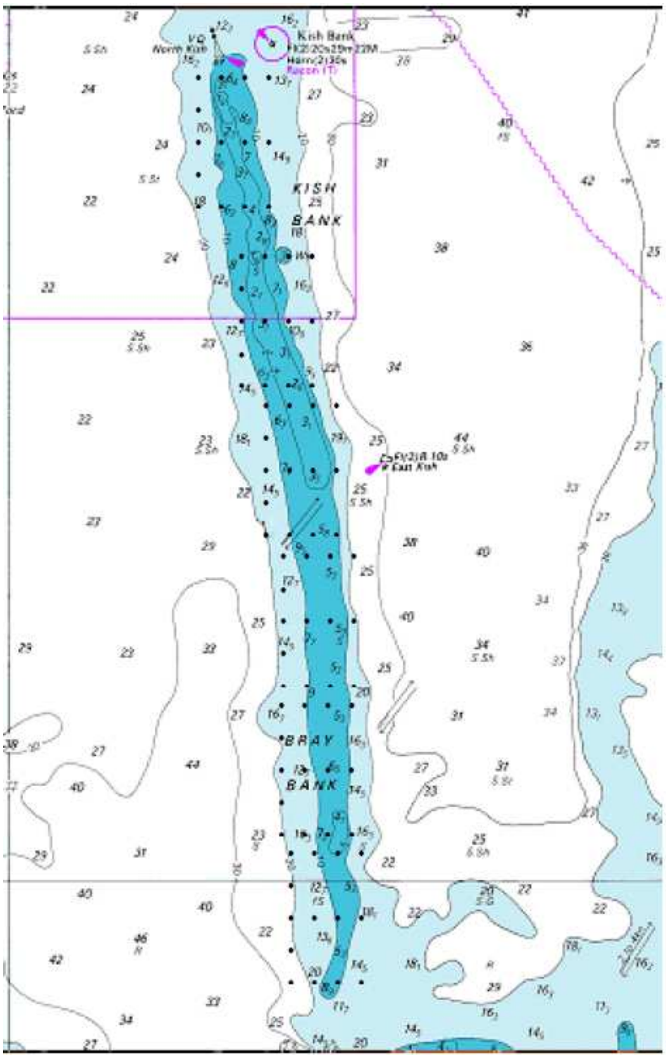

Fig. 6

10.3 Traffic

10.3.1 Commercial

10.3.1.1 East/West Transit of Banks

Based on our analysis, commercial vessels do not cross the Kish/Bray Bank due to the shallow water found therein. The routes for commercial vessels is well documented and detailed in Sector Analysis (Section 9) of this study. Therefore, risk of collision with commercial vessels intentionally crossing the banks is remote. However, this remote threat from commercial vessels indicated in the study may be from Human Factors in the navigation of these vessels or in operational error in the Navigation systems caused by errors in the GPS systems operating in close proximity to the wind farm turbines. At the time of writing, there is no evidence to support that such errors are induced into GPS systems or that incidents have occurred related to this phenomena.

10.3.1.2 North Kish

The traffic operating in the vicinity of North Kish is, in the main, well ordered and systematic. Ferry/RoRo traffic account for approximately 87% of this traffic operating on approximately reciprocal courses for their respective services.

Of this 87% of ferry traffic, only 7% (Stena Holyhead – Dun Laoghaire) operate in close proximity (one/two cables) to the Kish Bank Light House/ North Kish Buoy with the balance of the Holyhead - Dublin Traffic favouring the more Northerly Bennet Bank Buoy. Flexibility is exercised in way of the Bennet Bank Buoy in that vessels can and do pass close up North of the mark. The Balance of the ferry traffic passes well North of the Bennet Bank Buoy and has no impact.

In addition to the Holyhead – Dun Laoghaire traffic there is approximately 13% (5 passages per day) scheduled and unscheduled traffic destined for Dublin. This 13% is further broken down to 3.5 passages per day operating in the East West mode and as such will favour the Bennets Bank Buoy leaving 1.5 passages per day rounding the Kish destined for Dublin.
These unscheduled ships approaching from the South, although comparatively slowly (approximately 14/16 knots) will interact with the High Speed Craft[9] on the Holyhead –Dun Laoghaire service and other East/West traffic in the vicinity. Vessels arriving[10] and departing will be in contact with the Dublin Port – Vessel Traffic Service[11] who will advise such traffic of vessels in their immediate vicinity and as such advise the arriving/departing vessels of traffic which will impact on their approach. Similarly, the Ferries are monitored by the VTS and duly advised of traffic in their immediate vicinity.

[9] SWATH (**S**mall **W**aterplane **A**rea **T**win **H**ull)
[10] Vessel are in contact with Dublin VTS up to two hours before arrival.
[11] **V**essel **T**raffic **S**ervice

It should be understood that collision with these High Speed Ferries is remote, due to their ability to virtually stop within a very short distance. Care must be exercised when navigating in this area and in this respect tidal streams are well documented see Tidal Streams in way of the Banks

Risk of contact with turbines in this well monitored, well-ordered and well-marked sector is remote. The Qinetic report (February 2009) documents that it is in the eastern and southern part there is screening effect which is not an issue for Dublin Port (see Appendix VI of this report).
The turbines are 0.5 km apart in an east/west and north/south configuration. Therefore, other traffic in the area will be clearly visible

10.3.1.3 South Kish

The Dublin traffic which consist of approximately 10 passages per day will pass within 1 nautical mile of its Southern extremity en-route to the West Codling Buoy.

Risk of contact with turbine structures, particularly in the construction phase in this unmarked area of strong unpredictable tides will be remote due to the fitting of navigational lights on selected turbine towers.

10.3.1.4 East Kish

The traffic passing to the East of Kish originating from or destined to East coast Irish ports either originates at or is destined to the Codling (Lanby) [Fl.4s.12m.15M]. In total there are approx 13 passages per day. No East West Traffic (crossing traffic) is identified in this section.

Belfast Traffic

Of the above 13 passages, 6 passages are allocated to Belfast and as such have a closest point of approach to the Kish Bank (Bray Bank in the South) of approximately 9 nautical miles and therefore are of no consequence to our study.

Dundalk,Drogheda,Greenore & Warrenpoint Traffic

Approximately 4 passages per day are apportioned to these ports**.** The route takes the vessels to and from Codling to the Rockabill [*Fl.WR.12s.45m.22/18M- Horn(4)60s*.].
Vessel closest point of approach will not be less than 4 nautical miles having good navigation marks, both visual and as a Radar target in the Kish Bank L/H.

Dublin Traffic

The balance of 3 passages per day for those vessels destined for Dublin have a southern closest point of approach of approximately 4.5 nautical miles in the South in way of the southern extremity of the Bray Bank to an average of 1.5

nautical miles off over that part of the Kish Bank marked by the Red Can Buoy, **East Kish** [*Fl.(2)R.10s*] in the East to the Kish Bank L/H in the North.
Over the 12 nautical mile passage bordering East Kish there are good navigation marks in the Red Can Buoy **East Codling** [Fl.(4) R.10s] in the south which is passed at approximately 1 nautical mile and the above mentioned East Kish which is passed approximately 1.5 nautical miles off.

Risk of collision will be remote by the existing Dublin traffic navigating off the East Kish Buoy in relatively open deep water and the navigational lights fitted to selected turbines.

10.3.1.5 West Kish

The traffic operating to the West of Kish Bank consists of approximately 12.5 passages per day.
The 'Inshore Traffic' represents 2.5 vessels per day passing approximately 1 nautical mile to the West of North Kish [VQ] in the North to some 2 nautical miles to the West in the South.
Traffic originating from or destined for Dublin accounts for 10 passages per day having 'way points' of South Burford [*VQFl(6)+LF.10s*] in the North and West Codling [*Fl.G.10s*] in the South. The closest point of approach to the Kish Bank is approximately 1 nautical mile at its Southern extremity.

Risk of collision with structures will be remote due to navigation lightsfitted to selected turbines and located appropriately at a point on the structure above the Highest Astronomical Tide (HAT) but below the lowest point on the arc formed by the turbines rotor blades.

10.3.2 Trawlers

Indications from the study have revealed that trawling on the Kish/Bray Banks is negligible but once the wind farm is operational 'Bottom Trawling' on the Banks should be discouraged by means of notations and markings on Admiralty Charts for the area to ensure that trawl gear does not snag on the turbine cables. The turbine cables should be buried to a depth of at least one (1) metre to take into account of the aforementioned.

10.3.3 Recreational Traffic

Consultation with the various Sailing Clubs mentioned in Recreational Traffic (Section 6) have revealed that most of the boats and dinghies favour inshore sailing within 3 kilometres from the shore and when engaged in racing do so in a well defined area within Dublin Bay. For those craft engaged in offshore or coastal racing (e.g. Round Ireland Race) the ISA have indicated that provided the development was adequately buoyed as per recommendations from the Commissioners of Irish Lights the development would not cause concern for navigation. Indeed it would assist navigation.

11.0 Mitigation Measures Against Collision

11.1 Promulgation of Information

Promulgation of information should in the first instance be made available on the respective Admiralty Chart and should include general information to be agreed with the Commissioners of Irish Lights which will address passing distances and warnings against mooring alongside the structure. The aforementioned notations and markings on Admiralty Charts should be included and further extended to include mention of possible Radar impact, as applicable. Further, co-operation should be obtained from all Irish ports and sailing associations on the East coast, namely Rosslare through Dundalk to promote a safety and awareness culture amongst Mariners and recreation craft owners navigating in the vicinity of the Wind Farm. In addition to the information mentioned above further information should be made available in the form:

- Layout of Wind farm.
- Numbering of Units and Position (Latitude and Longitude).

11.2 Marking of Offshore Wind Farms[12 + 13]

Offshore Wind farms should be marked so as to be conspicuous by day or night giving due regard to prevailing visibility and traffic. Where possible multiple wind generators should be contained within a defined block in order for the wind farm to be defined as a single unit. Numbering of turbines (units) should be with appropriately sized numerals conspicuously positioned

11.3 Construction Period

Vessels other than those associated with construction should be excluded from the construction area during the construction period, as would be the case in any on-shore construction site. During the construction period of the wind farm, working areas should be established and an Exclusion Zone implemented and marked in accordance with the IALA MBS (Maritime Buoyage System). Such implementation would be arranged through the Commissioners of Irish Lights and promulgated through Notices to Mariners. The active construction area will be about 10% of the site area at any one time.

Cable laying to shore will take 5 - 10 days approx. Cable laying within the windfarm wil not affect shipping.

Shipping during construction will consist of one /two ship movements per day at the most, excluding small service boats

[12] IALA Recommendation O-117, May 2000

[13] Offshore Wind Farms Conspicuity Requirements – Advisory Material for the Protection of Air Navigation Safety – OAM 09/02. Irish Aviation Authority.

11.4 Operational Period

11.4.1 Lighting Requirements

11.4.1.1 Lighting Requirements to Protect Marine Navigation Safety [15]

Yellow Lights will be fixed to all turbines and located appropriately at a point on the structure above the Highest Astronomical Tide (HAT) but below the lowest point on the arc formed by the turbines rotor blades. The lights to be visible through 360º in azimuth and for a distance of at least 5 nautical miles with a minimum of 99% availability.

With reference to above. Turbine tower structures chosen for representing the **periphery of Wind Farms** are termed **Significant Peripheral Structures (SPS).**
Such structures, fitted with navigation lights, will be spaced at intervals of no more than 3 nautical miles, where practicable. The lighting of these structures shall be of a distinctive flashing characteristic fitted above the Highest Astronomical Tide (HAT) but below the lowest point of the arc of the structures rotor. The lights will be visible through 360˚ in azimuth and a range of 10 nautical miles. This range of light of 10 nm applies to the SPS. The range of lights for the inner turbines may be less.

11.4.1.2 Lighting Requirements to Protect Air Navigation Safety[14].

The lighting required to protect Air Navigation will be the lighting as specified for protecting Marine Navigation.
All Significant Peripheral Structures of height ≥ 90mtrs, to the highest point of the structure (including the top of the blade spin) will be fitted with a high intensity warning light meeting certain criteria given below:

- Lighting to be mounted on highest point practicable on structure.
- Light to comply with International Civil Aviation Organisation (ICAO) Annex 14 standards, on a H24 basis, for High Intensity Type A lighting meeting following criteria.
  - The light to be white with a flash rate of 40-60 fpm.
  - Effective intensity of 200,000 cd ∓ 25%, with background luminence above 500cd/m^2
  - Effective intensity of 20,000 cd ∓ 25%, with background luminence 50∽500cd/m^2
  - Effective intensity of at least 2,000 cd, with background luminence below 50cd/m^2

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[15] Specifications for Lighting Requirements provided by the Commissioners of Irish Lights. – see Offshore Wind Farms Conspicuity Requirements – Advisory Material for the Protection of Air Navigation Safety – OAM 09/02. Irish Aviation Authority.
[14] Specifications for Lighting Requirements provided by the Irish Aviation Authority(IAA). – see Offshore Wind Farms Conspicuity Requirements – Advisory Material for the Protection of Air Navigation Safety – OAM 09/02. Irish Aviation Authority.

  - Light fitting will be so constructed so that practically no light will be emitted below the horizontal (or as agreed with IAA)
  - Light throughout farm to be synchronised.
  - Visible through 360° in azimuth
- Light failure to be remotely monitored by system agreed with IAA. Repair/replacement of failed light to be effected as soon as reasonably practicable.

11.4.2 Marking Requirements

11.4.2.1 Marking Requirements to Protect Marine Navigation Safety[15].

- High visibility yellow from high water mark to the specified level of the marine navigation protection lights.
- Double yellow bands as specified.
- Fog signals *may* be required to be fitted on Significant Peripheral Structures in Wind Farm developments.

11.4.2.2 Marking Requirements to Protect Air Navigation Safety

As for the marking in Protecting Marine Navigation as in 11.4.2.1 above.

11.4.3 Radar Enhancers/Reflectors

11.4.3.1 Radar Enhancers to Protect Marine Navigation Safety[16]

Significant Peripheral Structures may be required to be fitted with Radar Enhancers, Transponders, Reflectors and/or Automatic Identification Systems (AIS)[17] as determined by the Commissioners of Irish Lights.

11.4.3.2 Radar Reflectors to Protect Air Navigation Safety[18]

Significant Peripheral Structures should be fitted with Radar reflectors.

[15] Specification provided by the Commissioners of Irish Lights. see Offshore Wind Farms Conspicuity Requirements – Advisory Material for the Protection of Air Navigation Safety – OAM 09/02. Irish Aviation Authority.
[16] Specification provided by the Commissioners of Irish Lights. see Offshore Wind Farms Conspicuity Requirements – Advisory Material for the Protection of Air Navigation Safety – OAM 09/02. Irish Aviation Authority.
[17] See North and South extremity of Arklow Bank Wind Farm
[18] Specifications for Lighting Requirements provided by the Irish Aviation Authority(IAA). – see Offshore Wind Farms Conspicuity Requirements – Advisory Material for the Protection of Air Navigation Safety – OAM 09/02. Irish Aviation Authority

11.4.4 Dublin Port – Vessel Traffic Service

Dublin Port operates a Vessel Traffic Service (VTS) which, by definition,[19] is a service implemented by a competent authority, designed to improve the safety and efficiency of vessel traffic and protect the environment. The service has the capability to interact with traffic and respond to traffic situations developing in the VTS area. The VTS can rightly be described as 'control of the space' of the area in which it exercises authority recognising, that at all times Master's control and navigate ships within that space.
In this respect the services rendered by the VTS are best described as that of a Harbour/Port rendering a level of service offering:

1. Maintaining a traffic organisation service to prevent dangerous maritime traffic situations[20] and to promote and provide for safe and efficient movement of vessels within the VTS area.
2. Maintaining an information service that ensures essential information is readily available for onboard navigational decision-making.
3. A service to assist with the onboard navigational decision making process.
4. A service which assists in the co-ordination of the supply of pilots together with the necessary information to assist in the formulation of a passage plan for their intended task.
5. Providing information relating to Dublin Port and its approaches to ships outside the Authorities area as and when requested.
6. Monitor shipping movements, including vessel routeing & speed, together with tidal and shipping movements within the ports area of authority and to provide timely information concerning hazardous situations.
7. To act as coordinating authority in the event of an incident within the ports jurisdiction and area of authority which involves other organisations, services or authorities.

Dublin Port VTS Operators monitor traffic in the vicinity of the Kish/Bray Bank and in this respect should be considered a mitigating factor in collision reduction.

As mentioned in 10.3.1.2 the turbines will be spaced 0.5 km apart in an east/ west and north/ south configuration which will render traffic in the area visible and detectable. This will be further enhanced by the chamfering of the northern/southern corners by moving four (4) turbines to other, less critical parts of the site.

Further, all vessels navigating on the high seas are subject to the International Regulations for Preventing Collisions at Sea 1972 (COLREGS). Published by IMO (International Maritime Organisation). These 'rules of the road' are followed by all ships and vessels in order to prevent collisions between two or more vessels.

[19] IMO Resolution A857(20) – Adopted 27.11.97
[20] Instructions to be '***result orientated***'.

11.5 Notification to Responsible Bodies[19]

11.5.1 Information Required by IAA Prior to Erection of Structures

The following information should be made available to the Irish Aviation Authority (IAA) at least three months in advance of erection of Wind Machines:

a. Estimated position of each machine or structure to be erected
b. Estimated maximum elevation for each structure
c. Lighting details for each structure
d. Marking details of each structure
e. Conspicuity details: (Radar Enhancer/Transponder/Reflector/AIS)
f. Spacing between structures
g. Estimated earliest date of erection
h. Any other relevant information, which may impact on Air Navigation.

11.5.2 Information Required by the Commissioners of Irish Lights.

At least three months in advance of the erection of any structure, the information listed above with the proviso that 11.5.1 (h) will apply to marine navigation.

[19] The Commissioners of Irish Lights & Irish Aviation Authority.

Appendix I – North South Traffic Flow

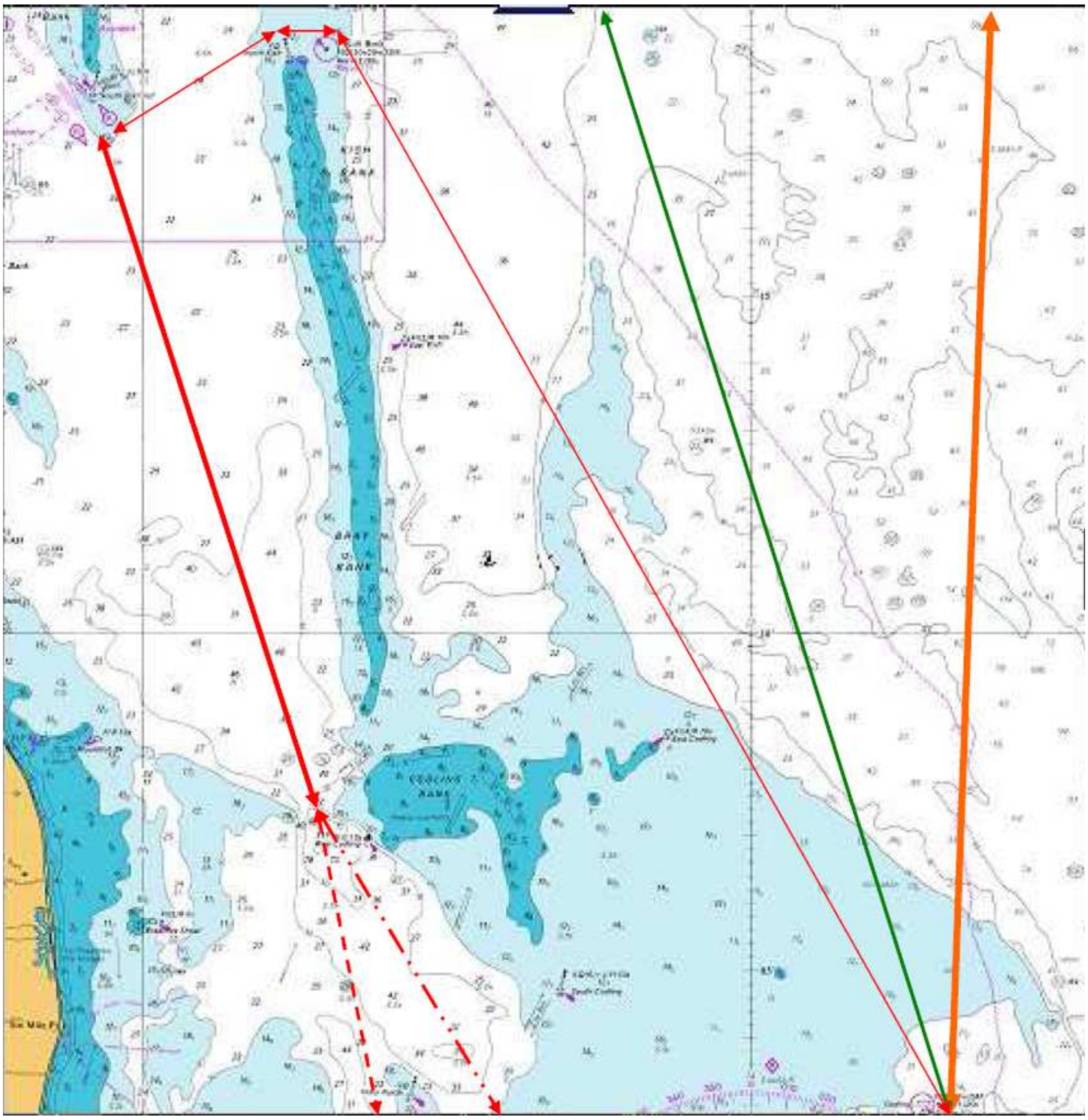

Fig. 7

- ***North Bound Traffic destined for Glasgow, Belfast and Larne (Codling – South Rock)***
- ***North Bound Traffic destined for the Drogheda, Dundalk, Warrenpoint range.***
- ***North Bound Traffic destined for Dublin. Note the options available.***

Appendix II – South Bound Traffic Flow

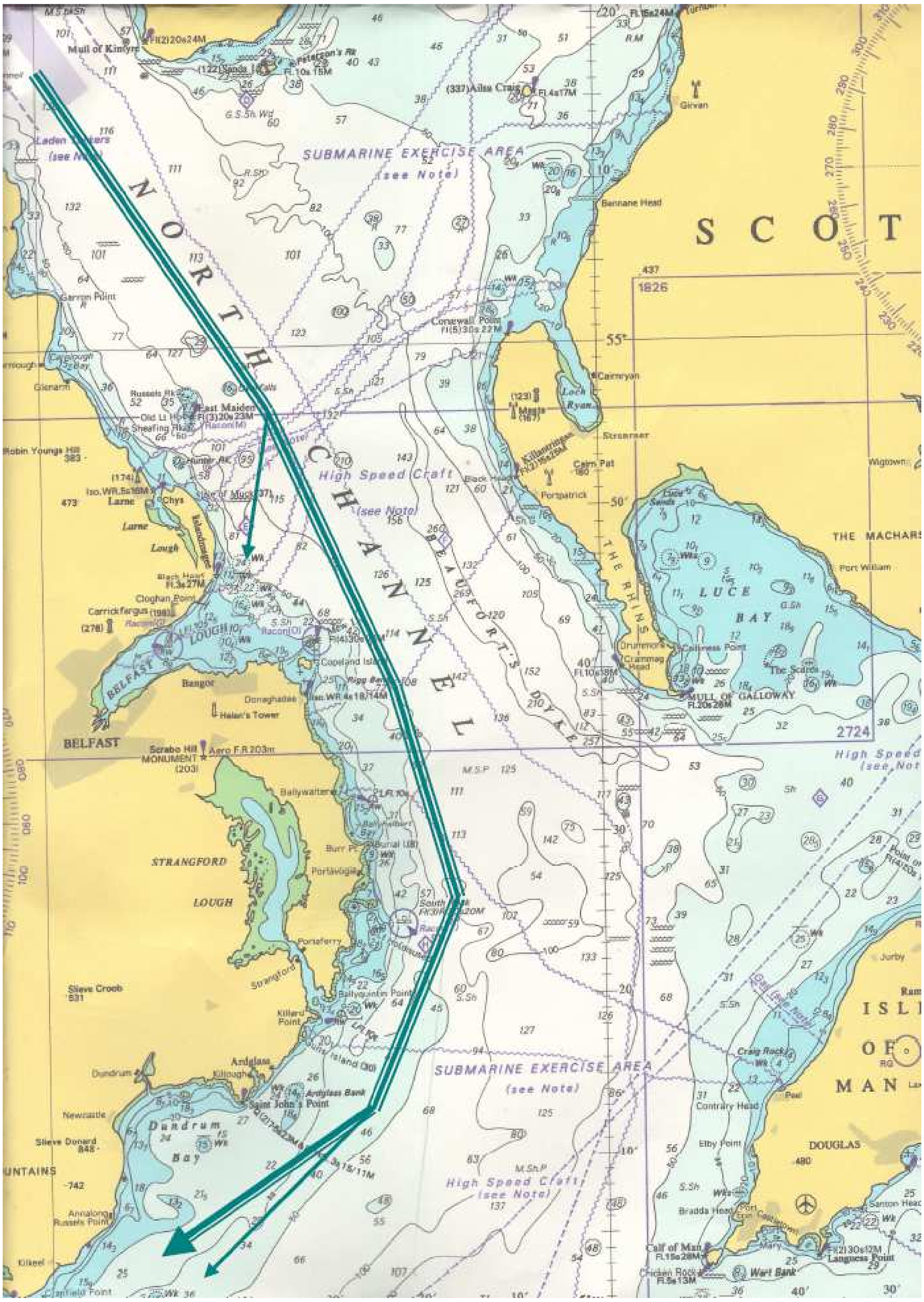

Fig. 8

The South bound traffic is made up in the main from the larger vessels arriving from the US and other vessel from Scandinavia.

Appendix III – East/West Traffic Flow

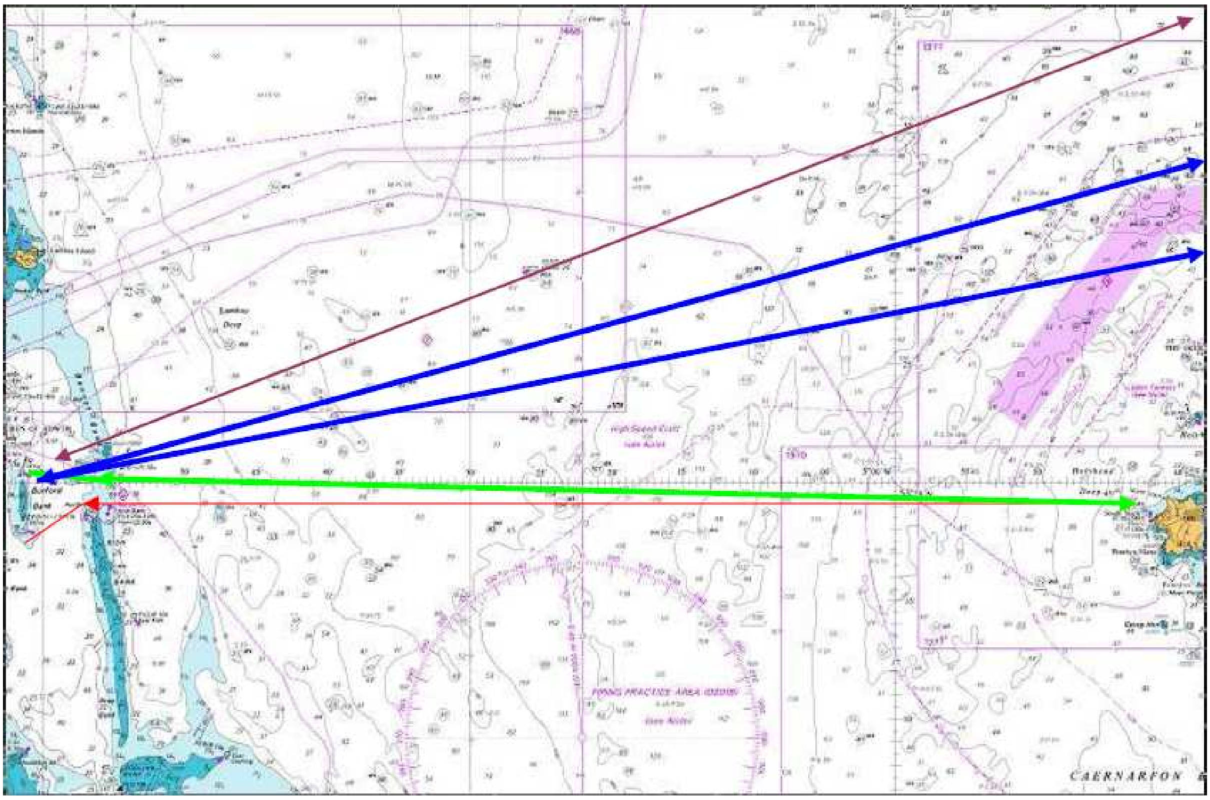

Fig. 9

The East West corridor is monopolised by the Ferries and Container feeder traffic.

1. **Holyhead – Dun Laoghaire:** **2 services per day (4 ship movements) (Seasonal – Summer months only)**
2. **Holyhead – Dublin :** **8 services per day (16 ship movements)**
3. **Mersey – Dublin :** **5 services per day (10 ship movements)**
4. **Heysham – Dublin :** **1 service per day (2 ship movements)**

Appendix IV – Ferry / RoRo Services

FERRY COMPANIES OPERATING WITHIN DUBLIN BAY				
PORT	**COMPANY**	**SAILINGS PER DAY**	**ARRIVAL TIME**	**DEPARTING TIME**
Dublin/Holyhead	***Irish Ferries***	***2 Cruise***	***05:55 17:50***	***08:05 21:00***
		2 Fast Ferry	***13:50 19:15***	***14:30 08:45***
Dublin/Holyhead	**Stena Line**	**4**	**00:45 05:45 11:35 17:05**	**02:15 08:20 16:00 21:15**
Dublin/Liverpool	**P & O Irish Ferries**	**3**	**05:30 11:30 17:30**	**10:00 15:00 22:00**
Dublin/Liverpool	**Seatruck Ferries**	***2***	***05:45 17:45***	***09:45 21:45***
Dublin/Heysham		***0.70***	***TBA***	***TBA***
Dublin/Rotterdam-Zeebrugge	**Cobelfret**	***0.45***	***TBA***	***TBA***
Dublin/Douglas	**Isle of Man Steam Packet**	***Seasonal 0.666***	***TBA***	***TBA***
DunLaoghaire/Holyhead	**Stena**	***Seasonal 0.333***	***TBA***	***TBA***
TOTAL		**15.15**		

Table. 5

Annual Ferry Traffic :	5529
Annual Traffic :	7822
Ferry % :	**71%**

Appendix V – Initial Report Data Amendment

Dublin Port Statistics 2004 -2010

	2004	2005	2006	2007	2008	2009	2010
Vessels - Total Arrivals	7,502	7,579	7,427	7,872	7,621	7,379	7,579
Throughput ('000 tonnes)							
RoRo	14,306	14,901	16,075	17,137	16,351	15,344	17,107
LoLo	5,202	5,811	6,778	7,151	6,556	5,422	5,675
Bulk Liquid	3,907	4,037	4,055	4,075	4,077	4,051	3,788
Bulk Solid	1,756	2,085	2,285	2,503	2,429	1,583	1,475
Break Bulk	87	89	73	70	164	102	73
Total	25,258	26,923	29,266	30,933	29,577	26,502	28,118
RoRo Units ('000)	608	630	693	733	704	645	726
LoLo Units ('000)	541	590	681	744	677	548	554
Passengers (millions)	1.3	1.2	1.2	1.3	1.3	1.5	1.8

Table 6

The annual ship movements to Port of Dublin are therefore in the order of **15158.**

1. Dun Laoghaire Port Statistics 2010

The traffic to Dun Laoghaire can now be described as seasonal.
Over a four month period in the summer two trips a day is suggested, which gives 243.5 arrival per annum. Four movements a day which equates to approximately 487 movements to the port of Dun Laoghaire.

2. Dublin to Douglas (IOM) Statistics

The traffic to Douglas can now be described as seasonal.
Over a four month period in the summer two trips a day is suggested, which gives 121.666 arrival per annum.Two movements a day which equates to approximately 243.5 movements to the port of Dublin.

Combining these figures we have a total of 15645.

Appendix VI – Radar Shadow

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DUBLIN PORT COMPANY

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8th November 2011

Gene McGillycuddy
Saorgus Energy Ltd.,
Enterprise House,
Kerry Technology Park,
Listowel Road,
Tralee,
Co. Kerry.

Dear Gene,

Further to our conversation and following my email to you on the 12th August 2010, I can confirm that the radar shadow to the East and South of the proposed area (Kish & Bray Banks) will not be a problem for Dublin Port Company.

Yours sincerely,

Seamus McLoughlin
Head of Operations