East Anglia
Offshore Wind

VATTENFALL

SCOTTISHPOWER RENEWABLES

East Anglia THREE

Appendix 16.1

Aviation Radar

Environmental Statement
Volume 3
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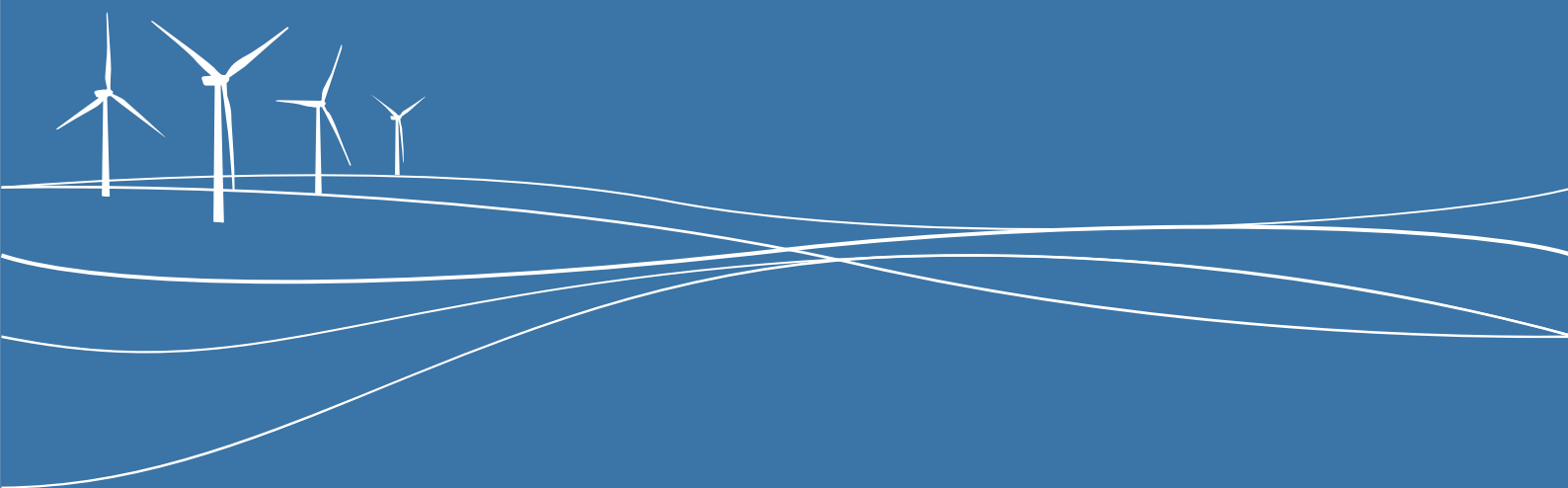

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16.1 AVIATION RADAR

16.1.1 Introduction

1. Initial consultation and research has identified a potential impact of the East Anglia THREE site on aviation radars.

2. The aviation radars potentially affected are NATS Cromer PSR and MOD Trimingham PSR. This Appendix focuses on the impacts on these PSRs; as explained in *Chapter 16 Aviation and MOD*, any impacts of the East Anglia THREE site on SSR have been scoped out. This Appendix uses the acronyms set out in *Chapter 16 Aviation and MOD*.

3. Wind turbines are a problem for aviation PSRs as the characteristics of a moving wind turbine blade are similar to an aircraft. The PSR is unable to differentiate between wanted aircraft targets and clutter targets introduced by the presence of wind turbines.

4. The significance of any radar impacts depends on the airspace usage and the nature of the ATS provided in that airspace. The classification of the airspace in the vicinity of the East Anglia THREE site and the uses of that airspace (civil and military) are set out in *Chapter 16 Aviation and MOD*.

5. Radar impacts may be mitigated by either operational or technical solutions or a combination of both. In either case, the efficacy and acceptability of any operational and / or technical mitigation options available can only be determined by protracted consultations with the radar operators.

6. Initial investigations have addressed the identification of the maximum turbine sizes across the East Anglia THREE site that would not be detected by the Trimingham and Cromer PSRs, and sets out the footprint of any potential technical mitigations which may be available in light of the findings of this Appendix.

16.1.2 Data

7. The following data has been used to establish the drawings and calculations used in this report.

16.1.2.1 MOD Trimingham radar

8. MOD Trimingham radar from MOD Defence Equipment and Support (DE&S) Air Defence and Air Traffic Systems (ADATS)

- Grid Ref: TG 28846 38256 (E628846, N338256)
- Site Height : 69.8m AMSL

- Antenna Aperture: 4.9m AGL

9. MOD confirms that the Trimingham radar is a Lockheed Martin TPS-77 used in the Air Defence role.

10. MOD is unable to provide any technical information or specifications as these are ITAR (International Traffic in Arms Regulations) protected.

11. Additional data was derived from Lockheed Martin Factsheet.

16.1.2.2 NATS Cromer radar

12. Data is sourced from Ofcom S-Band radar 'Protected Radar List' October 2013.

- Latitude 57N3835
- Longitude 001E2059
- Antenna Height 17.5m AGL

13. The radar is a Raytheon ASR10-SS used for en-route Air Traffic Control (ATC).

14. Additional data was derived from Raytheon ASR10-SS factsheet.

16.1.2.3 The East Anglia THREE site

15. The boundaries of the East Anglia THREE site were provided by EATL as geo-referenced Shapefiles.

- EAST ANGLIA THREE – BDFP_EAST ANGLIA THREE_SiBdry_v14.shp

16.1.2.4 Wind turbines

16. Wind turbine data was provided to Cyrrus by EATL as per *Table 16.1.1.*

Table 16.1.1 Wind turbine data

Wind Turbine	7MW	10MW a	10MW b	12MW
Blade Length (m)	75	89	97	108
Blade Chord (m)	5.0	6	6	6.5
Minimum Blade Clearance (m) (Mean High Water Springs)	25	25	25	25
Maximum Rotor Diameter (m)	154	180	196	220
Minimum Hub Height (m) (Lowest Astronomical Tide)	102	116	123	150
Maximum Tip Height (m) (Lowest Astronomical Tide)	181	207	223	247
Nacelle dimensions including hub (m) (HxWxL)	9.0x9.2x20.6	10x10x24	10x10x24	12x12x26
Operating Wind Speed Range (m/s) (cut-in / cut-out)	3 / 25	3 / 30	3 / 30	2 / 35
Operating speed range (rpm)	5 to 11	4.0 to 10.1	4.0 to 10.1	3 to 9
Swept Area (m^2) (per wind turbine)	18.627	25.447	30.172	38.013

Maximum number of wind turbines in site	172	120	120	100
Minimum Spacing (m)	675 x 900	675 x 900	675 x 900	675 x 900
Layout pattern	Blocks with regular rows			

NOTE: wind turbine heights in table are above Lowest Astronomical Tide (LAT). Radar assessments are based on Ordnance Datum (OD), which is notified as 0.86m above LAT at the East Anglia THREE site. Given the small difference, no correction to OD has been undertaken and radar calculations have assumed LAT = OD to incorporate a small margin for error.

17. As the wind turbine dimensions and layout have not been determined, an indicative layout provided by EATL based on a 1,000m wind turbine spacing has been used. These "simulated" wind turbine locations are shown in the following diagrams as white dots.

16.1.2.5 Terrain Data

- ASTER GDEM 1.5 arc seconds resolution.
- NextMap 25m DTM in area around radars (Perpetual Licence)

16.1.2.6 Analysis Tools

- ATDI ICS Designer v 3.4.1 x64 R1343 Radio Network analysis tool
- Global Mapper v14
- ATDI plugin for Global Mapper V1.00
- AutoCAD 2014 and ZWCAD 2011

18. Radar data was supplied in Ordnance Survey National Grid Reference (OSGB36) format.

19. Indicative wind turbine layout was supplied in geo-referenced Shapefile format.

20. Lat/long (WGS84 datum) is used as a common working datum for all mapping and geodetic references.

21. Mapping datum transformations are made using Global Mapper (Blue Marble) or OS Grid Inquest (OSTN2).

22. All heights are AMSL. Newlyn datum.

23. The following radar impact assessment first addresses the radar Line of Sight (LoS) and then examines the Probability of Detection (Pd) of the various wind turbines in light of the known technical characteristics of the radar.

16.1.3 East Anglia THREE Site

24. The relative location of the East Anglia THREE site to the radars under consideration is shown at *Diagram 16.1.1.* The East Anglia THREE site has a total footprint of 305km^2.

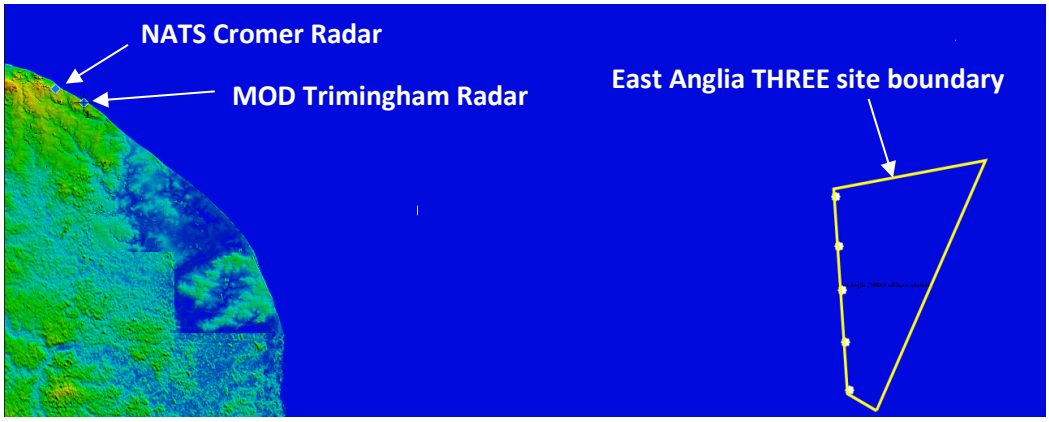

Diagram 16.1.1 East Anglia THREE site and PSR in context

25. The East Anglia THREE site lies within the coverage areas of both radars under consideration.

16.1.4 MoD Trimingham

26. The closest point of the East Anglia THREE site is 50.21NM (92.99km) from the Trimingham PSR.

27. There is no intervening terrain to provide any screening of the East Anglia THREE site; however, earth curvature provides significant screening of the East Anglia THREE site. The absence of terrain screening means that the edge of radar cover follows an arc.

16.1.4.1 Radar Line of Sight

28. Initial assessments carried out established the radar LoS to various wind turbine heights across the East Anglia THREE site. These are reproduced in the following diagrams. Radar LoS is indicated by the magenta shading.

29. *Diagram 16.1.2* illustrates that radar LoS from the Trimingham PSR to 181m tip height wind turbines does not exist in the East Anglia THREE site.

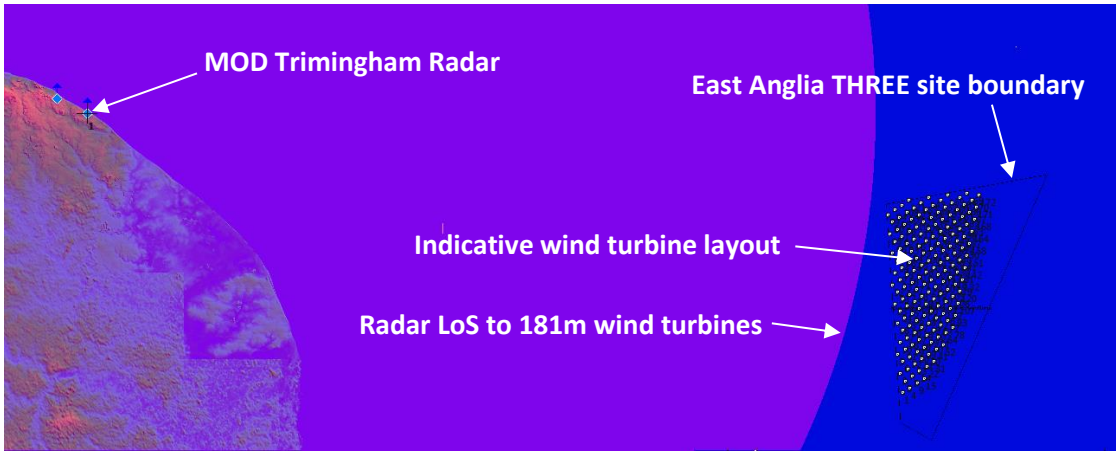

Diagram 16.1.2 LoS Trimingham Radar to 181m tip height wind turbines

30. *Diagram 16.1.3* illustrates that radar LoS from the Trimingham PSR exists to 207m tip height wind turbines at the extreme north-west corner of the East Anglia THREE site.

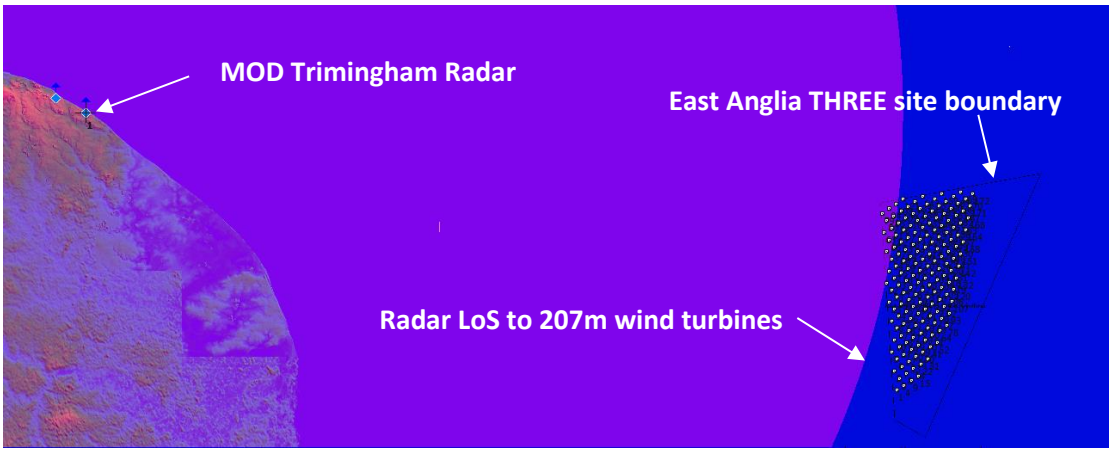

Diagram 16.1.3 LoS Trimingham Radar to 207m tip height wind turbines

31. *Diagram 16.1.4* illustrates the radar LoS from the Trimingham PSR to 207m tip height wind turbines in more detail. Radar LoS exists to nine of the 172 wind turbines (5.2%) of the indicative layout with a tip height of 207m.

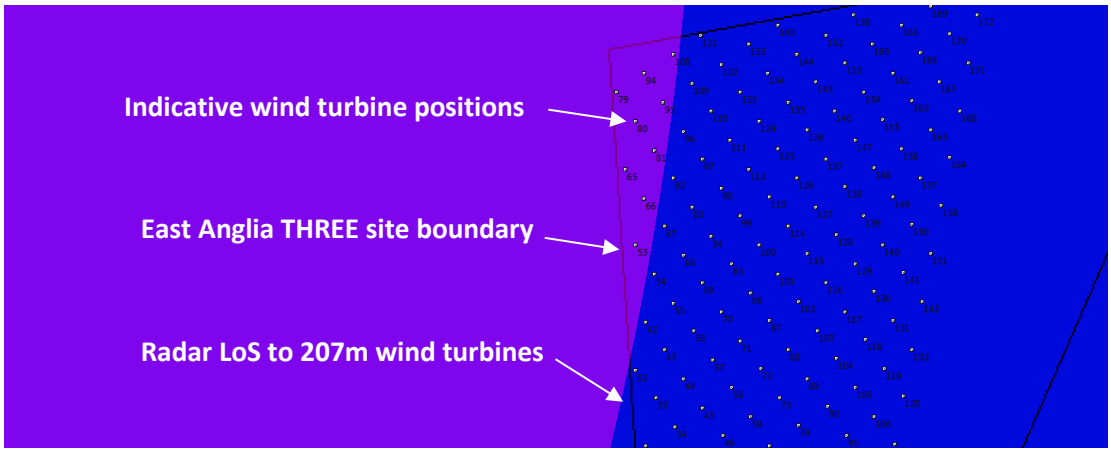

Diagram 16.1.4 LoS Trimingham Radar to 207m tip height wind turbines - detail

32. *Diagram 16.1.5* illustrates that radar LoS from the Trimingham PSR exists to 223m tip height wind turbines in the north-west corner of the East Anglia THREE site.

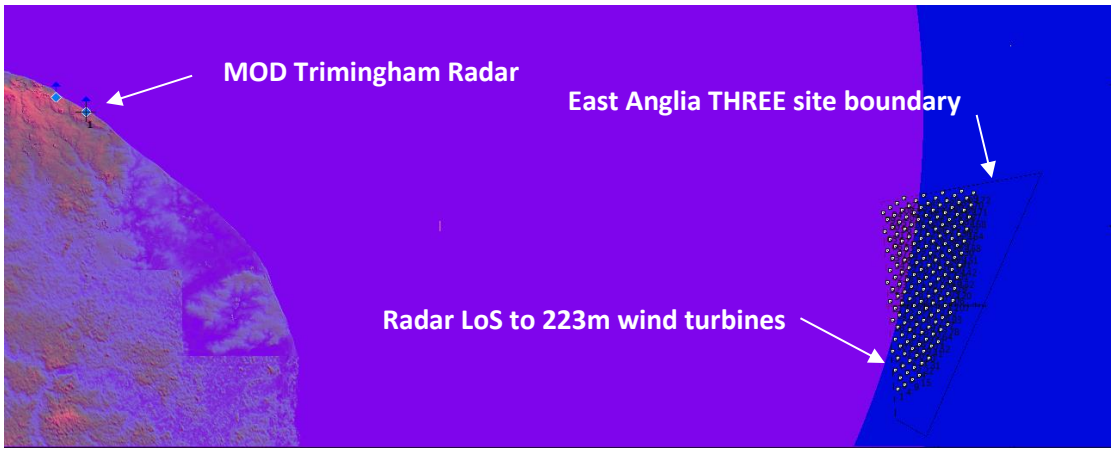

Diagram 16.1.5 LoS Trimingham Radar to 223m tip height wind turbines

33. *Diagram 16.1.6* illustrates the radar LoS from the Trimingham PSR to 223m tip height wind turbines in more detail. Radar LoS exists to 37 of the 172 wind turbines (21.5%) of the indicative layout with a tip height of 223m.

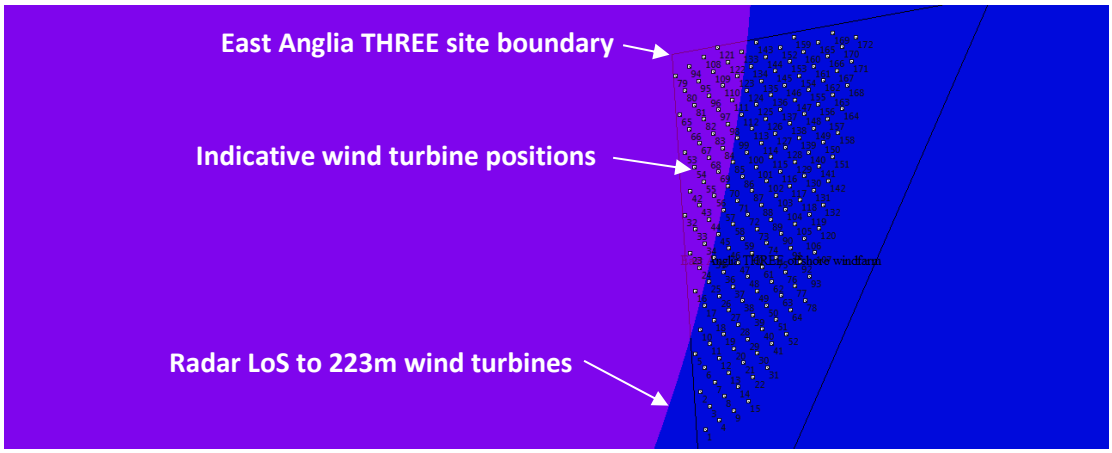

Diagram 16.1.6 LoS Trimingham Radar to 223m tip height wind turbines - detail

34. *Diagram 16.1.7* illustrates that radar LoS from the Trimingham PSR at 247m extends into the west side of the East Anglia THREE site.

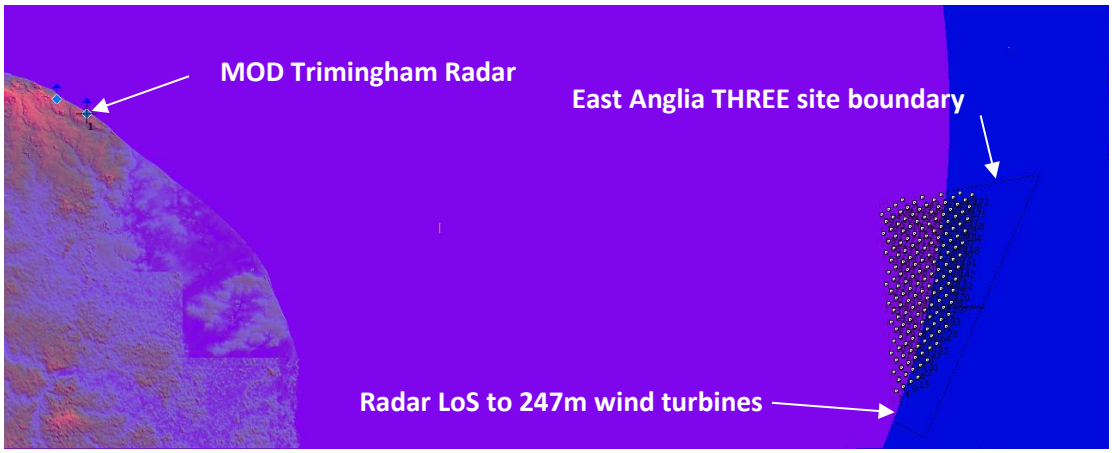

Diagram 16.1. 7 LoS Trimingham Radar to 247m tip height wind turbines

35. *Diagram 16.1.8* illustrates the radar LoS from the Trimingham PSR to 247m tip height wind turbines in more detail. Radar LoS exists to 112 of the 172 wind turbines (65.1%) of the indicative layout with a wind turbine tip height of 247m.

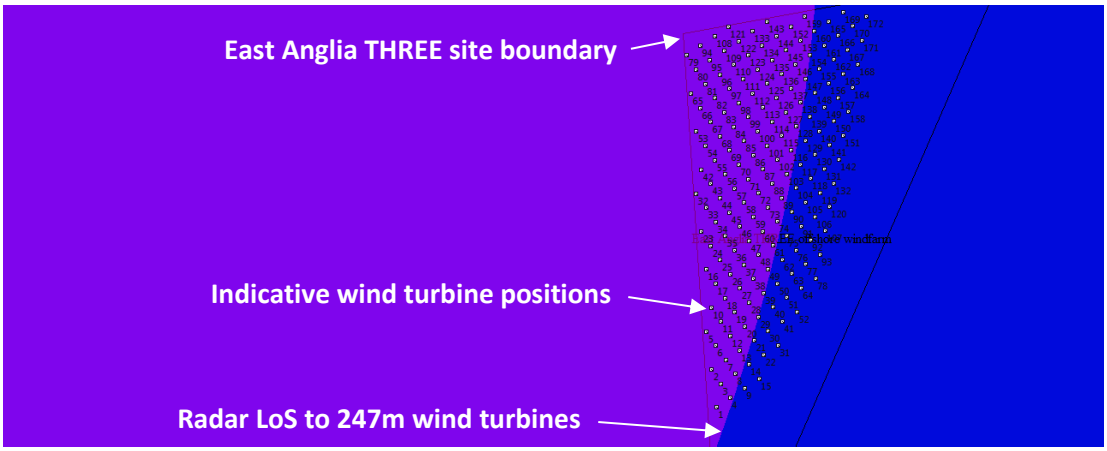

Diagram 16.1.8 LoS Trimingham Radar to 247m tip height wind turbines - detail

36. Trimingham radar LoS at East Anglia THREE site, wind turbine 79 in the indicative layout, is 196m AMSL. Trimingham radar LoS at the north-western corner point of the East Anglia THREE site is 193m AMSL.

37. Trimingham Radar LoS contours to varying wind turbine heights across the East Anglia THREE site along with an indicative wind turbine layout are depicted at *Diagram 16.1.9.*

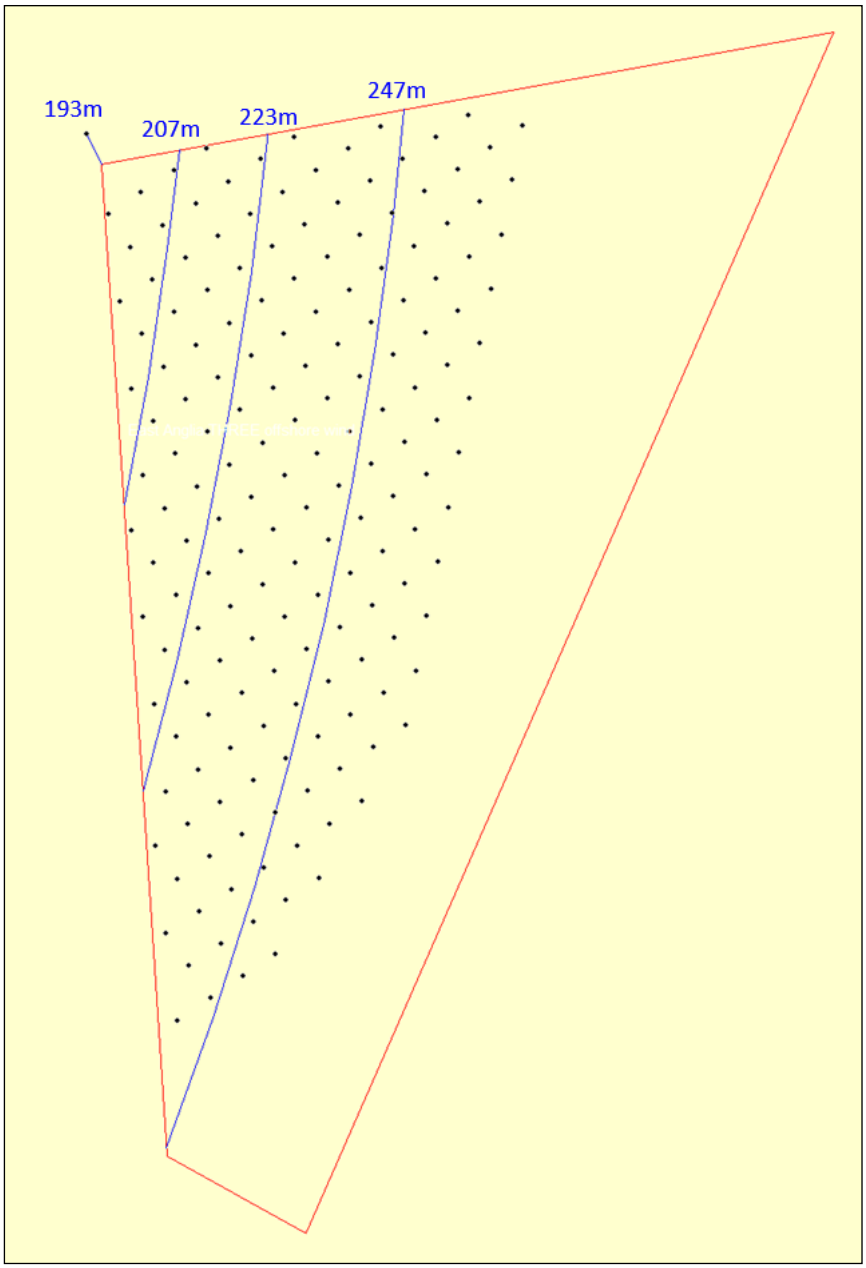

Diagram 16.1.9 Trimingham Radar LoS contours across East Anglia THREE site

16.1.4.2 Radar Probability of Detection

38. Radar LoS is only an indication as to whether the radar will 'see' a wind turbine. Depending on the radar configuration and the nature of the screening, the Probability of Detection (Pd) may be greater or less than the LoS distance.

39. Pd may be calculated using a radio propagation model and the technical characteristics of the radar.

40. The MOD is unable to release full technical details of the Trimingham radar due to ITAR which restricts the divulgence of certain data. Therefore, it is necessary to make some assumptions on the Pd performance of the TPS-77 radar based on publically available data from the Lockheed Martin TPS-77 Factsheet. In particular, information on the TPS-77 antenna parameters is not directly available.

41. From the Lockheed Martin TPS-77 Factsheet, the detection capabilities of the radar are quoted as detecting a target with a Radar Cross Section (RCS) of $1m^2$ at 160NM (300km) with a Pd of 80%. The transmitted power is quoted at 19.9kW. Using this information, it is possible to estimate the parameters required to calculate the turbine Pd.

42. Assuming the operating frequency of the radar to be 1,250MHz, the free space path loss (amount of energy absorbed by the atmosphere without any terrain or shielding) to a target at 300km is calculated to be -143.9dB.

43. The amount of energy reflected back towards the radar is proportional to the RCS. For any particular radar frequency, the amount of reflected energy can be calculated from the RCS, known as RCS gain. A $1m^2$ RCS target at 1,250MHz has an effective RCS gain of 23.4dB.

44. The radar sensitivity can be assumed to be 2 x Path loss + RCS Gain

= (2 x -143.9) +23.4 = **264.4dB**

45. If the receiver sensitivity of the TPS-77 radar is assumed to be similar to current generation radars, a figure of -125dBm is typical when using pulse compression techniques. Using these figures, this would indicate an antenna gain of circa 34dBi to achieve the quoted Pd. These figures are not dissimilar to an equivalent state of the art L-Band ATC radar such as a Raytheon ASR-23SS. An illustrative calculation is shown at *Diagram 16.1.10.*

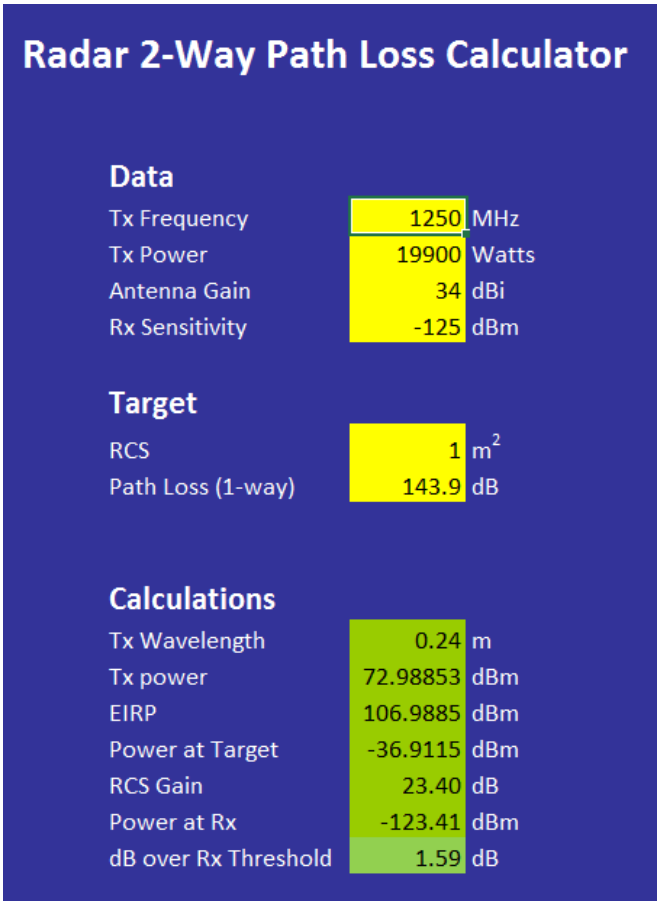

Diagram 16.1.10 TPS-77 Pd calculation

46. In the absence of actual data, the calculated data will be used to determine the Pd of a wind turbine at the limits of LoS.

47. Path loss calculations are made to the closest wind turbine to the radar (wind turbine 79 of the indicative layout). Wind turbine tip heights of 181m, 207m, 223m, and 247m were used for the calculation in addition to wind turbines with tip heights at 195m and 196m to confirm LoS height at the closest wind turbine.

48. The path loss from the radar to the wind turbine tips from the Trimingham radar was calculated using the ITU526 propagation model as depicted at *Diagram 16.1.11.*

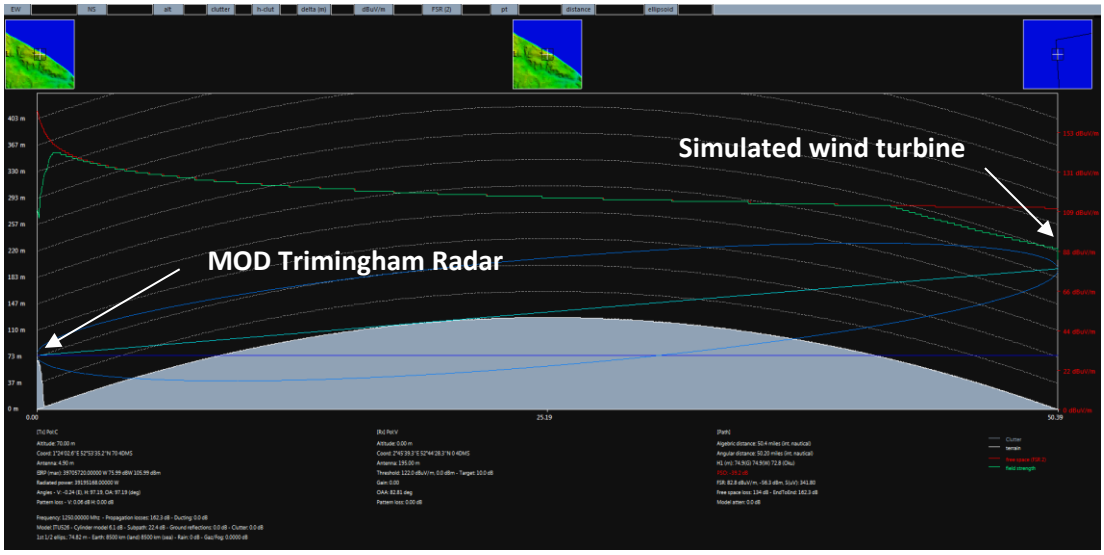

Diagram 16.1.1 Example path loss calculation to tip of 195m wind turbine.

49. The results are tabulated at *Table 16.1.2.* For each example wind turbine tip height, the free space path loss to the wind turbine 79 location (the closest wind turbine to the radar – see *Diagram 16.1.4*) is shown together with the calculated actual path loss to the wind turbine tip.

Table 16.1.2 Path loss calculations

Trimingham: Path loss calculations – wind turbine 79		
Wind turbine tip height (m)	Equivalent Free Space path loss (dB)	Path loss to wind turbine tip (dB)
181	-134	-165.50
195	-134	-162.30
196	-134	-156.10
207	-134	-154.20
223	-134	-151.30
247	-134	-146.70

50. Path loss increases significantly between the wind turbine tip at the LoS height (196m) and a point 1m below the tip (195m). The majority of the reflected signal will be from the portion of a vertical blade above the LoS height.

51. The amount of radar energy reflected will depend on the RCS of the wind turbine blade. For wind turbine blades of the dimensions under consideration, the nominal RCS will be in the range 2.2 to 3.3m^2 per metre of blade length[1].

52. Using the derived data from *Diagram 16.1.10*, calculations have been made on the Pd of the tip of wind turbine 79 using RCS values of 10m^2, 50m^2, and 100m^2.

[1] Source – CAP764 First Edition Appendix 7

53. Maximum on-axis antenna gain has been assumed, notwithstanding that the elevation angle from the radar to the wind turbine tip is circa -0.25°. Results are shown at *Table 16.1.3*.

Table 16.1.3 Trimingham Radar - Wind Turbine 79 Probability of Detection

Trimingham: Probability of Detection – wind turbine 79					
Wind turbine tip height (m)	Equivalent Free Space path loss (dB)	Path loss to wind turbine tip (dB)	dB over RX threshold RCS=10m^2 (dB)	dB over RX threshold RCS=50m^2 (dB)	dB over RX threshold RCS=100m^2 (dB)
181	-134	-165.50	-20.01	-13.01	-10.01
195	-134	-162.30	-16.81	-9.81	-6.81
196	-134	-156.10	-10.61	-3.61	-0.61
207	-134	-154.20	-8.71	-1.71	1.29
223	-134	-151.30	-5.81	1.19	4.19
247	-134	-146.70	-1.21	5.79	8.79

54. In *Table 16.1.3*, the radar received signal level (dB over RX threshold) is colour coded to aid interpretation. Red is >-6dB below the receiver threshold and unlikely to be detected. Levels between -3dB and -6dB are shaded orange with a low probability of detection. Levels between -3dB and +3dB are shaded yellow with a possibility of detection. Levels above +3dB are shaded green, with a high probability of detection.

55. The LoS height at wind turbine 79 is 196m. Considering the rapid increase in path attenuation below the blade tip, the wind turbine would not be expected to be detected by the radar at the LoS height.

56. Calculations illustrate that in the absence of detailed technical data on the TPS-77 radar, Pd and LoS are effectively the same. Radar LoS at the closest point of the East Anglia THREE site is 193m. Wind turbines with a tip height of 193m or less would be below the LoS of the Trimingham radar and would require no further mitigation. If the wind turbine tip heights exceed the LoS height by more than a few metres, then a technical mitigation solution may be required for the MOD Trimingham radar.

16.1.5 NATS Cromer Radar

57. The closest point of the East Anglia THREE site is 52.12NM (96.5km) from Cromer radar.

58. There is no intervening terrain to provide any screening of the East Anglia THREE site; however, earth curvature provides significant screening of the East Anglia THREE site. The absence of terrain screening means that the edge of radar cover follows an arc.

16.1.5.1 Radar Line of Sight

59. Initial assessments carried out established the radar Line of Sight (LoS) to various wind turbine heights across the East Anglia THREE site. These are reproduced in the following diagrams. Radar LoS is indicated by the magenta shading.

60. *Diagram 16.1.12* illustrates that Cromer Radar LoS to 181m tip height wind turbines does not exist in the East Anglia THREE site.

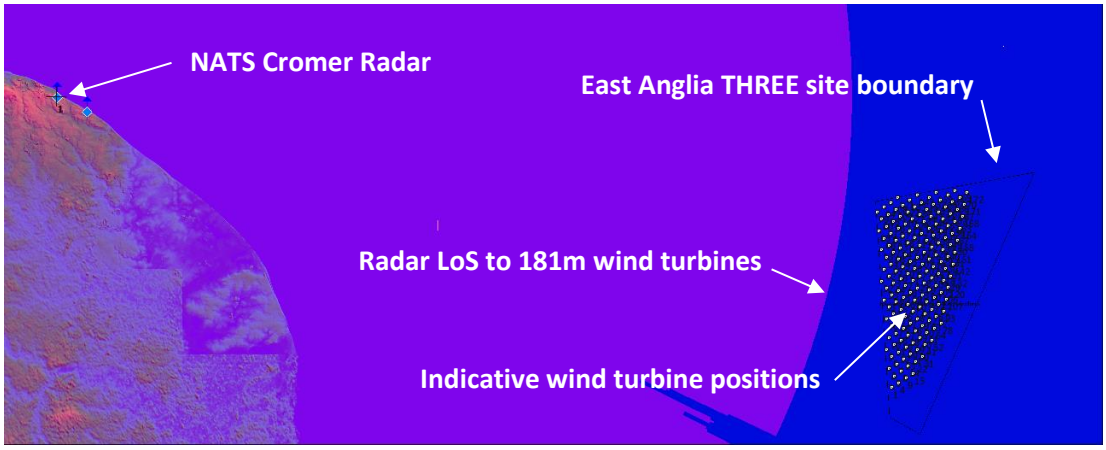

Diagram 16.1.12 LoS Cromer Radar to 181m tip height wind turbines

61. *Diagram 16.1.3* illustrates that the Cromer radar LoS at the extreme north-west corner of the East Anglia THREE site is 207m.

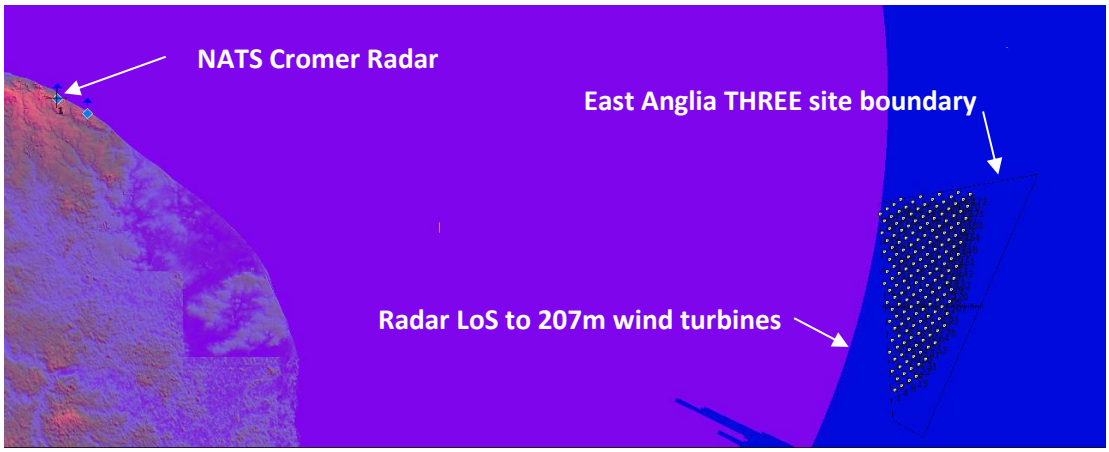

Diagram 16.1.13 LoS Cromer Radar to 207m tip height wind turbines

62. *Diagram 16.1.14* illustrates the radar LoS from the NATS Cromer PSR to 207m tip height wind turbines in more detail. No radar LoS exists to wind turbines of the indicative layout with a wind turbine tip height of 207m.

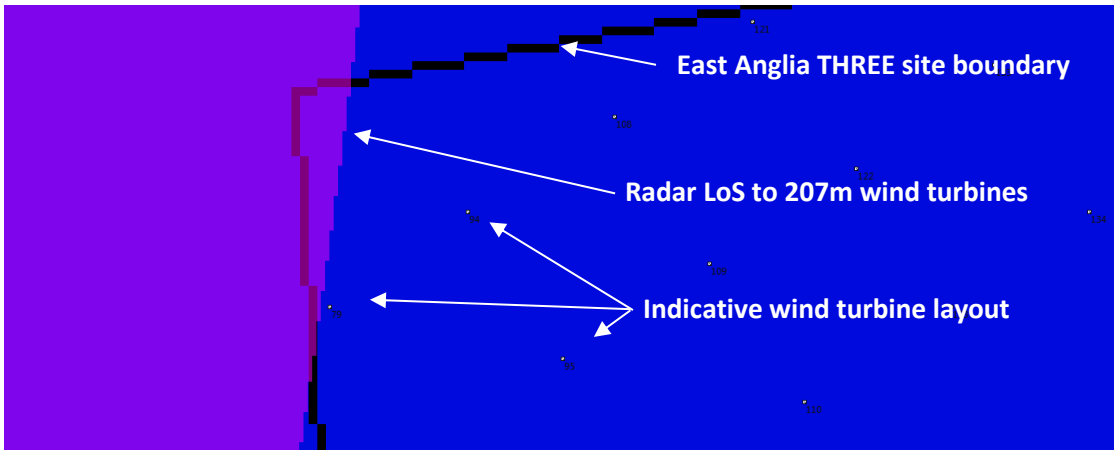

Diagram 16.1.14 LoS Cromer Radar to 207m tip height wind turbines - detail

63. *Diagram 16.1.15* illustrates that radar LoS from the Cromer PSR exists to 223m tip height wind turbines in the extreme north-west corner of the East Anglia THREE site.

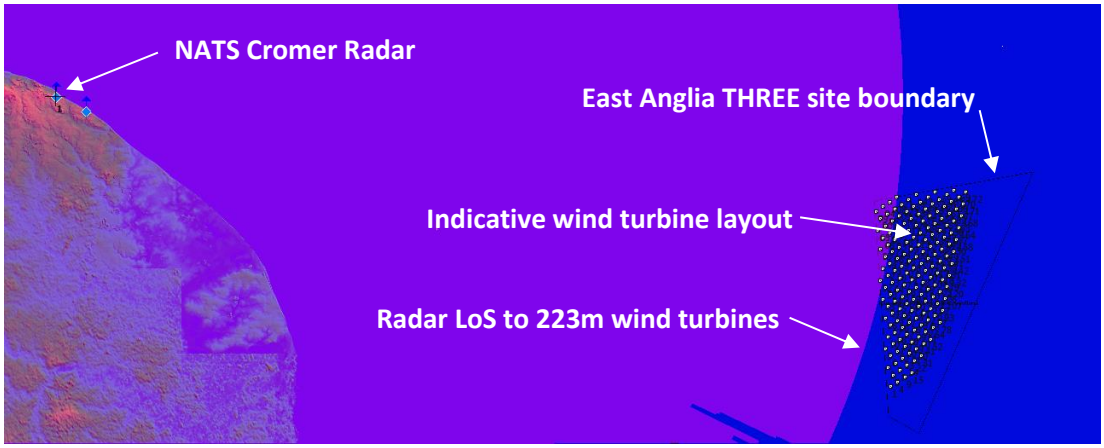

Diagram 16.1.15 LoS Cromer Radar to 223m tip height wind turbines

64. *Diagram 16.1.16* illustrates the radar LoS from the NATS Cromer PSR to 223m tip height wind turbines in more detail. Radar LoS exists to 16 of the 172 wind turbines (9.3%) of the indicative layout with a tip height of 223m.

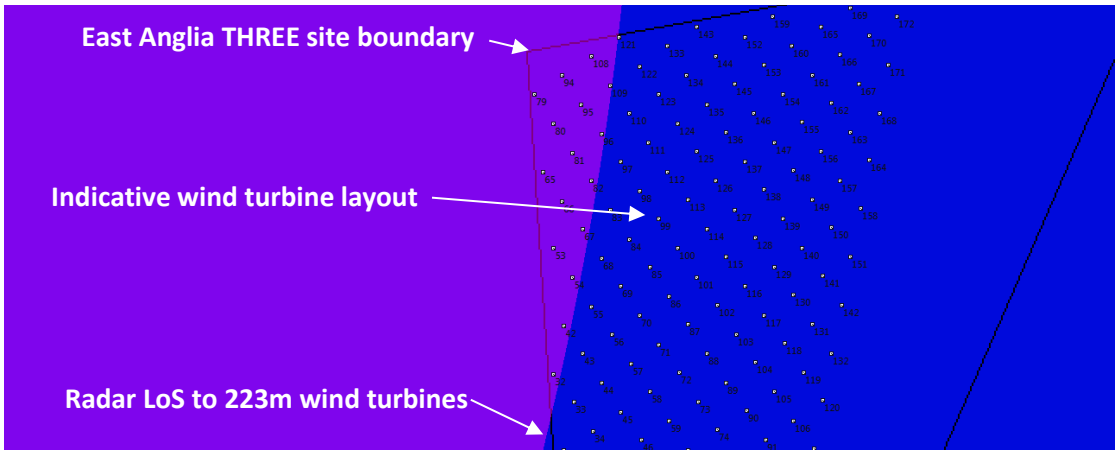

Diagram 16.1.16 LoS Cromer Radar to 223m tip height wind turbines - detail

65. *Diagram 16.1.17* illustrates that radar LoS from the Cromer Radar PSR exists to 247m tip height wind turbines in the north-west corner of the East Anglia THREE site.

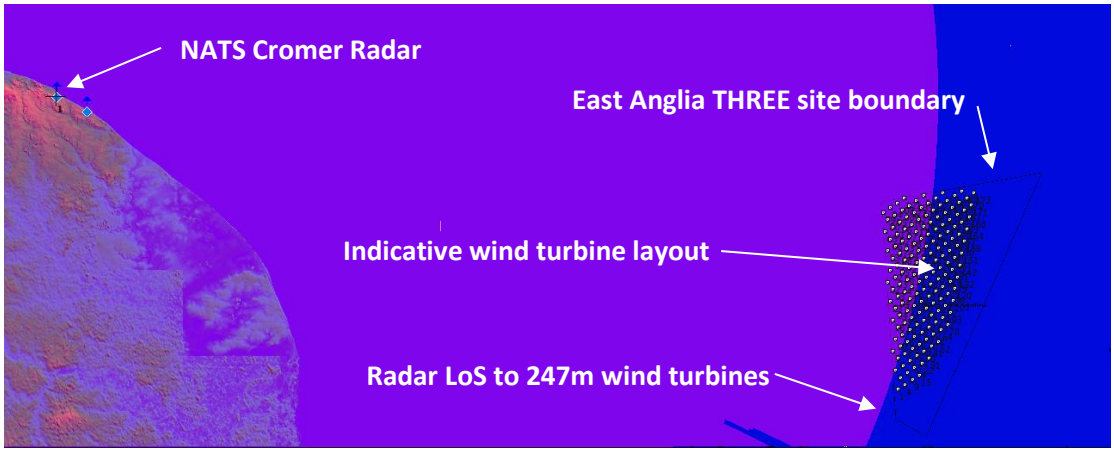

Diagram 16.1.17 LoS Cromer Radar to 247m tip height wind turbines

66. *Diagram 16.1.18* illustrates the radar LoS from the NATS Cromer PSR to 247m tip height wind turbines in more detail. Radar LoS exists to 64 of the 172 wind turbines (37.2%) of the indicative layout with a tip height of 247m.

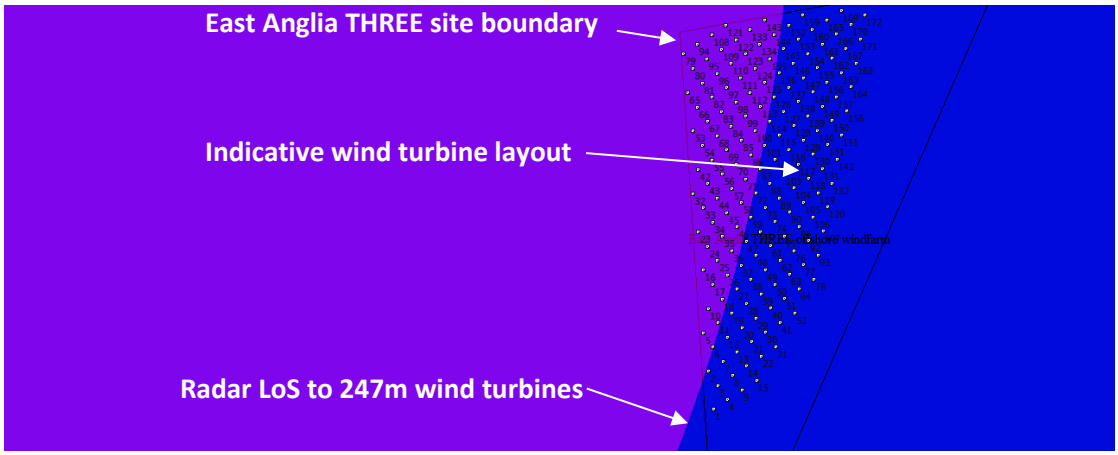

Diagram 16.1.18 LoS Cromer Radar to 247m tip height wind turbines - detail

67. Cromer Radar LoS contours to varying wind turbine heights across the East Anglia THREE site are depicted at *Diagram 16.1.19*. The extent of Air-To-Air Refuelling Area (AARA) 9 is depicted by the cyan shading: this is relevant as the Cromer PSR will be used by military air traffic controllers embedded in NATS to provide an ATS to aircraft utilising the AARA. Illustrative wind turbine positions are depicted by the small black dots.

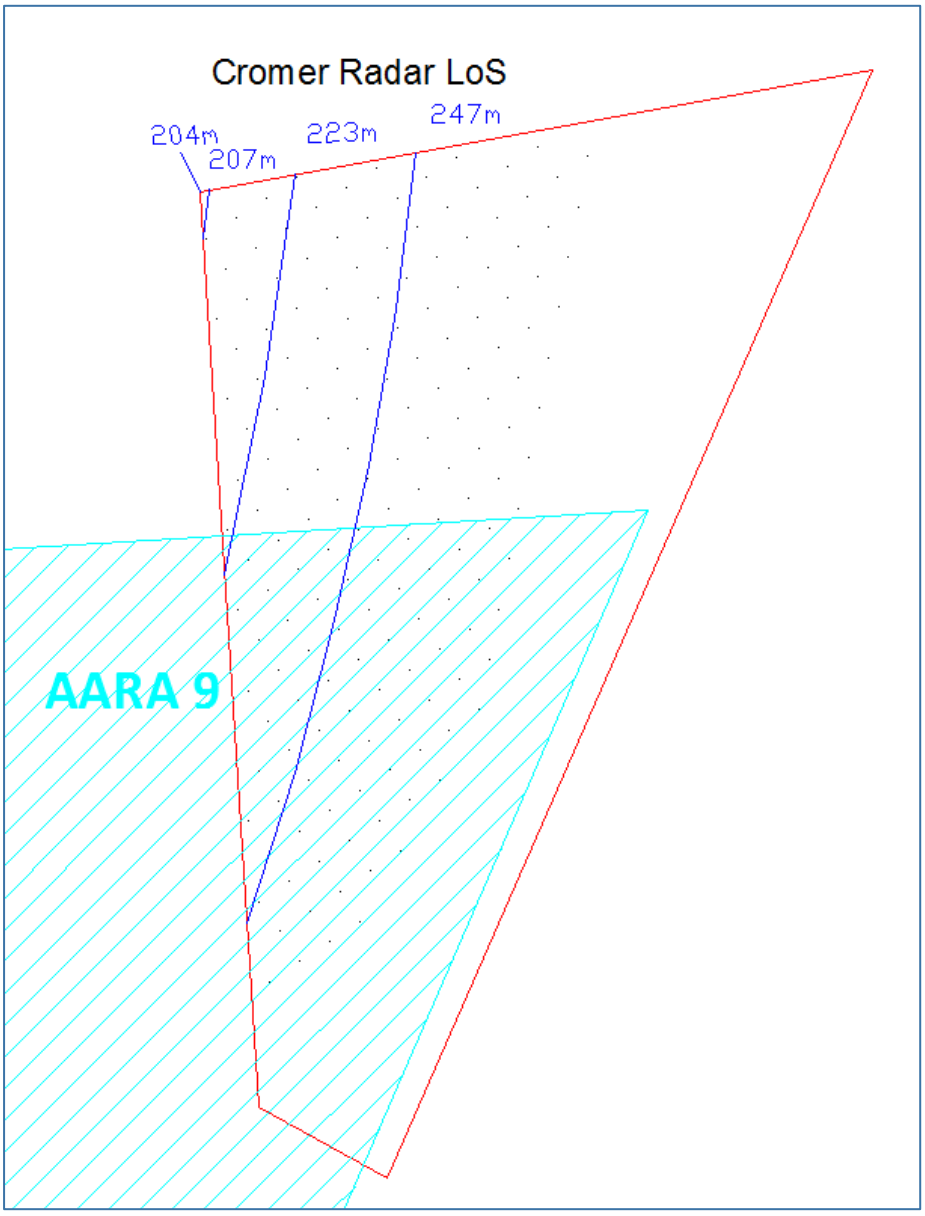

Diagram 16.1.19 Cromer Radar LoS contours across the East Anglia THREE site

16.1.5.2 Radar Probability of Detection

68. Radar LoS is only an indication as to whether the radar will 'see' a wind turbine. Depending on the radar configuration and the nature of the screening, the Probability of Detection (Pd) may be greater or less than the LoS distance.

69. Pd may be calculated using a radio propagation model and the technical characteristics of the radar.

70. Cromer Radar is a Raytheon ASR-10SS. Parameters are taken from data published by Raytheon for a 16-Module radar.

71. Path loss calculations are made to the closest wind turbine to the radar (wind turbine 79 of the indicative layout). Wind turbine tip heights of 181m, 207m, 223m, and 247m were used for the calculation.

72. The path loss from the radar to the wind turbine tips from the NATS Cromer radar was calculated as depicted at *Table 16.1.4.*

Table 16.1.4 Path loss calculations

Cromer: Path loss calculations – wind turbine 79		
Wind turbine tip height (m)	Equivalent Free Space path loss (dB)	Path loss to wind turbine tip (dB)
181	-141	-178.20
207	-141	-169.60
223	-141	-159.30
247	-141	-152.40

73. Using the available radar data, calculations have been made on the Pd to the tip of wind turbine 79 using RCS values of $10m^2$, $50m^2$, and $100m^2$. The LoS height at wind turbine 79 is 208m. The parameters used for the calculation are shown at *Diagram 16.1.20.* Maximum on-axis antenna gain has been assumed, notwithstanding that the elevation angle from the radar to the turbine tip is circa -0.25°.

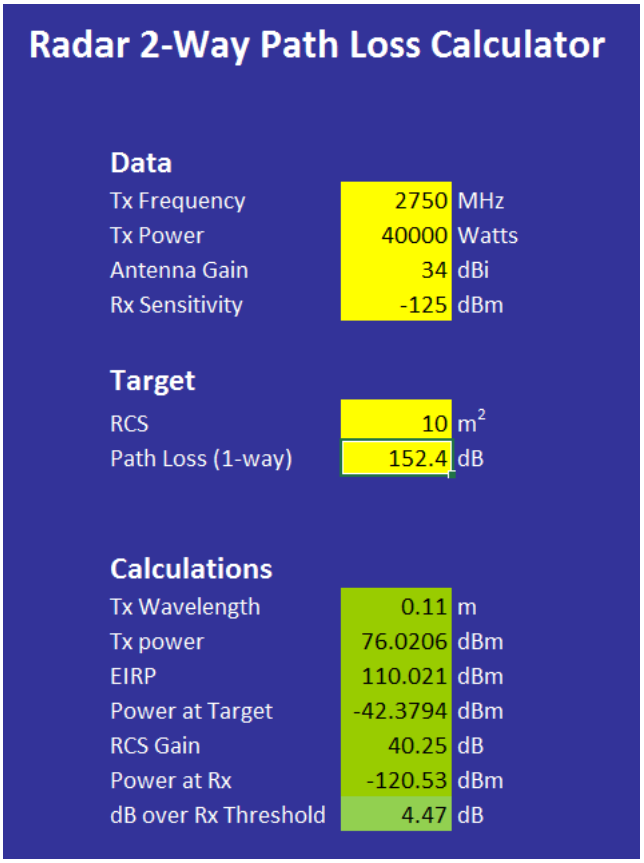

Diagram 16.1.20 Cromer Radar example Pd calculation

74. Results are shown at *Table 16.1.5.*

Table 16.1.5 Cromer Radar – Wind Turbine 79 Probability of Detection

Cromer: Probability of Detection - wind turbine 79					
Wind turbine tip height (m)	Equivalent Free Space path loss (dB)	Path loss to wind turbine tip (dB)	dB over RX threshold RCS=10m^2 (dB)	dB over RX threshold RCS=50m^2 (dB)	dB over RX threshold RCS=100m^2 (dB)
181	-141	-178.20	-21.28	-14.29	-11.28
207	-141	-169.60	-12.73	-5.73	-2.73
223	-141	-159.30	-2.43	4.57	7.57
247	-141	-152.40	4.47	11.46	14.47

75. The radar received signal level (dB over RX threshold) is colour coded to aid interpretation. Red is >-6dB below the receiver threshold and unlikely to be detected. Levels between -3dB and -6dB are shaded orange with a low probability of detection. Levels between -3dB and +3dB are shaded yellow with a possibility of detection. Levels above +3dB are shaded green, with a high probability of detection.

76. *Table 16.1.5* represents worst-case using maximum on-axis antenna gain. The figures illustrate that wind turbines at or below the LoS will not be detected.

77. Cromer radar uses a modified Cosec^2 vertical antenna pattern which has reduced gain at low elevation angles to moderate the effects of ground clutter. The actual antenna gain at the wind turbine tip elevation (circa -0.25°) is expected to be significantly lower than the on-axis gain. If the antenna gain at -0.25° is assumed to be 10dB lower than the on-axis gain, then the Probability of Detection calculations may be revised as shown at *Table 16.1.6.*

Table 16.1.6 Cromer Radar – Wind Turbine 79 Probability of Detection with reduced antenna gain

Cromer: Probability of Detection – wind turbine 79 - Antenna gain reduced by 10dB					
Wind turbine tip height (m)	Equivalent Free Space path loss (dB)	Path loss to wind turbine tip (dB)	dB over RX threshold RCS=10m^2 (dB)	dB over RX threshold RCS=50m^2 (dB)	dB over RX threshold RCS=100m^2 (dB)
181	-141	-178.20	-41.28	-34.29	-31.28
207	-141	-169.60	-32.73	-25.73	-22.73
223	-141	-159.30	-22.43	-15.43	-12.43
247	-141	-152.40	-15.53	-8.54	-5.53

78. With a 10dB reduction in antenna gain, Cromer Radar is unlikely to detect any wind turbines in the East Anglia THREE site up to a wind turbine height of 247m.

79. NATS Technical and Operational Assessment (TOPA) confirms that Cromer Radar is unlikely to detect any wind turbines in the East Anglia THREE site

16.1.6 Consultation engagement

80. A draft of this Appendix was prepared as part of the PEIR and provided to both the MOD and NATS for consideration.

81. The MOD was provided with the same indicative layout as used in this modelling and undertook LoS modelling of these simulated turbine locations. The MOD uses HTZ Warfare, another ATDI radar propagation tool. EATL was not informed of the terrain data used by the MOD in its modelling.

82. The results of the MD's radar modelling largely reflect those obtained by Cyrrus as set out in the Appendix. The MOD's modelling shows radar LoS by blue shading.

83. *Diagram 16.1.21* illustrates that radar LoS from the Trimingham PSR to 181m tip height wind turbines does not exist in the East Anglia THREE site.

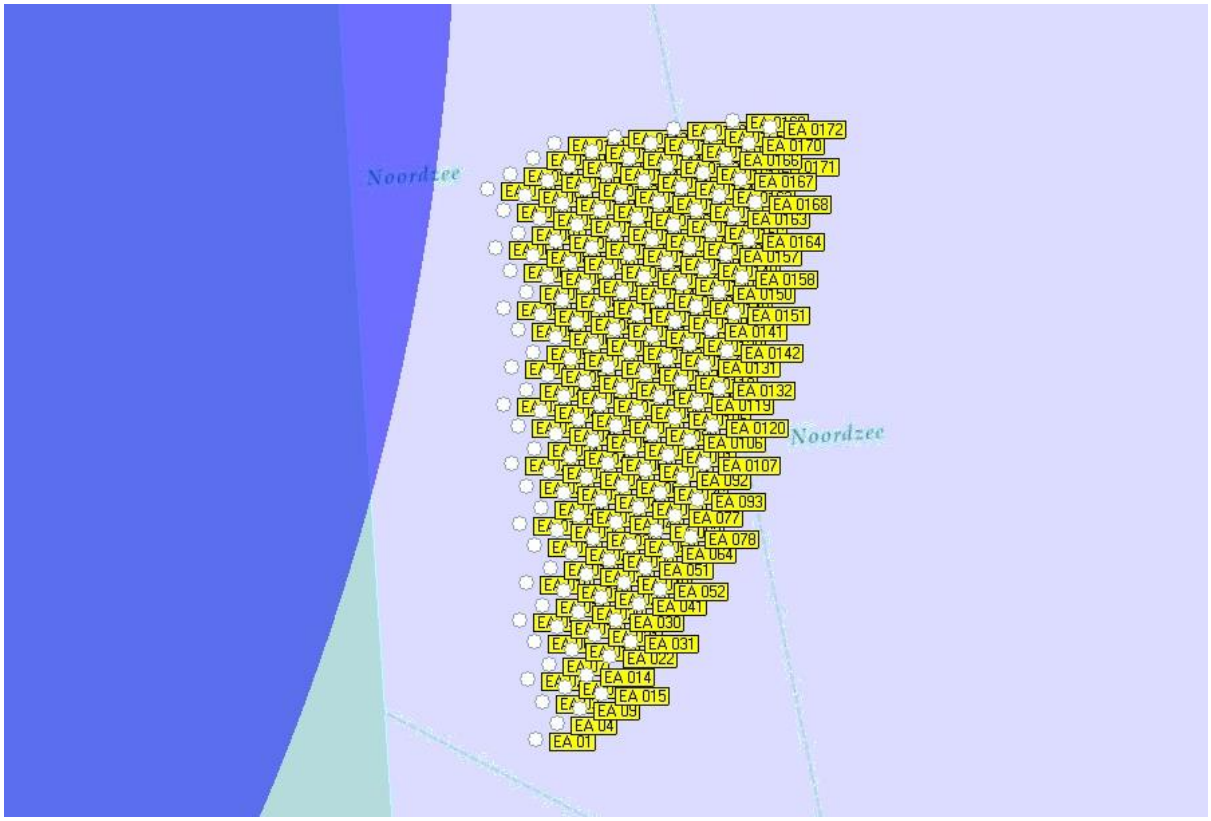

Diagram 16.1.21 LoS Trimingham Radar to 181m tip height turbines (MOD modelling)

84. *Diagram 16.1.22**Error! Reference source not found.*** illustrates the radar LoS from the Trimingham PSR to 207m tip height wind turbines.

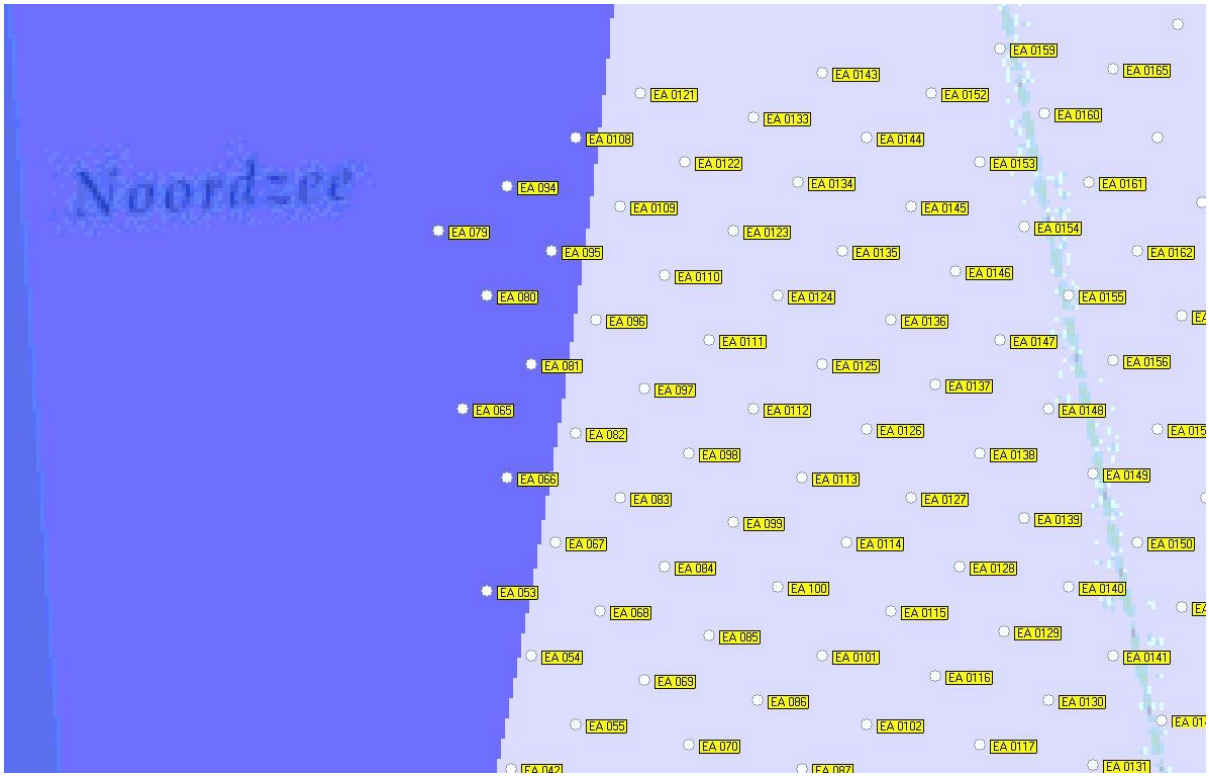

Diagram 16.1.22 LoS Trimingham Radar to 207m tip height turbines (MOD modelling)

85. *Diagram 16.1.23* illustrates the radar LoS from the Trimingham PSR to 223m tip height wind turbines.

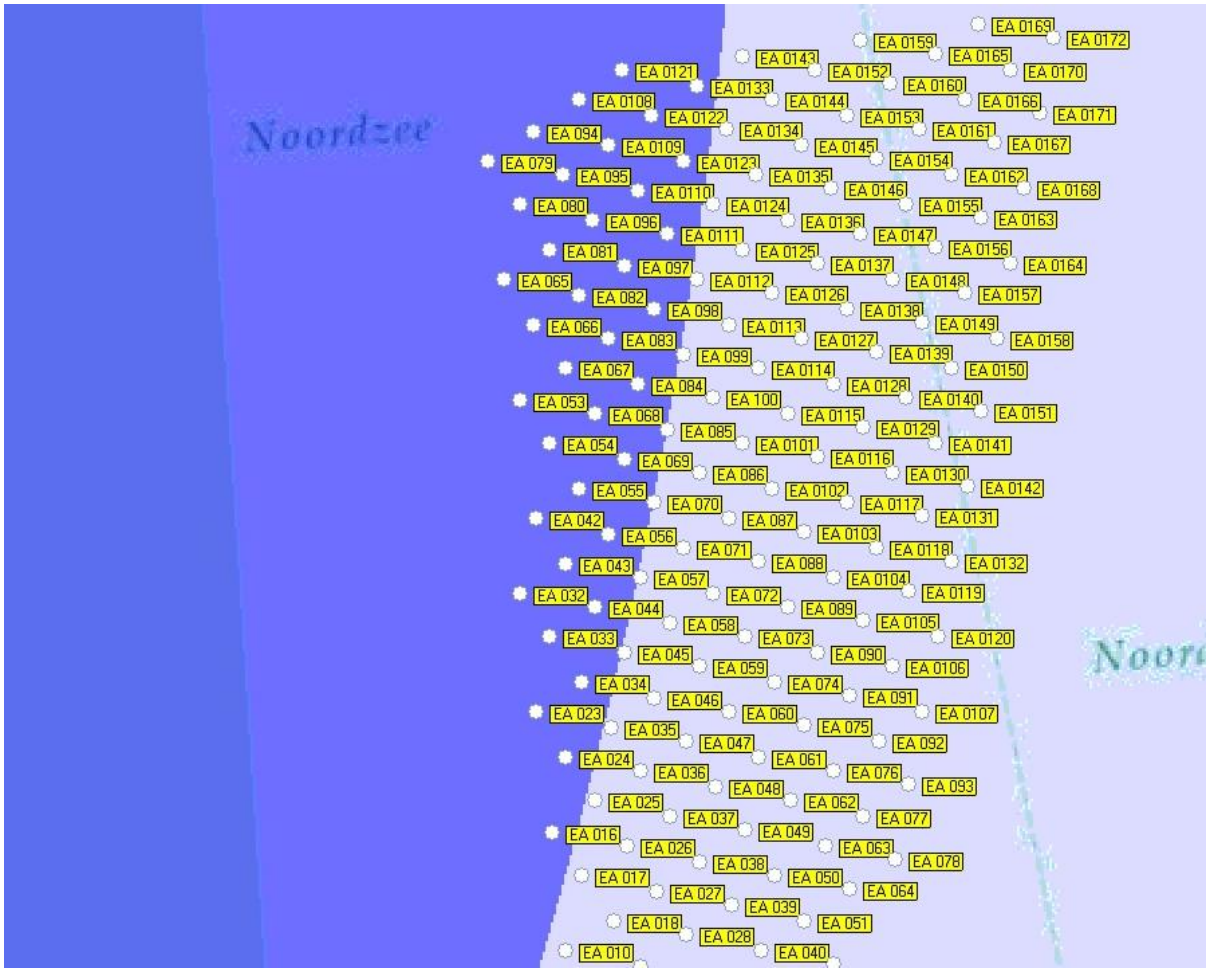

Diagram 16.1.23 LoS Trimingham Radar to 223m tip height turbines (MOD modelling)

86. *Diagram 16.1.24* and *Diagram 16.1.25* illustrate the radar LoS from the Trimingham PSR to 247m tip height wind turbines.

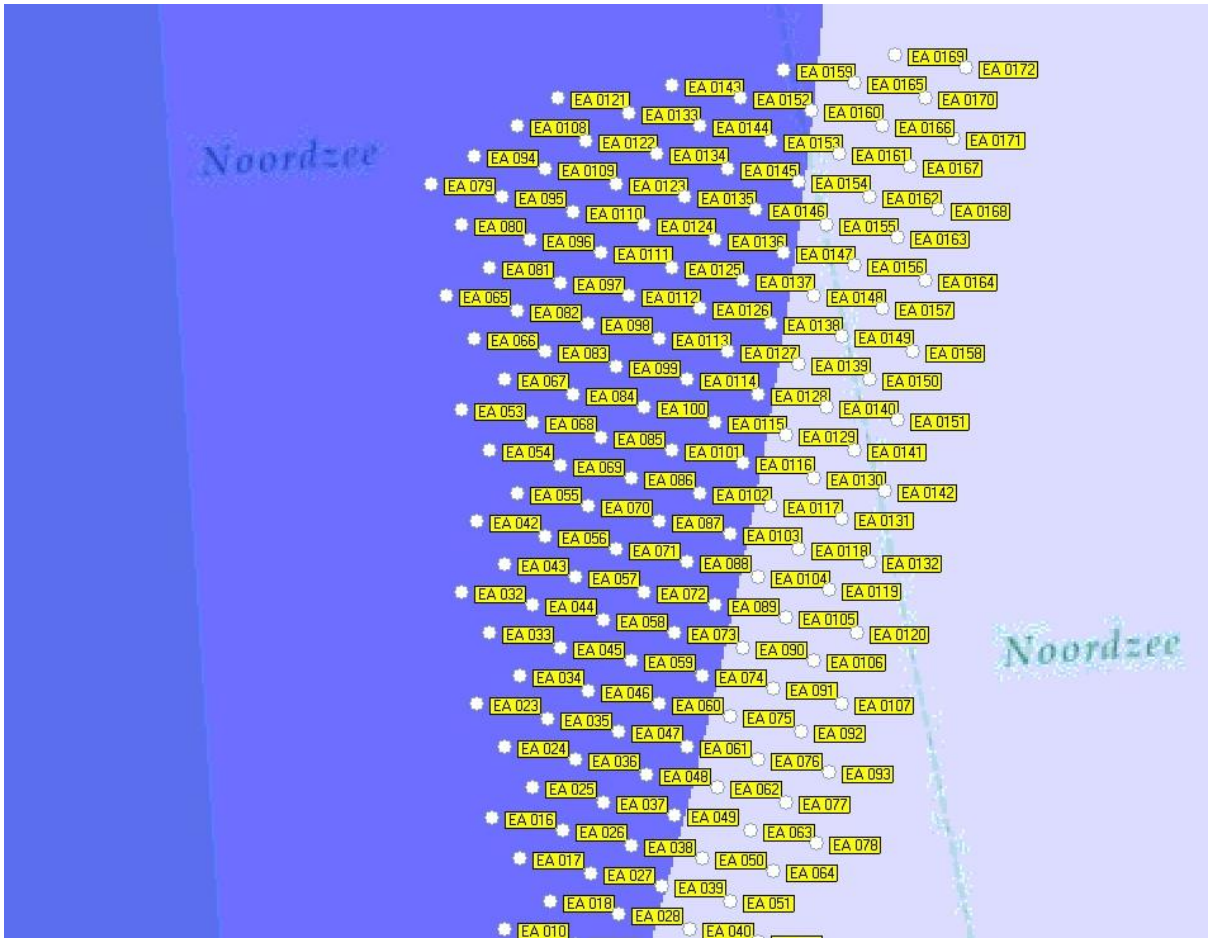

Diagram 16.1.24 LoS Trimingham Radar to 247m tip height turbines (MOD modelling) - north

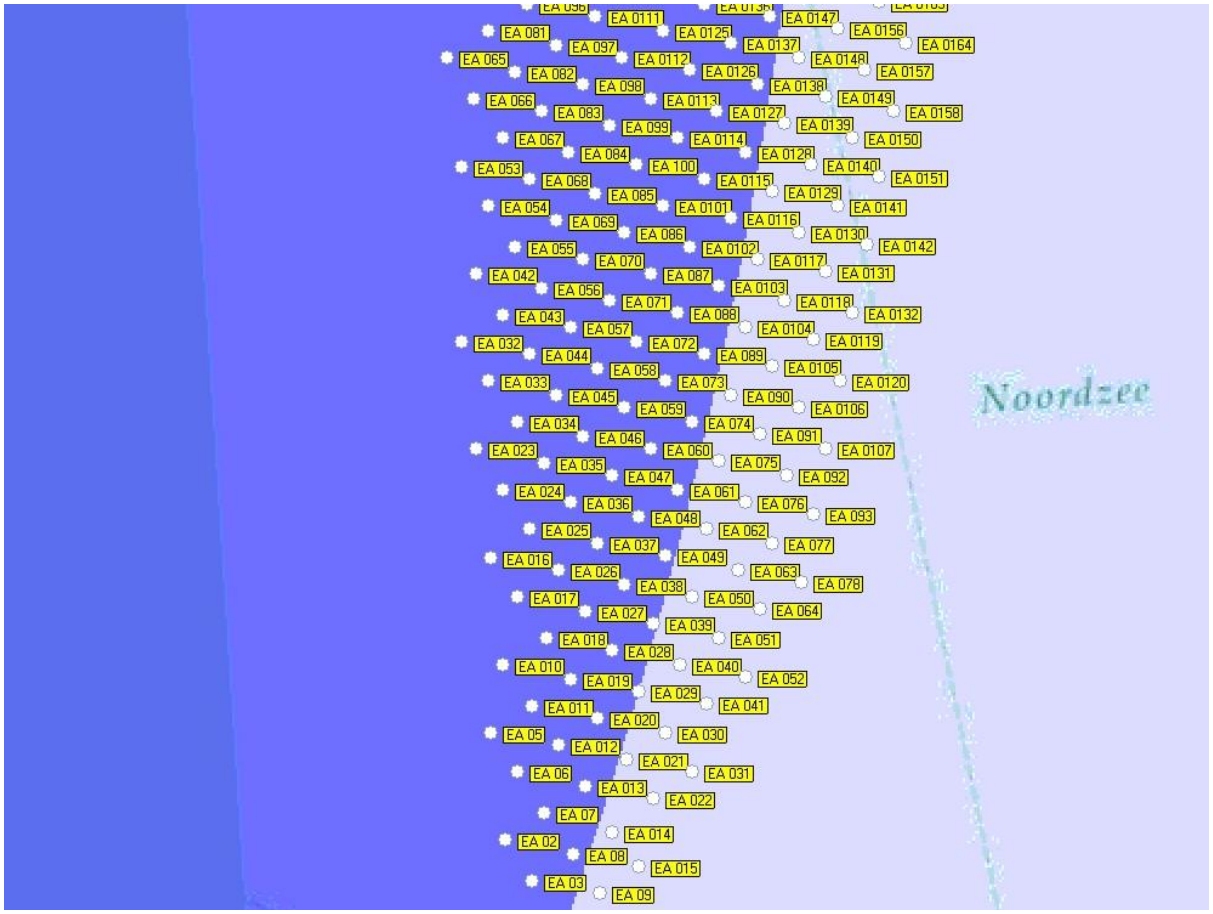

Diagram 16.1.25 LoS Trimingham Radar to 247m tip height turbines (MOD modelling) - south

87. EATL met with MOD to discuss these modelling results on 20 August 2014 and to explore the way forward with regards to mitigation options in the event that the final configuration of the East Anglia THREE site includes turbines of the requisite height within the areas of radar LoS. The MOD subsequently confirmed by email dated 8 December 2014 that its assessment to determine the maximum acceptable radar LoS height at boundary point 4 in terms of the Trimingham PSR would be 193 metres AMSL.

88. MOD modelling indicated a lower height at the closest boundary of the East Anglia THREE site compared to the initial Cyrrus modelling (193m v 195m). All other modelling was consistent. Investigations determined that the 195m figure was derived from digital terrain map ground elevation at Trimingham, which was rounded down to 69m AMSL. This gave an actual height at the boundary of East Anglia THREE of 194.6m, which was rounded up to 195m. The actual ground elevation at Trimingham, as notified by MOD is 69.8m AMSL. Rounding up the ground elevation to 70m AMSL produces a radar Line of Sight elevation of 193m. All

other Cyrrus calculations were based on a radar ground elevation of 70m, as evidenced in *Diagram 16.1.11*.

89. NATS also reviewed the draft Appendix and undertook its own pre-planning review of the corner points of the East Anglia THREE site (a TOPA or technical and operational assessment). NATS concluded in its TOPA dated July 2014 that no impact is predicted on NATS' radars and therefore the East Anglia THREE project would not attract any objection from NERL.

16.1.7 Conclusions (including potential mitigation)

90. The following paragraphs draw together the conclusions of the radar modelling undertaken in this Appendix and set out the areas in which mitigation may be required if wind turbines of specified heights are utilised.

91. EATL recognises that any mitigation will need to be agreed in consultation with the relevant aviation stakeholder, but it is hoped that these findings will act as a focus to these discussions.

16.1.7.1 MOD Trimingham Radar

92. In the absence of detailed technical data on the TPS-77 radar, calculations set out in this Appendix illustrate that Pd and LoS for the Trimingham PSR are effectively the same. Radar LoS at the closest point of the East Anglia THREE site is 193m. Wind turbines with a tip height of 193m or less would be below the LoS of the Trimingham radar and would require no further mitigation.

93. Wind turbines higher than the contours depicted at *Diagram 16.1.9* may be detected by MOD Trimingham radar. If larger wind turbines are utilised on the north western area of the East Anglia THREE site, then technical mitigation may be required by MOD.

94. As explained in *Chapter 16 Aviation and MOD*, the TPS-77 has a 3D non-auto-initiation zone (NAIZ) function which EATL understands can be applied to mitigate the impacts of wind turbine detections. Given that, at any given wind turbine height, only part of the East Anglia THREE site would be detected by the Trimingham PSR, this means that the footprint of the area for which mitigation (and any concomitant NAIZs) may be required would be limited.

16.1.7.2 NATS Cromer Radar

95. Cromer radar has no LoS to wind turbines with a tip height of 207m or lower in the East Anglia THREE site.

96. Probability of detection calculations indicate that the East Anglia THREE site may accommodate wind turbines up to a tip height of 247m without being detected by Cromer Radar provided that the antenna gain at the wind turbine elevation angle is 10dB or less than the maximum on-axis antenna gain. This has been confirmed by NATS in its pre-planning TOPA of July 2015.

97. In the event that the East Anglia THREE site wind turbines are detected by Cromer radar, EATL anticipates that, consistent with NATS' approach for other offshore windfarms (particularly Round 3 windfarms), the most likely mitigation strategy to be adopted by NATS would be to blank the Cromer PSR in any impacted area. The alternative mitigation option would be to ensure that no visible wind turbines are installed in the impacted area.

16.1.8 References

- Lockheed Martin TPS-77 radar: Lockheed Martin AN/TPS-77 Factsheet. B013-03.
- MOD Trimingham radar positional data: Positional data pertaining to MOD Trimingham radar was received by email from MOD DES ADATS on 13/12/2013 12:33.
- NATS Cromer Radar Site data: Ofcom Protected Radar List (Annex 3) 01 October 2013.
- Raytheon ASR-10SS radar: Raytheon ASR-10SS Factsheet.

Appendix 16.1 Ends Here