



PAGERPOWER

Seagreen (Perwinnes)

Radar Line of Sight Assessment (Eurocontrol, CAA, RAF, NATS) Perwinnes PSR (NATS)

Pager Power

Seagreen (Perwinnes)

7th February 2018

Without Expert Commentary

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Report Issue	Date and Time of Request
1	07 Feb 2018 at 09:22 BST

This assessment was requested by Mike Watson of Pager Power on 7th February 2018.

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1 SUMMARY (EXECUTIVE)

Pager Power

Pager Power was registered in England in 1997 and is made up of a team of specialist professionals, based near Cambridge. We are a truly international business with more than 250 clients from across the globe.

Our reputation has been established as experts able to assess and provide solutions to issues that can arise with any combination of wind turbines, radar, radio communications and construction interaction. We strongly believe that our greatest assets are our people and our software.

Purpose

The purpose of this assessment is to enable swift and cost effective decision making by wind turbine developers and radar operators. The optional Expert Commentary offers advice as to the next steps that should be taken as a result of the findings of this report.

Radar Line of Sight Calculations are used extensively in the planning stages of wind farm development and are referenced by many leading authorities and organisations, including civil and military radar operators.

Wind Turbine	Result
A1	VISIBLE
A2	VISIBLE
A3	VISIBLE
A4	VISIBLE
A5	VISIBLE
A6	VISIBLE
A7	HIDDEN
A8	VISIBLE

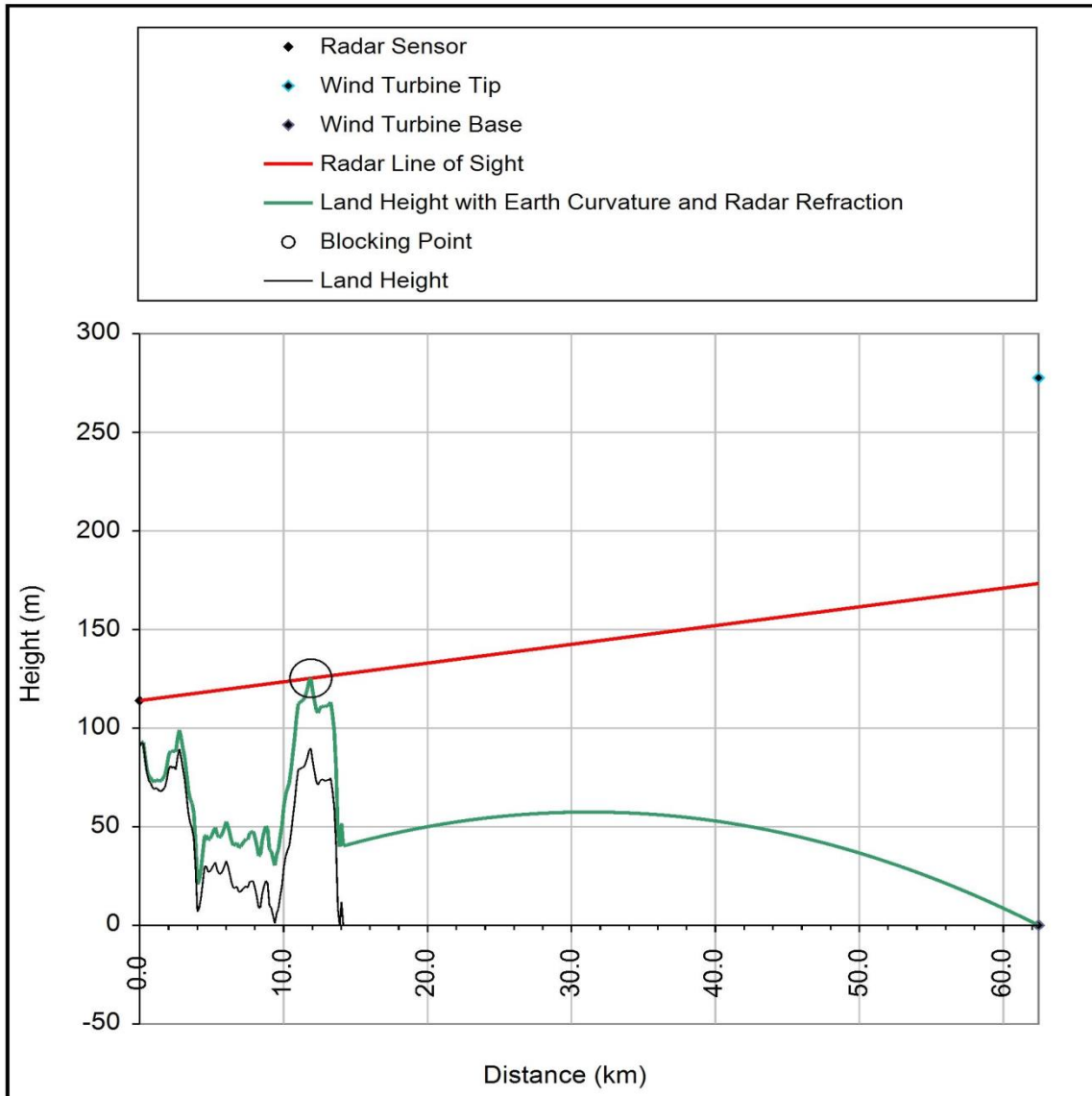
B1	VISIBLE
B2	VISIBLE
B3	VISIBLE
B4	VISIBLE
B5	VISIBLE
B6	VISIBLE
Explanation: There is one Radar Line of Sight Calculation page for each turbine assessed. Each calculation shows whether the turbine is VISIBLE or HIDDEN. Visible turbines are likely to affect the radar whereas hidden turbines are unlikely to affect the radar.	

Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	A1
Result	VISIBLE
Certainty	104.3 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E405537 N752516
Distance to radar (km)	62.5
Blocking Point Location	E394733 N801890
Distance to BP (km)	50.5

Additional Analysis

Angle (Radar to Tip)	0.060 degrees down
Maximum Tip Height	173.38 metres

See Appendix for further information

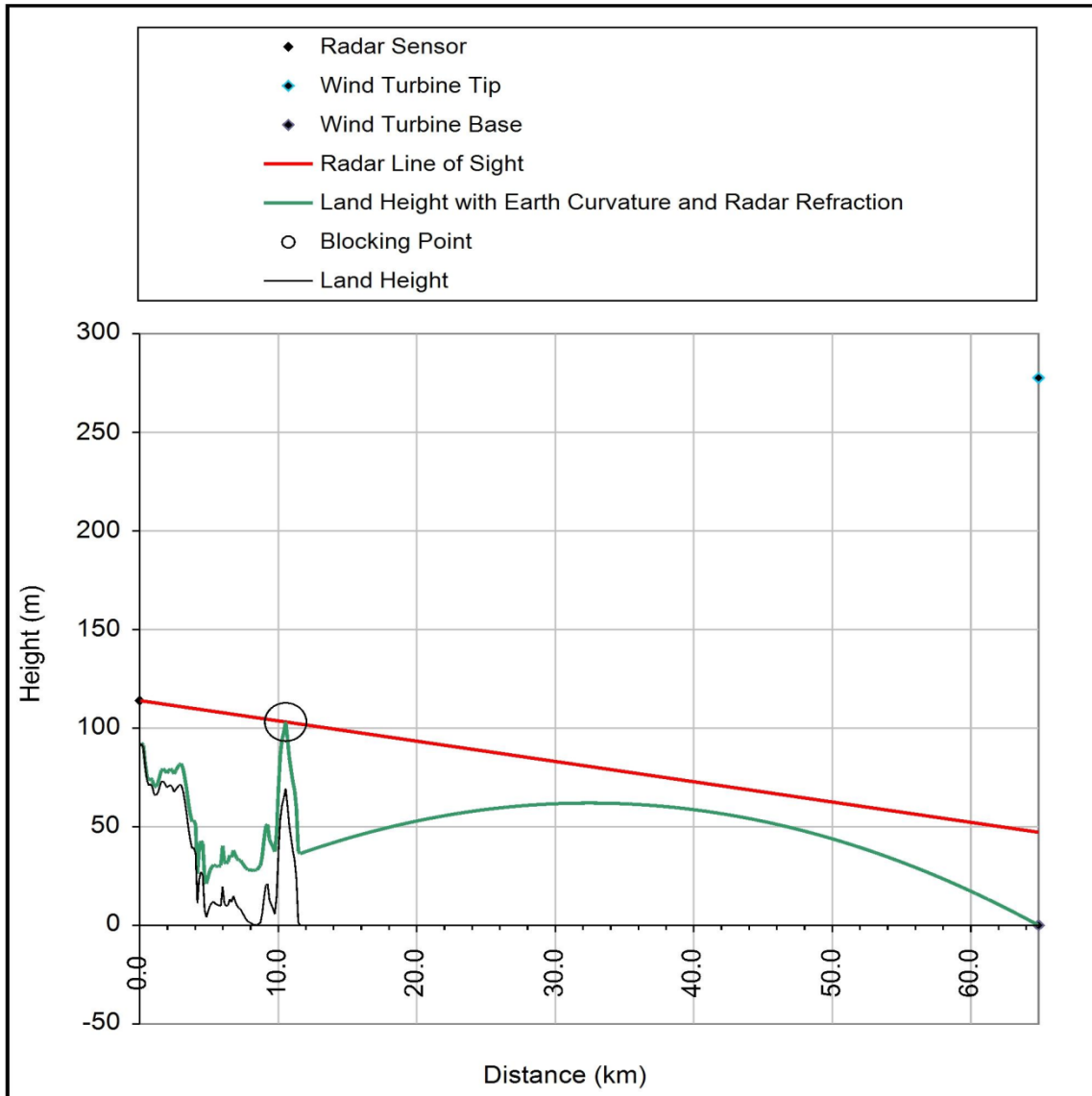
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	A2
Result	VISIBLE
Certainty	230.5 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E416645 N753421
Distance to radar (km)	64.9
Blocking Point Location	E396161 N803747
Distance to BP (km)	54.3

Additional Analysis

Angle (Radar to Tip)	0.074 degrees down
Maximum Tip Height	47.20 metres

See Appendix for further information

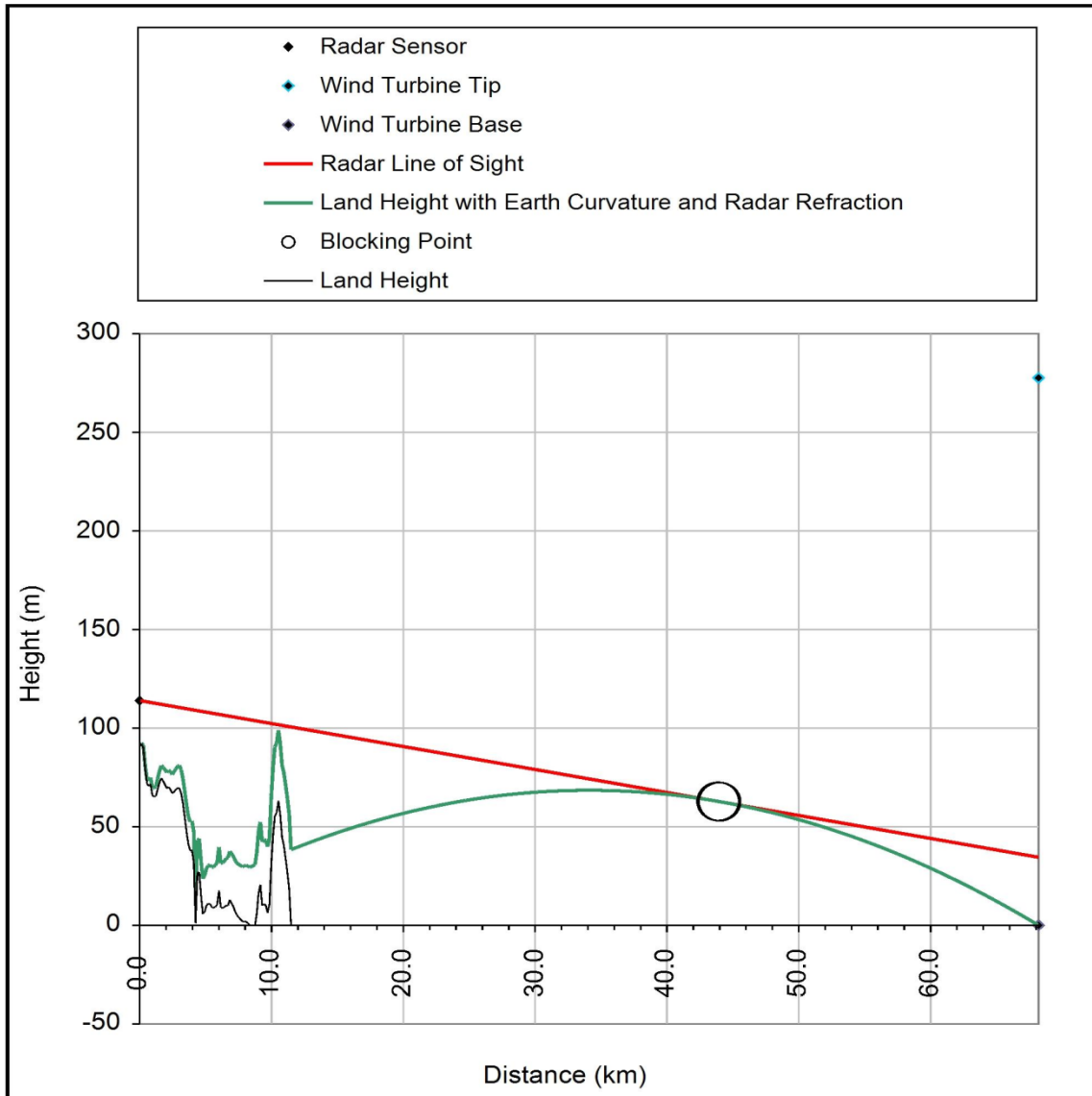
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	A3
Result	VISIBLE
Certainty	243.2 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E418820 N750751
Distance to radar (km)	68.2
Blocking Point Location	E409375 N773008
Distance to BP (km)	24.2

Additional Analysis

Angle (Radar to Tip)	0.092 degrees down
Maximum Tip Height	34.52 metres

See Appendix for further information

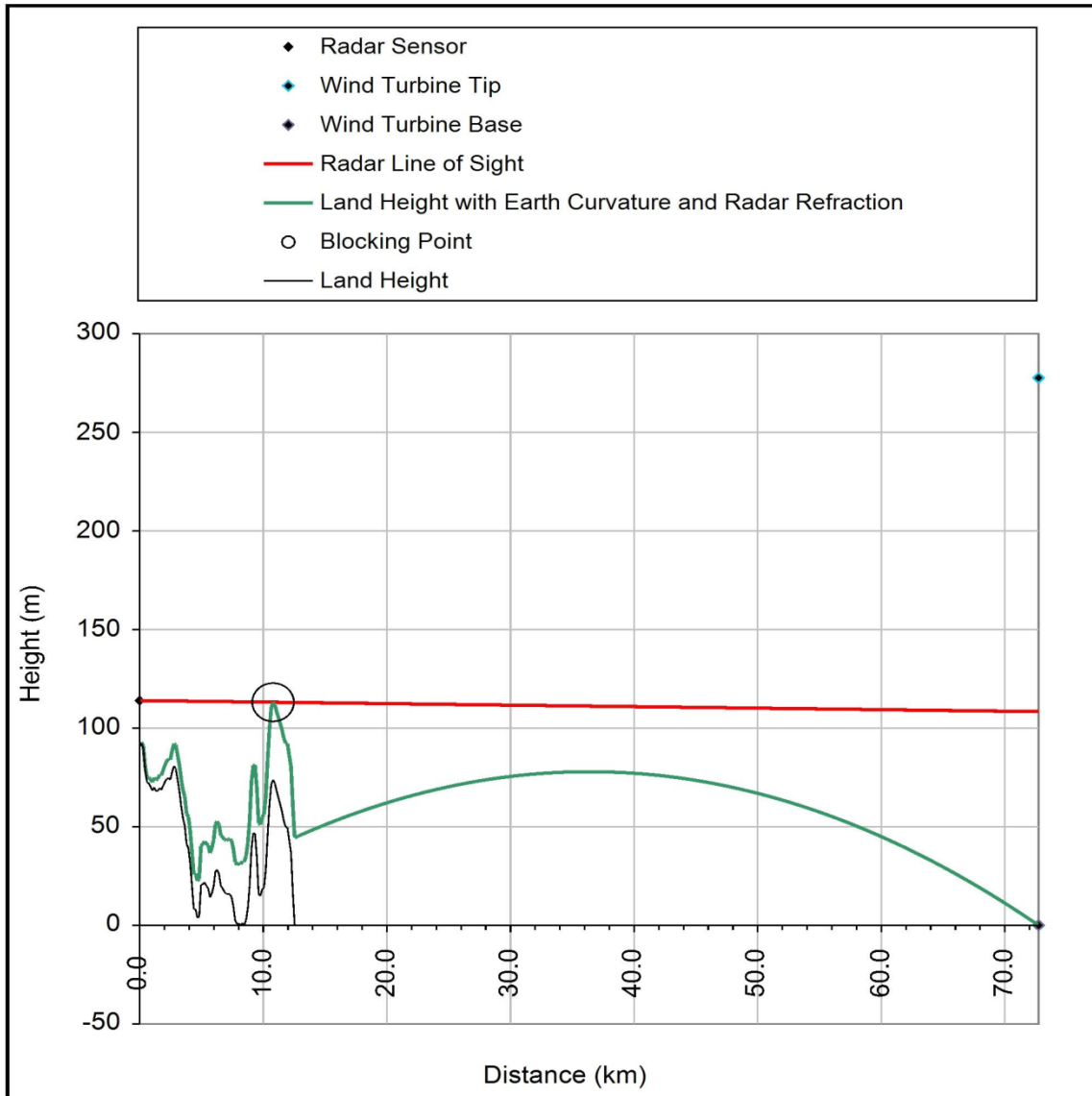
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	A4
Result	VISIBLE
Certainty	169.3 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E414574 N744331
Distance to radar (km)	72.7
Blocking Point Location	E395511 N803242
Distance to BP (km)	61.9

Additional Analysis

Angle (Radar to Tip)	0.116 degrees down
Maximum Tip Height	108.41 metres

See Appendix for further information

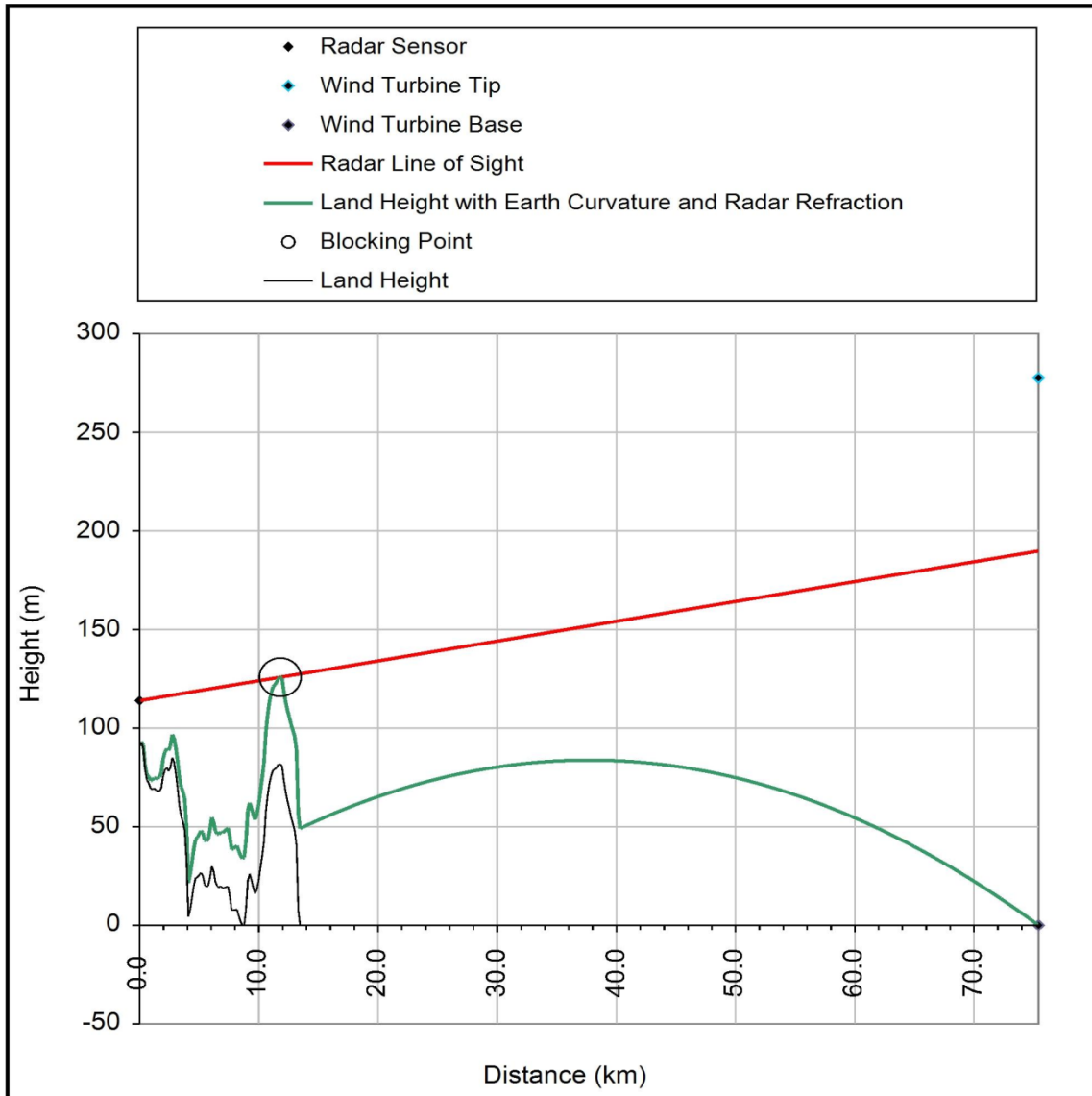
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	A5
Result	VISIBLE
Certainty	87.9 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E410664 N740406
Distance to radar (km)	75.4
Blocking Point Location	E395079 N802074
Distance to BP (km)	63.6

Additional Analysis

Angle (Radar to Tip)	0.130 degrees down
Maximum Tip Height	189.83 metres

See Appendix for further information

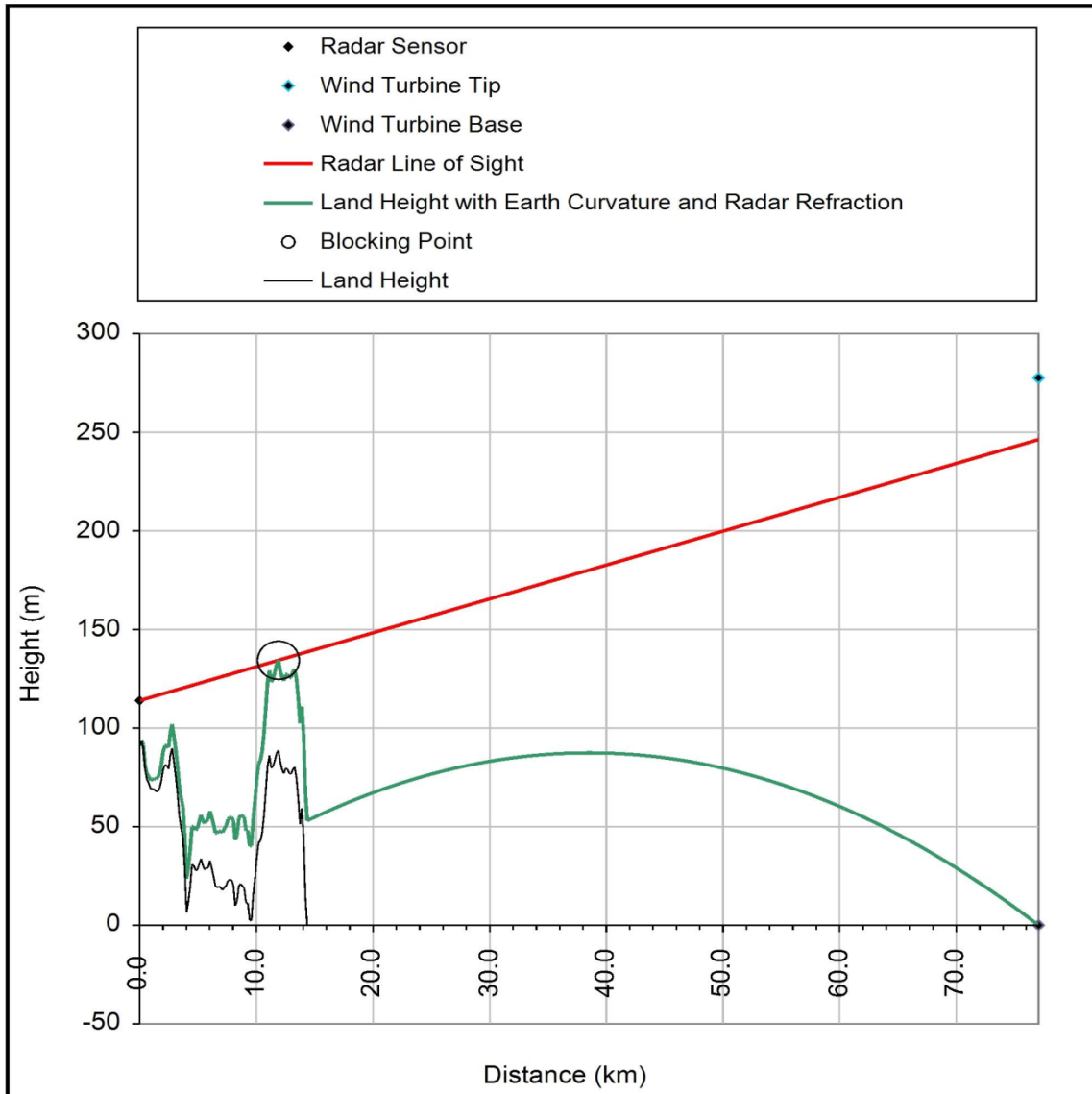
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	A6
Result	VISIBLE
Certainty	31.3 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E407815 N738086
Distance to radar (km)	77.0
Blocking Point Location	E394603 N801863
Distance to BP (km)	65.1

Additional Analysis

Angle (Radar to Tip)	0.138 degrees down
Maximum Tip Height	246.38 metres

See Appendix for further information

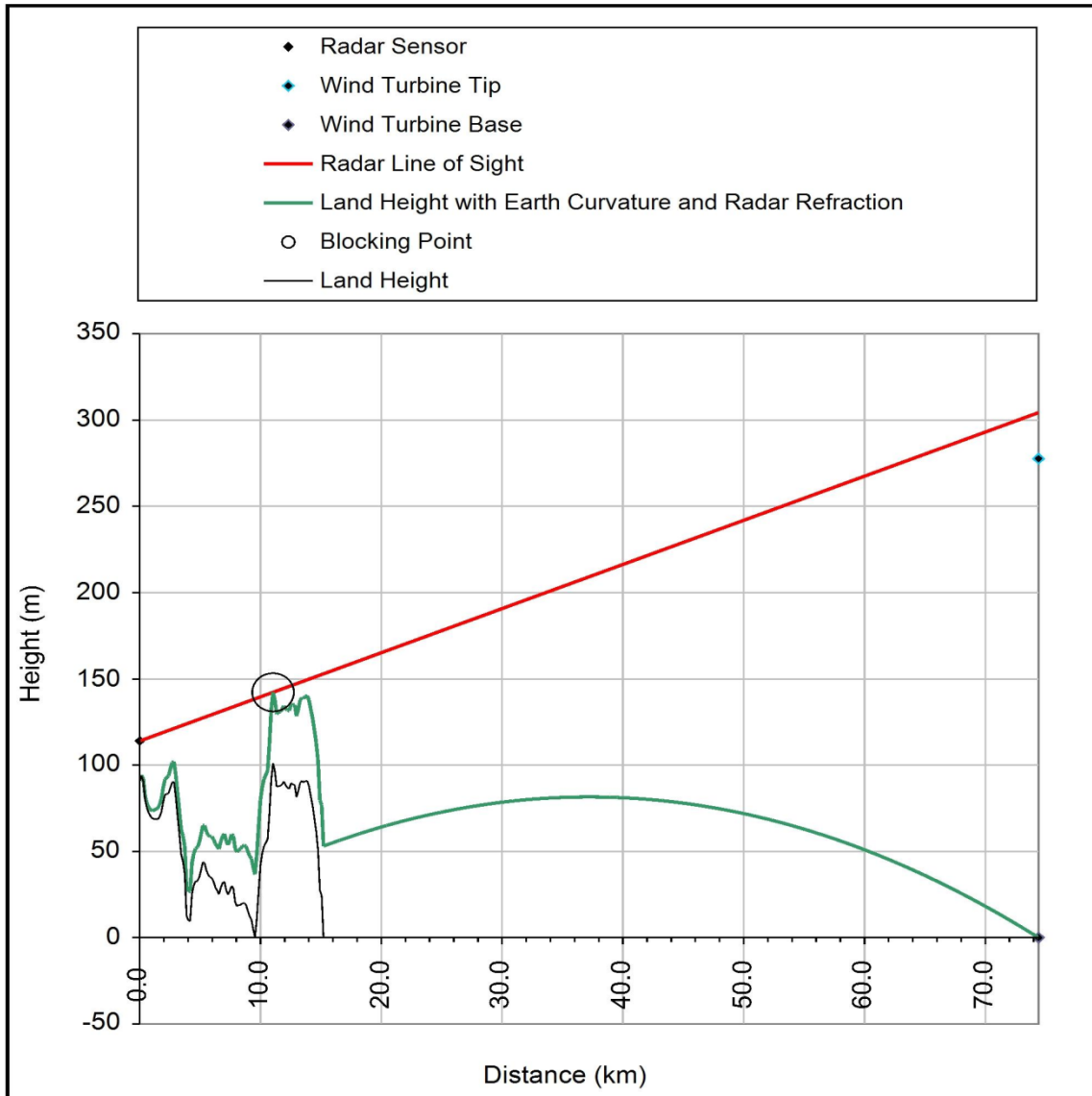
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	A7
Result	HIDDEN
Certainty	26.7 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E403854 N740041
Distance to radar (km)	74.4
Blocking Point Location	E393922 N802606
Distance to BP (km)	63.3

Additional Analysis

Angle (Radar to Tip)	0.125 degrees down
Maximum Tip Height	304.39 metres

See Appendix for further information

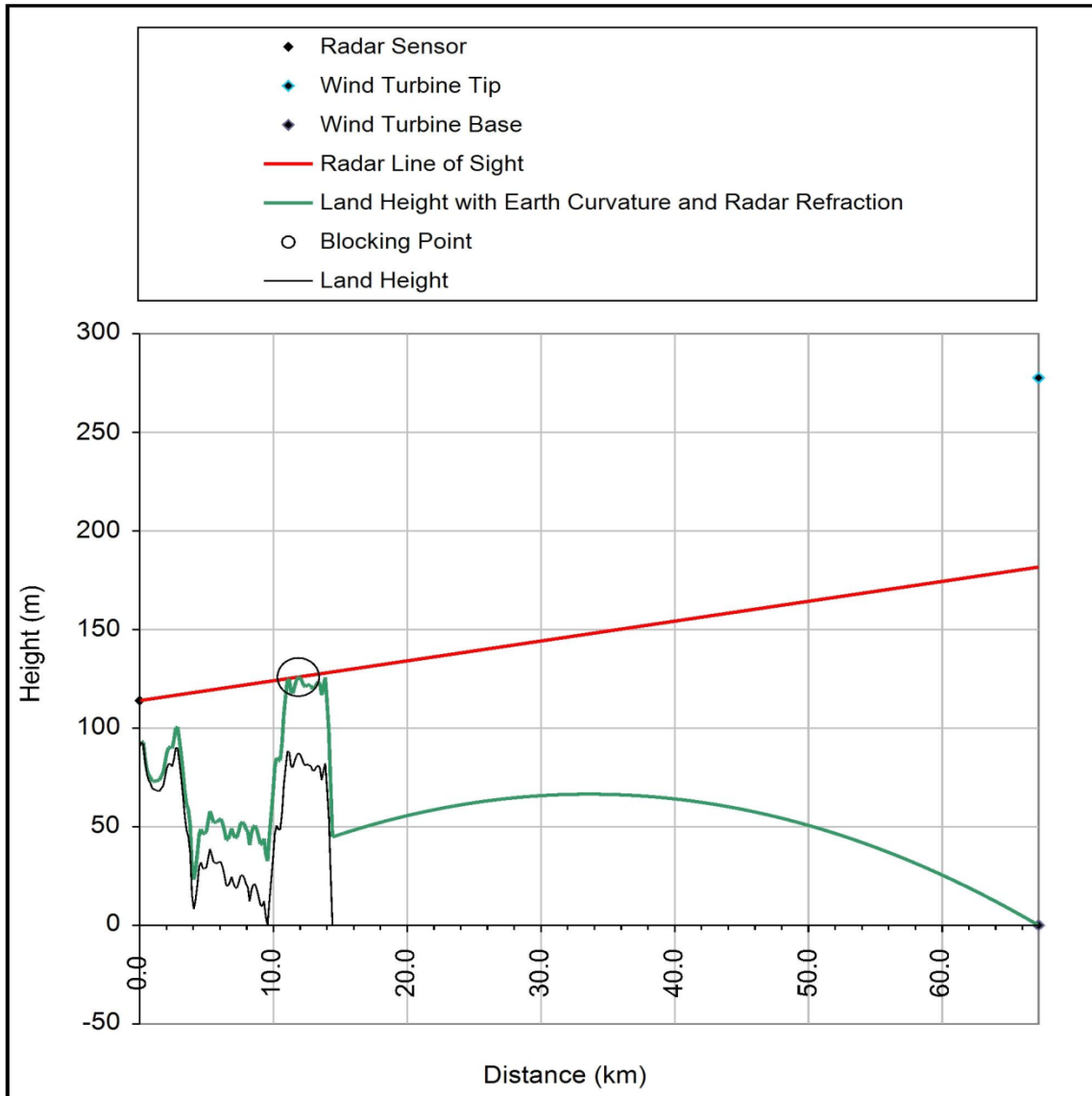
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	A8
Result	VISIBLE
Certainty	96.0 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E404864 N747526
Distance to radar (km)	67.2
Blocking Point Location	E394427 N801865
Distance to BP (km)	55.3

Additional Analysis

Angle (Radar to Tip)	0.087 degrees down
Maximum Tip Height	181.70 metres

See Appendix for further information

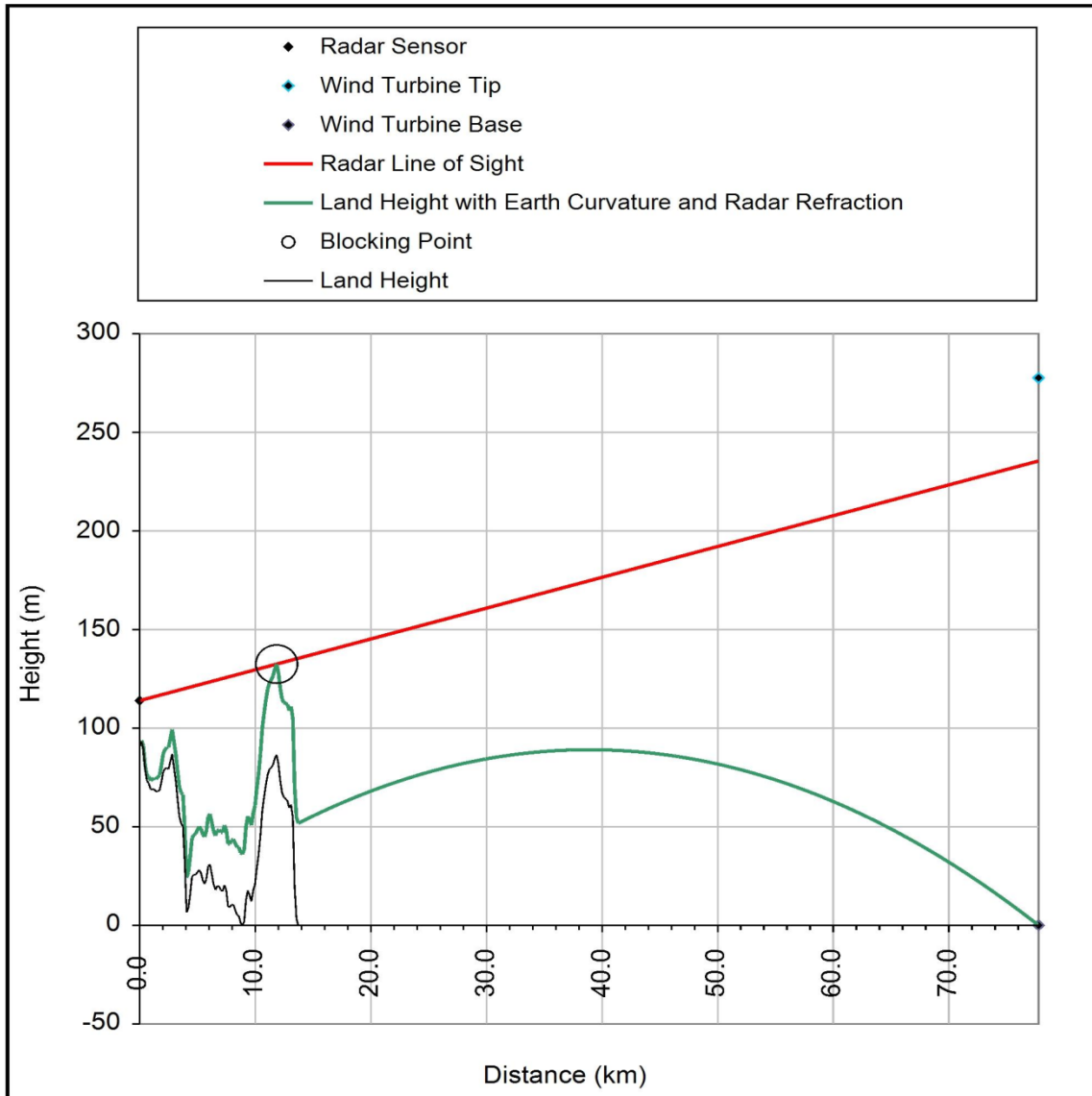
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	B1
Result	VISIBLE
Certainty	42.1 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E410328 N737911
Distance to radar (km)	77.8
Blocking Point Location	E394954 N801987
Distance to BP (km)	65.9

Additional Analysis

Angle (Radar to Tip)	0.142 degrees down
Maximum Tip Height	235.55 metres

See Appendix for further information

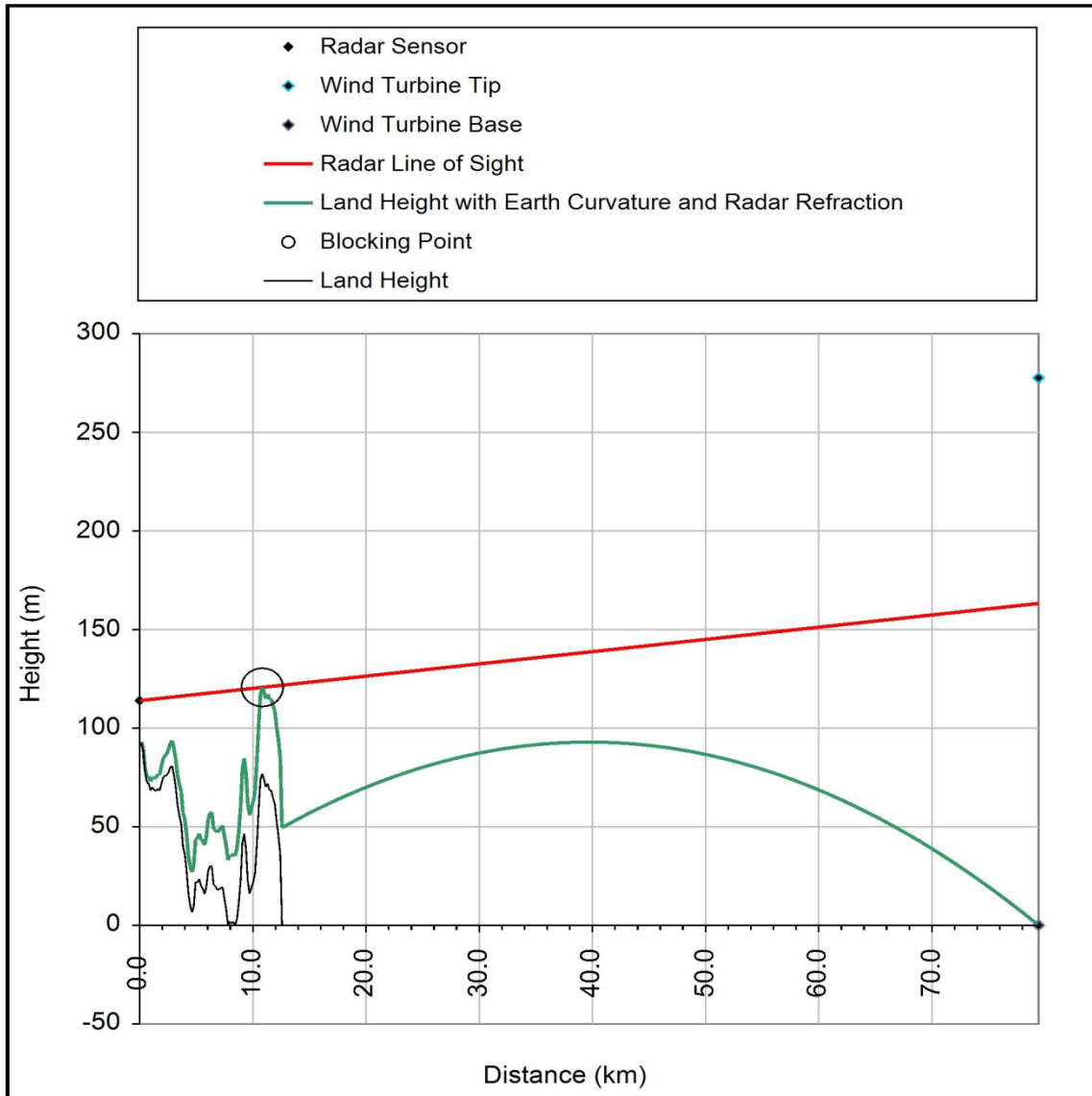
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	B2
Result	VISIBLE
Certainty	114.4 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E415351 N737561
Distance to radar (km)	79.4
Blocking Point Location	E395348 N803151
Distance to BP (km)	68.6

Additional Analysis

Angle (Radar to Tip)	0.150 degrees down
Maximum Tip Height	163.28 metres

See Appendix for further information

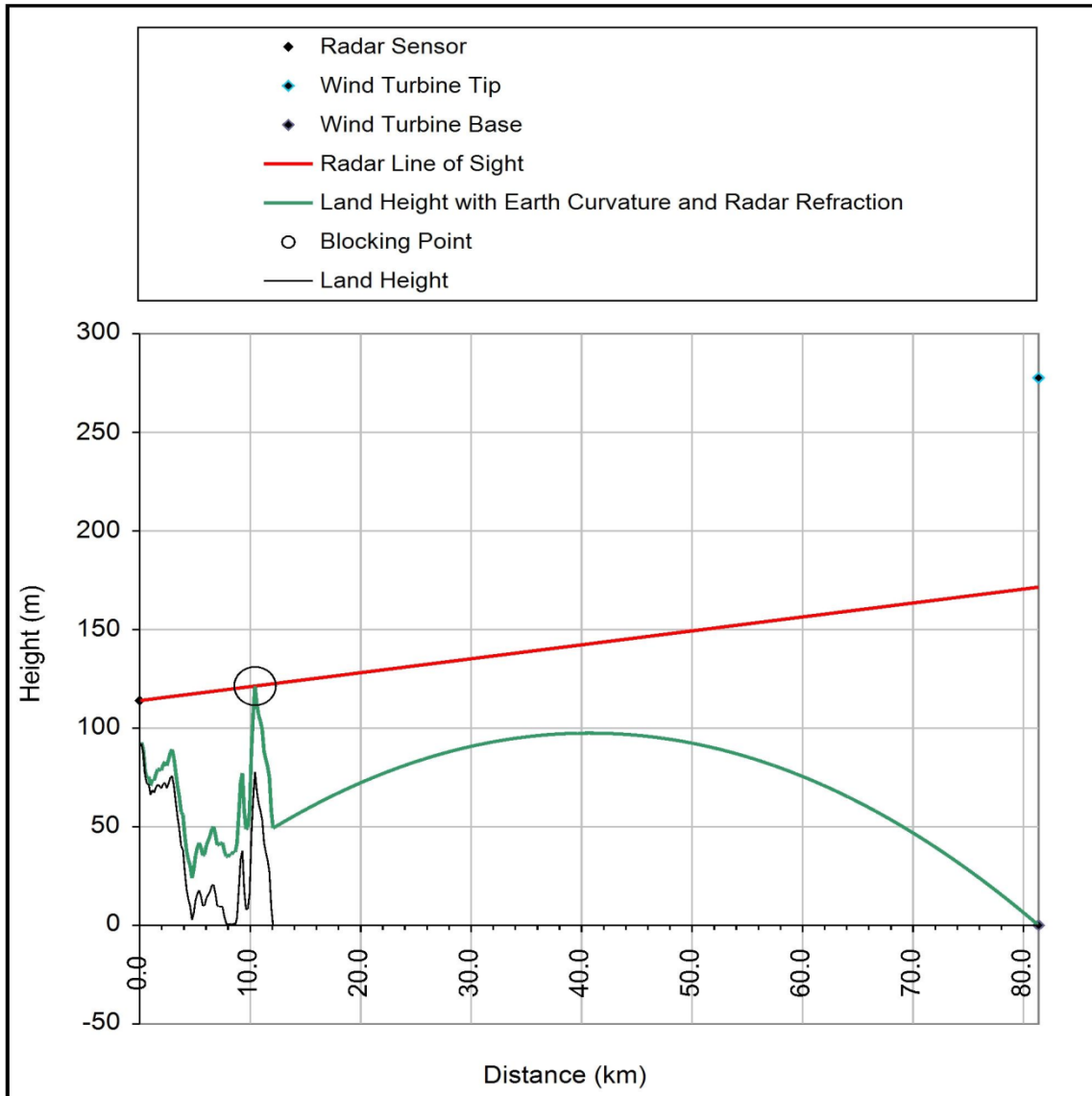
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	B3
Result	VISIBLE
Certainty	106.2 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E420374 N737211
Distance to radar (km)	81.4
Blocking Point Location	E395807 N803715
Distance to BP (km)	70.9

Additional Analysis

Angle (Radar to Tip)	0.159 degrees down
Maximum Tip Height	171.53 metres

See Appendix for further information

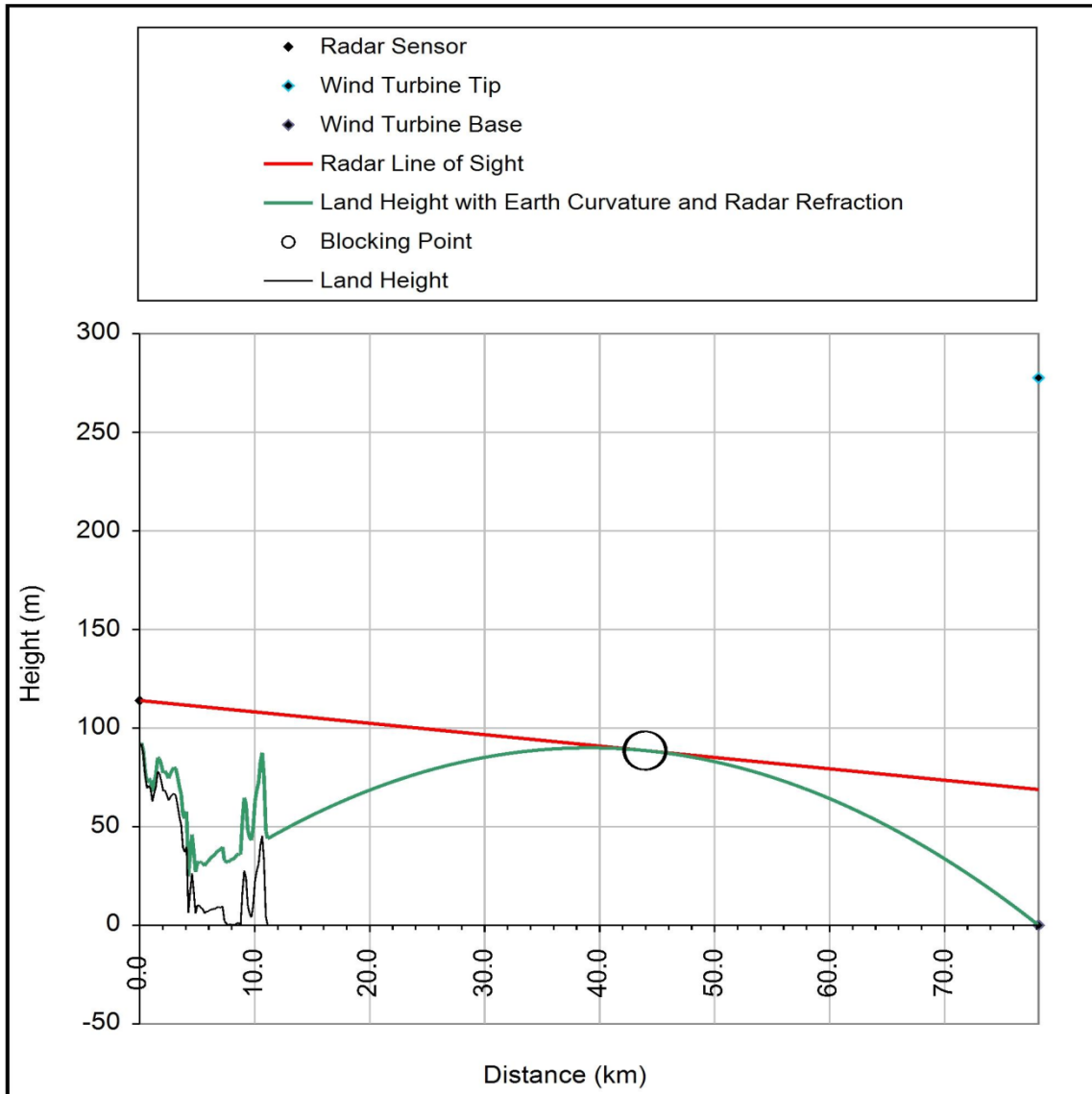
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	B4
Result	VISIBLE
Certainty	208.9 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E425345 N742741
Distance to radar (km)	78.2
Blocking Point Location	E410861 N773654
Distance to BP (km)	34.1

Additional Analysis

Angle (Radar to Tip)	0.144 degrees down
Maximum Tip Height	68.85 metres

See Appendix for further information

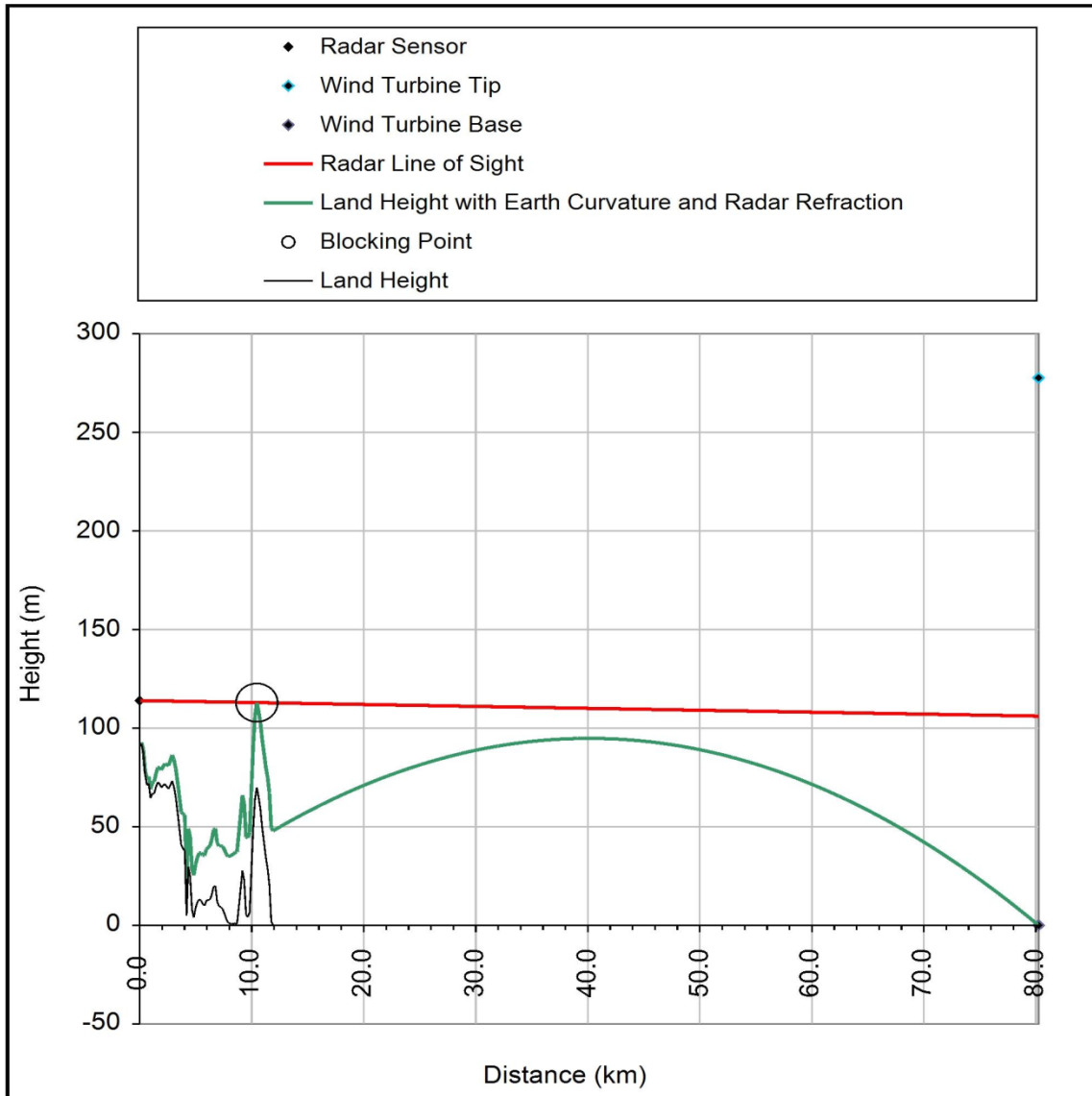
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	B5
Result	VISIBLE
Certainty	171.6 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E421435 N738816
Distance to radar (km)	80.2
Blocking Point Location	E396001 N803771
Distance to BP (km)	69.8

Additional Analysis

Angle (Radar to Tip)	0.154 degrees down
Maximum Tip Height	106.12 metres

See Appendix for further information

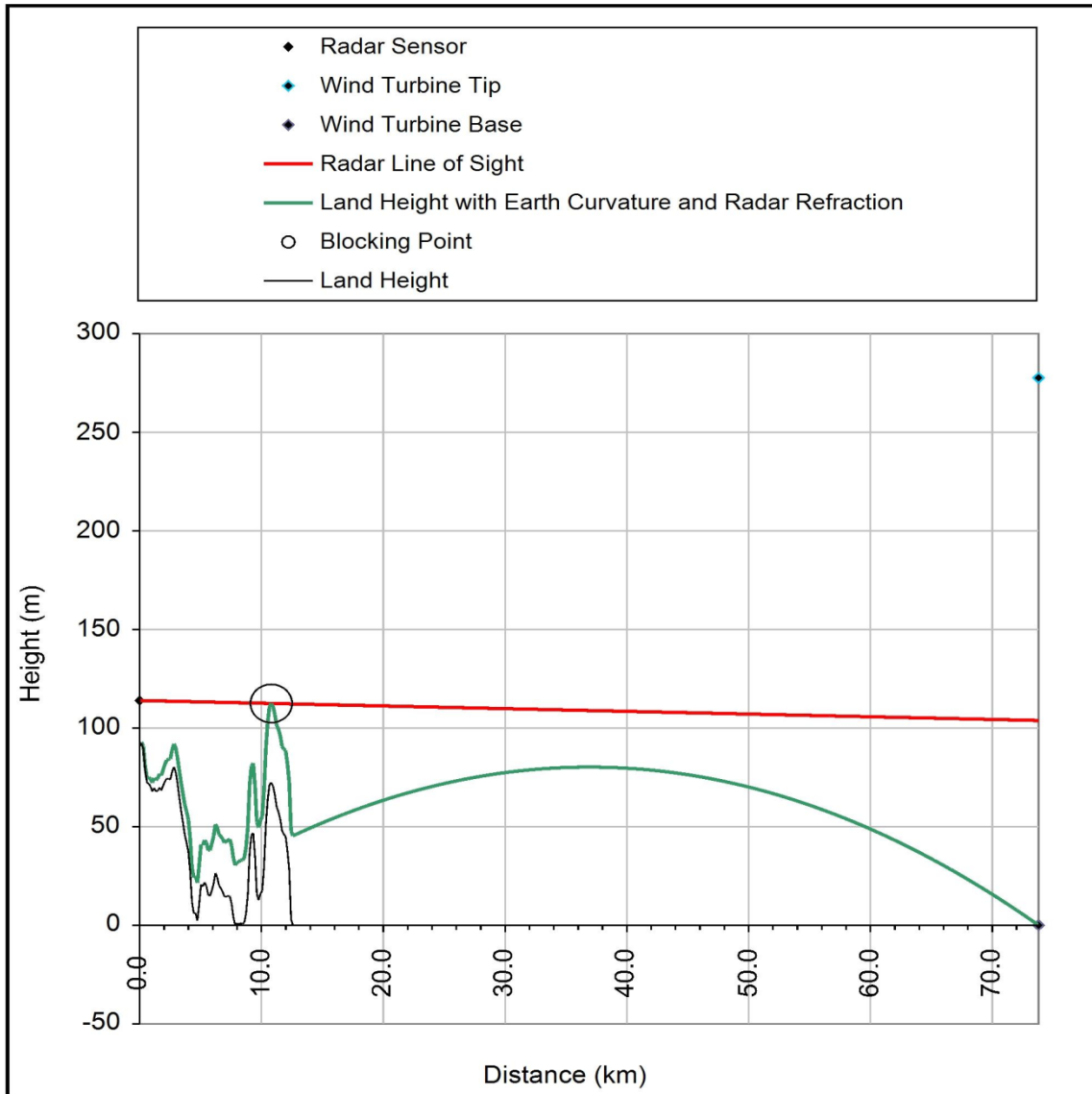
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Radar Line of Sight Calculation

Prepared for Pager Power
Perwinnes PSR (NATS)

Seagreen (Perwinnes)

Turbine	B6
Result	VISIBLE
Certainty	173.8 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E415299 N743441
Distance to radar (km)	73.8
Blocking Point Location	E395572 N803251
Distance to BP (km)	63.0

Additional Analysis

Angle (Radar to Tip)	0.122 degrees down
Maximum Tip Height	103.88 metres

See Appendix for further information

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2 RESULTS SUMMARY

Wind Turbine	Result	Certainty	Angle (Radar to Tip)	Maximum Height
A1	VISIBLE	104.3 metres	0.060 degrees down	173.38 metres
A2	VISIBLE	230.5 metres	0.074 degrees down	47.20 metres
A3	VISIBLE	243.2 metres	0.092 degrees down	34.52 metres
A4	VISIBLE	169.3 metres	0.116 degrees down	108.41 metres
A5	VISIBLE	87.9 metres	0.130 degrees down	189.83 metres
A6	VISIBLE	31.3 metres	0.138 degrees down	246.38 metres
A7	HIDDEN	26.7 metres	0.125 degrees down	304.39 metres
A8	VISIBLE	96.0 metres	0.087 degrees down	181.70 metres
B1	VISIBLE	42.1 metres	0.142 degrees down	235.55 metres
B2	VISIBLE	114.4 metres	0.150 degrees down	163.28 metres
B3	VISIBLE	106.2 metres	0.159 degrees down	171.53 metres
B4	VISIBLE	208.9 metres	0.144 degrees down	68.85 metres
B5	VISIBLE	171.6 metres	0.154 degrees down	106.12 metres
B6	VISIBLE	173.8 metres	0.122 degrees down	103.88 metres

Column Descriptions	
Wind Turbine	Turbine Number as entered or uploaded
Result	VISIBLE turbines are likely to affect the radar whereas HIDDEN turbines are unlikely to affect the radar.

Certainty	This is a vertical distance in metres and is the distance from the turbine tip to the line of sight. The higher the number the greater the certainty.
Angle (Radar to Tip)	This is the vertical angle from the radar to the wind turbine tip. Some radar are less likely to be affected by a wind turbine if this angle is down and more likely to be affected if this angle is up.
Maximum Height	A turbine having this tip height would be HIDDEN . A turbine that was any higher would be VISIBLE .

3 REQUESTED ASSESSMENT

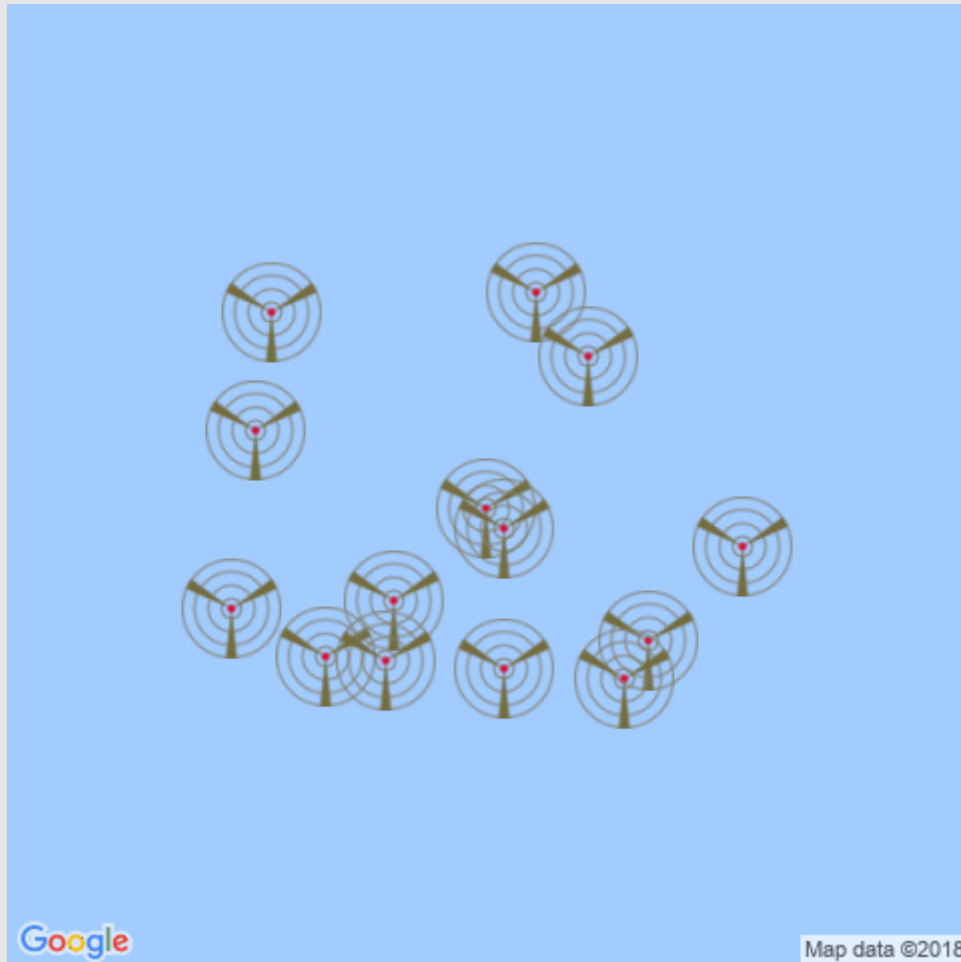
Key Parameters
• This Radar Line of Sight Assessment for Seagreen (Perwinnes) was requested by Mike Watson of Pager Power on 7th February 2018. • Assessment Methodology = Radar Line of Sight Calculation using advanced terrain data processing algorithm. • Coordinate System = Local Grid • Vertical Units = Metres

Radar
• The assessed radar was Perwinnes PSR (NATS) • Location and height information for preselected radar are sourced from a managed database

Development Location Data (as entered in online system)				
Coordinate (E)	Coordinate (N)	Hub Height (Metres AGL)	Tip Height (Metres AGL)	Wind Turbine Reference
405537.29	752516.24	220	277.7	A1
416644.98	753420.86	220	277.7	A2
418819.9	750750.77	220	277.7	A3
414573.7	744330.85	220	277.7	A4
410664.08	740405.88	220	277.7	A5
407815	738085.89	220	277.7	A6
403854.44	740040.99	220	277.7	A7
404864.12	747526.15	220	277.7	A8
410327.54	737910.85	220	277.7	B1
415350.59	737560.78	220	277.7	B2

420373.6	737210.72	220	277.7	B3
425344.67	742740.62	220	277.7	B4
421435.12	738815.7	220	277.7	B5
415298.69	743440.83	220	277.7	B6

Map Showing Assessed Turbine Locations



Seagreen (Perwinnes)

Aerial Photograph Showing Assessed Turbine Locations



Seagreen (Perwinnes)

4 METHODOLOGY AND BACKGROUND

Introduction

This report indicates whether wind turbines at the Seagreen (Perwinnes) will be detected by the Perwinnes PSR (NATS). This assessment shows:

- Whether wind turbines are **VISIBLE** or **HIDDEN**
- A level of certainty as to whether each wind turbine is likely to affect the radar or not
- A profile chart showing the radar, each wind turbine and intervening terrain

Scope

This assessment:

- Is new and takes no previous assessment into account
- Determines whether each assessed wind turbine at Seagreen (Perwinnes) will be within Radar Line of Sight of the Perwinnes PSR (NATS)
- Does not account for diffraction effects or any other radar
- Does account for terrain, earth curvature and refraction effects
- Uses an advanced terrain data processing algorithm optimized for accurate and reliable wind farm radar calculations

Official Guidance Details

The following organisations have published documents that refer to the use of Radar Line of Sight Calculations for determining whether a wind turbine will affect a radar.

1. European Organisation for the Safety of Air Navigation (EUROCONTROL)
2. UK Civil Aviation Authority (CAA)
3. UK Royal Air Force (RAF)
4. UK Wind Energy, Defence and Civil Aviation Interests Working Group
5. UK National Air Traffic Services (NATS)
6. US Department of Defense (DoD)
7. US Department of Commerce
8. US Federal Aviation Authority (FAA)
9. South African Weather Service (SAWS)
10. Radio Advisory Board of Canada (RABC)
11. Canadian Wind Energy Association (CanWEA)

Report Preparation

This report has been created by a custom-built advanced online service which has the following features:

- Fast report delivery by email
- Responsive and knowledgeable technical support team
- Advanced terrain data processing algorithms

Radar Line of Sight Calculation – Accuracy Details

- Terrain data used normally has a vertical accuracy of better than 3 metres.
- Comparisons and site measurements suggest the terrain data used has a vertical accuracy of around 2 metres.
- This gives a typical accuracy of 4 metres for Radar Line of Sight Calculation results.
- Process accuracy is enhanced and designed to give cautious results by:
 - A. Using software developed specifically for wind turbine radar calculations
 - B. Using a weighted average algorithm to determine terrain elevation from terrain data
 - C. Using an algorithm that underestimates, rather than overestimates, terrain peaks
 - D. Using terrain rather than surface data (Great Britain only)
 - E. Using terrain data that sometimes under-represents peaks (Great Britain only)
 - F. Continuous software development and improvement specifically for Radar Line of Sight Calculations
 - G. Continuous process for managing radar position and height data

5 APPENDIX - CALCULATION NOTES

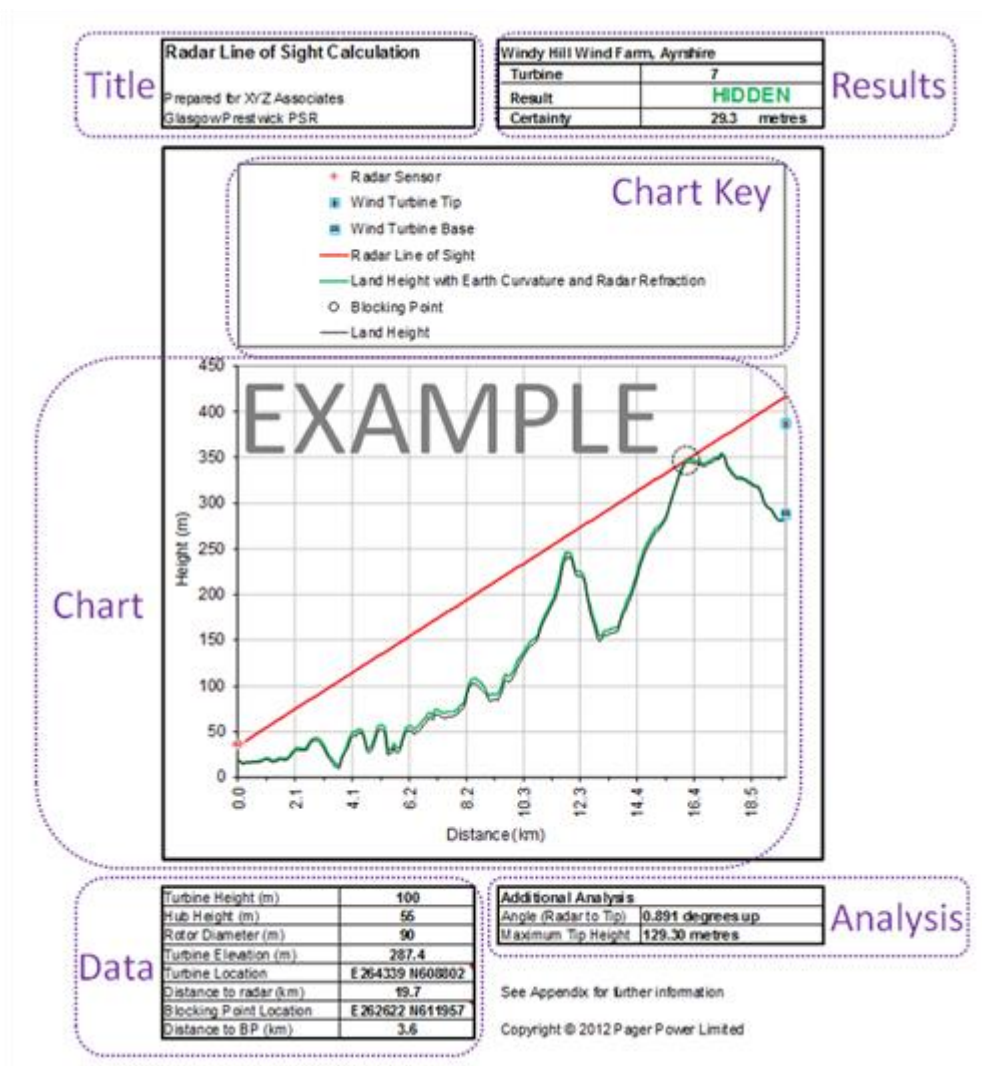


Diagram showing areas of a Radar Line of Sight Calculation

The information in the various areas of the calculation sheet is described below:

Title Details
Name of organisation that has requested the calculation (As given when setting up Pager Power Online user account)
Name of the radar (As selected or entered)

Results	
Name of the development (As entered)	
Turbine	Turbine Number as entered or uploaded
Result	VISIBLE turbines are likely to affect the radar whereas HIDDEN turbines are unlikely to affect the radar.
Certainty	This is a vertical distance in metres and is the distance from the turbine tip to the line of sight. The higher the number the greater the certainty.

Chart Key	
Radar Sensor	This is the radar antenna. It is a single point at the left of the chart.
Wind Turbine Tip	This is the highest point of the wind turbine. It is a single point at the right of the chart.
Wind Turbine Base	This is the bottom of the turbine. It is a single point at the right of the chart.
Radar Line of Sight	This is a straight line from the Radar Sensor towards the turbine which coincides with the terrain between the radar and the wind turbine.
Land Height with Earth Curvature and Radar Refraction	This is the terrain profile between the radar and the turbine. Calculation accuracy is increased by including both Earth curvature and standard radar refraction. Refraction means that the radar signal bends slightly as it passes through the atmosphere.
Blocking Point	This is a single point where the Radar Line of Sight is the same as Land Height with Earth Curvature and Refraction.
Land Height	This is calculated accurately using an advanced weighted average algorithm and height data from a terrain database.

Chart	
Vertical Axis	Height above sea level in metres
Horizontal Axis	Distance from the radar in kilometres

Data	
Turbine Height (m)	The maximum turbine tip height above ground level in metres.
Hub Height (m)	The turbine hub height above ground level in metres.
Rotor Diameter (m)	The diameter of the area swept by the turbine blades in metres. The Rotor Radius is half of the Rotor Diameter.
Turbine Elevation (m)	The height of the ground on which the turbine stands relative to sea level.
Turbine Location	The coordinates of the turbine location.
Distance to radar (km)	The horizontal distance from the radar to the turbine in kilometres.
Blocking Point Location	The coordinates of the Blocking Point. Buildings and trees at this location might mean the radar is less likely to be affected by the wind turbine.
Distance to BP (km)	The horizontal distance from the turbine to the Blocking Point in kilometres.

Analysis	
Angle (Radar to Tip)	This is the vertical angle from the radar to the wind turbine tip. Some radar are less likely to be affected by a wind turbine if this angle is down.
Maximum Height	A turbine having this tip height would be HIDDEN . A turbine that was any higher would be VISIBLE .