



PAGERPOWER

Seagreen (Leuchars)

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

Pager Power

Seagreen (Leuchars)

7th February 2018

Without Expert Commentary

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Report Issue	Date and Time of Request
1	07 Feb 2018 at 09:21 BST

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

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1 SUMMARY (EXECUTIVE)

Pager Power
<p>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.</p> <p>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.</p>

Purpose
<p>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.</p> <p>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.</p>

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

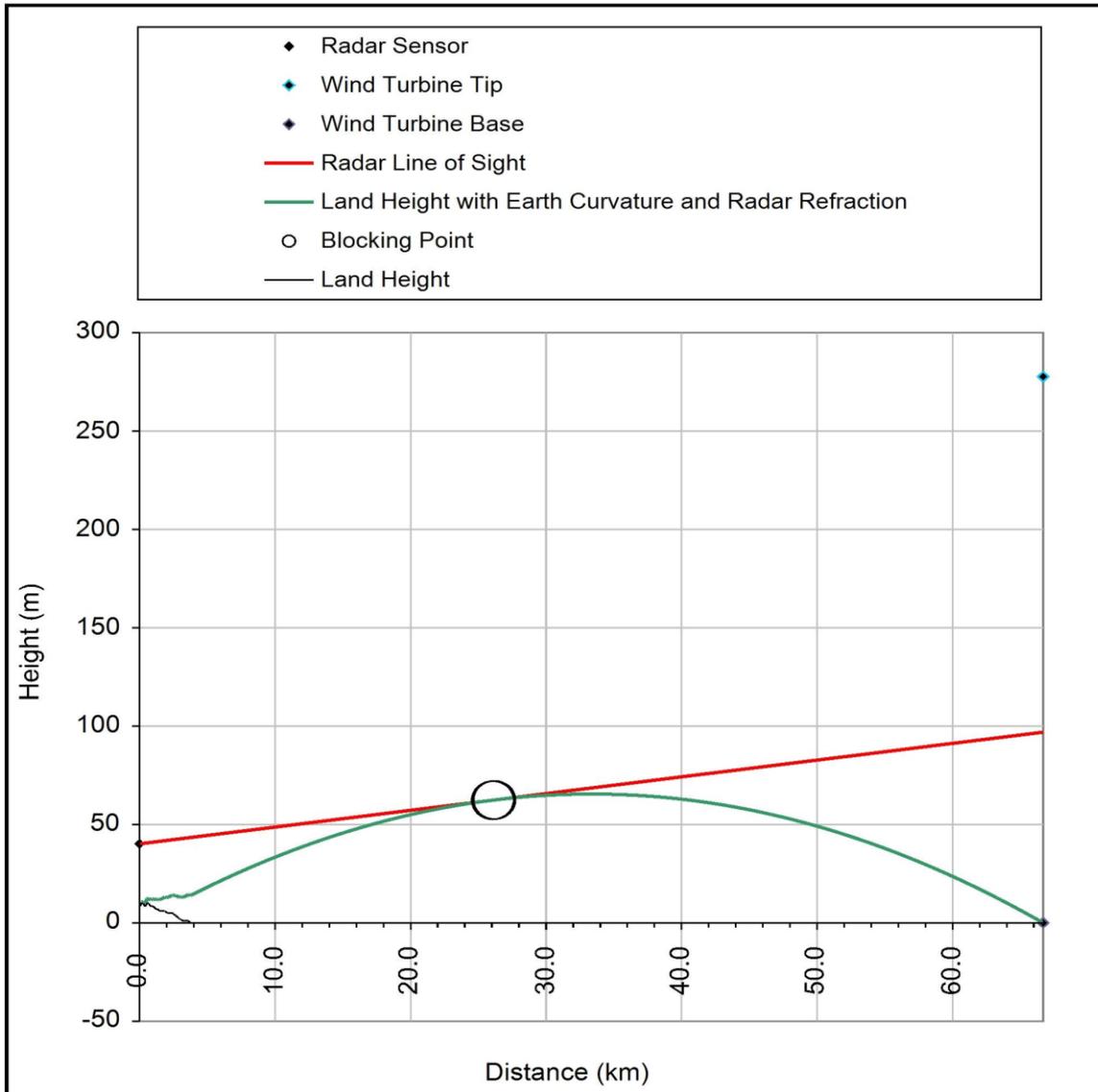
B1	VISIBLE
B2	VISIBLE
B3	VISIBLE
B4	VISIBLE
B5	VISIBLE
B6	VISIBLE
<p>Explanation: There is one Radar Line of Sight Calculation page for each turbine assessed. Each calculation shows whether the turbine is VISIBLE or HIDDEN. Visible turbines are likely to affect the radar whereas hidden turbines are unlikely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

Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	A1
Result	VISIBLE
Certainty	180.7 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)	66.7
Blocking Point Location	E369693 N733427
Distance to BP (km)	40.6

Additional Analysis	
Angle (Radar to Tip)	0.021 degrees down
Maximum Tip Height	96.95 metres

See Appendix for further information

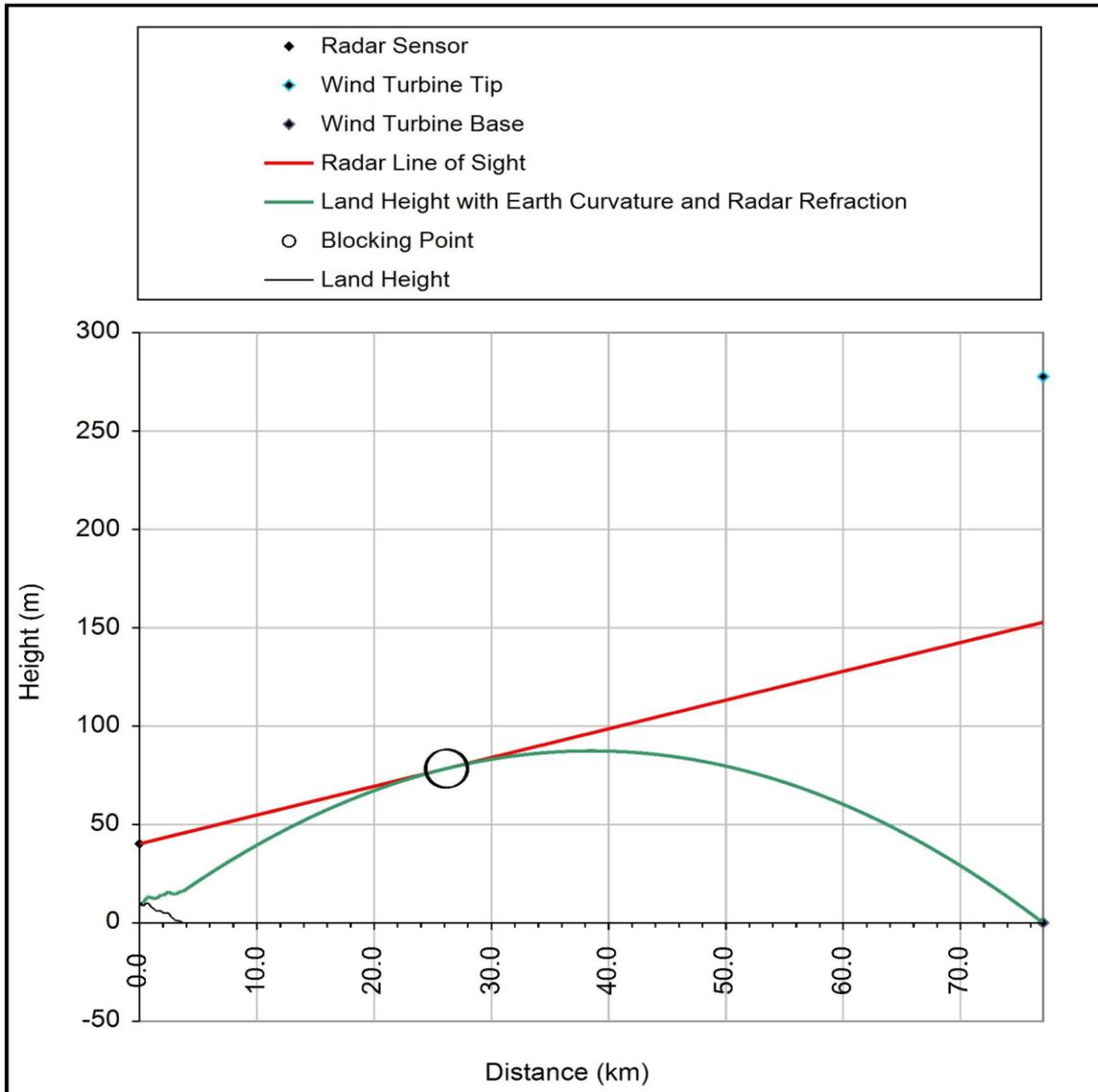
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	A2
Result	VISIBLE
Certainty	124.9 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)	77.0
Blocking Point Location	E370389 N732100
Distance to BP (km)	50.9

Additional Analysis	
Angle (Radar to Tip)	0.083 degrees down
Maximum Tip Height	152.80 metres

See Appendix for further information

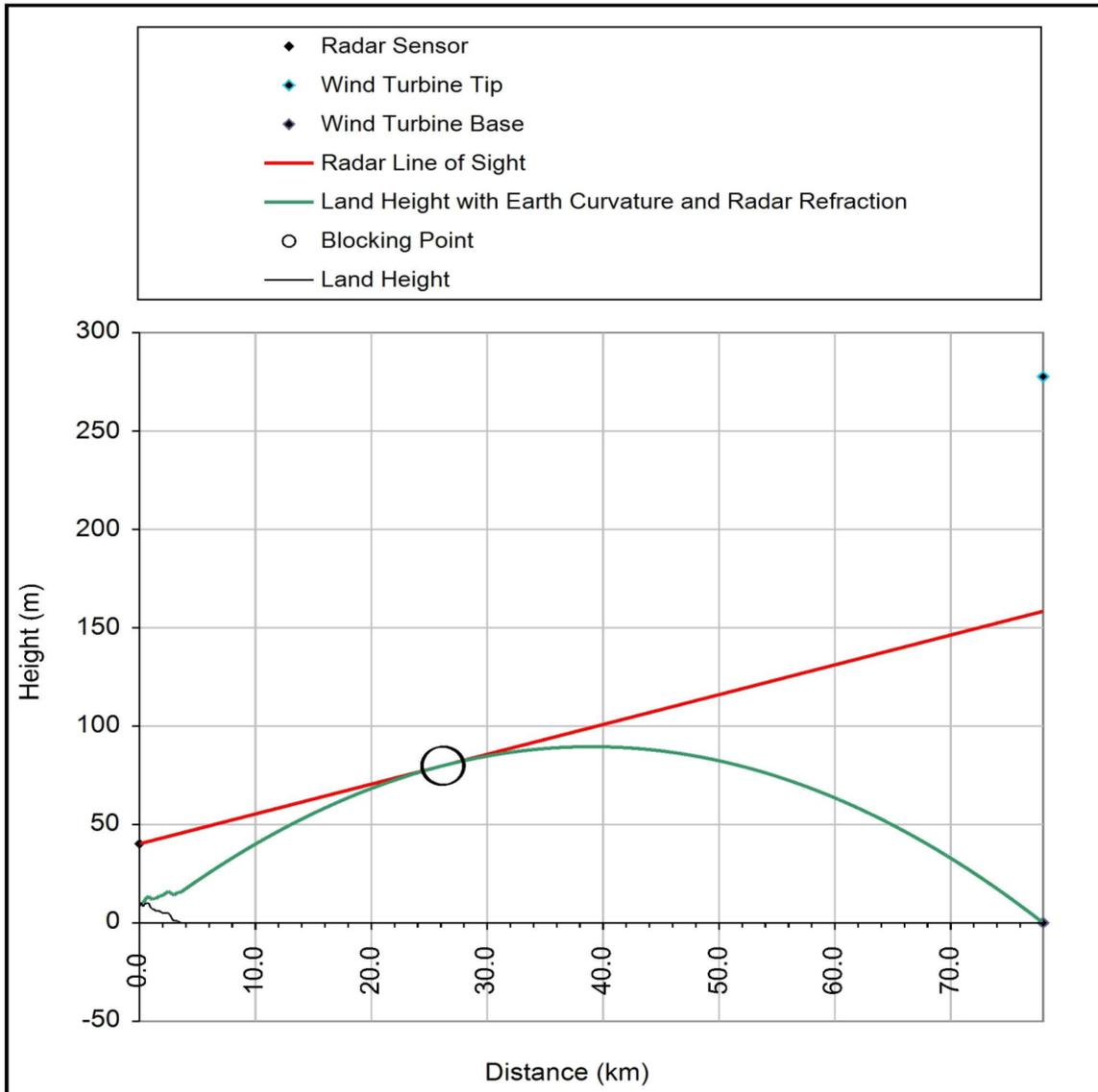
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	A3
Result	VISIBLE
Certainty	119.3 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)	78.0
Blocking Point Location	E370837 N731077
Distance to BP (km)	51.9

Additional Analysis	
Angle (Radar to Tip)	0.088 degrees down
Maximum Tip Height	158.43 metres

See Appendix for further information

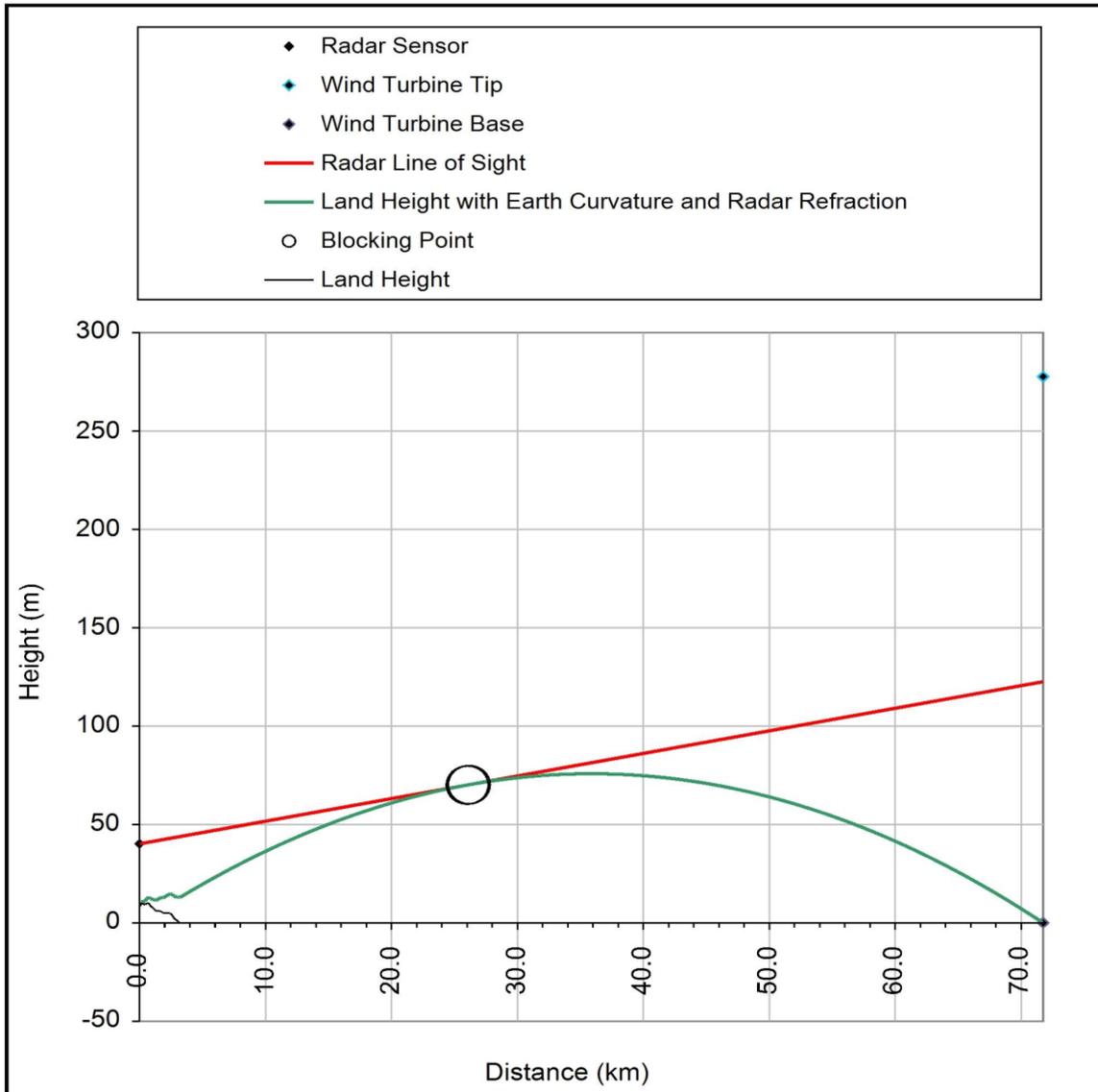
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	A4
Result	VISIBLE
Certainty	155.1 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)	71.7
Blocking Point Location	E371456 N729625
Distance to BP (km)	45.6

Additional Analysis	
Angle (Radar to Tip)	0.052 degrees down
Maximum Tip Height	122.62 metres

See Appendix for further information

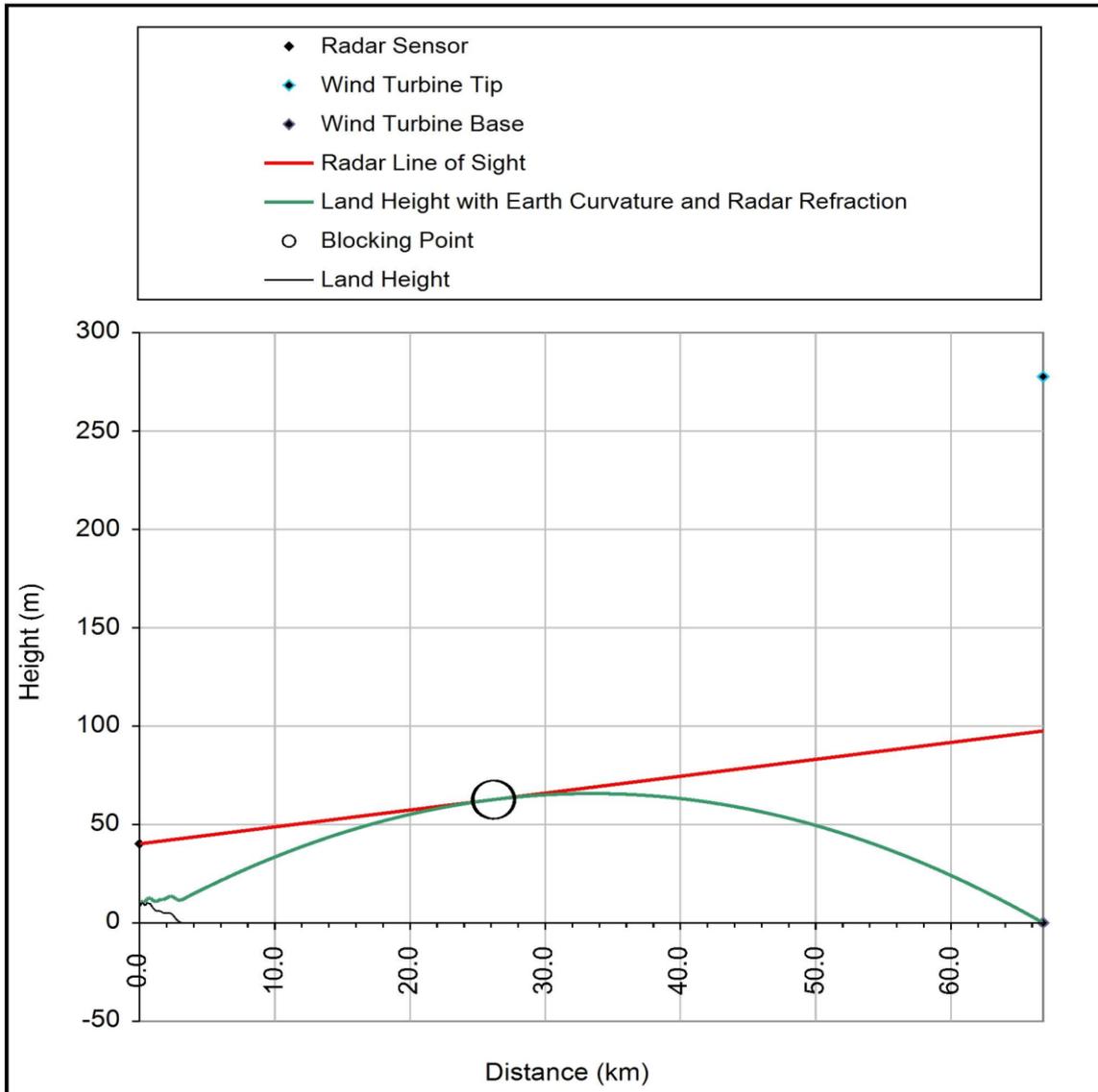
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	A5
Result	VISIBLE
Certainty	180.1 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)	66.8
Blocking Point Location	E371697 N728694
Distance to BP (km)	40.7

Additional Analysis	
Angle (Radar to Tip)	0.022 degrees down
Maximum Tip Height	97.57 metres

See Appendix for further information

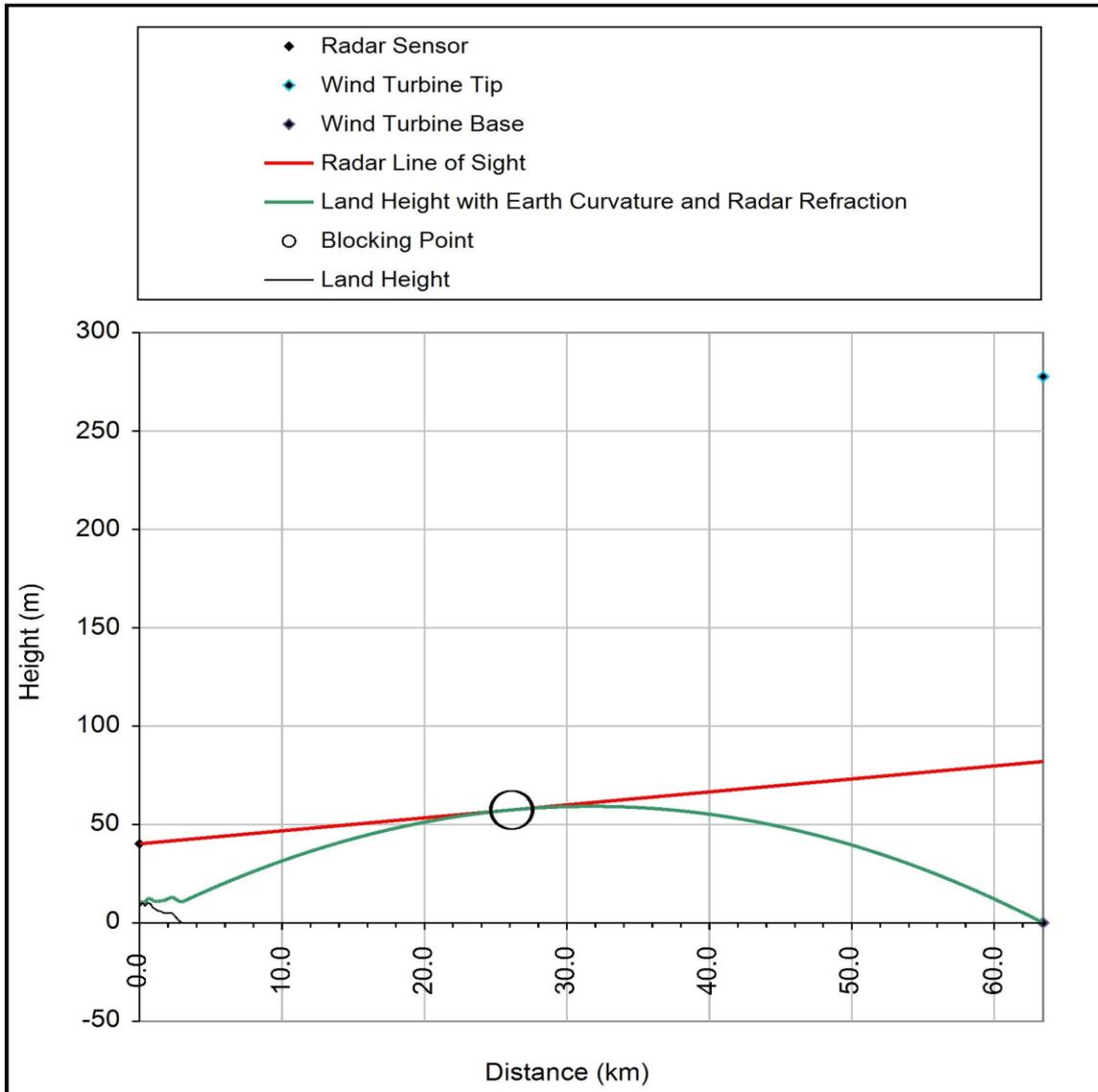
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	A6
Result	VISIBLE
Certainty	195.7 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)	63.4
Blocking Point Location	E371808 N728126
Distance to BP (km)	37.4

Additional Analysis	
Angle (Radar to Tip)	0.001 degrees up
Maximum Tip Height	82.03 metres

See Appendix for further information

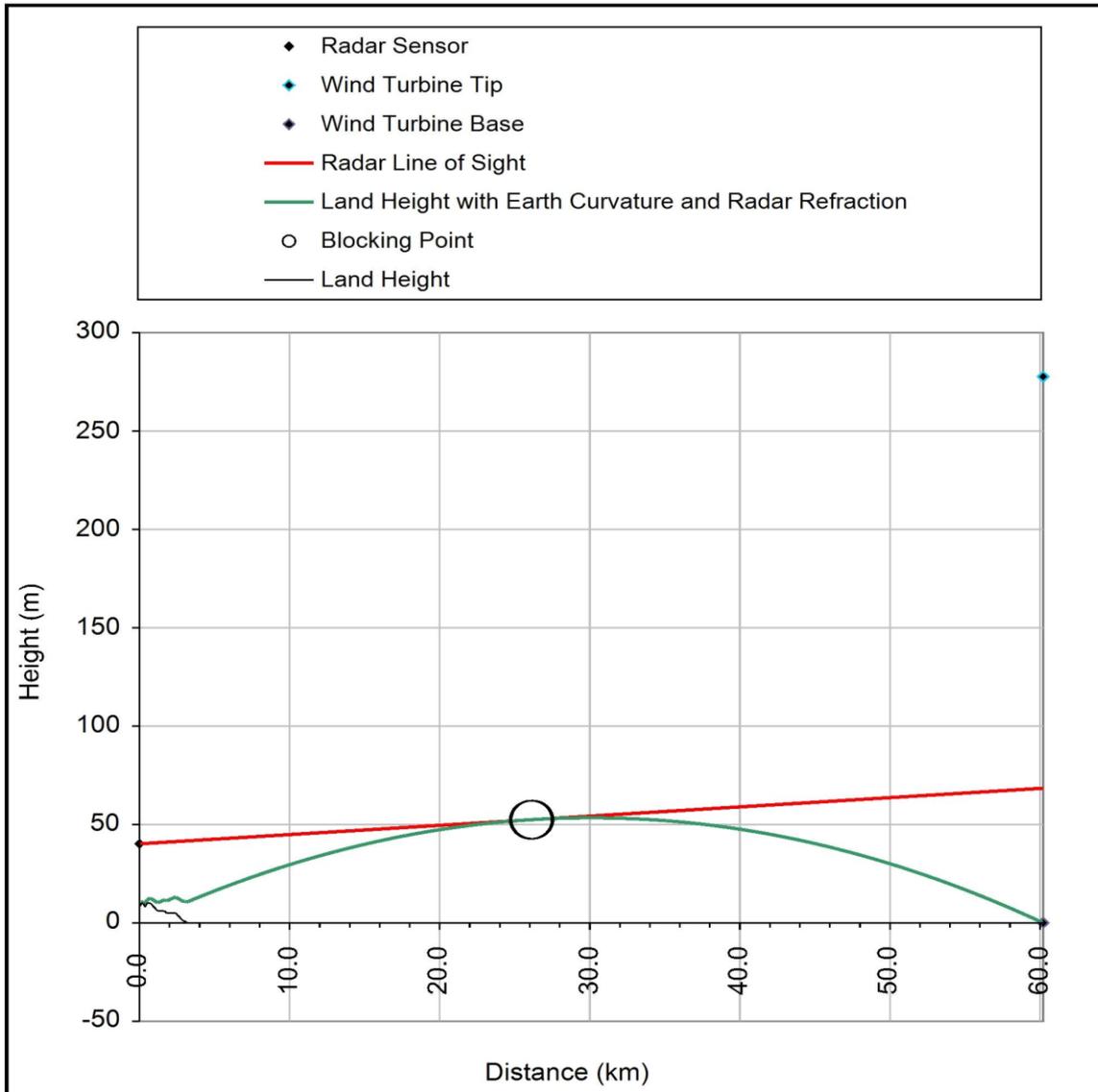
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	A7
Result	VISIBLE
Certainty	209.2 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)	60.2
Blocking Point Location	E371441 N729345
Distance to BP (km)	34.1

Additional Analysis	
Angle (Radar to Tip)	0.023 degrees up
Maximum Tip Height	68.46 metres

See Appendix for further information

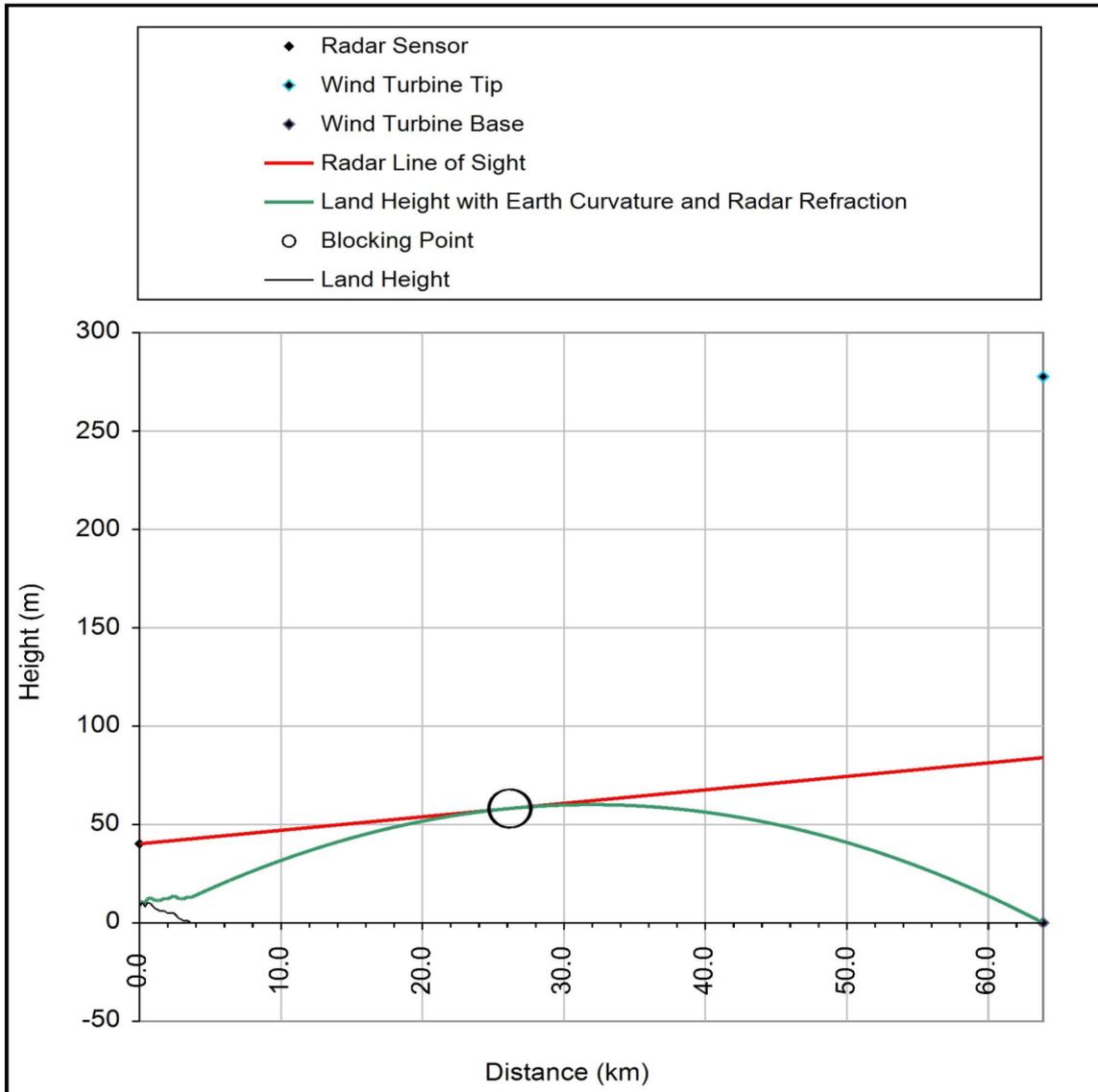
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	A8
Result	VISIBLE
Certainty	193.7 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)	63.9
Blocking Point Location	E370479 N731952
Distance to BP (km)	37.7

Additional Analysis	
Angle (Radar to Tip)	0.002 degrees down
Maximum Tip Height	83.99 metres

See Appendix for further information

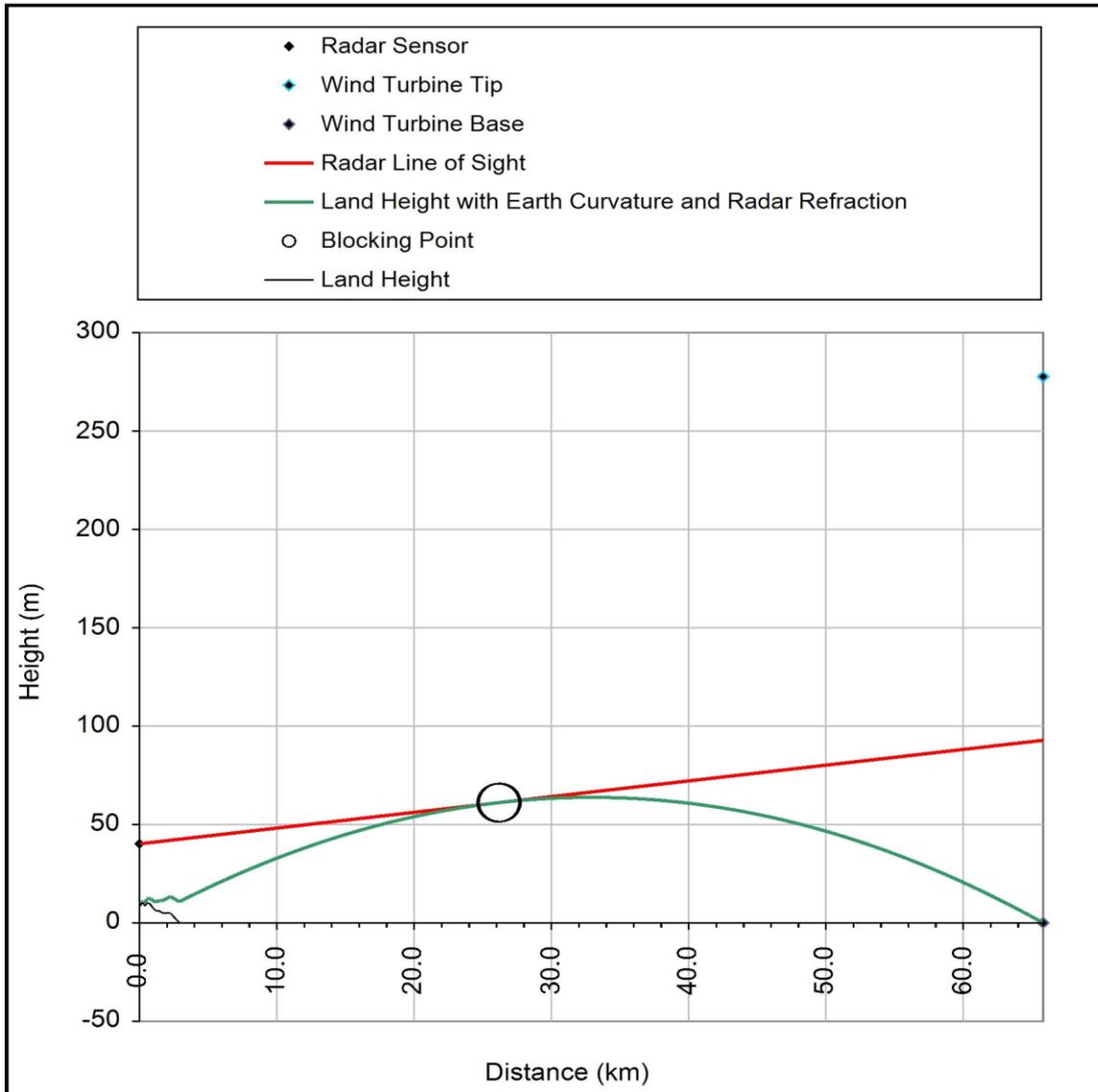
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	B1
Result	VISIBLE
Certainty	184.9 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)	65.8
Blocking Point Location	E371948 N727819
Distance to BP (km)	39.7

Additional Analysis	
Angle (Radar to Tip)	0.015 degrees down
Maximum Tip Height	92.83 metres

See Appendix for further information

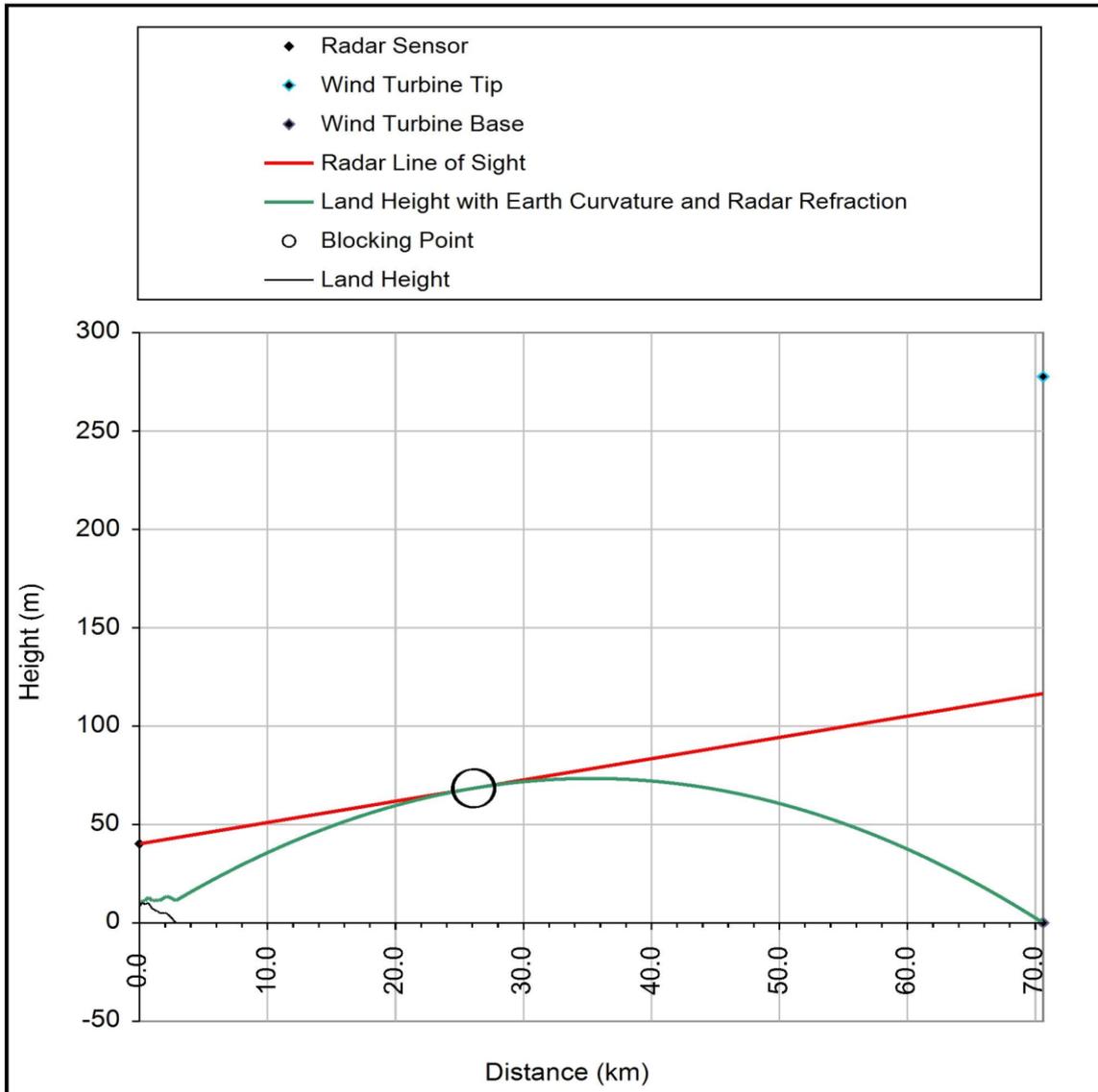
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	B2
Result	VISIBLE
Certainty	161.1 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)	70.6
Blocking Point Location	E372152 N727254
Distance to BP (km)	44.4

Additional Analysis	
Angle (Radar to Tip)	0.045 degrees down
Maximum Tip Height	116.59 metres

See Appendix for further information

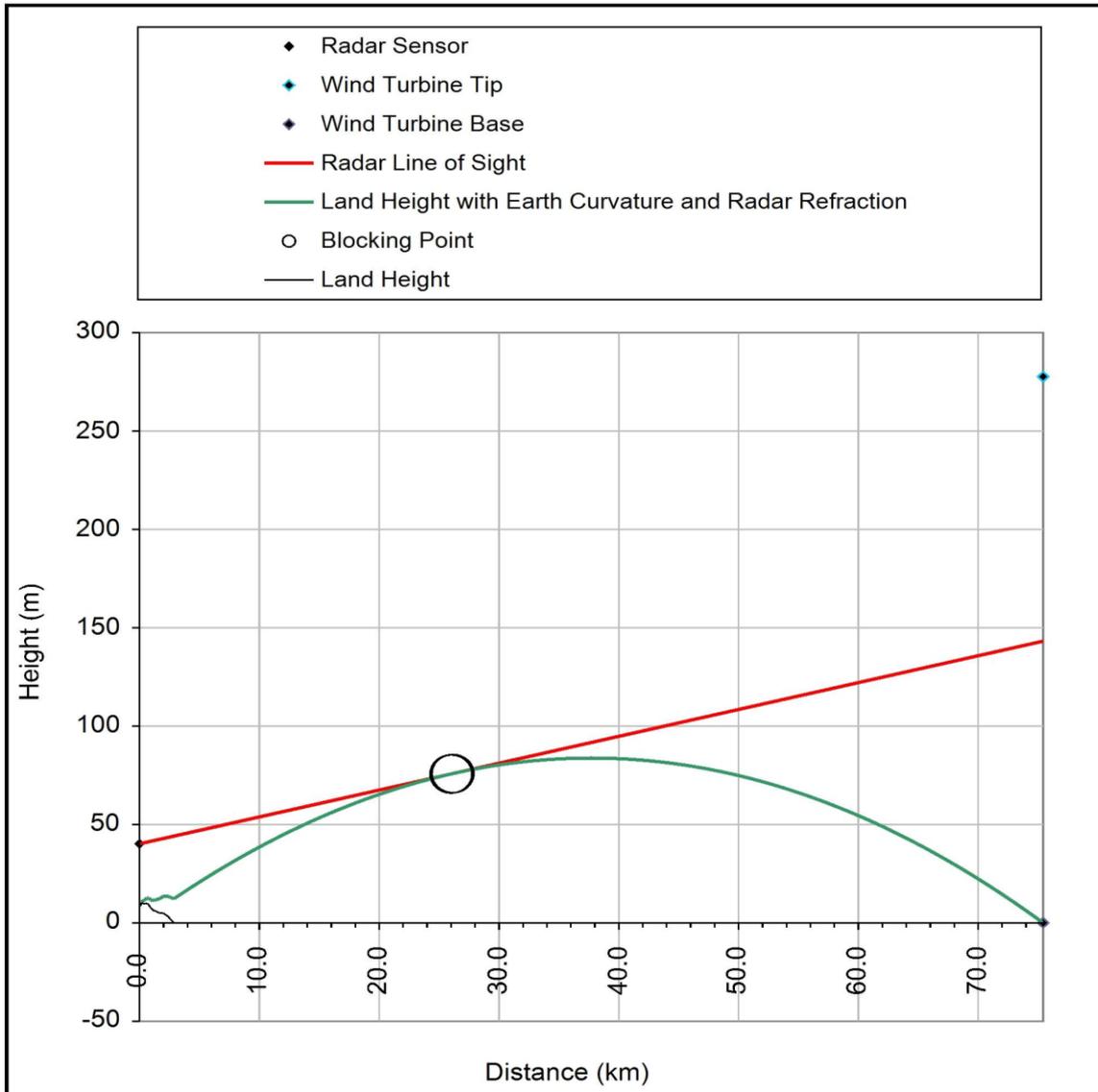
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	B3
Result	VISIBLE
Certainty	134.5 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)	75.4
Blocking Point Location	E372243 N726739
Distance to BP (km)	49.3

Additional Analysis

Angle (Radar to Tip)	0.074 degrees down
Maximum Tip Height	143.23 metres

See Appendix for further information

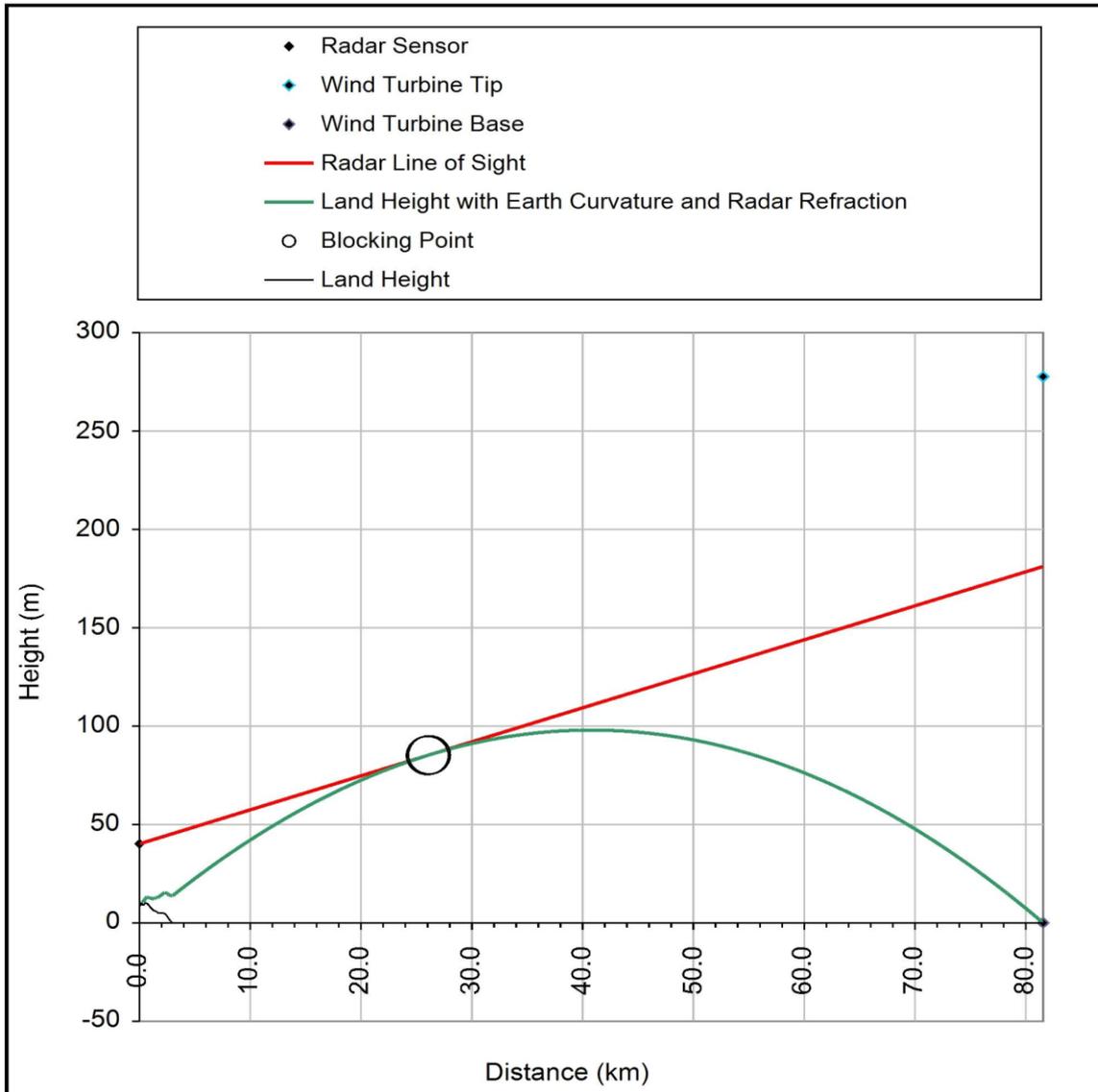
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	B4
Result	VISIBLE
Certainty	96.5 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)	81.6
Blocking Point Location	E371917 N728094
Distance to BP (km)	55.4

Additional Analysis	
Angle (Radar to Tip)	0.108 degrees down
Maximum Tip Height	181.20 metres

See Appendix for further information

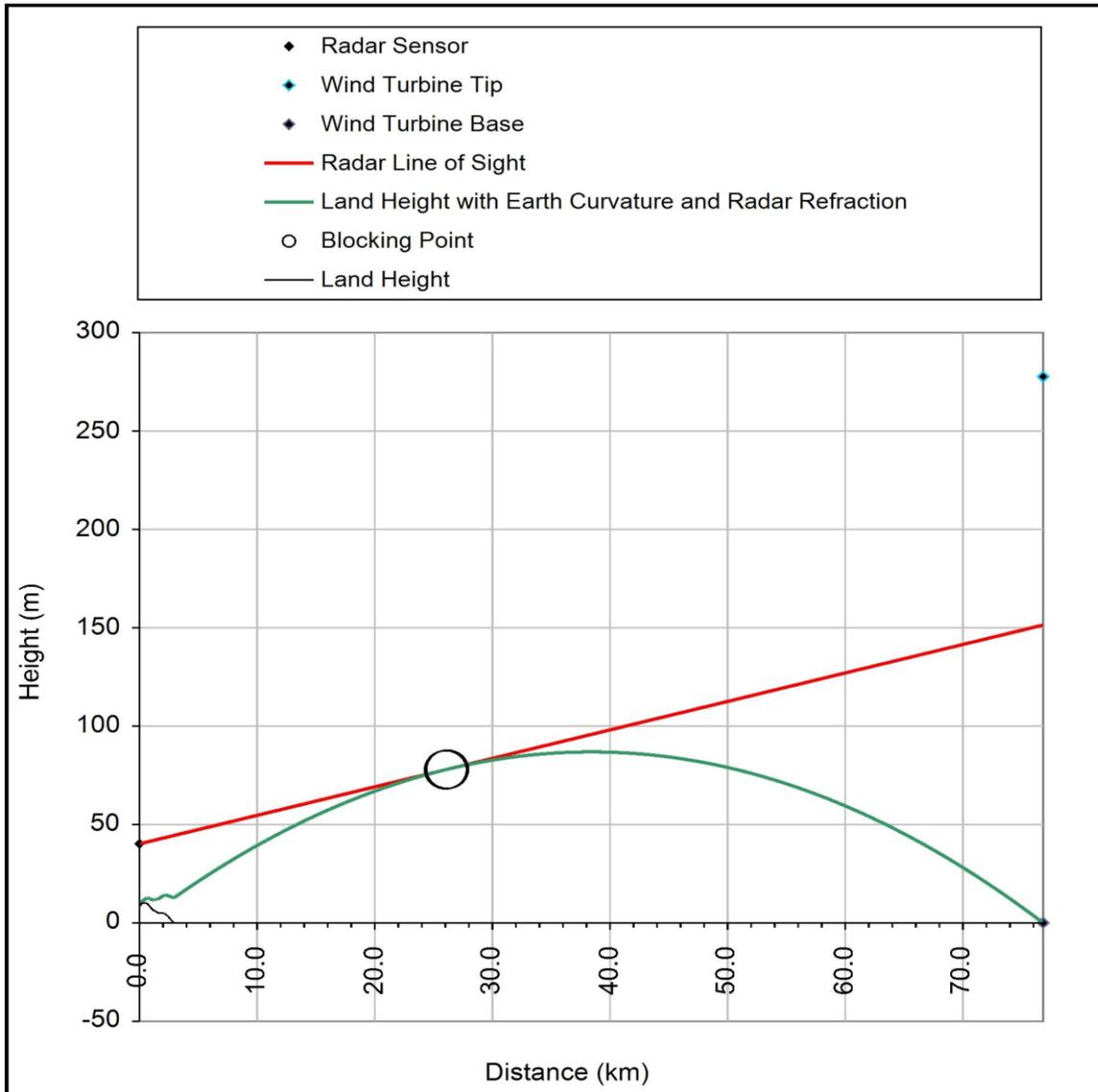
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	B5
Result	VISIBLE
Certainty	126.3 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)	76.8
Blocking Point Location	E372161 N727189
Distance to BP (km)	50.6

Additional Analysis	
Angle (Radar to Tip)	0.082 degrees down
Maximum Tip Height	151.42 metres

See Appendix for further information

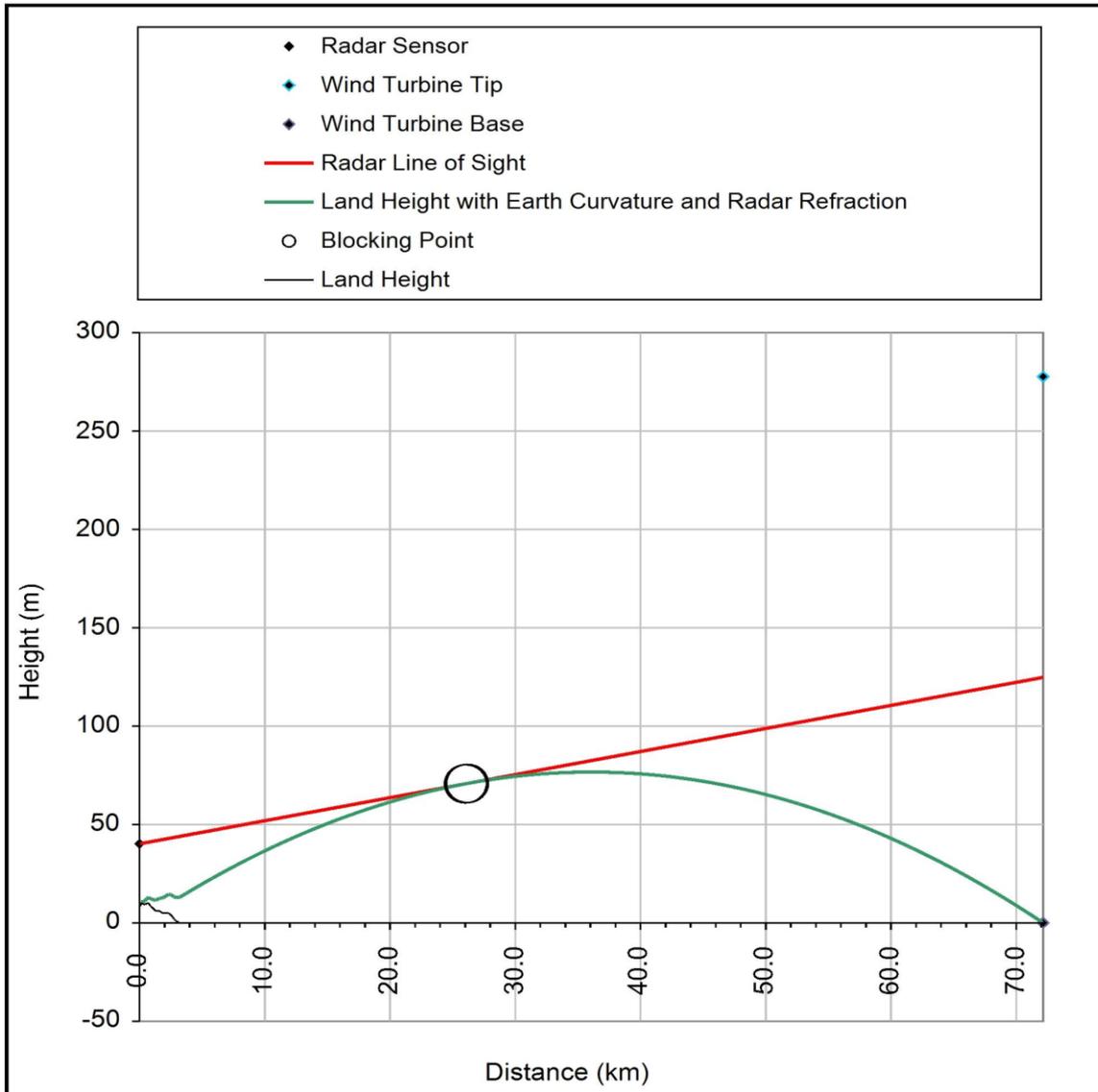
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Radar Line of Sight Calculation

Prepared for Pager Power
Leuchars PSR (Closing)

Seagreen (Leuchars)

Turbine	B6
Result	VISIBLE
Certainty	152.9 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)	72.1
Blocking Point Location	E371583 N729255
Distance to BP (km)	46.0

Additional Analysis	
Angle (Radar to Tip)	0.055 degrees down
Maximum Tip Height	124.81 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	180.7 metres	0.021 degrees down	96.95 metres
A2	VISIBLE	124.9 metres	0.083 degrees down	152.80 metres
A3	VISIBLE	119.3 metres	0.088 degrees down	158.43 metres
A4	VISIBLE	155.1 metres	0.052 degrees down	122.62 metres
A5	VISIBLE	180.1 metres	0.022 degrees down	97.57 metres
A6	VISIBLE	195.7 metres	0.001 degrees up	82.03 metres
A7	VISIBLE	209.2 metres	0.023 degrees up	68.46 metres
A8	VISIBLE	193.7 metres	0.002 degrees down	83.99 metres
B1	VISIBLE	184.9 metres	0.015 degrees down	92.83 metres
B2	VISIBLE	161.1 metres	0.045 degrees down	116.59 metres
B3	VISIBLE	134.5 metres	0.074 degrees down	143.23 metres
B4	VISIBLE	96.5 metres	0.108 degrees down	181.20 metres
B5	VISIBLE	126.3 metres	0.082 degrees down	151.42 metres
B6	VISIBLE	152.9 metres	0.055 degrees down	124.81 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
<ul style="list-style-type: none"> • This Radar Line of Sight Assessment for Seagreen (Leuchars) 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
<ul style="list-style-type: none"> • The assessed radar was Leuchars PSR (Closing) • 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



Aerial Photograph Showing Assessed Turbine Locations



Seagreen (Leuchars)



4 METHODOLOGY AND BACKGROUND

Introduction

This report indicates whether wind turbines at the Seagreen (Leuchars) will be detected by the Leuchars PSR (Closing). 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 (Leuchars) will be within Radar Line of Sight of the Leuchars PSR (Closing)
- 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

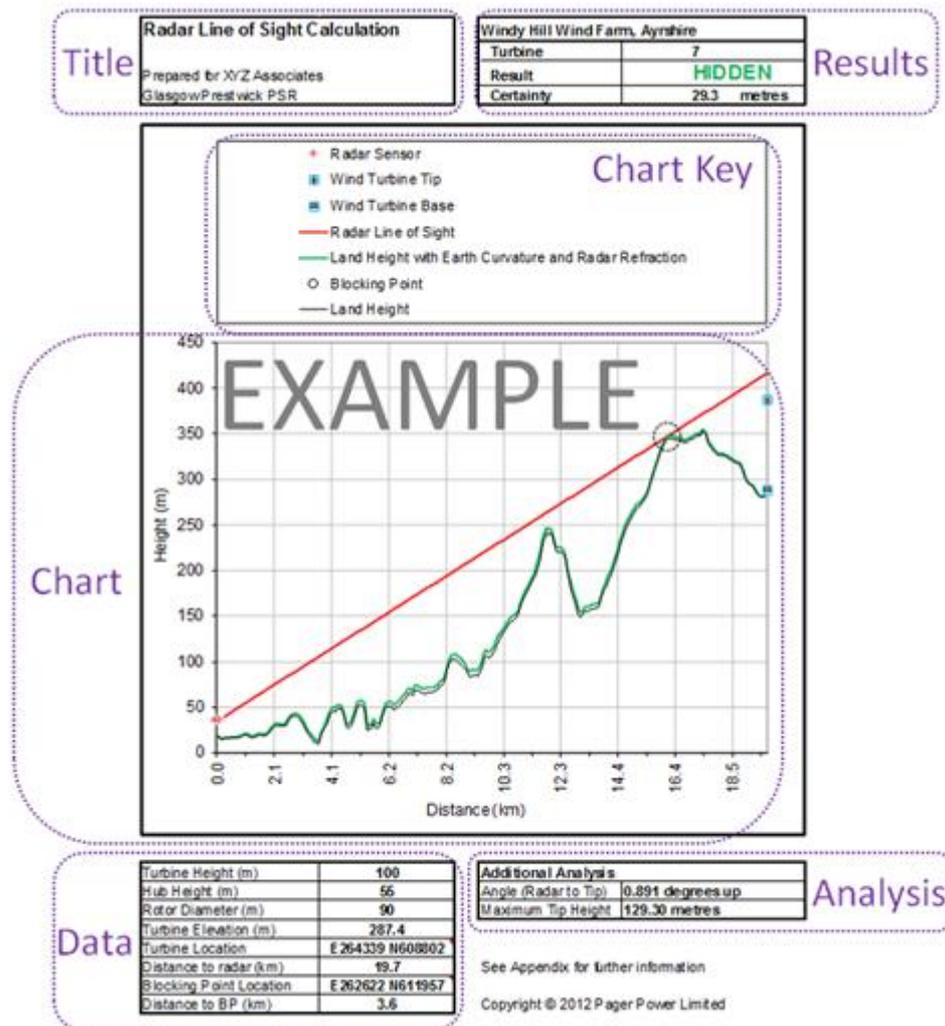


Diagram showing areas of a Radar Line of Sight Calculation

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 .