



PAGERPOWER

Seagreen (Edinburgh)

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

Pager Power

Seagreen (Edinburgh)

7th February 2018

Without Expert Commentary

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CONTENTS

1	Summary (Executive).....	3
2	Results Summary	19
3	Requested Assessment	21
4	Methodology and Background	25
5	Appendix - Calculation Notes.....	27

Report Issue	Date and Time of Request
1	07 Feb 2018 at 09:20 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	HIDDEN
A2	HIDDEN
A3	HIDDEN
A4	HIDDEN
A5	HIDDEN
A6	HIDDEN
A7	HIDDEN
A8	HIDDEN

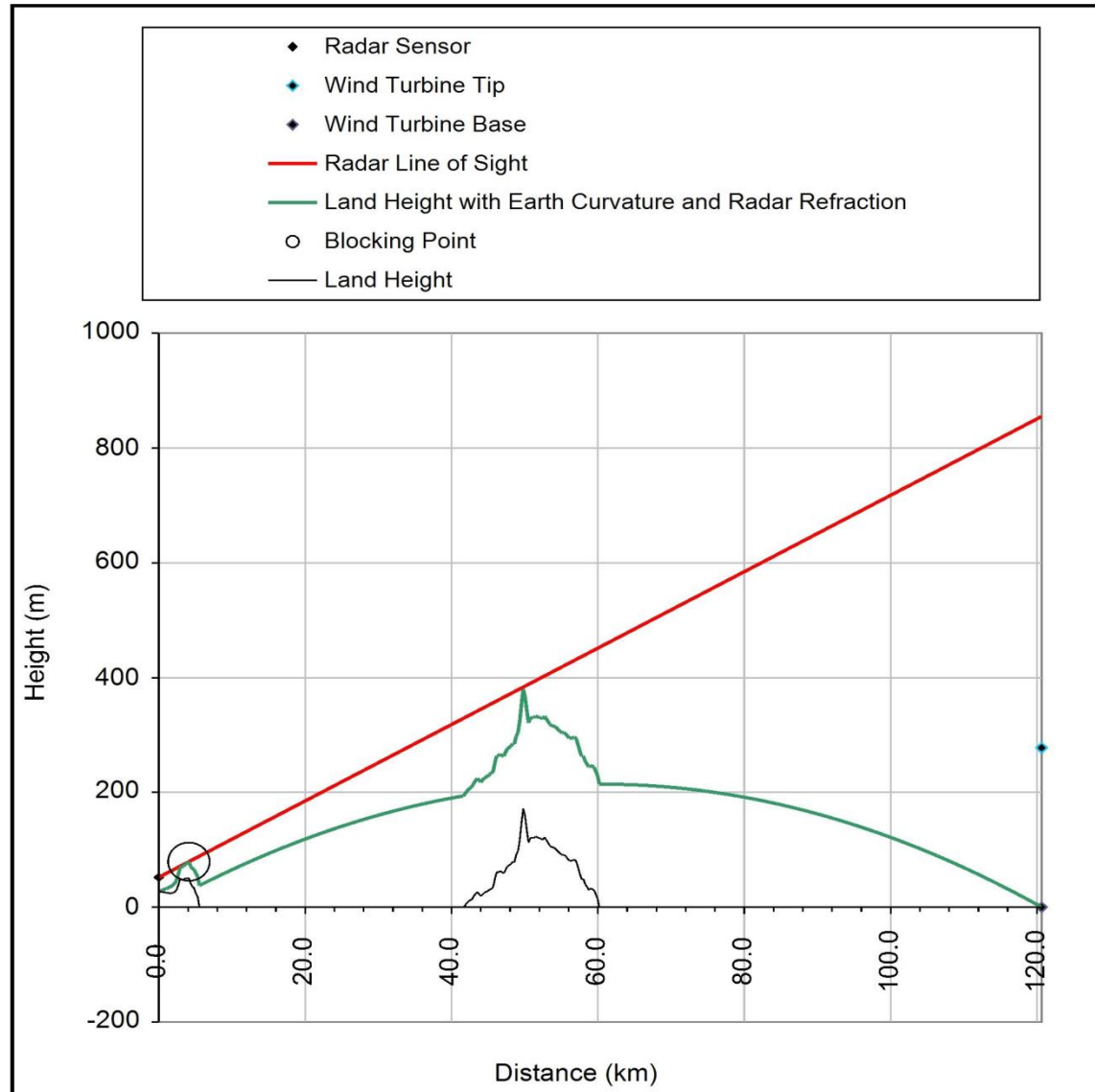
B1	HIDDEN
B2	HIDDEN
B3	HIDDEN
B4	HIDDEN
B5	HIDDEN
B6	HIDDEN
<p>Explanation: There is one Radar Line of Sight Calculation page for each turbine assessed. Each calculation shows whether the turbine is VISIBLE or HIDDEN. Visible turbines are likely to affect the radar whereas hidden turbines are unlikely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

Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	A1
Result	HIDDEN
Certainty	577.4 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)	120.6
Blocking Point Location	E317101 N676695
Distance to BP (km)	116.5

Additional Analysis

Angle (Radar to Tip)	0.300 degrees down
Maximum Tip Height	855.07 metres

See Appendix for further information

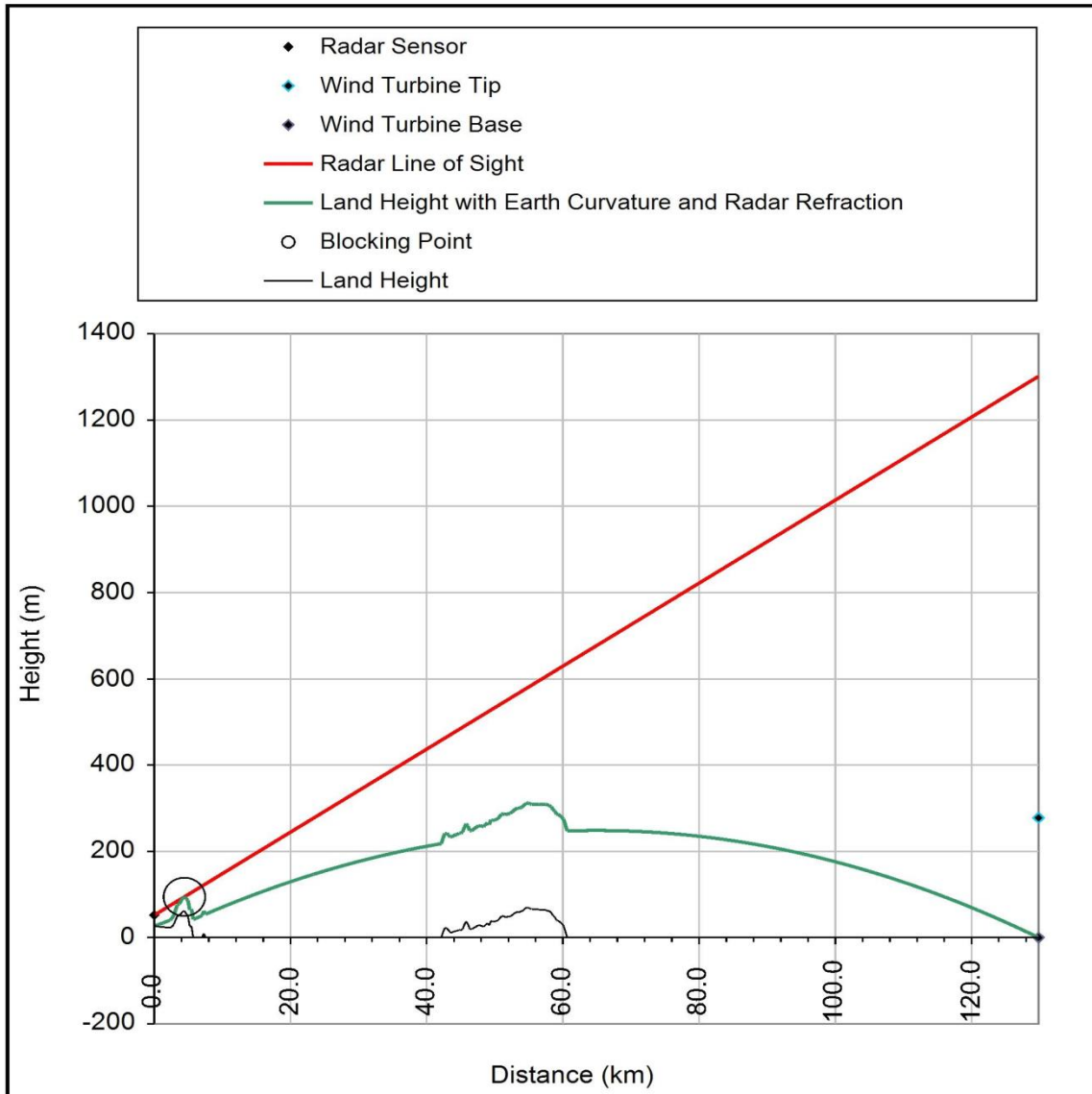
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	A2
Result	HIDDEN
Certainty	1024.0 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)	129.8
Blocking Point Location	E317480 N676725
Distance to BP (km)	125.4

Additional Analysis

Angle (Radar to Tip)	0.338 degrees down
Maximum Tip Height	1301.72 metres

See Appendix for further information

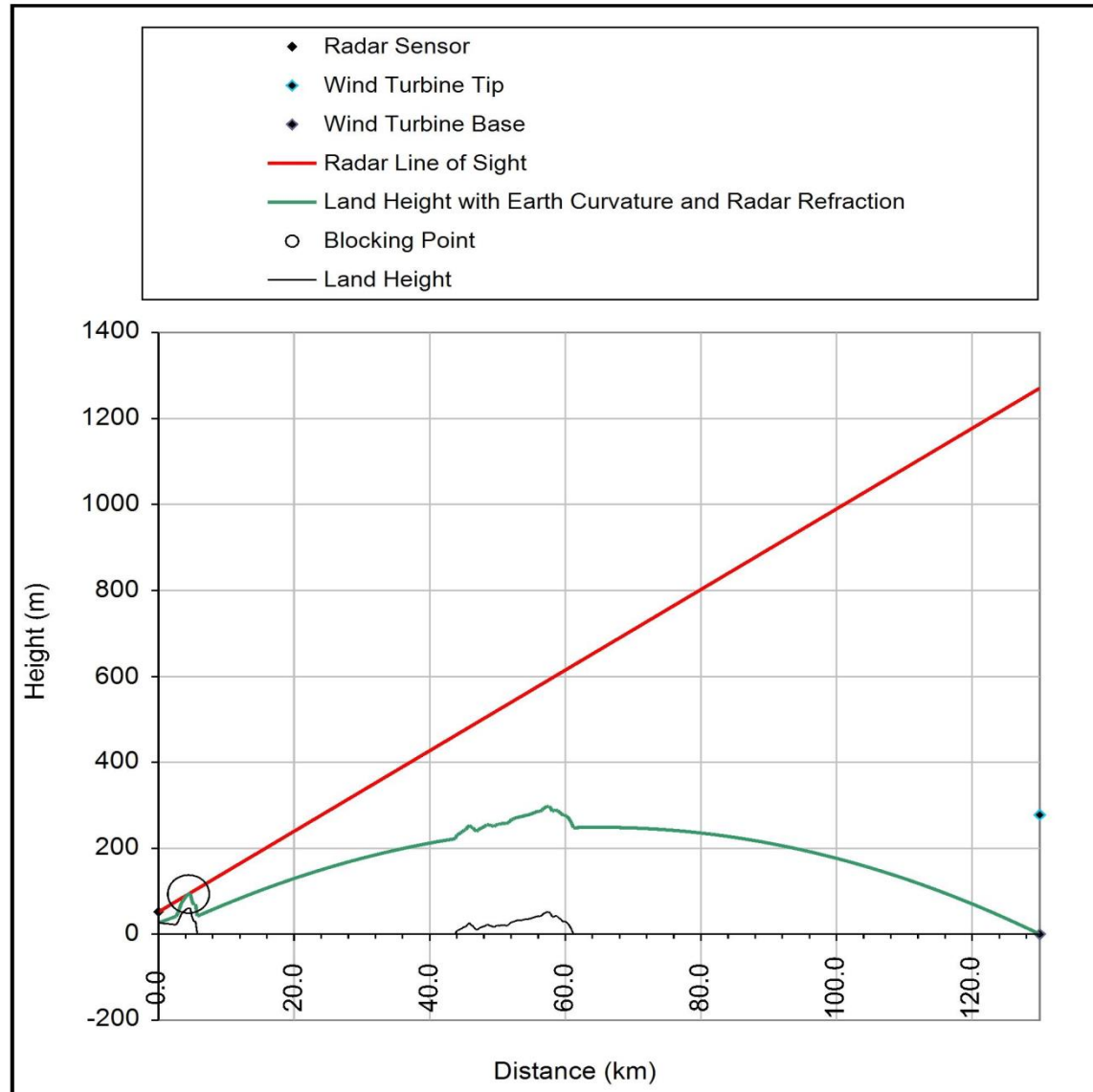
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	A3
Result	HIDDEN
Certainty	993.2 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)	130.0
Blocking Point Location	E317554 N676634
Distance to BP (km)	125.5

Additional Analysis

Angle (Radar to Tip)	0.339 degrees down
Maximum Tip Height	1270.91 metres

See Appendix for further information

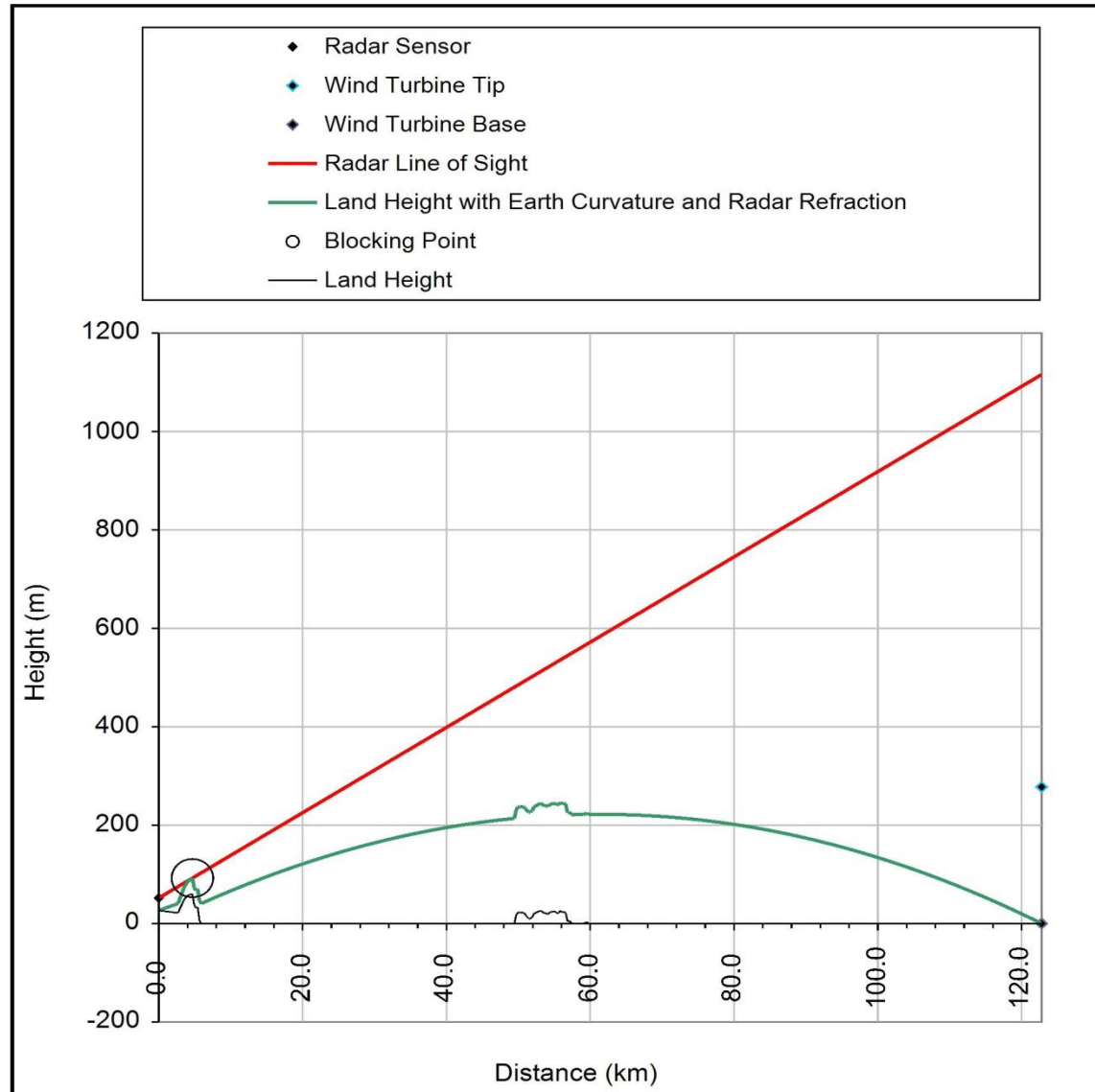
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	A4
Result	HIDDEN
Certainty	838.5 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)	122.8
Blocking Point Location	E317812 N676697
Distance to BP (km)	118.1

Additional Analysis

Angle (Radar to Tip)	0.309 degrees down
Maximum Tip Height	1116.18 metres

See Appendix for further information

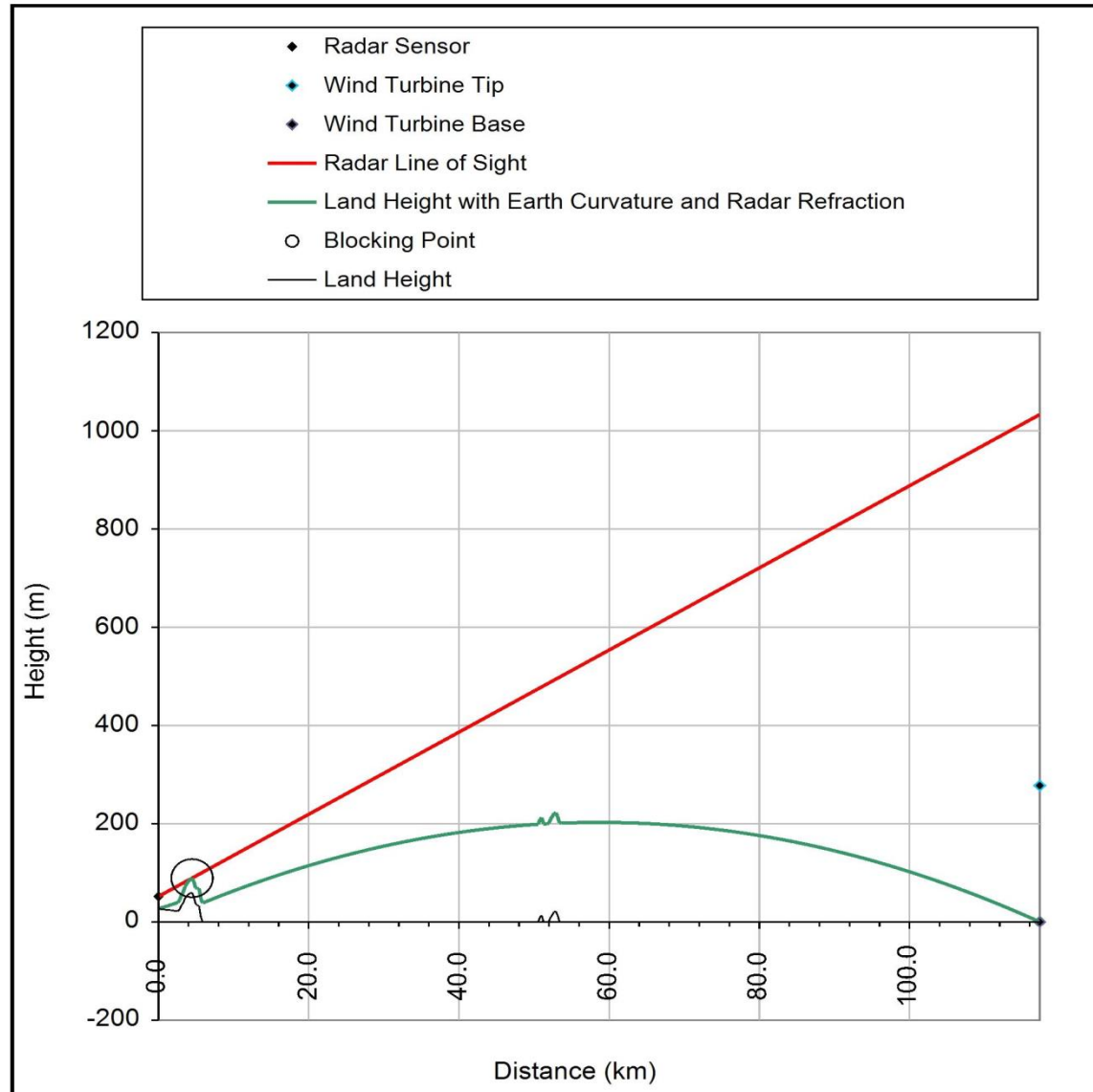
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	A5
Result	HIDDEN
Certainty	755.6 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)	117.3
Blocking Point Location	E317663 N676548
Distance to BP (km)	112.8

Additional Analysis

Angle (Radar to Tip)	0.285 degrees down
Maximum Tip Height	1033.28 metres

See Appendix for further information

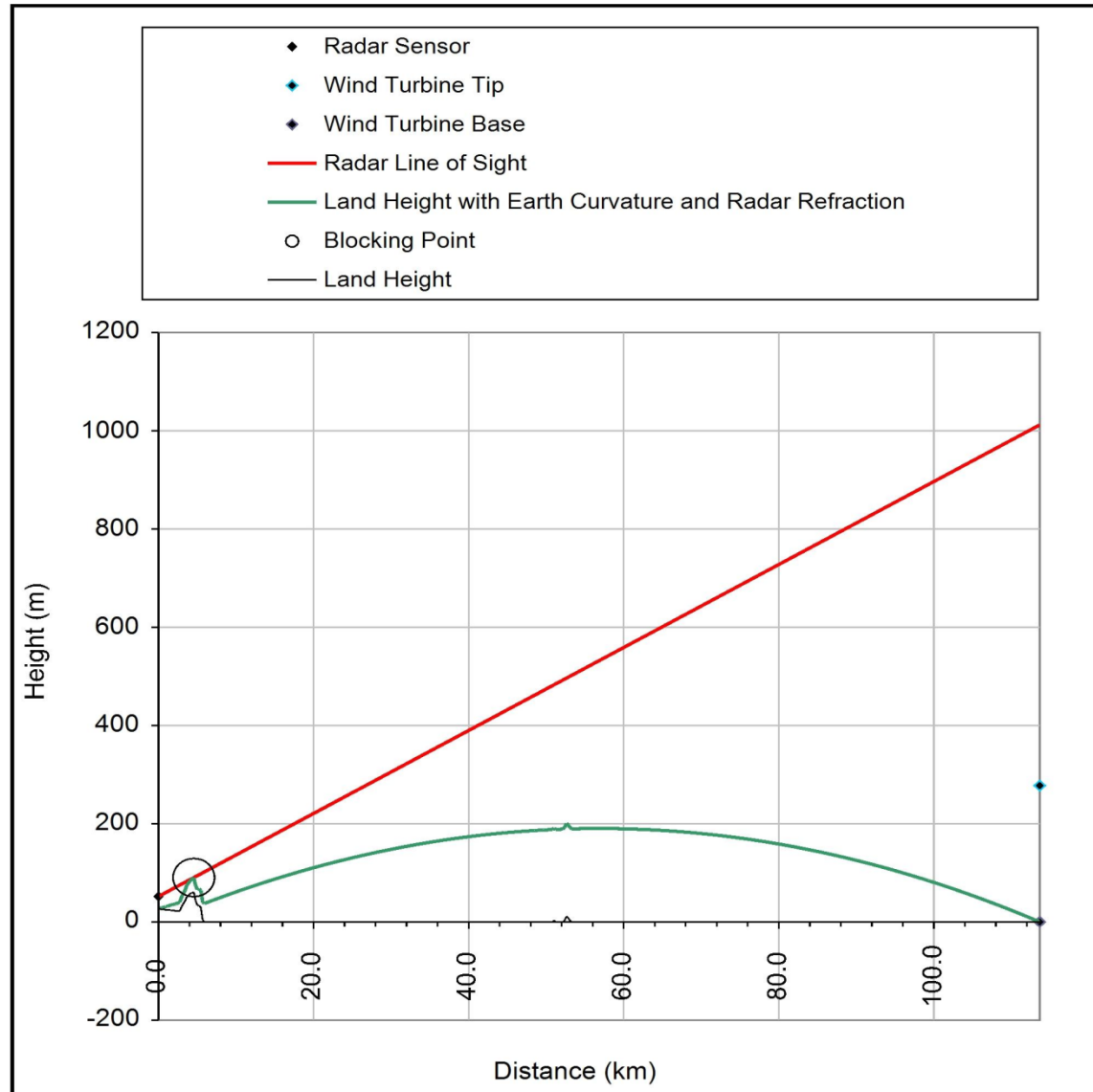
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	A6
Result	HIDDEN
Certainty	734.6 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)	113.7
Blocking Point Location	E317743 N676588
Distance to BP (km)	109.1

Additional Analysis

Angle (Radar to Tip)	0.269 degrees down
Maximum Tip Height	1012.28 metres

See Appendix for further information

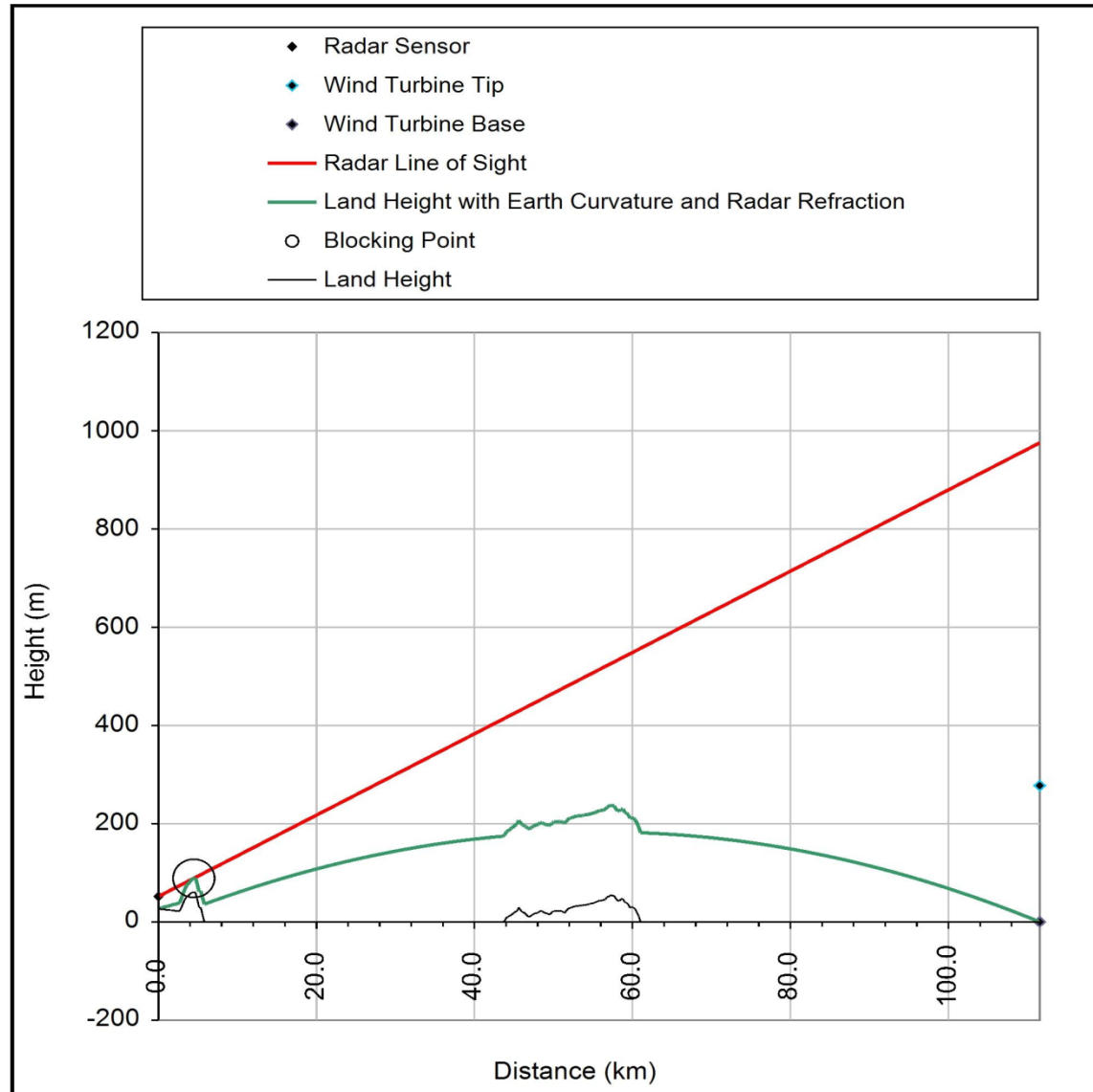
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	A7
Result	HIDDEN
Certainty	698.0 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)	111.6
Blocking Point Location	E317584 N676666
Distance to BP (km)	107.0

Additional Analysis

Angle (Radar to Tip)	0.260 degrees down
Maximum Tip Height	975.68 metres

See Appendix for further information

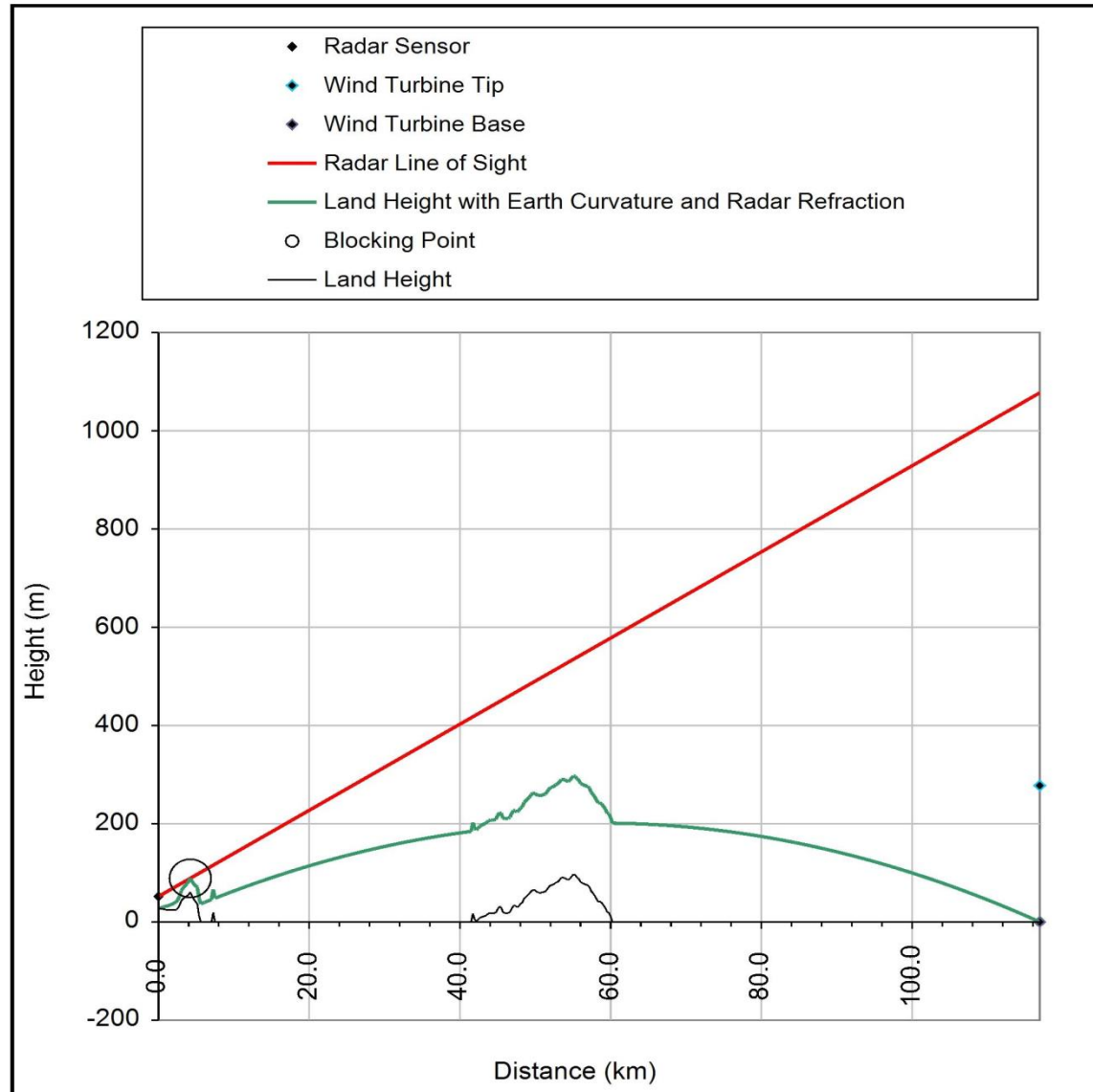
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	A8
Result	HIDDEN
Certainty	799.8 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)	116.9
Blocking Point Location	E317260 N676672
Distance to BP (km)	112.7

Additional Analysis

Angle (Radar to Tip)	0.284 degrees down
Maximum Tip Height	1077.53 metres

See Appendix for further information

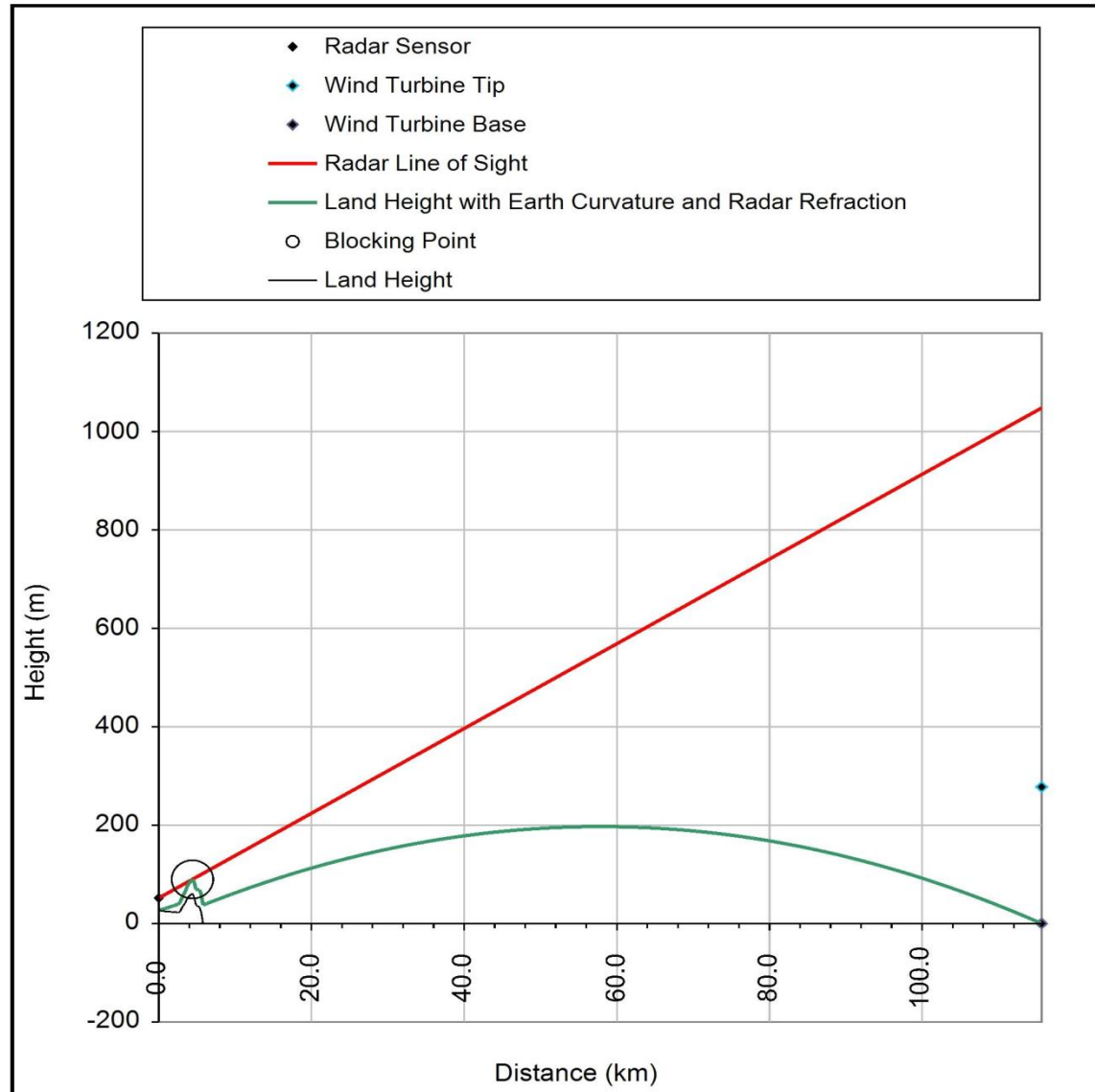
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	B1
Result	HIDDEN
Certainty	770.5 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)	115.6
Blocking Point Location	E317651 N676453
Distance to BP (km)	111.2

Additional Analysis

Angle (Radar to Tip)	0.278 degrees down
Maximum Tip Height	1048.19 metres

See Appendix for further information

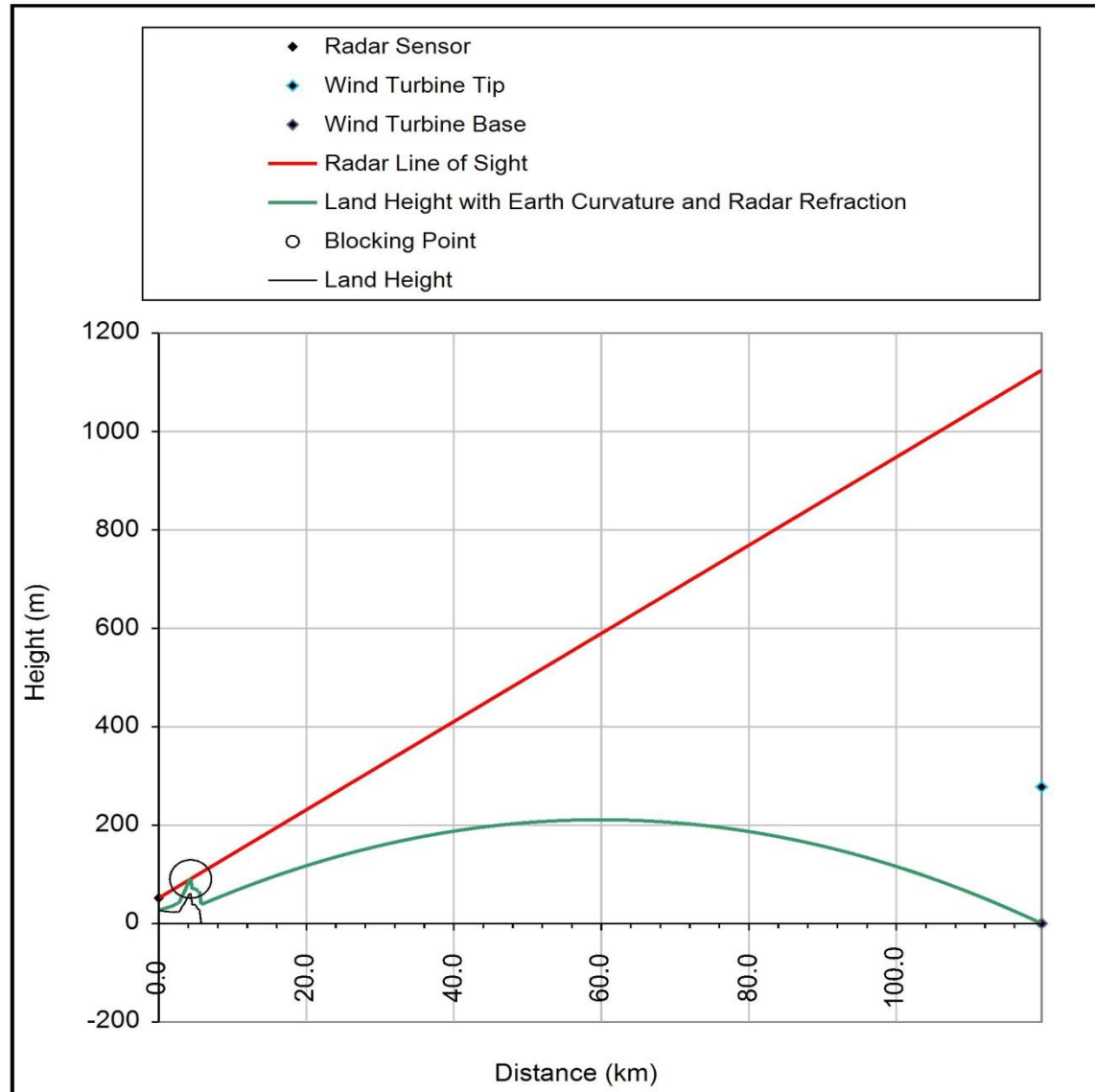
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	B2
Result	HIDDEN
Certainty	847.2 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)	119.7
Blocking Point Location	E317639 N676312
Distance to BP (km)	115.3

Additional Analysis

Angle (Radar to Tip)	0.296 degrees down
Maximum Tip Height	1124.88 metres

See Appendix for further information

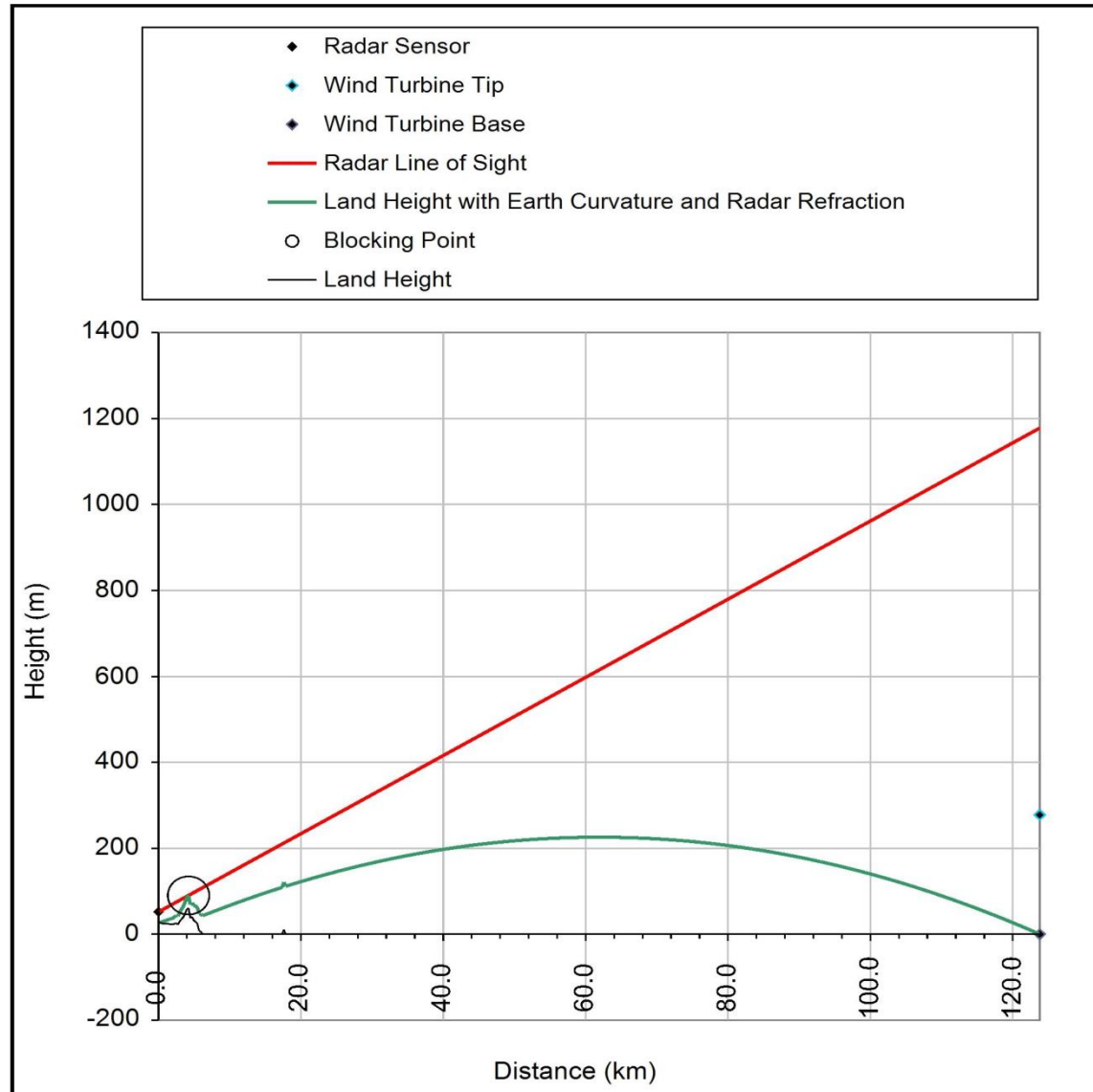
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	B3
Result	HIDDEN
Certainty	900.4 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)	123.8
Blocking Point Location	E317607 N676173
Distance to BP (km)	119.5

Additional Analysis

Angle (Radar to Tip)	0.313 degrees down
Maximum Tip Height	1178.05 metres

See Appendix for further information

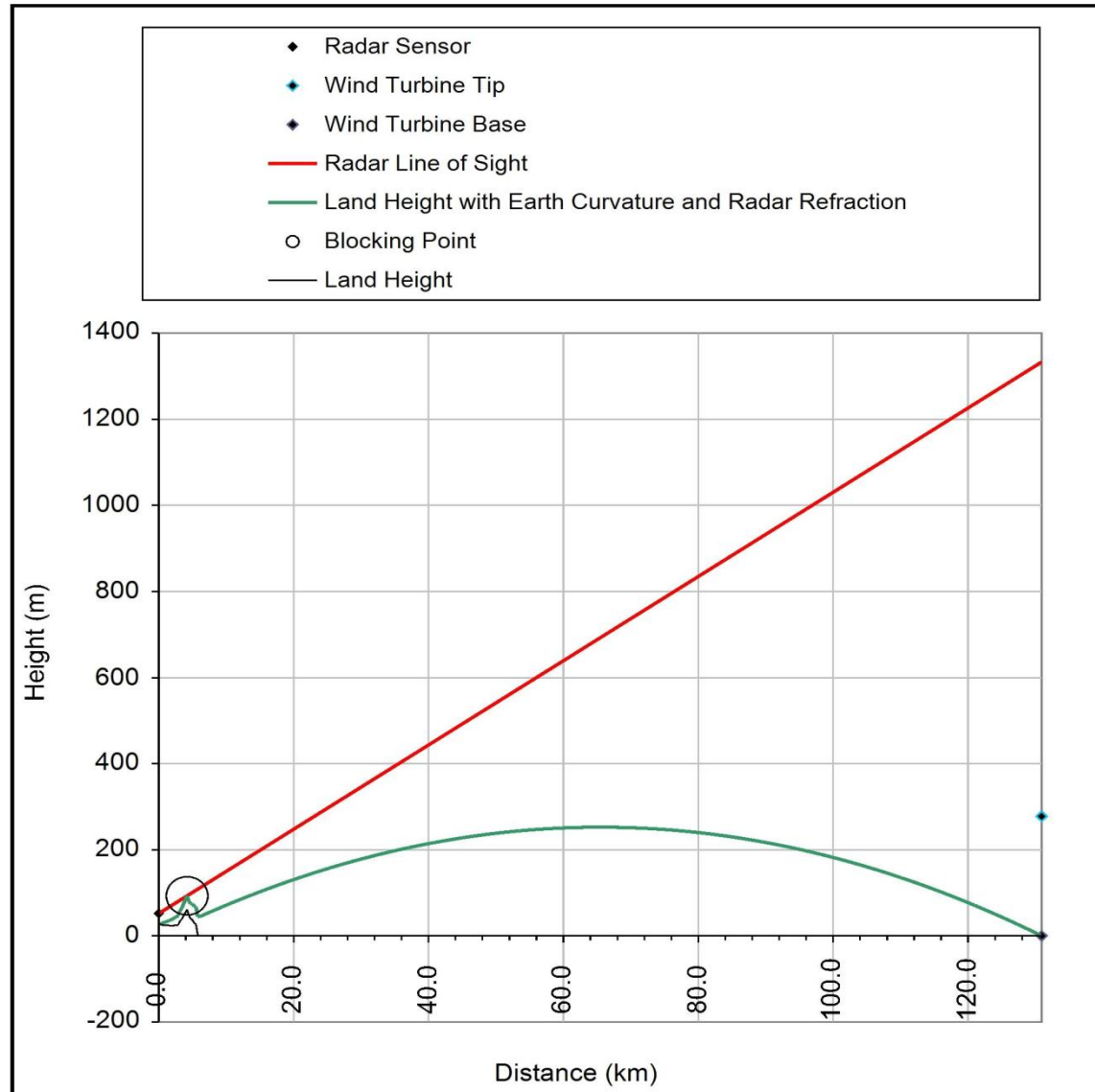
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	B4
Result	HIDDEN
Certainty	1055.5 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)	130.9
Blocking Point Location	E317553 N676224
Distance to BP (km)	126.7

Additional Analysis

Angle (Radar to Tip)	0.343 degrees down
Maximum Tip Height	1333.21 metres

See Appendix for further information

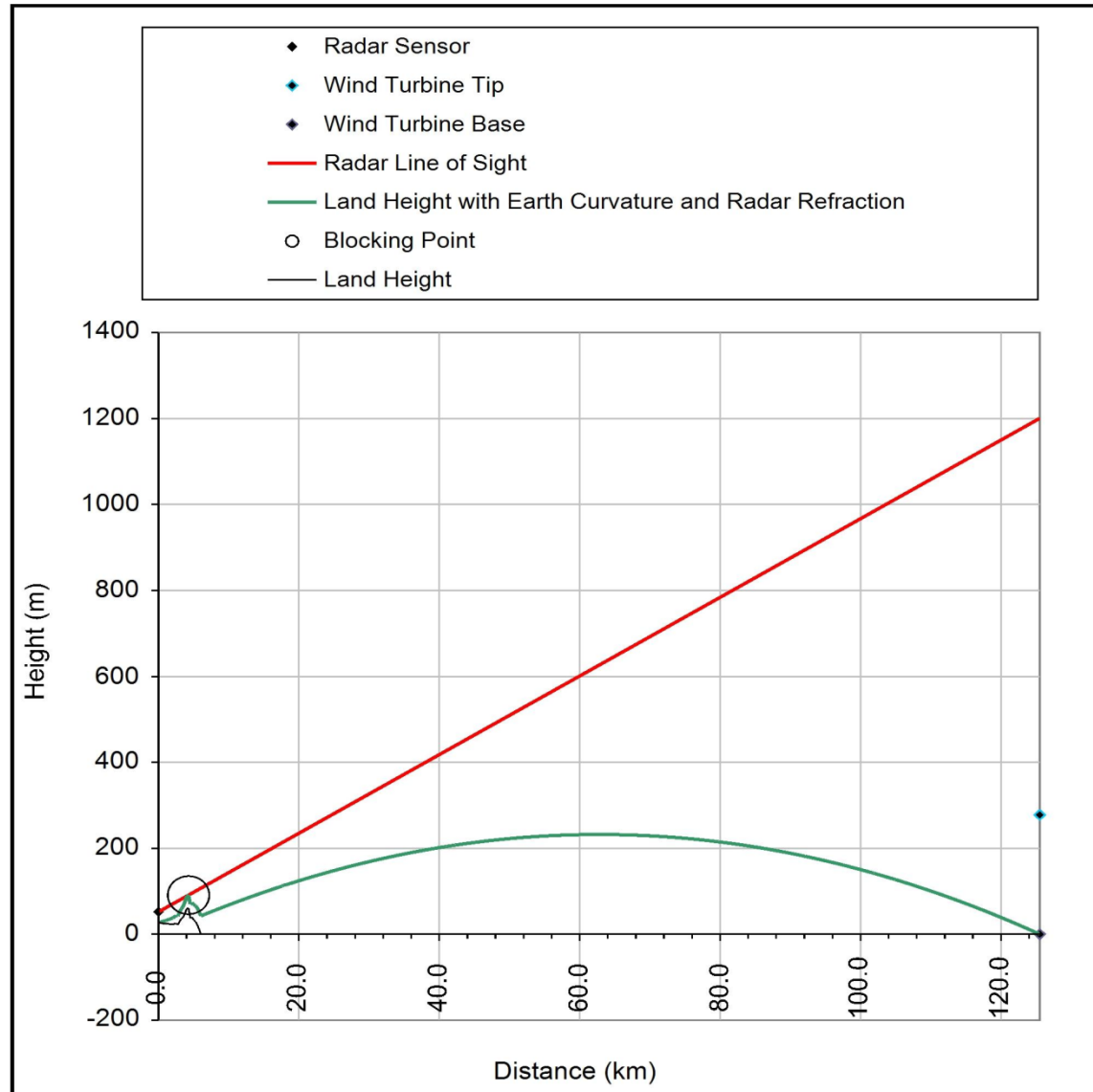
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	B5
Result	HIDDEN
Certainty	923.0 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)	125.5
Blocking Point Location	E317643 N676228
Distance to BP (km)	121.2

Additional Analysis

Angle (Radar to Tip)	0.320 degrees down
Maximum Tip Height	1200.68 metres

See Appendix for further information

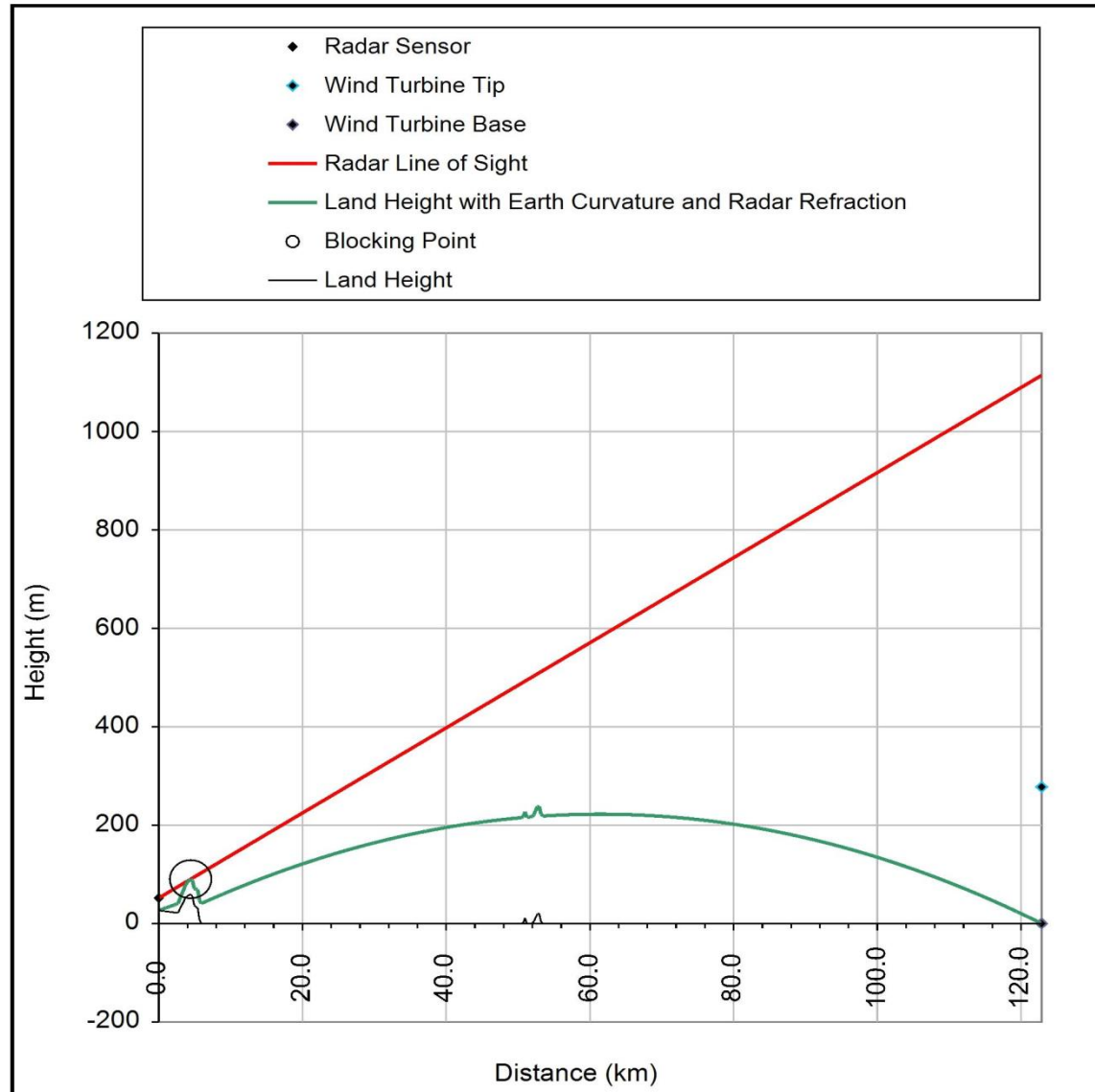
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Radar Line of Sight Calculation

Prepared for Pager Power
Edinburgh Airport PSR

Seagreen (Edinburgh)

Turbine	B6
Result	HIDDEN
Certainty	836.8 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)	122.9
Blocking Point Location	E317637 N676524
Distance to BP (km)	118.4

Additional Analysis

Angle (Radar to Tip)	0.309 degrees down
Maximum Tip Height	1114.54 metres

See Appendix for further information

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2 RESULTS SUMMARY

Wind Turbine	Result	Certainty	Angle (Radar to Tip)	Maximum Height
A1	HIDDEN	577.4 metres	0.300 degrees down	855.07 metres
A2	HIDDEN	1024.0 metres	0.338 degrees down	1301.72 metres
A3	HIDDEN	993.2 metres	0.339 degrees down	1270.91 metres
A4	HIDDEN	838.5 metres	0.309 degrees down	1116.18 metres
A5	HIDDEN	755.6 metres	0.285 degrees down	1033.28 metres
A6	HIDDEN	734.6 metres	0.269 degrees down	1012.28 metres
A7	HIDDEN	698.0 metres	0.260 degrees down	975.68 metres
A8	HIDDEN	799.8 metres	0.284 degrees down	1077.53 metres
B1	HIDDEN	770.5 metres	0.278 degrees down	1048.19 metres
B2	HIDDEN	847.2 metres	0.296 degrees down	1124.88 metres
B3	HIDDEN	900.4 metres	0.313 degrees down	1178.05 metres
B4	HIDDEN	1055.5 metres	0.343 degrees down	1333.21 metres
B5	HIDDEN	923.0 metres	0.320 degrees down	1200.68 metres
B6	HIDDEN	836.8 metres	0.309 degrees down	1114.54 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 (Edinburgh) 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 Edinburgh Airport PSR • 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

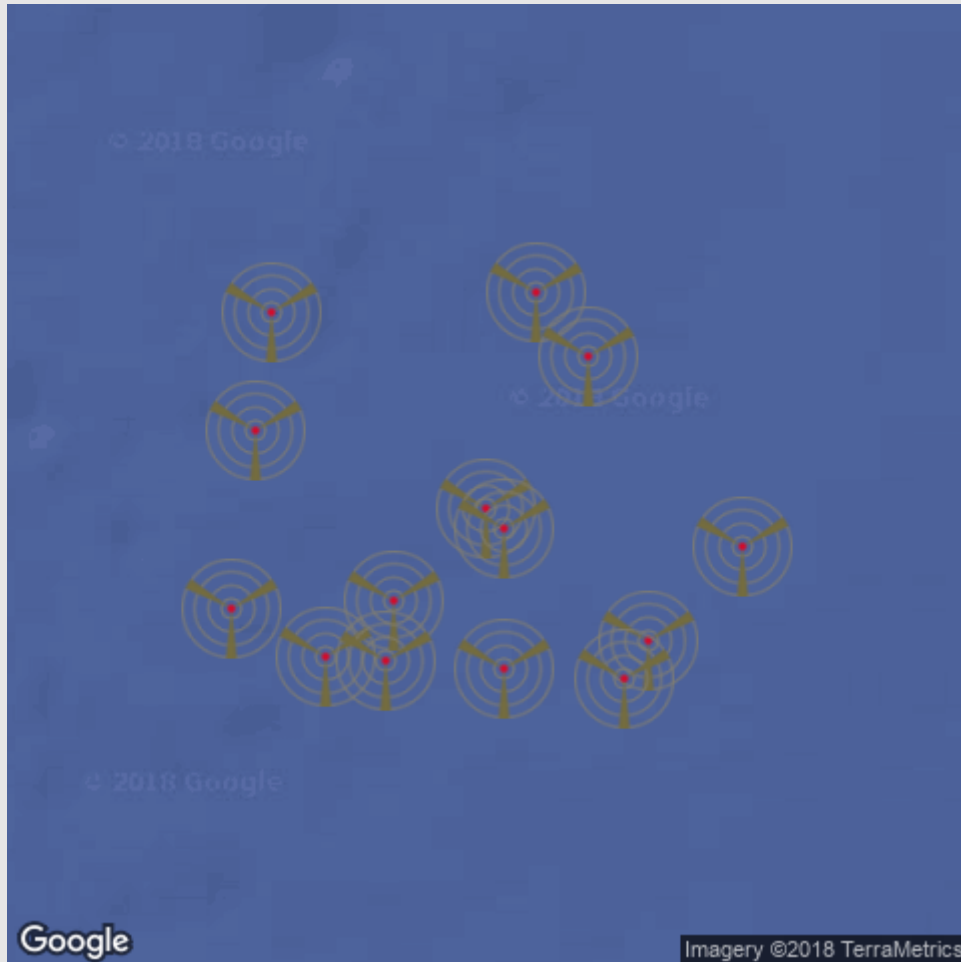
420373.6	737210.72	220	277.7	B3
425344.67	742740.62	220	277.7	B4
421435.12	738815.7	220	277.7	B5
415298.69	743440.83	220	277.7	B6

Map Showing Assessed Turbine Locations



Seagreen (Edinburgh)

Aerial Photograph Showing Assessed Turbine Locations



Seagreen (Edinburgh)

4 METHODOLOGY AND BACKGROUND

Introduction

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

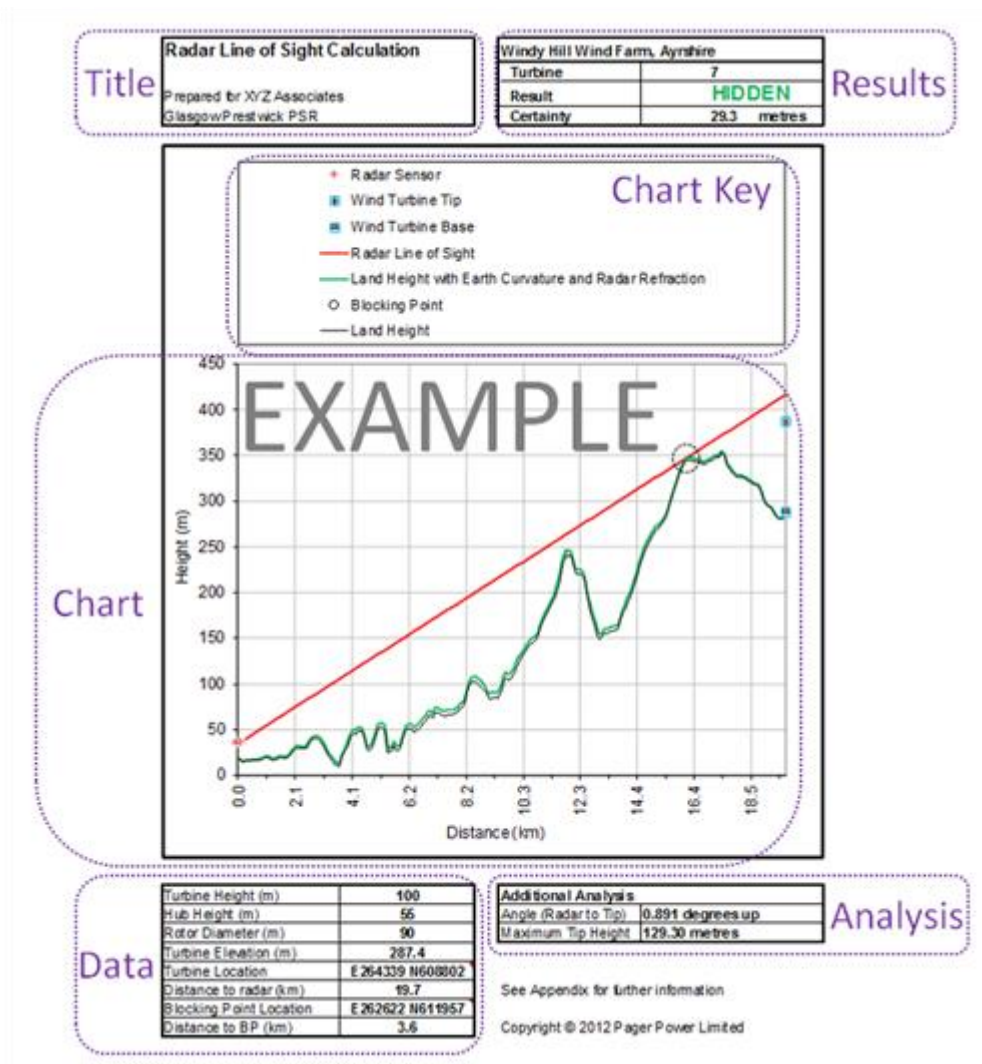


Diagram showing areas of a Radar Line of Sight Calculation

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 .