



# PAGERPOWER

Seagreen (Allanshill)

## **Radar Line of Sight Assessment (Eurocontrol, CAA, RAF, NATS) Allanshill PSR (NATS)**

**Pager Power**

**Seagreen (Allanshill)**

**7th February 2018**

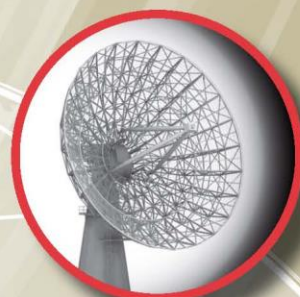
**Without Expert Commentary**

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Report Issue	Date and Time of Request
1	07 Feb 2018 at 09:24 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

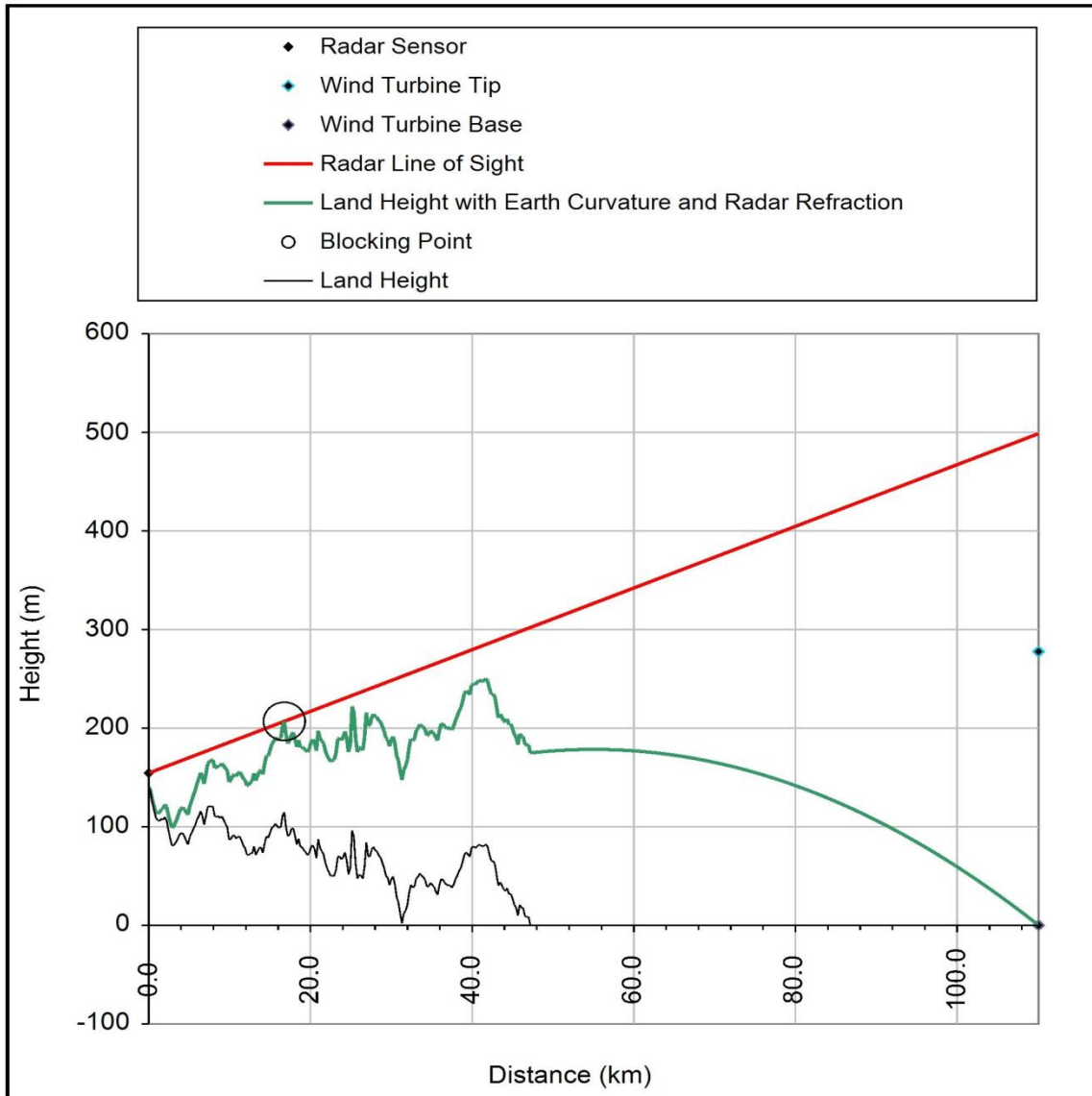
B1	HIDDEN
B2	HIDDEN
B3	HIDDEN
B4	HIDDEN
B5	HIDDEN
B6	HIDDEN
<p><b>Explanation:</b> There is one Radar Line of Sight Calculation page for each turbine assessed. Each calculation shows whether the turbine is <b>VISIBLE</b> or <b>HIDDEN</b>. Visible turbines are likely to affect the radar whereas hidden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

### Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

#### Seagreen (Allanshill)

Turbine	A1
Result	<b>HIDDEN</b>
Certainty	221.1 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	<b>E405537 N752516</b>
Distance to radar (km)	110.1
Blocking Point Location	<b>E392555 N844876</b>
Distance to BP (km)	93.3

#### Additional Analysis

Angle (Radar to Tip)	0.307 degrees down
Maximum Tip Height	498.84 metres

See Appendix for further information

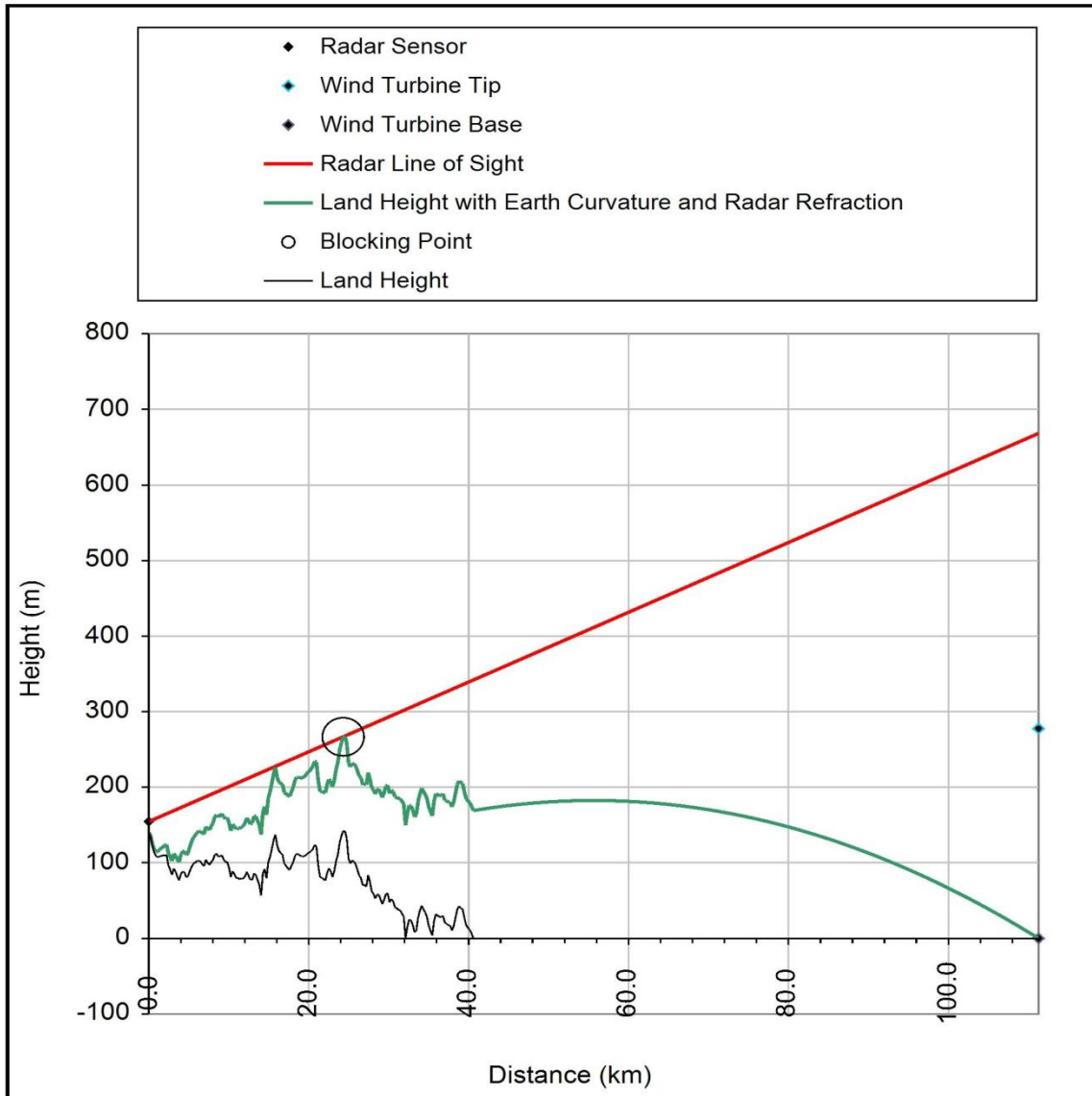
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## Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

### Seagreen (Allanshill)

Turbine	A2
Result	<b>HIDDEN</b>
Certainty	390.6 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)	111.3
Blocking Point Location	E395994 N837868
Distance to BP (km)	86.9

### Additional Analysis

Angle (Radar to Tip)	0.312 degrees down
Maximum Tip Height	668.33 metres

See Appendix for further information

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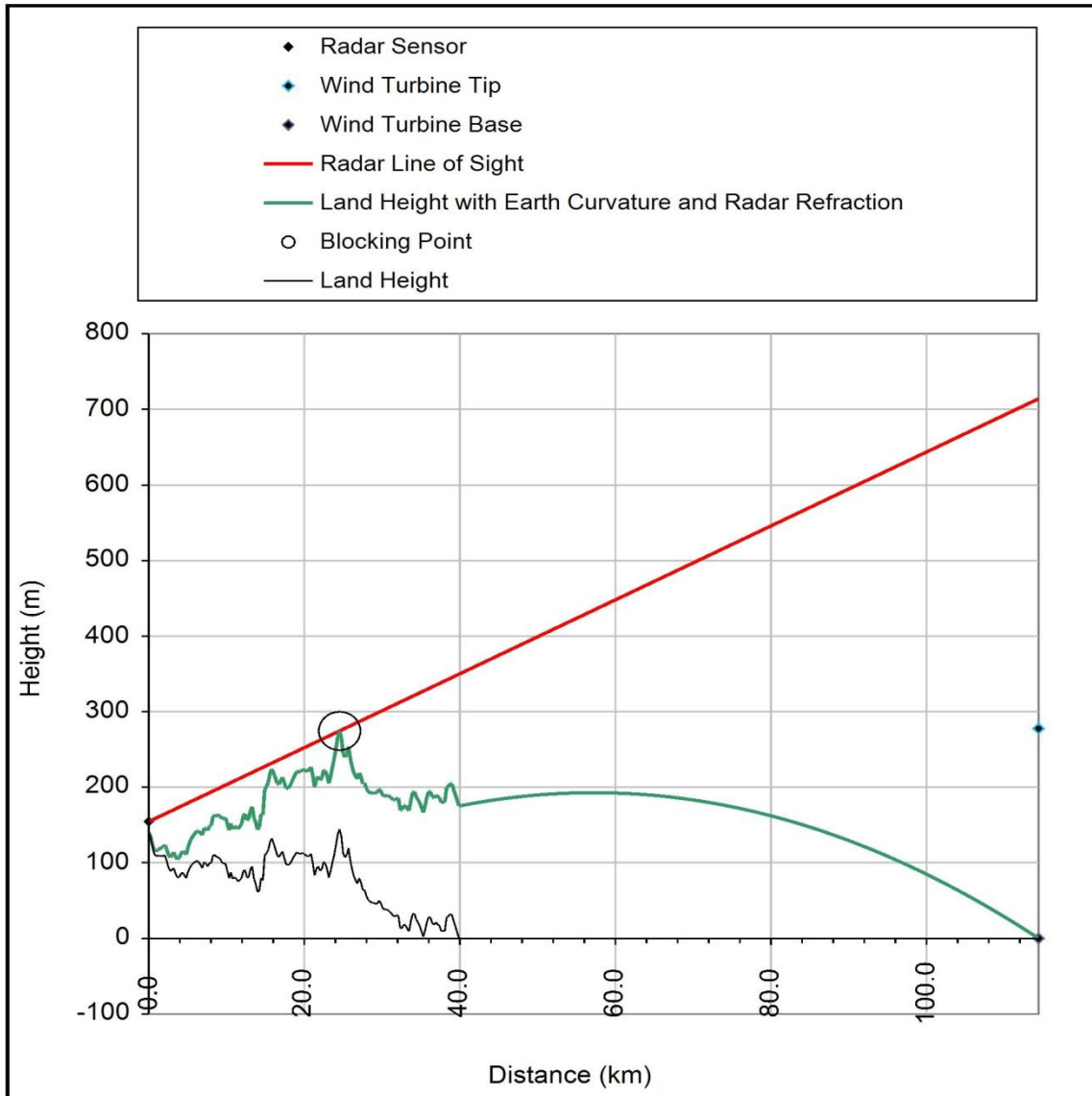


## Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

### Seagreen (Allanshill)

Turbine	A3
Result	<b>HIDDEN</b>
Certainty	436.4 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)	114.4
Blocking Point Location	E396354 N837728
Distance to BP (km)	89.8

### Additional Analysis

Angle (Radar to Tip)	0.324 degrees down
Maximum Tip Height	714.15 metres

See Appendix for further information

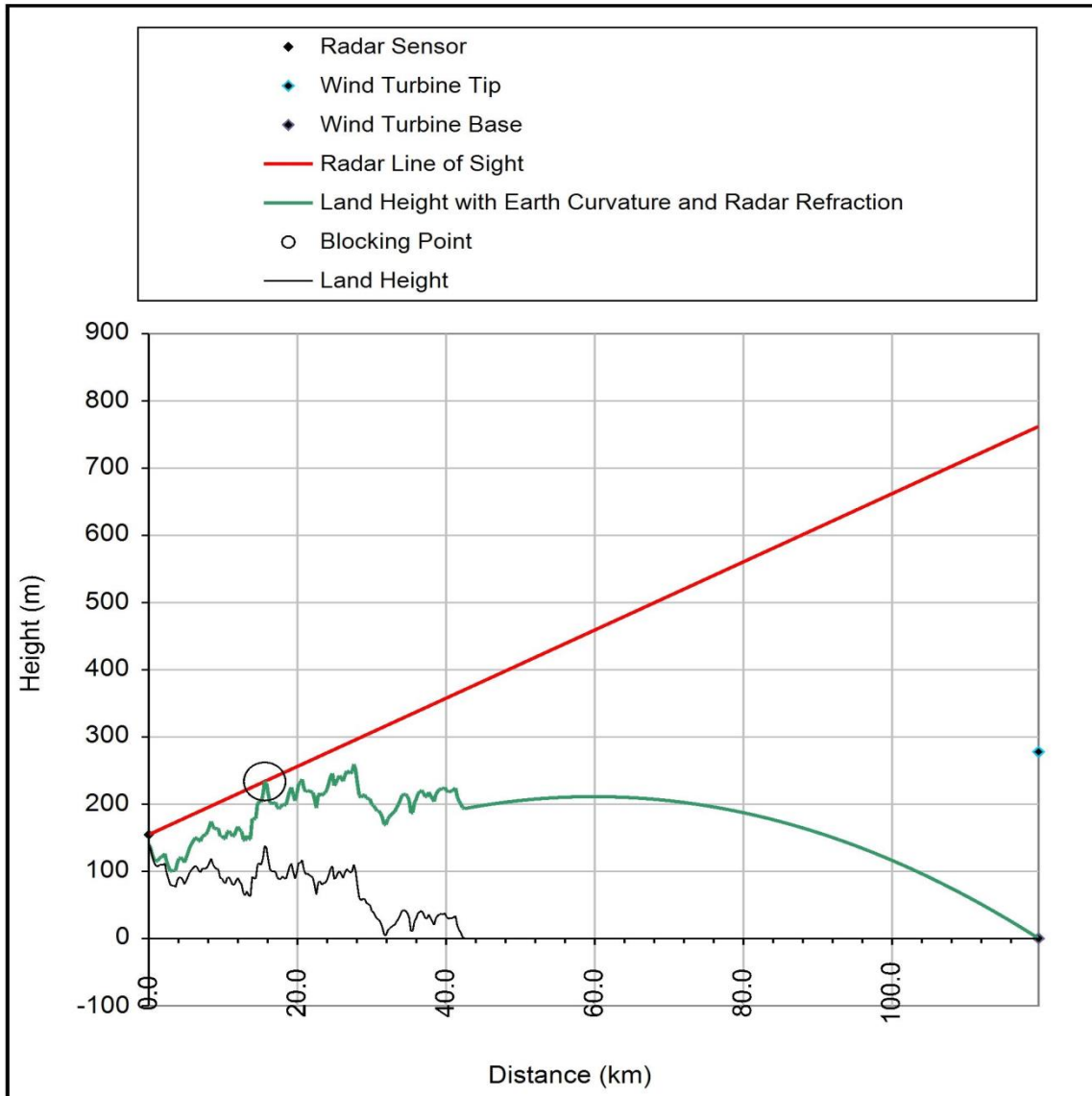
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## Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

### Seagreen (Allanshill)

Turbine	A4
Result	<b>HIDDEN</b>
Certainty	484.5 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)	119.7
Blocking Point Location	E393394 N846211
Distance to BP (km)	104.1

### Additional Analysis

Angle (Radar to Tip)	0.345 degrees down
Maximum Tip Height	762.19 metres

See Appendix for further information

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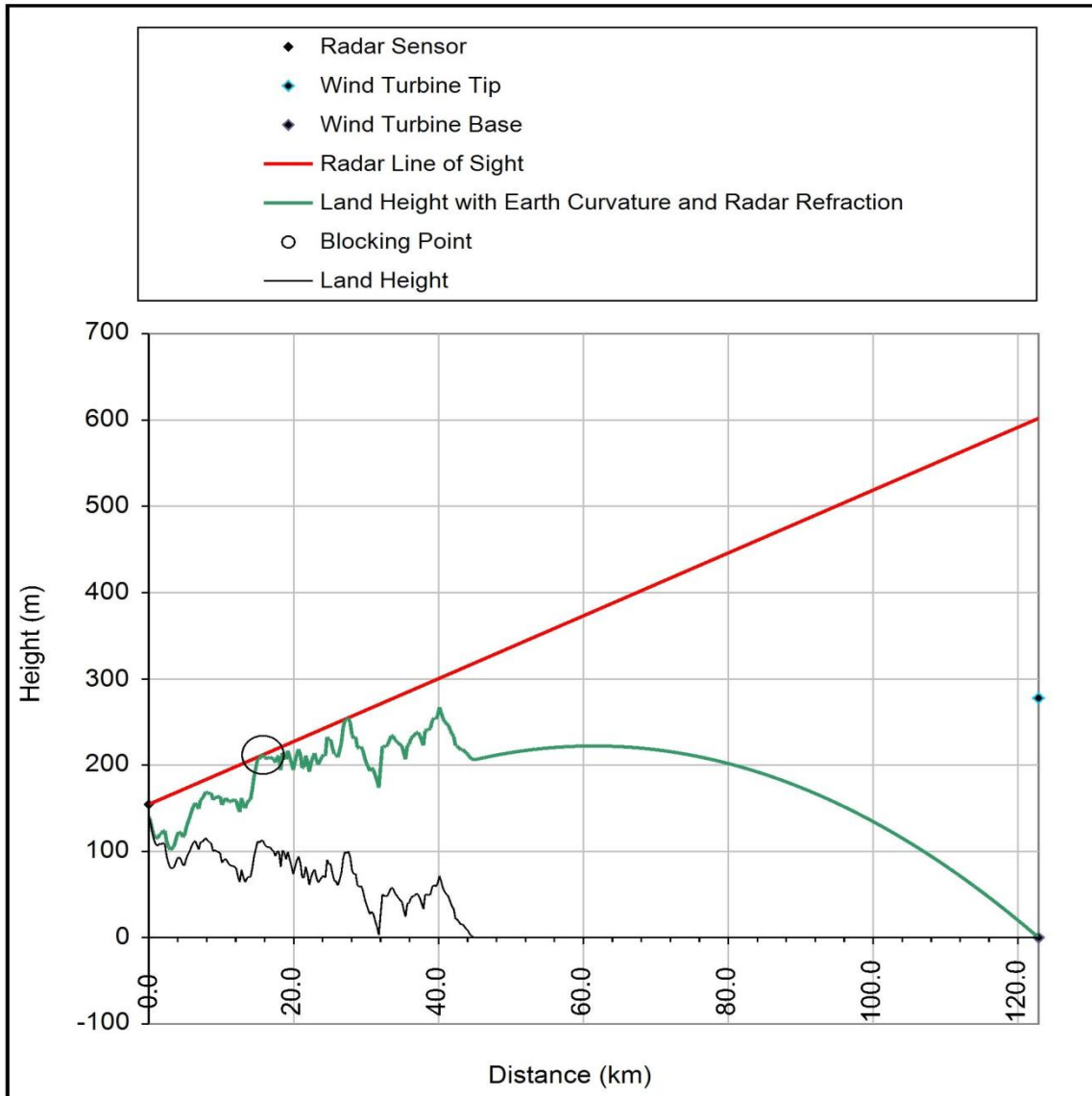


### Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

#### Seagreen (Allanshill)

Turbine	A5
Result	<b>HIDDEN</b>
Certainty	324.4 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)	122.8
Blocking Point Location	E392844 N845942
Distance to BP (km)	107.0

#### Additional Analysis

Angle (Radar to Tip)	0.357 degrees down
Maximum Tip Height	602.08 metres

See Appendix for further information

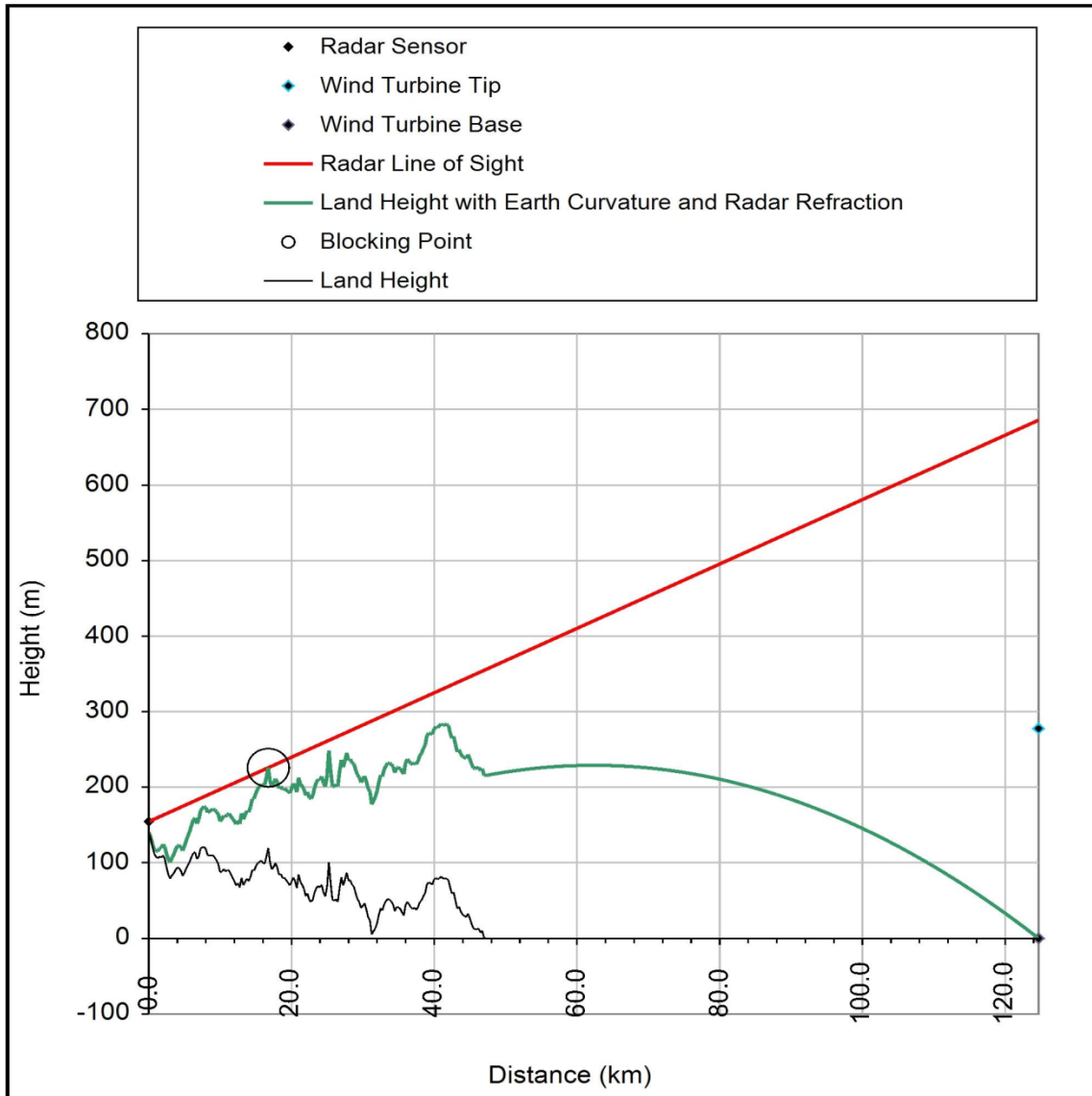
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### Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

#### Seagreen (Allanshill)

Turbine	A6
Result	<b>HIDDEN</b>
Certainty	408.2 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	<b>E407815 N738086</b>
Distance to radar (km)	124.7
Blocking Point Location	<b>E392584 N844903</b>
Distance to BP (km)	107.9

#### Additional Analysis

Angle (Radar to Tip)	0.364 degrees down
Maximum Tip Height	685.87 metres

See Appendix for further information

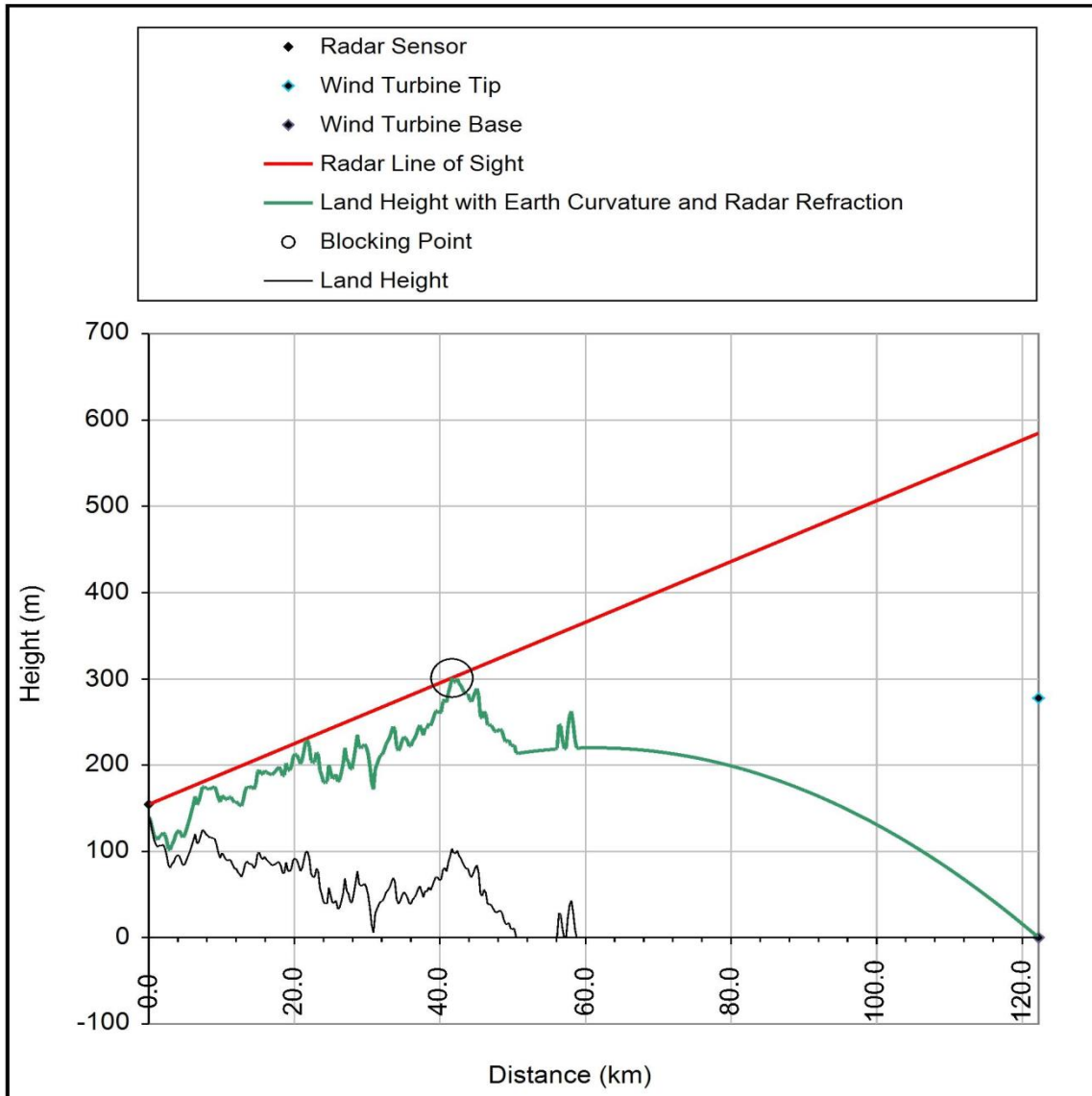
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### Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

#### Seagreen (Allanshill)

Turbine	A7
Result	<b>HIDDEN</b>
Certainty	307.1 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)	122.2
Blocking Point Location	E394866 N820101
Distance to BP (km)	80.6

#### Additional Analysis

Angle (Radar to Tip)	0.354 degrees down
Maximum Tip Height	584.81 metres

See Appendix for further information

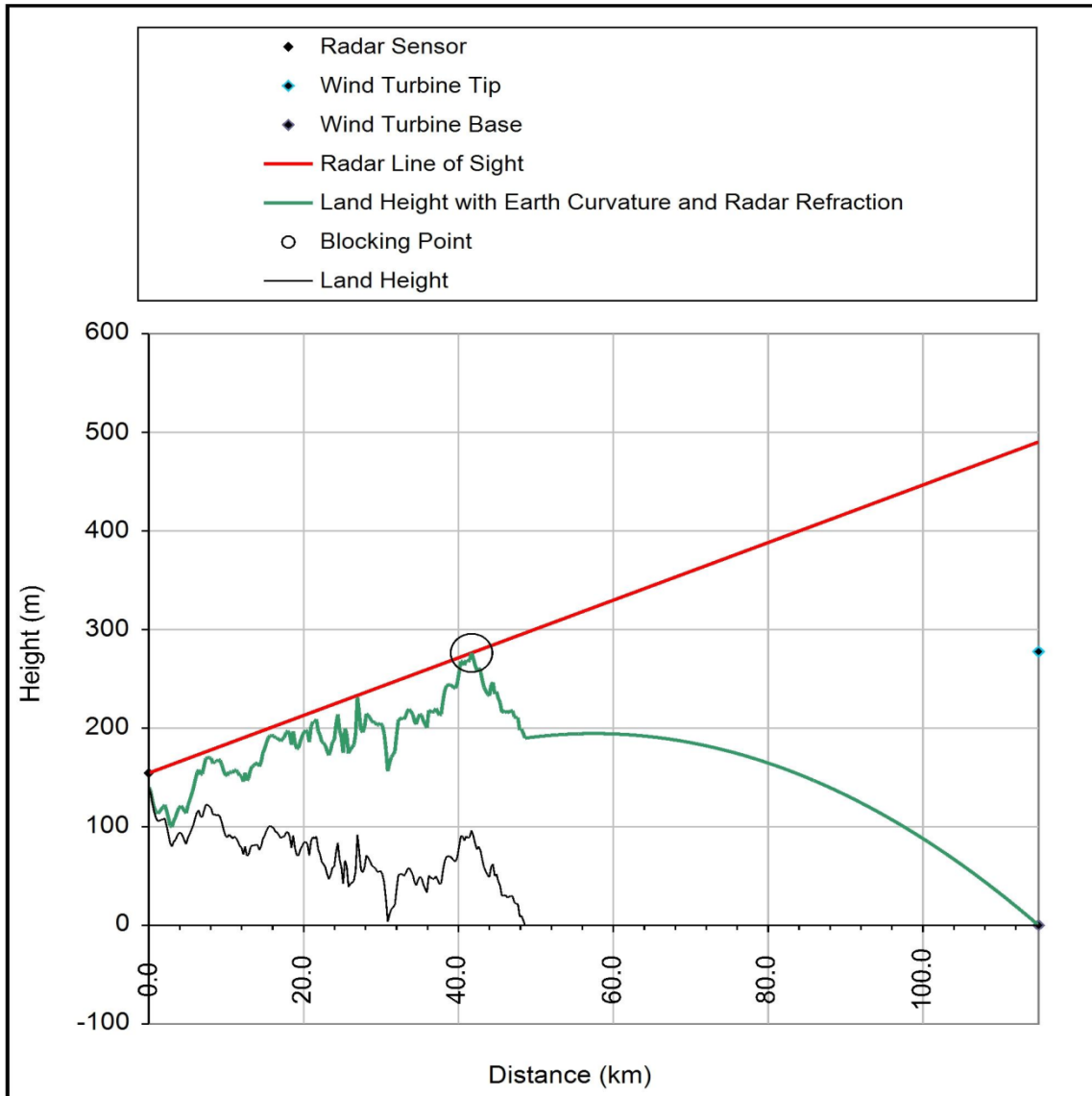
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### Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

#### Seagreen (Allanshill)

Turbine	A8
Result	<b>HIDDEN</b>
Certainty	212.7 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	<b>E404864 N747526</b>
Distance to radar (km)	114.9
Blocking Point Location	<b>E395533 N820139</b>
Distance to BP (km)	73.2

#### Additional Analysis

Angle (Radar to Tip)	0.326 degrees down
Maximum Tip Height	490.38 metres

See Appendix for further information

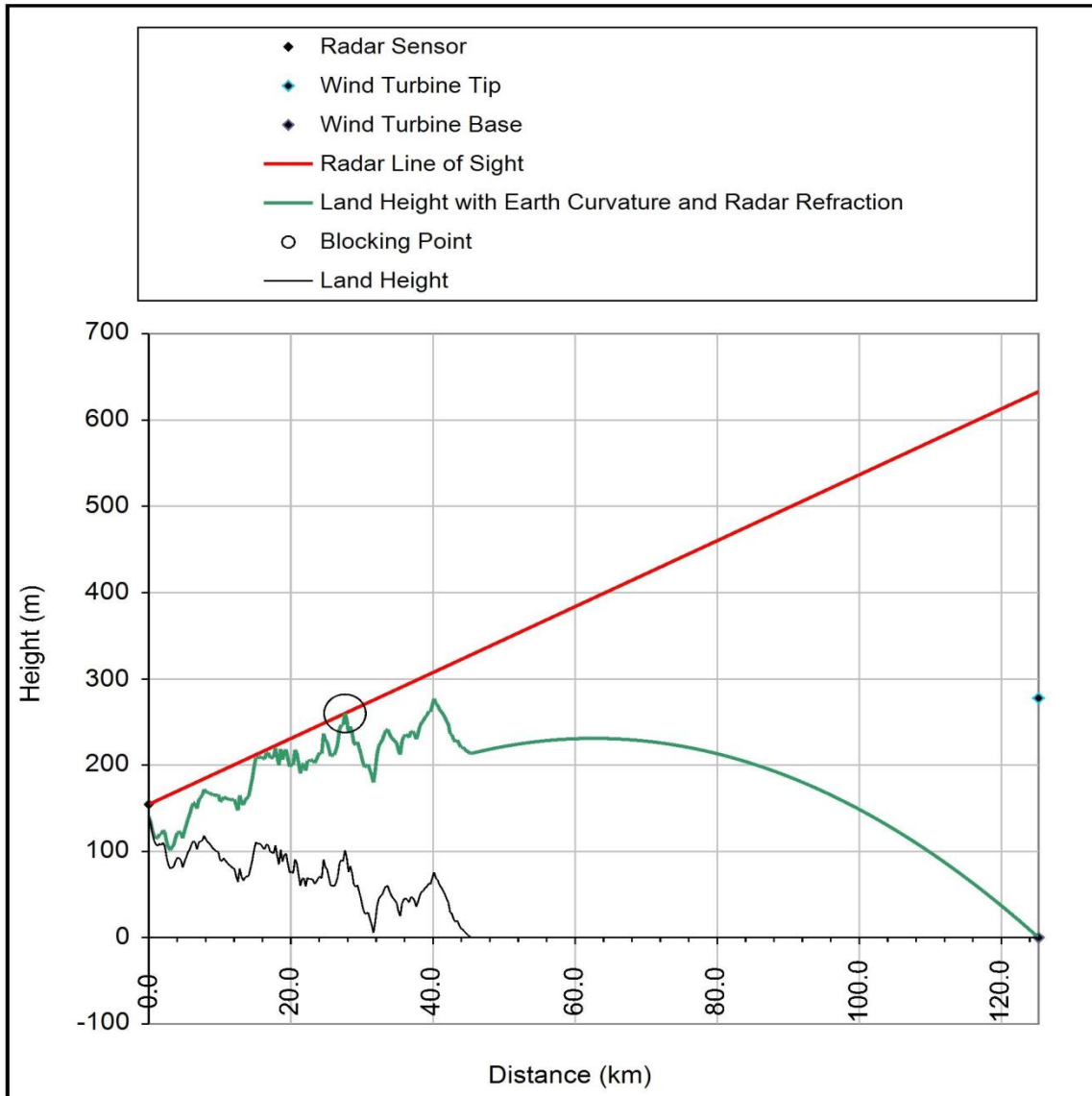
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### Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

#### Seagreen (Allanshill)

Turbine	B1
Result	<b>HIDDEN</b>
Certainty	355.4 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)	125.2
Blocking Point Location	E394654 N834232
Distance to BP (km)	97.6

#### Additional Analysis

Angle (Radar to Tip)	0.366 degrees down
Maximum Tip Height	633.06 metres

See Appendix for further information

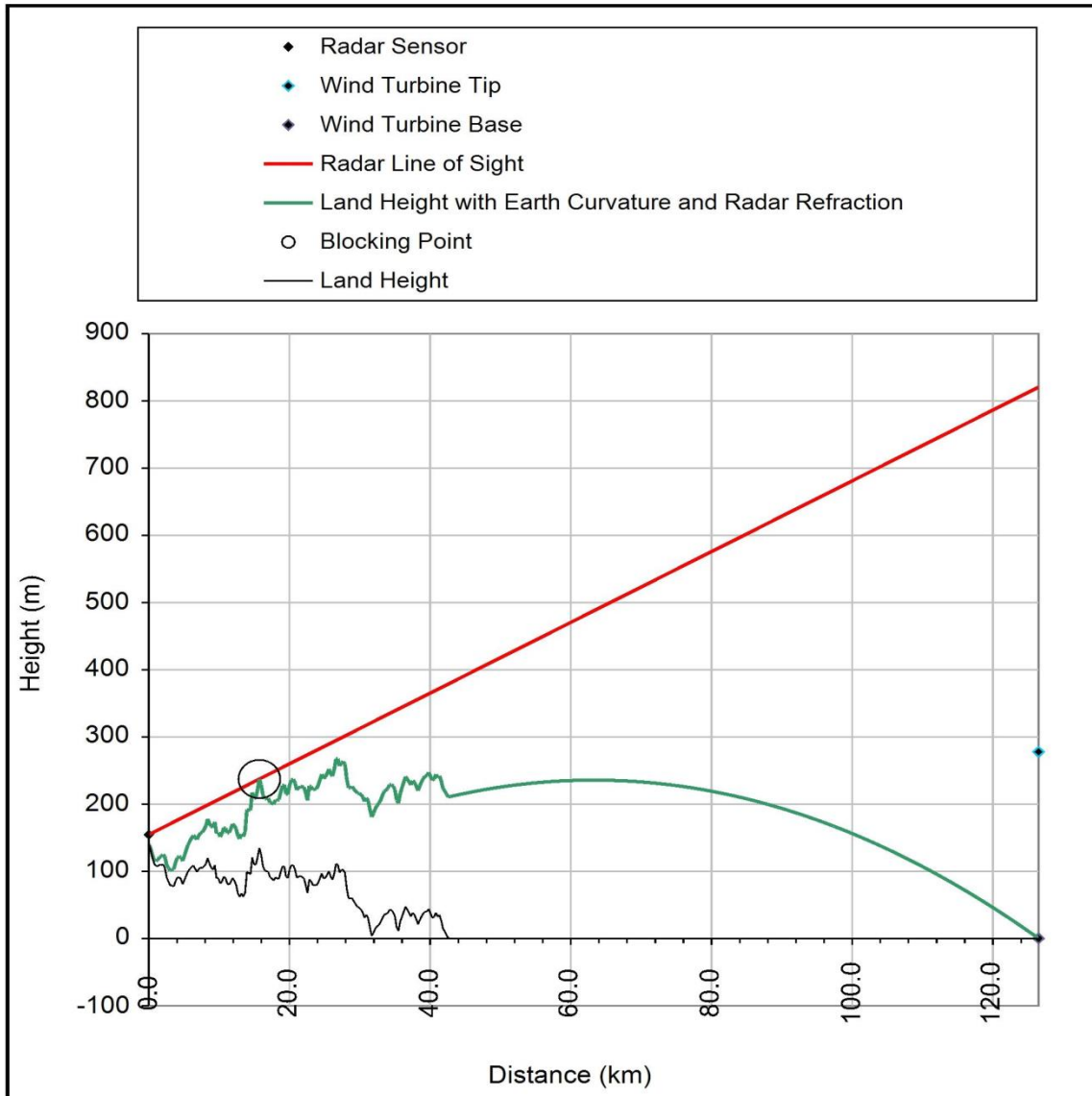
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## Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

### Seagreen (Allanshill)

Turbine	B2
Result	<b>HIDDEN</b>
Certainty	543.1 metres



Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	<b>E415351 N737561</b>
Distance to radar (km)	126.5
Blocking Point Location	<b>E393344 N846074</b>
Distance to BP (km)	110.7

### Additional Analysis

Angle (Radar to Tip)	0.371 degrees down
Maximum Tip Height	820.76 metres

See Appendix for further information

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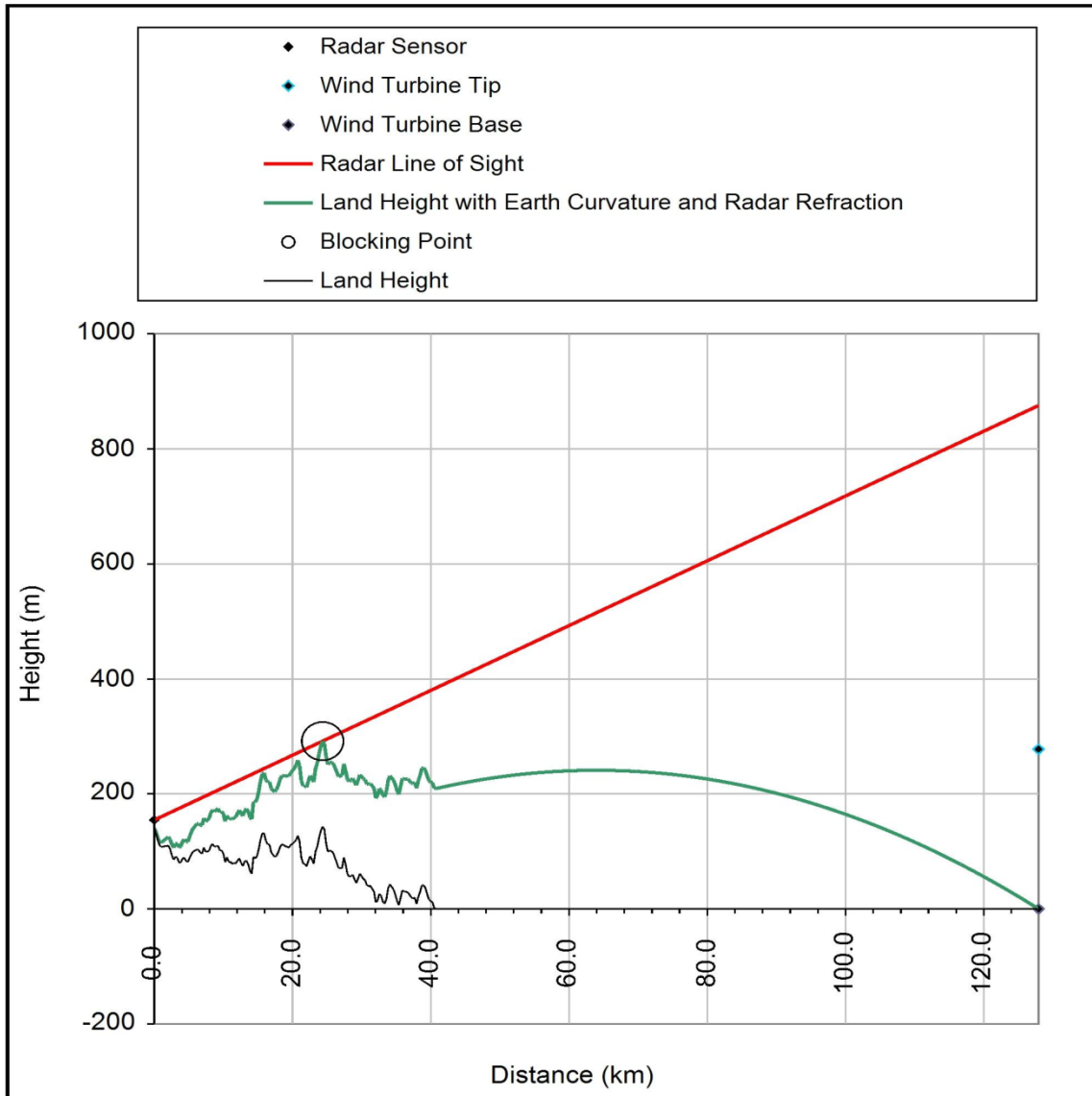


### Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

#### Seagreen (Allanshill)

Turbine	B3
Result	<b>HIDDEN</b>
Certainty	597.8 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)	127.9
Blocking Point Location	E395962 N837813
Distance to BP (km)	103.5

#### Additional Analysis

Angle (Radar to Tip)	0.376 degrees down
Maximum Tip Height	875.47 metres

See Appendix for further information

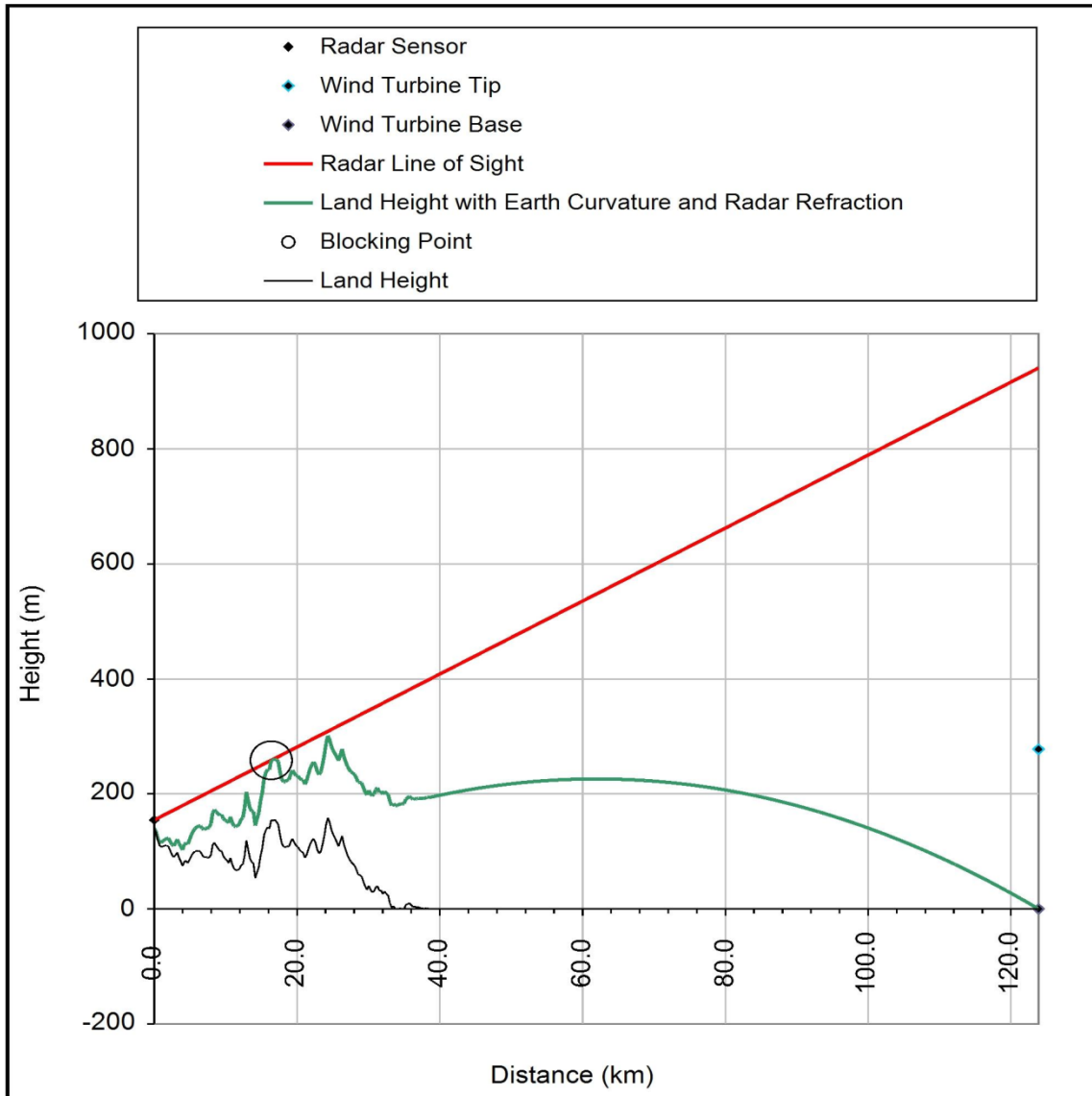
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### Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

#### Seagreen (Allanshill)

Turbine	B4
Result	<b>HIDDEN</b>
Certainty	663.0 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)	123.9
Blocking Point Location	E394868 N845766
Distance to BP (km)	107.4

#### Additional Analysis

Angle (Radar to Tip)	0.361 degrees down
Maximum Tip Height	940.74 metres

See Appendix for further information

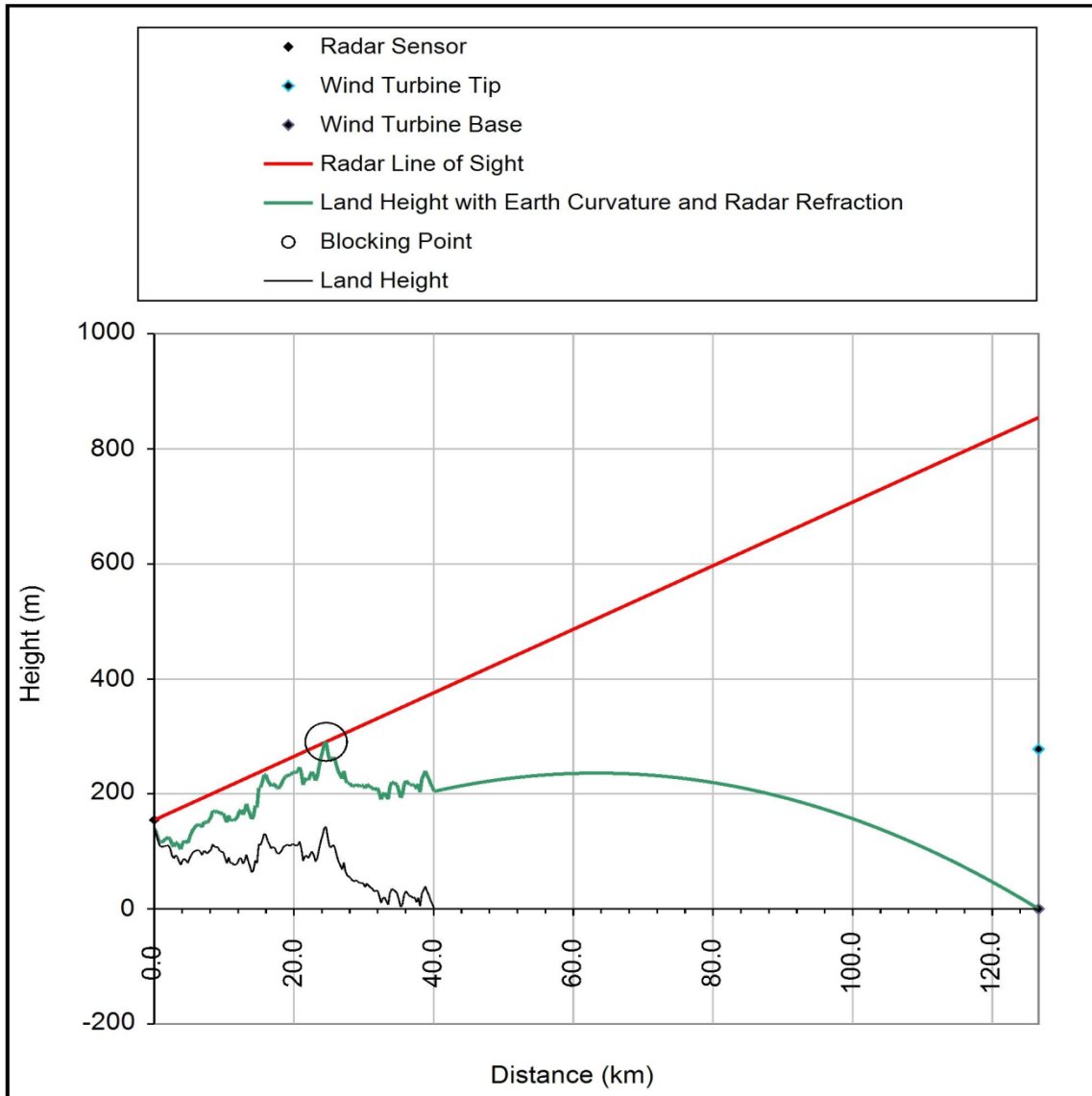
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## Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

### Seagreen (Allanshill)

Turbine	B5
Result	<b>HIDDEN</b>
Certainty	576.8 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)	126.6
Blocking Point Location	E396290 N837627
Distance to BP (km)	102.0

### Additional Analysis

Angle (Radar to Tip)	0.371 degrees down
Maximum Tip Height	854.53 metres

See Appendix for further information

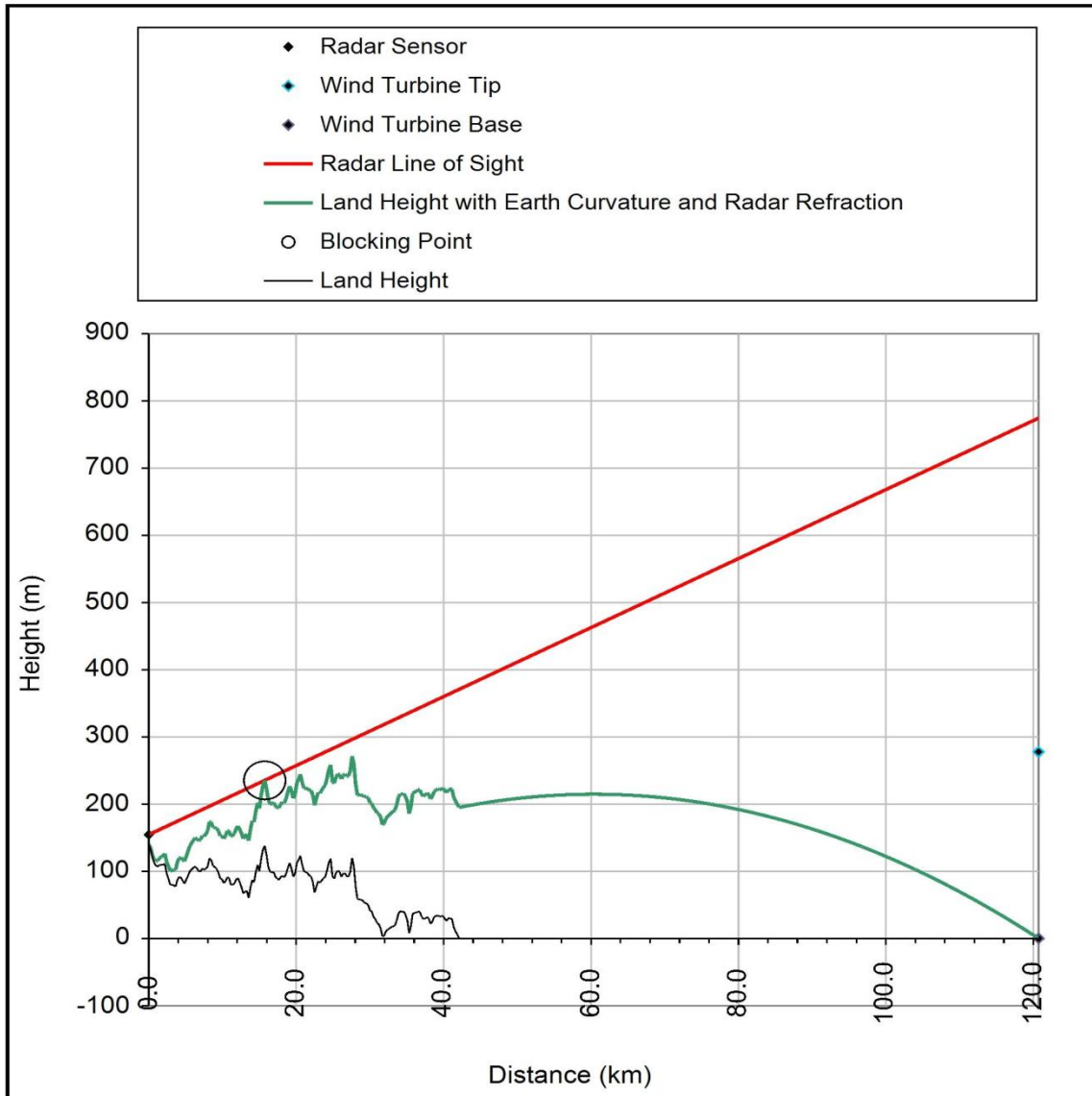
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### Radar Line of Sight Calculation

Prepared for Pager Power  
Allanshill PSR (NATS)

#### Seagreen (Allanshill)

Turbine	B6
Result	<b>HIDDEN</b>
Certainty	496.9 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)	120.7
Blocking Point Location	E393489 N846095
Distance to BP (km)	104.9

#### Additional Analysis

Angle (Radar to Tip)	0.349 degrees down
Maximum Tip Height	774.63 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	221.1 metres	0.307 degrees down	498.84 metres
A2	HIDDEN	390.6 metres	0.312 degrees down	668.33 metres
A3	HIDDEN	436.4 metres	0.324 degrees down	714.15 metres
A4	HIDDEN	484.5 metres	0.345 degrees down	762.19 metres
A5	HIDDEN	324.4 metres	0.357 degrees down	602.08 metres
A6	HIDDEN	408.2 metres	0.364 degrees down	685.87 metres
A7	HIDDEN	307.1 metres	0.354 degrees down	584.81 metres
A8	HIDDEN	212.7 metres	0.326 degrees down	490.38 metres
B1	HIDDEN	355.4 metres	0.366 degrees down	633.06 metres
B2	HIDDEN	543.1 metres	0.371 degrees down	820.76 metres
B3	HIDDEN	597.8 metres	0.376 degrees down	875.47 metres
B4	HIDDEN	663.0 metres	0.361 degrees down	940.74 metres
B5	HIDDEN	576.8 metres	0.371 degrees down	854.53 metres
B6	HIDDEN	496.9 metres	0.349 degrees down	774.63 metres

Column Descriptions	
Wind Turbine	Turbine Number as entered or uploaded
Result	<b>VISIBLE</b> turbines are likely to affect the radar whereas <b>HIDDEN</b> 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 <b>HIDDEN</b> . A turbine that was any higher would be <b>VISIBLE</b> .



### 3 REQUESTED ASSESSMENT

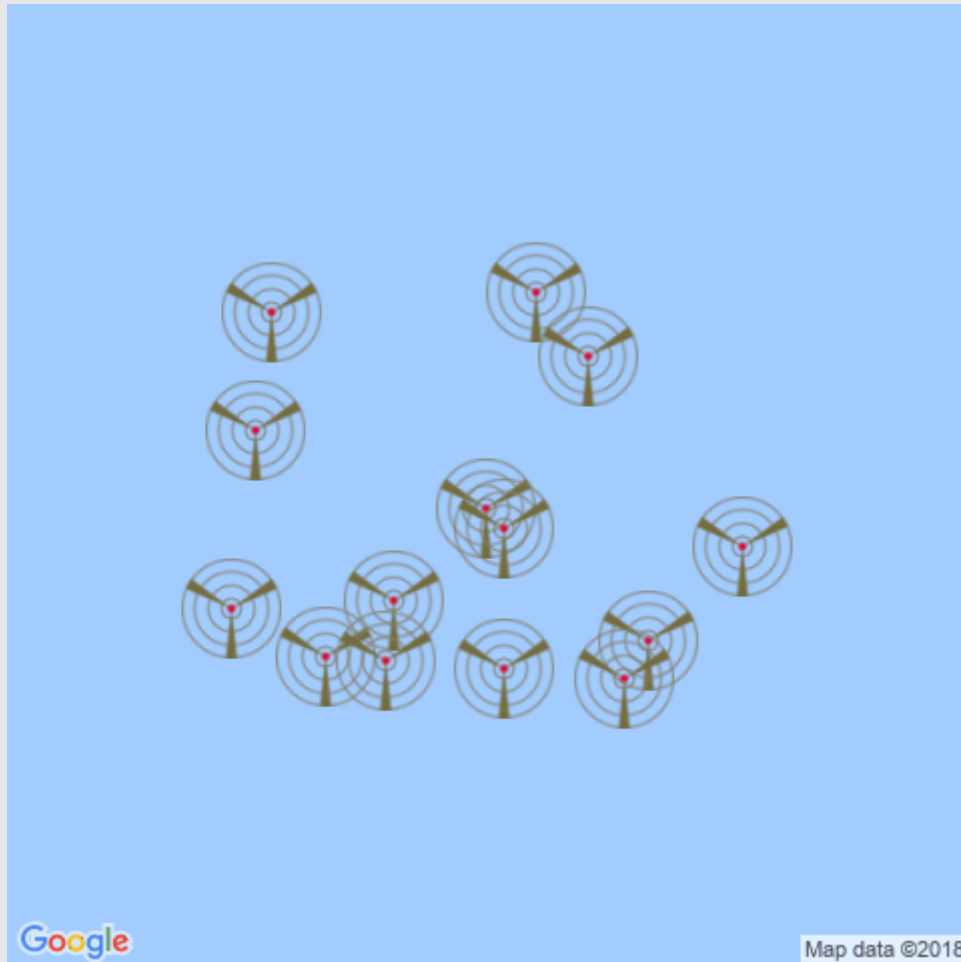
Key Parameters
<ul style="list-style-type: none"> <li>• This Radar Line of Sight Assessment for Seagreen (Allanshill) was requested by Mike Watson of Pager Power on 7th February 2018.</li> <li>• Assessment Methodology = Radar Line of Sight Calculation using advanced terrain data processing algorithm.</li> <li>• Coordinate System = Local Grid</li> <li>• Vertical Units = Metres</li> </ul>

Radar
<ul style="list-style-type: none"> <li>• The assessed radar was Allanshill PSR (NATS)</li> <li>• Location and height information for preselected radar are sourced from a managed database</li> </ul>

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 (Allanshill)

### Aerial Photograph Showing Assessed Turbine Locations



Seagreen (Allanshill)

## 4 METHODOLOGY AND BACKGROUND

### Introduction

This report indicates whether wind turbines at the Seagreen (Allanshill) will be detected by the Allanshill 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 (Allanshill) will be within Radar Line of Sight of the Allanshill 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

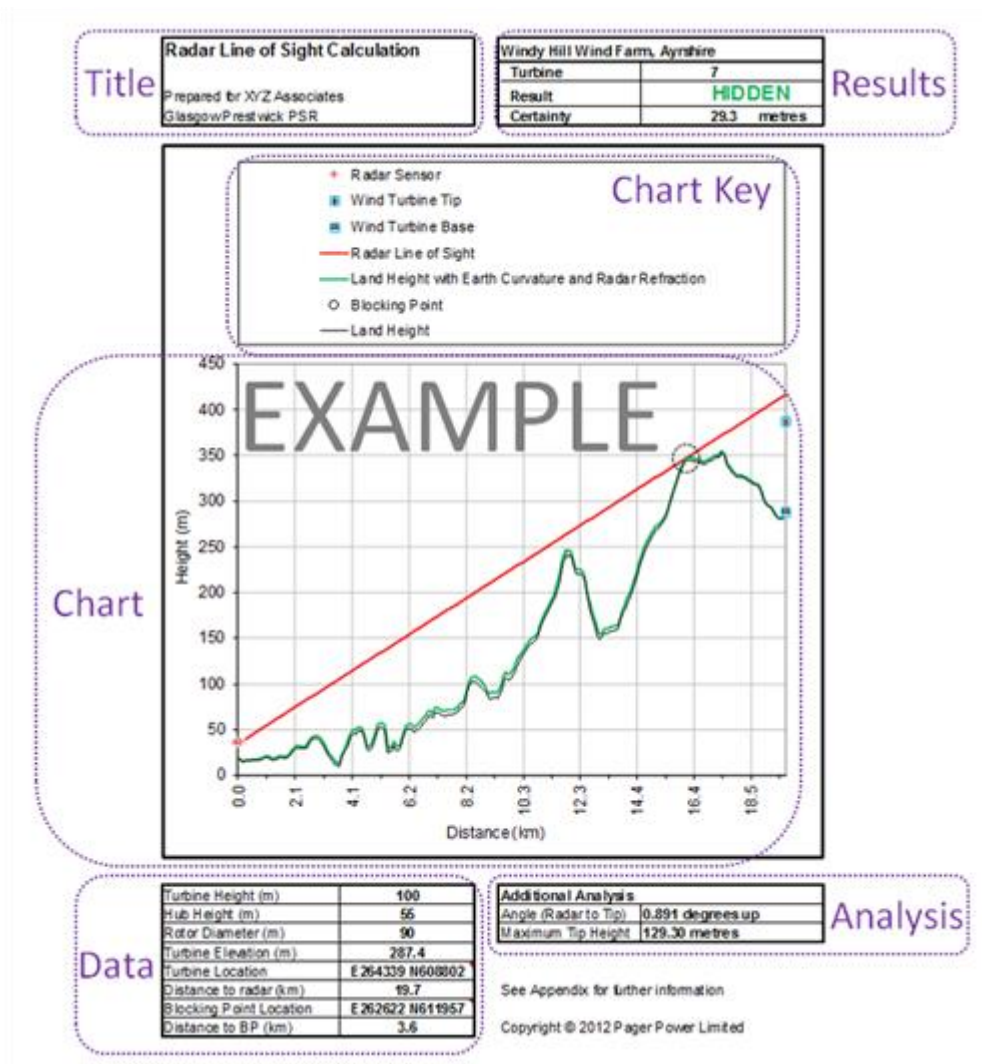


Diagram showing areas of a Radar Line of Sight Calculation

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	<b>VISIBLE</b> turbines are likely to affect the radar whereas <b>HIDDEN</b> 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 <b>HIDDEN</b> . A turbine that was any higher would be <b>VISIBLE</b> .