



PAGERPOWER

Seagreen (Buchan)

Radar Line of Sight Assessment (Eurocontrol, CAA, RAF, NATS) Buchan ASACS (RAF)

Pager Power

Seagreen (Buchan)

7th February 2018

Without Expert Commentary

Pager Power Ltd

New Mill, Bakers Court

Great Cornard, Suffolk, UK

T: +44 1787 319001



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 09:17 BST

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

Copyright © 2018 Pager Power Limited

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

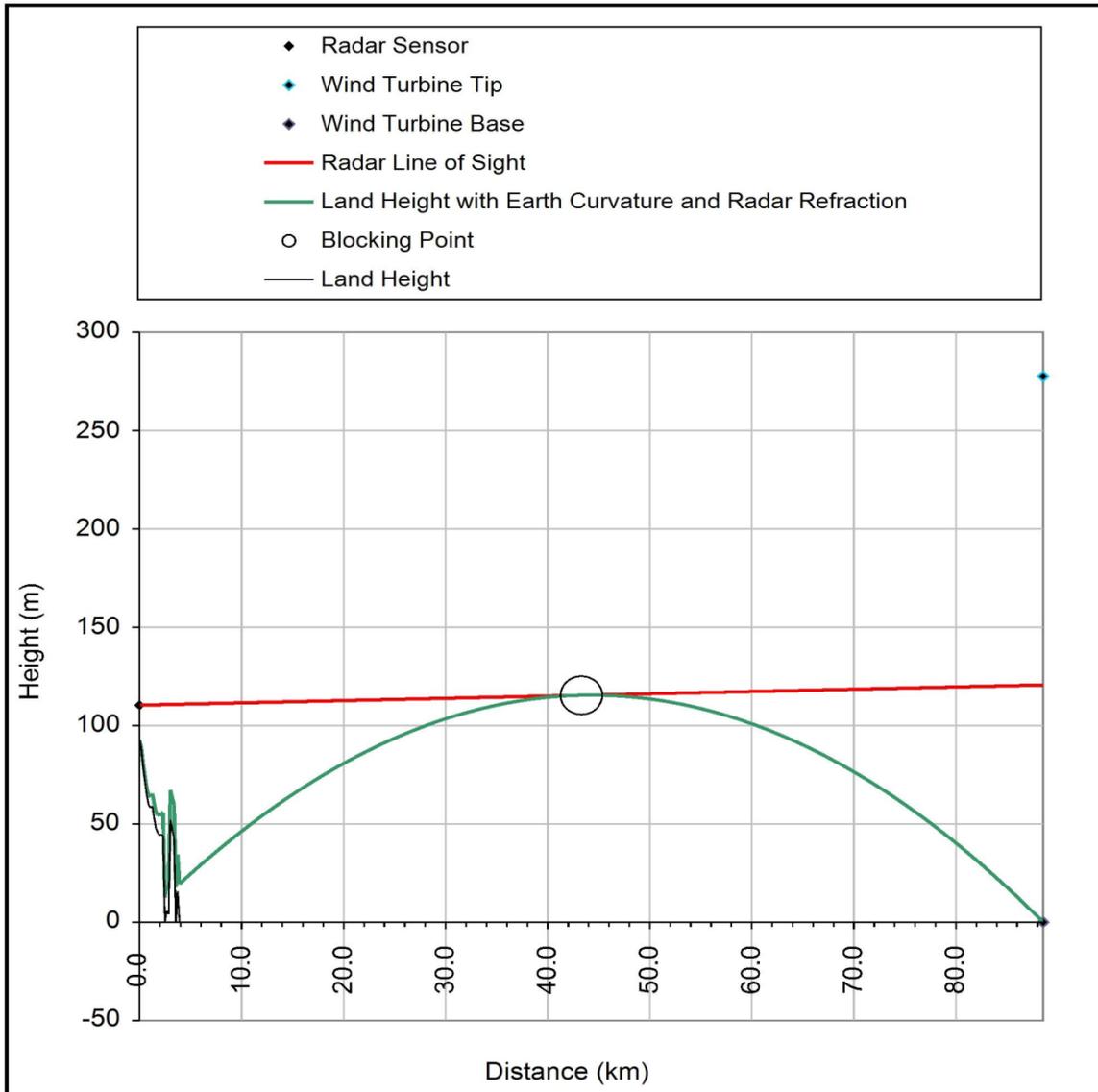
B1	VISIBLE
B2	VISIBLE
B3	VISIBLE
B4	VISIBLE
B5	VISIBLE
B6	VISIBLE
<p>Explanation: There is one Radar Line of Sight Calculation page for each turbine assessed. Each calculation shows whether the turbine is VISIBLE or HIDDEN. Visible turbines are likely to affect the radar whereas hidden turbines are unlikely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

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	A1
Result	VISIBLE
Certainty	157.0 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)	88.5
Blocking Point Location	E408446 N797653
Distance to BP (km)	45.2

Additional Analysis

Angle (Radar to Tip)	0.190 degrees down
Maximum Tip Height	120.68 metres

See Appendix for further information

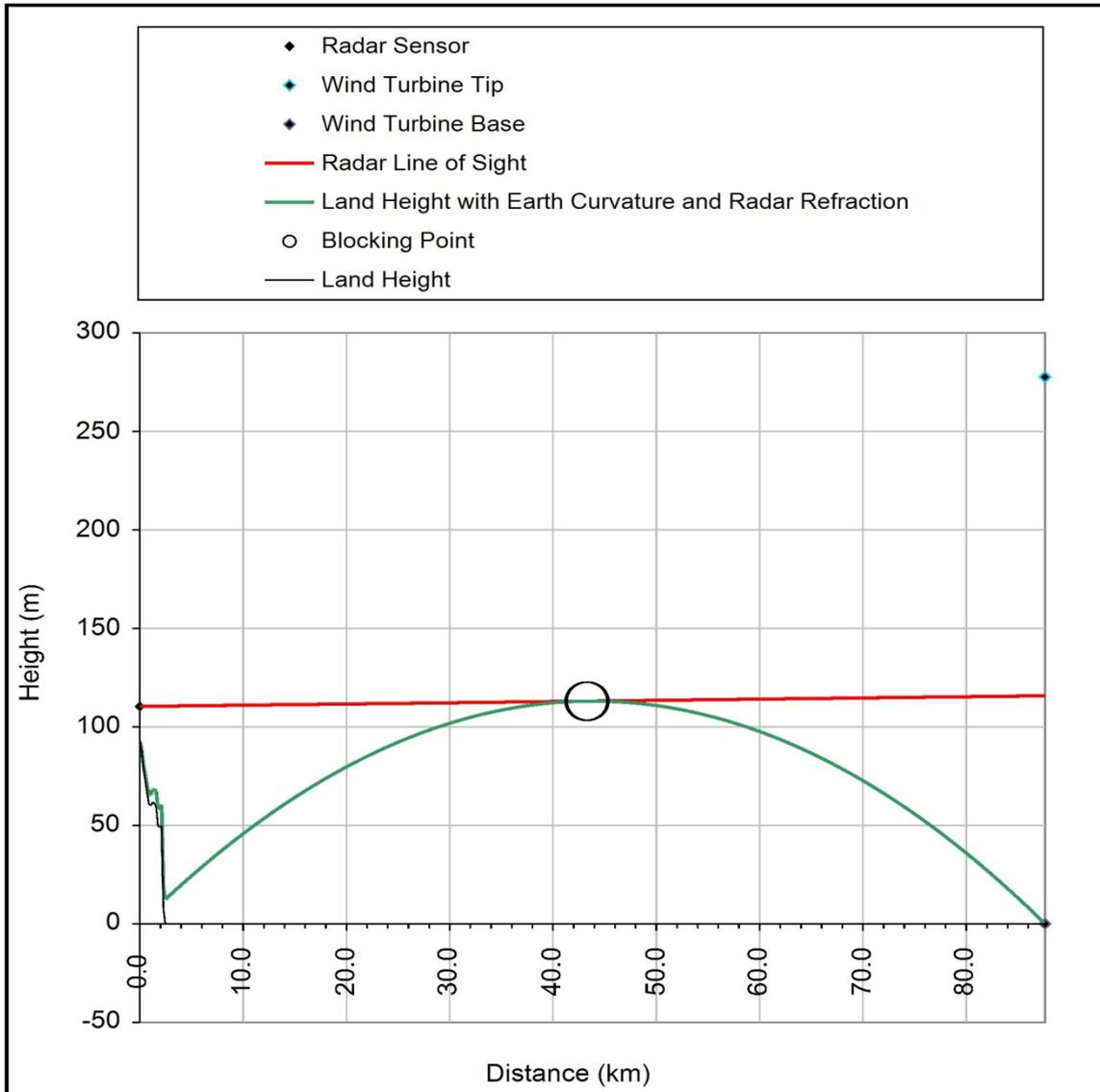
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	A2
Result	VISIBLE
Certainty	161.9 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)	87.6
Blocking Point Location	E413910 N797570
Distance to BP (km)	44.2

Additional Analysis

Angle (Radar to Tip)	0.186 degrees down
Maximum Tip Height	115.82 metres

See Appendix for further information

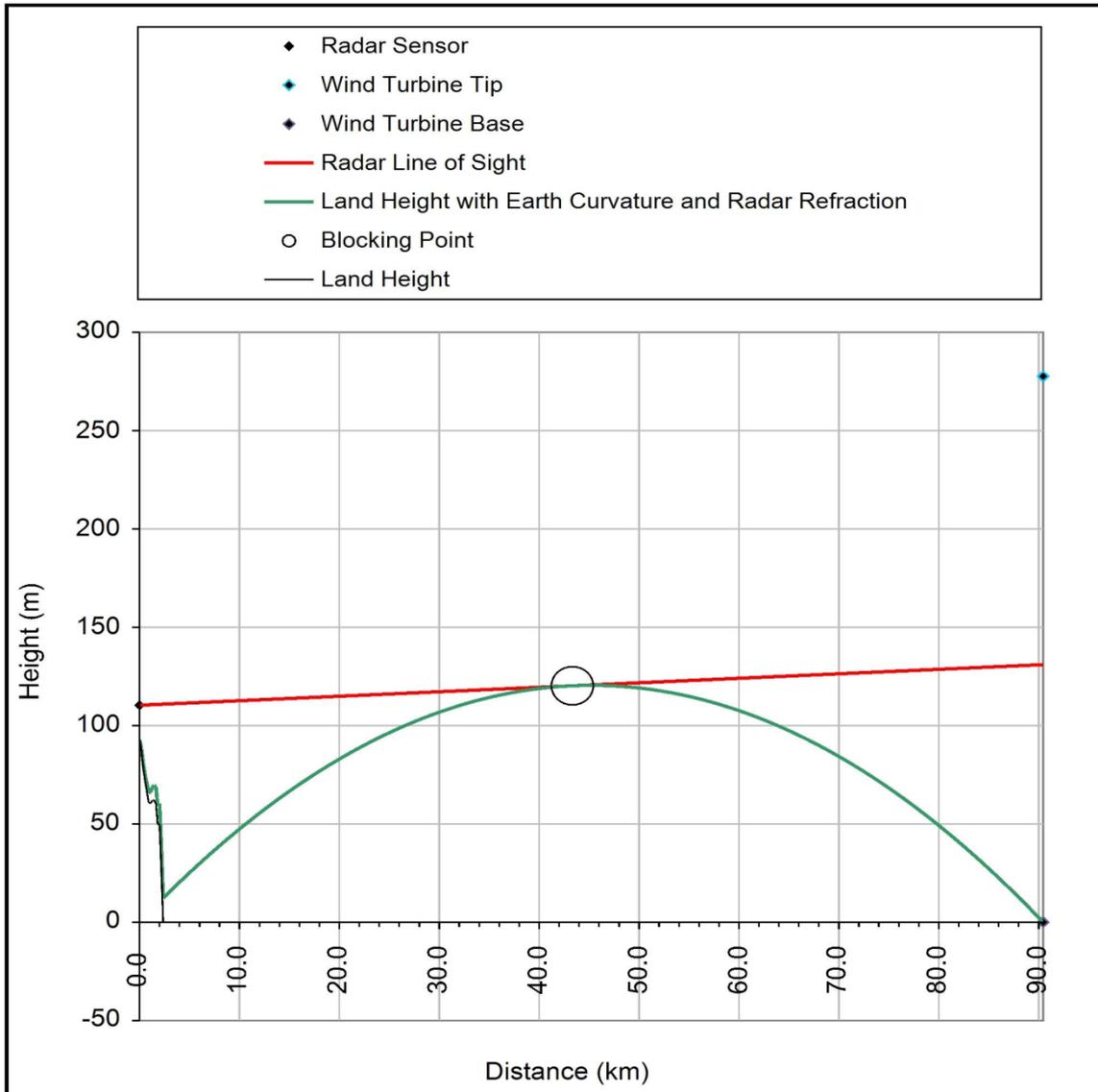
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	A3
Result	VISIBLE
Certainty	146.7 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)	90.4
Blocking Point Location	E414865 N797693
Distance to BP (km)	47.1

Additional Analysis

Angle (Radar to Tip)	0.199 degrees down
Maximum Tip Height	131.04 metres

See Appendix for further information

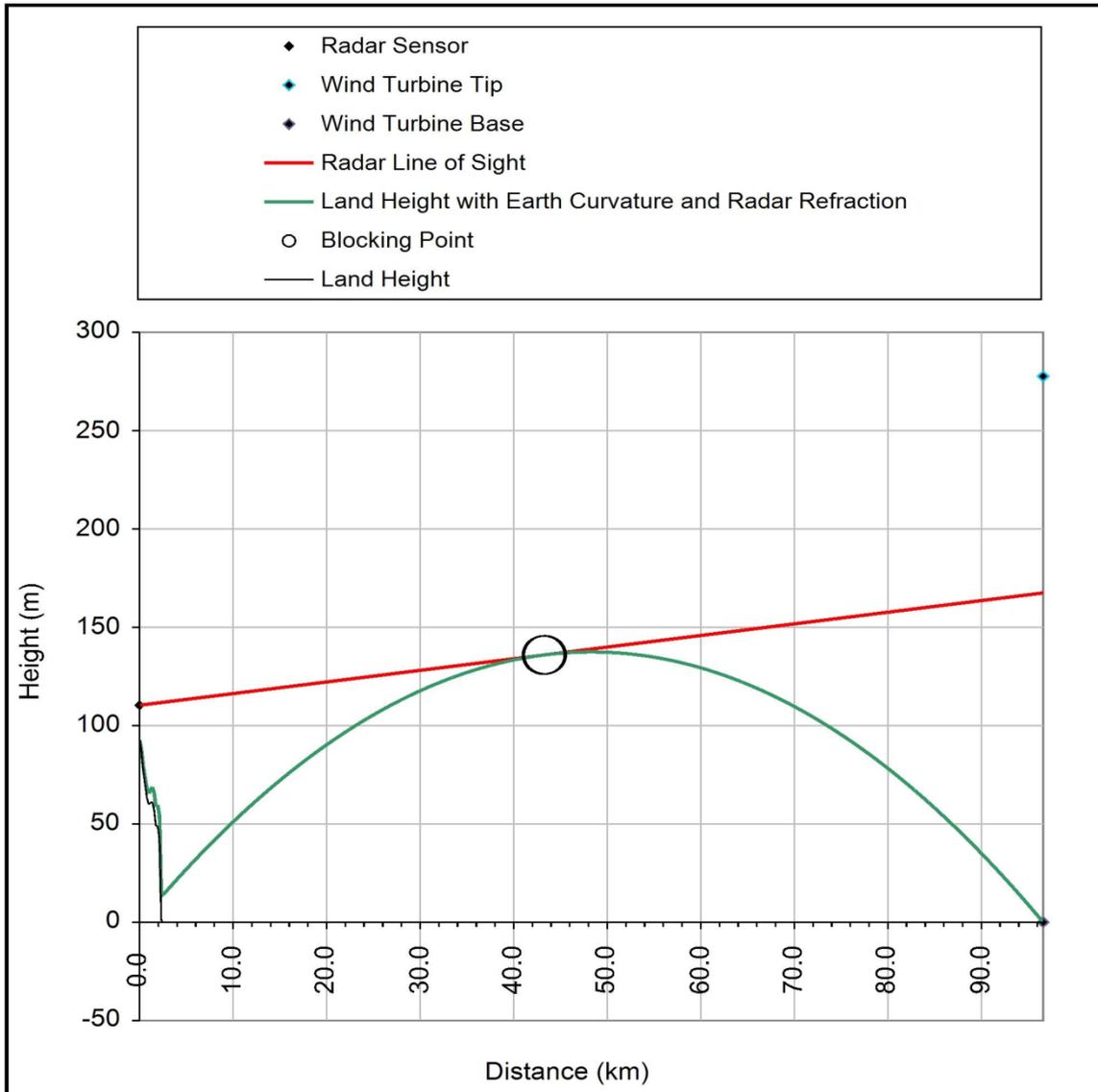
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	A4
Result	VISIBLE
Certainty	110.2 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)	96.6
Blocking Point Location	E412731 N797519
Distance to BP (km)	53.2

Additional Analysis	
Angle (Radar to Tip)	0.227 degrees down
Maximum Tip Height	167.52 metres

See Appendix for further information

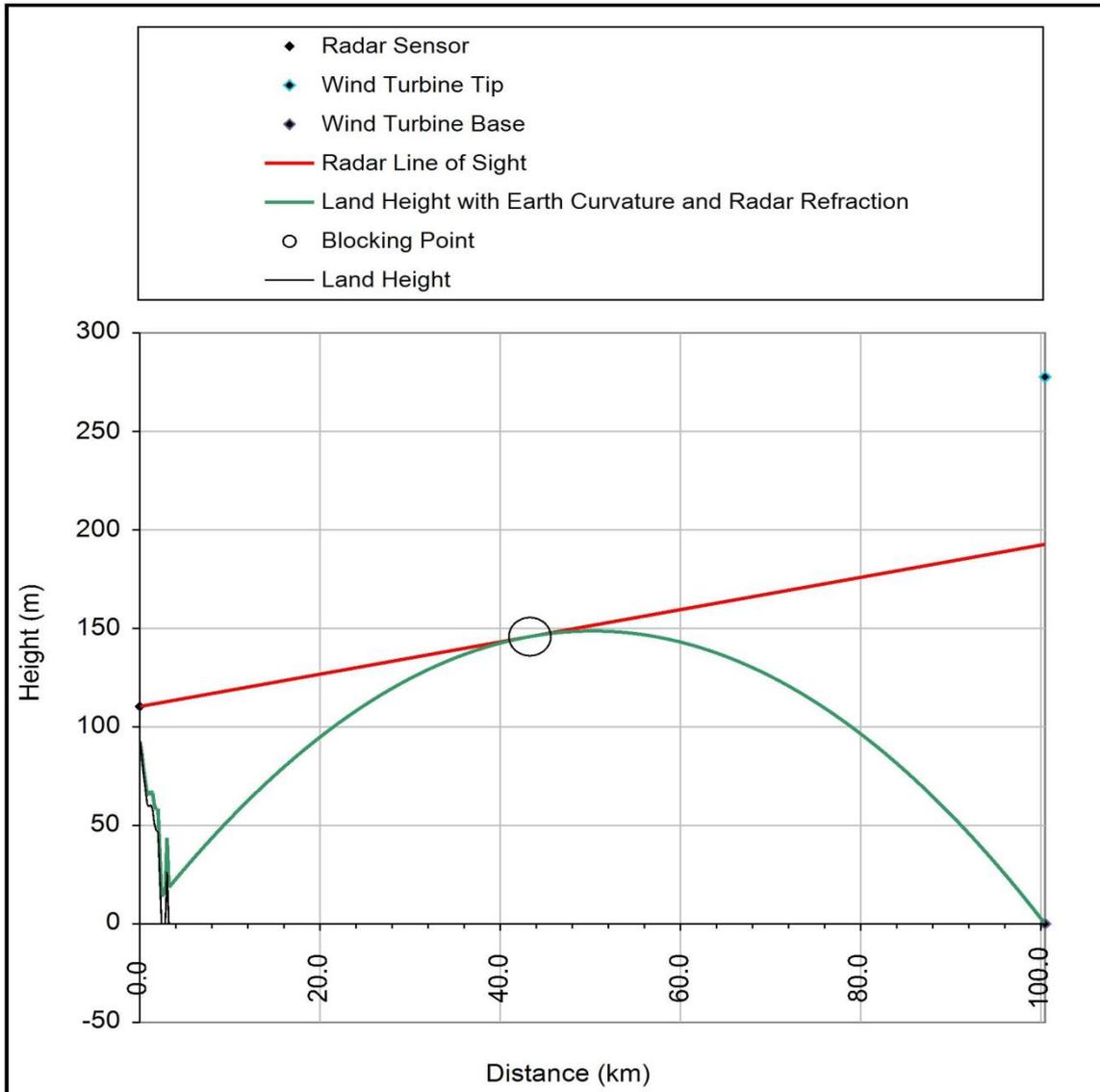
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	A5
Result	VISIBLE
Certainty	85.0 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)	100.5
Blocking Point Location	E410986 N797569
Distance to BP (km)	57.2

Additional Analysis	
Angle (Radar to Tip)	0.243 degrees down
Maximum Tip Height	192.72 metres

See Appendix for further information

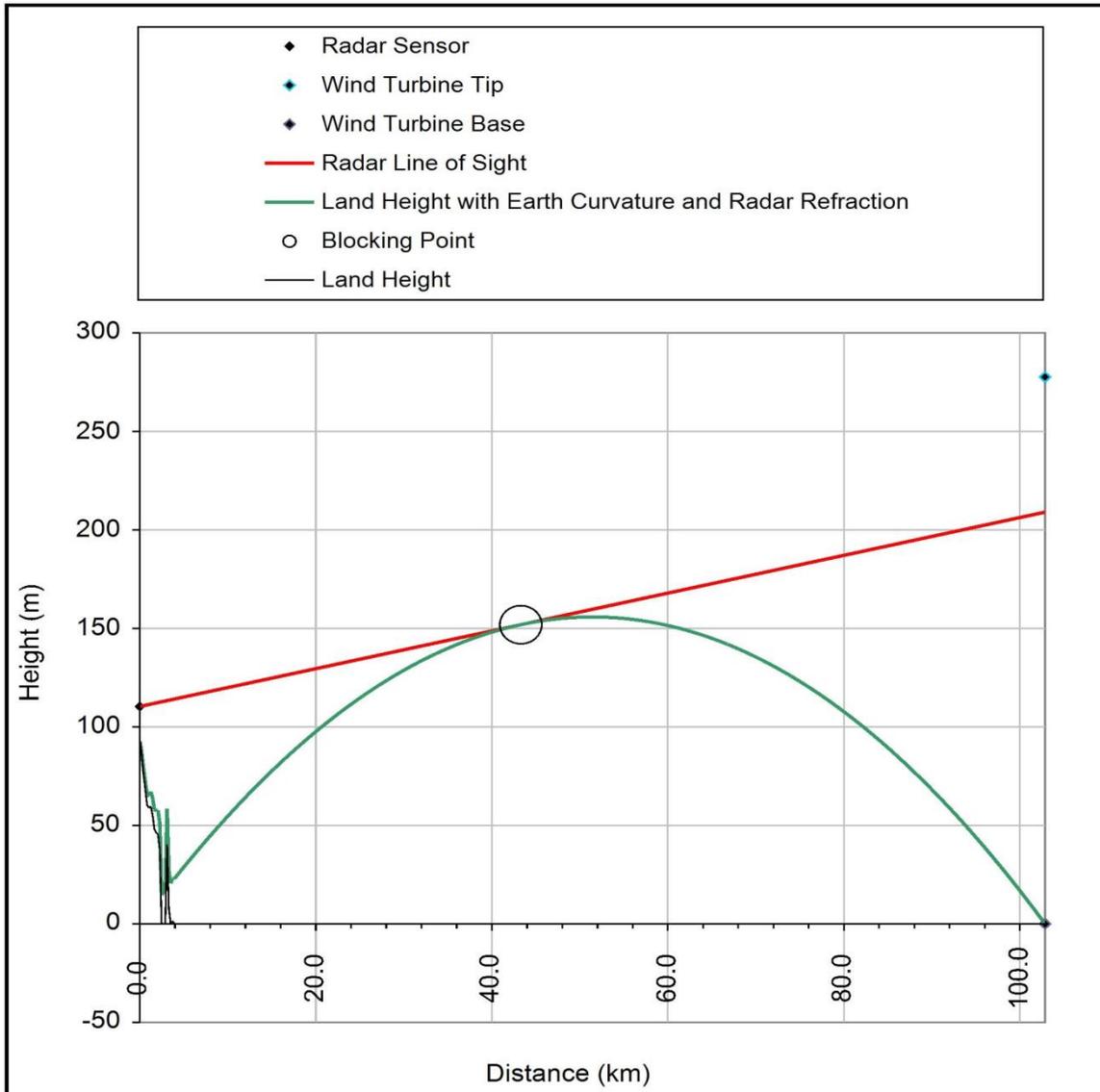
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	A6
Result	VISIBLE
Certainty	68.6 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)	102.9
Blocking Point Location	E409792 N797599
Distance to BP (km)	59.5

Additional Analysis

Angle (Radar to Tip)	0.254 degrees down
Maximum Tip Height	209.06 metres

See Appendix for further information

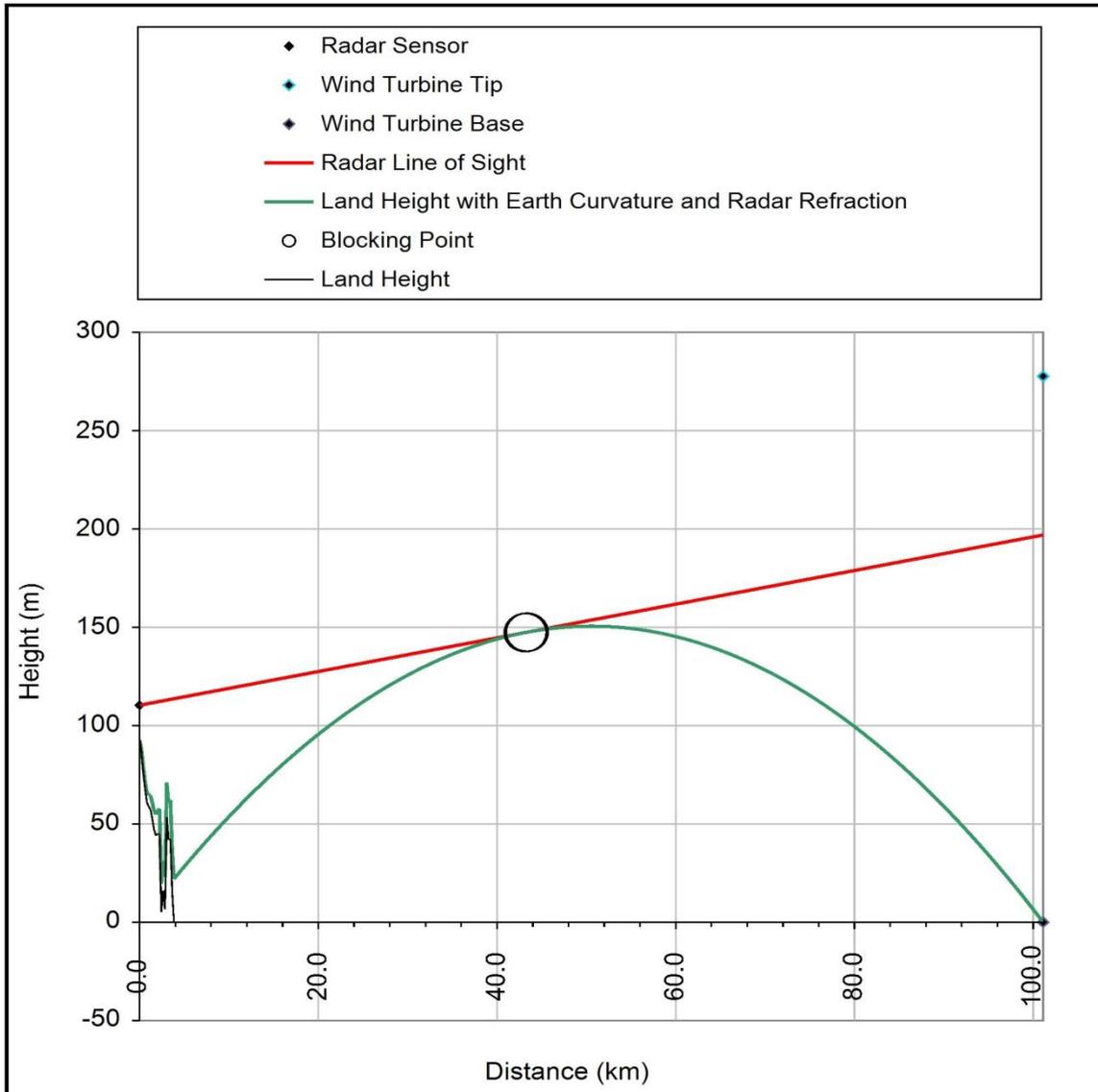
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	A7
Result	VISIBLE
Certainty	80.7 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)	101.1
Blocking Point Location	E408066 N797613
Distance to BP (km)	57.7

Additional Analysis

Angle (Radar to Tip)	0.246 degrees down
Maximum Tip Height	197.01 metres

See Appendix for further information

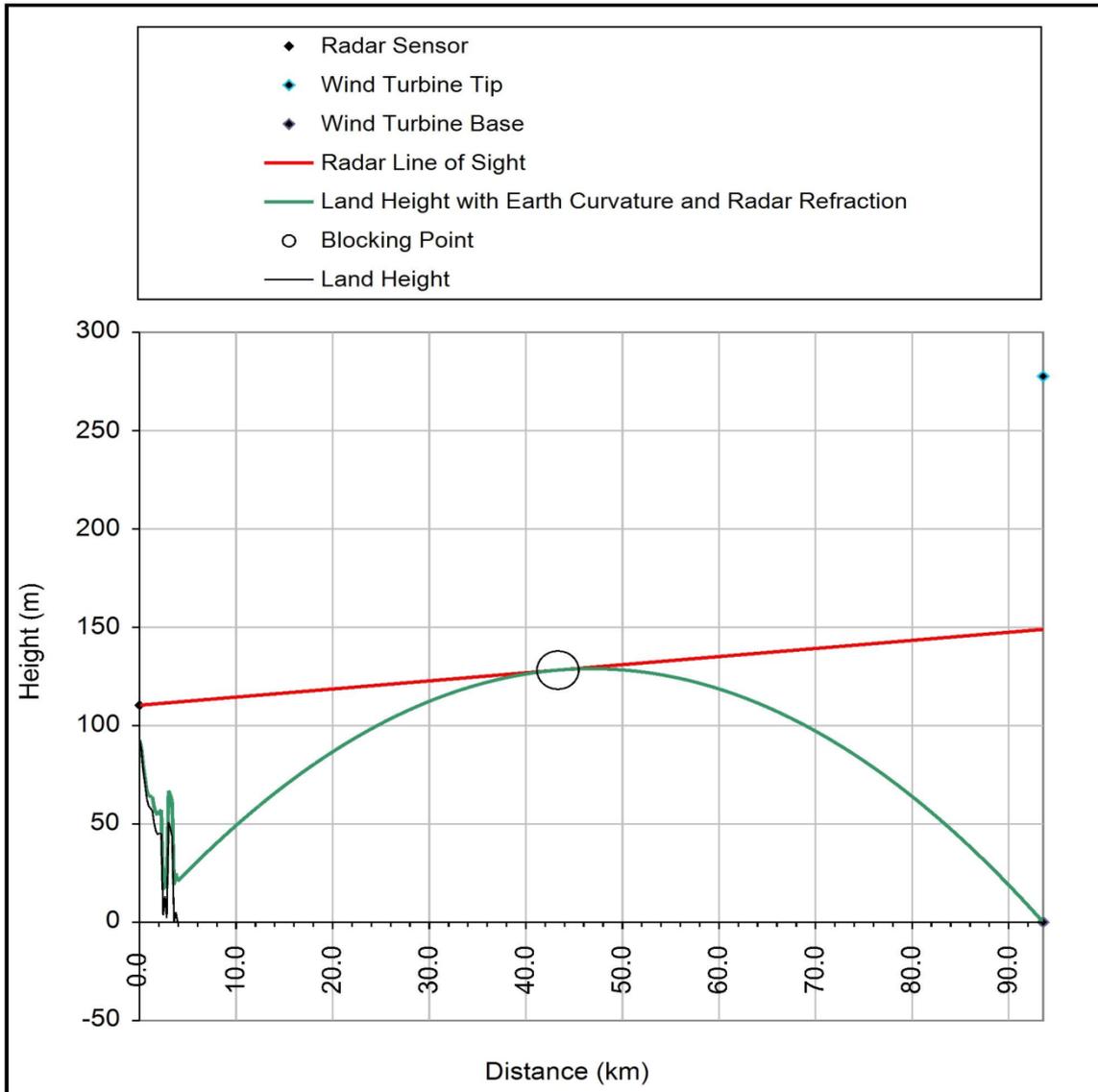
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	A8
Result	VISIBLE
Certainty	128.7 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)	93.6
Blocking Point Location	E408282 N797644
Distance to BP (km)	50.2

Additional Analysis

Angle (Radar to Tip)	0.213 degrees down
Maximum Tip Height	148.98 metres

See Appendix for further information

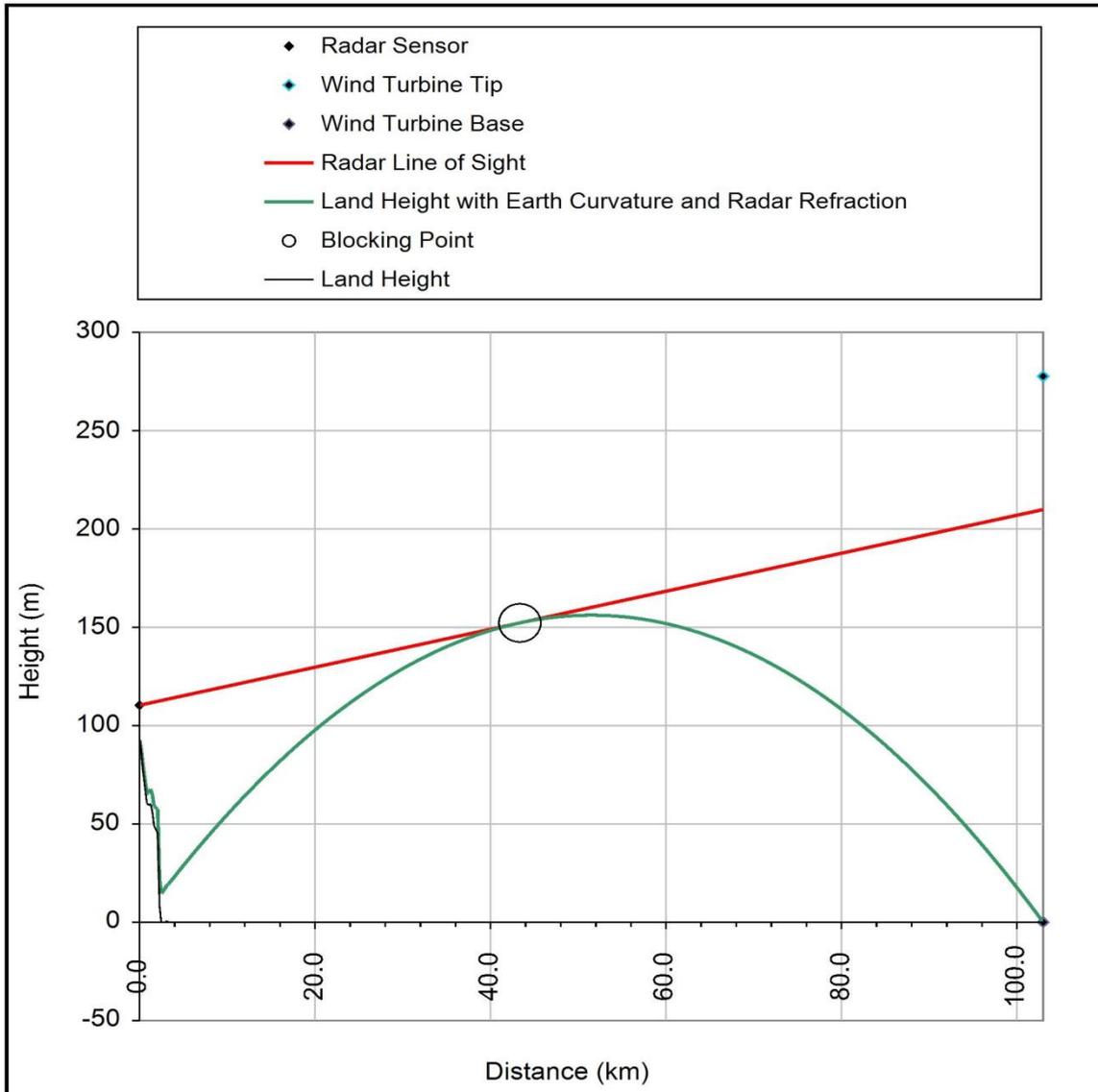
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	B1
Result	VISIBLE
Certainty	67.8 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)	103.0
Blocking Point Location	E410850 N797525
Distance to BP (km)	59.6

Additional Analysis

Angle (Radar to Tip)	0.254 degrees down
Maximum Tip Height	209.92 metres

See Appendix for further information

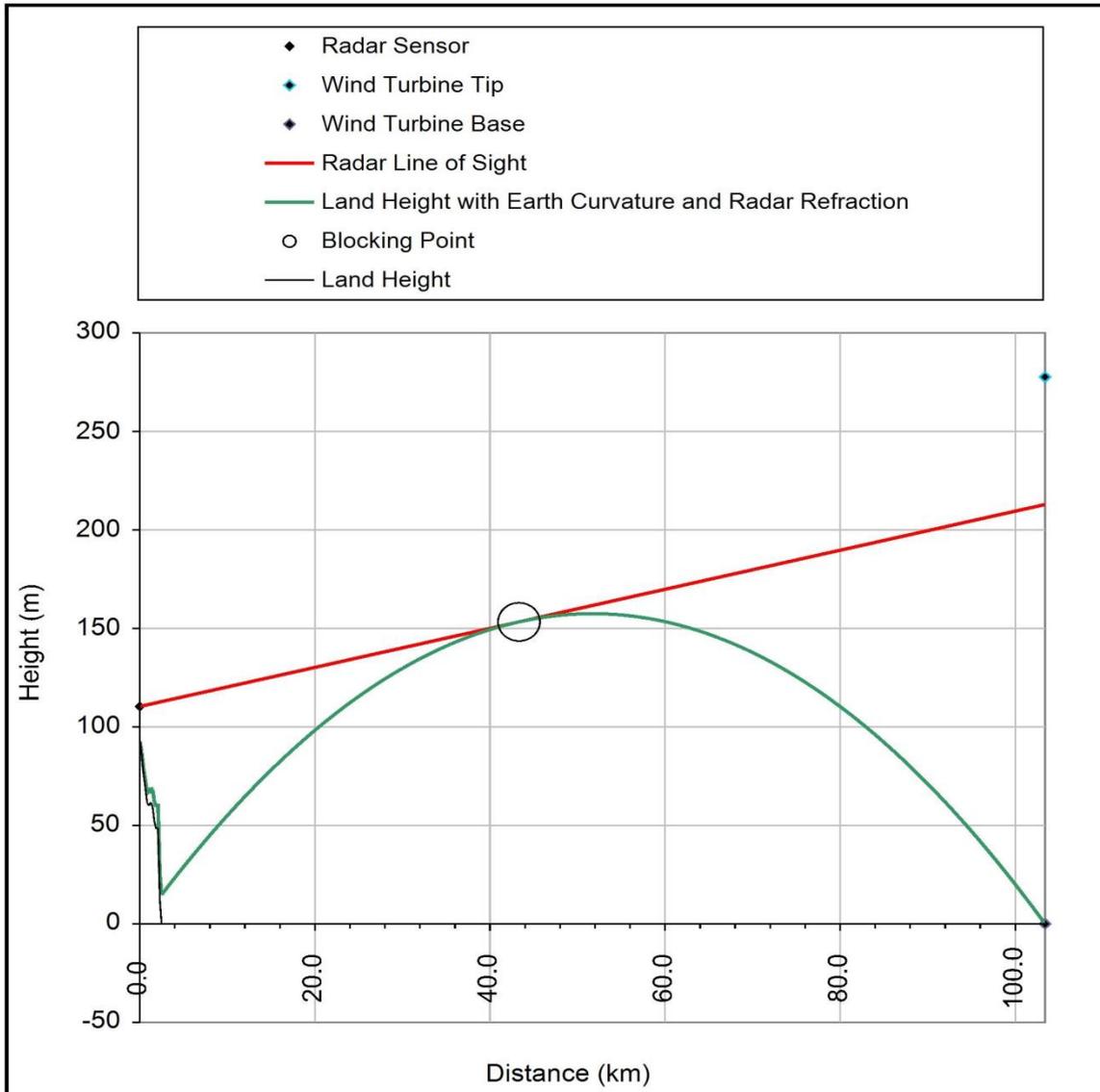
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	B2
Result	VISIBLE
Certainty	64.8 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)	103.4
Blocking Point Location	E412955 N797585
Distance to BP (km)	60.1

Additional Analysis

Angle (Radar to Tip)	0.256 degrees down
Maximum Tip Height	212.95 metres

See Appendix for further information

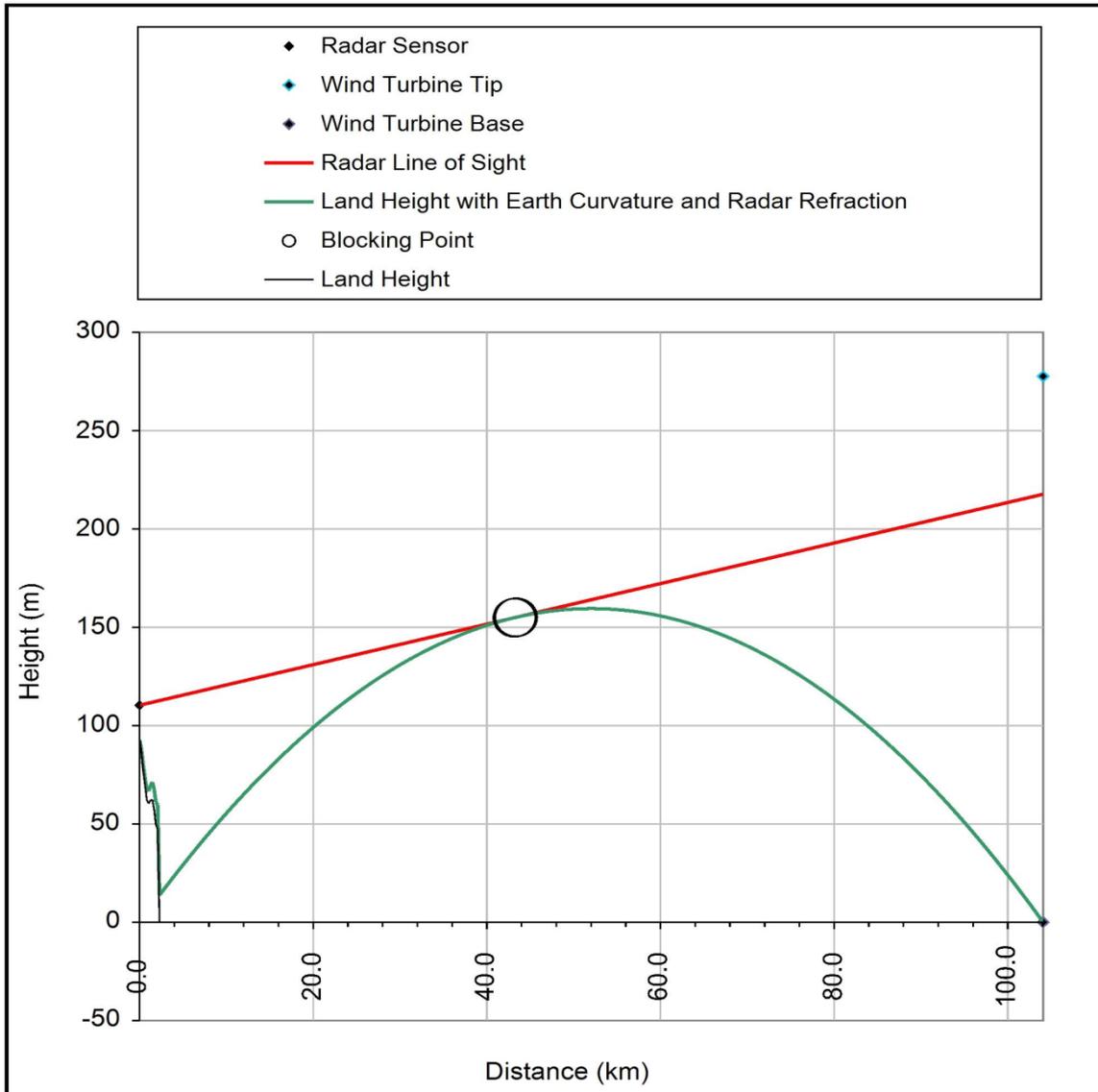
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	B3
Result	VISIBLE
Certainty	60.0 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)	104.1
Blocking Point Location	E415041 N797646
Distance to BP (km)	60.7

Additional Analysis

Angle (Radar to Tip)	0.259 degrees down
Maximum Tip Height	217.72 metres

See Appendix for further information

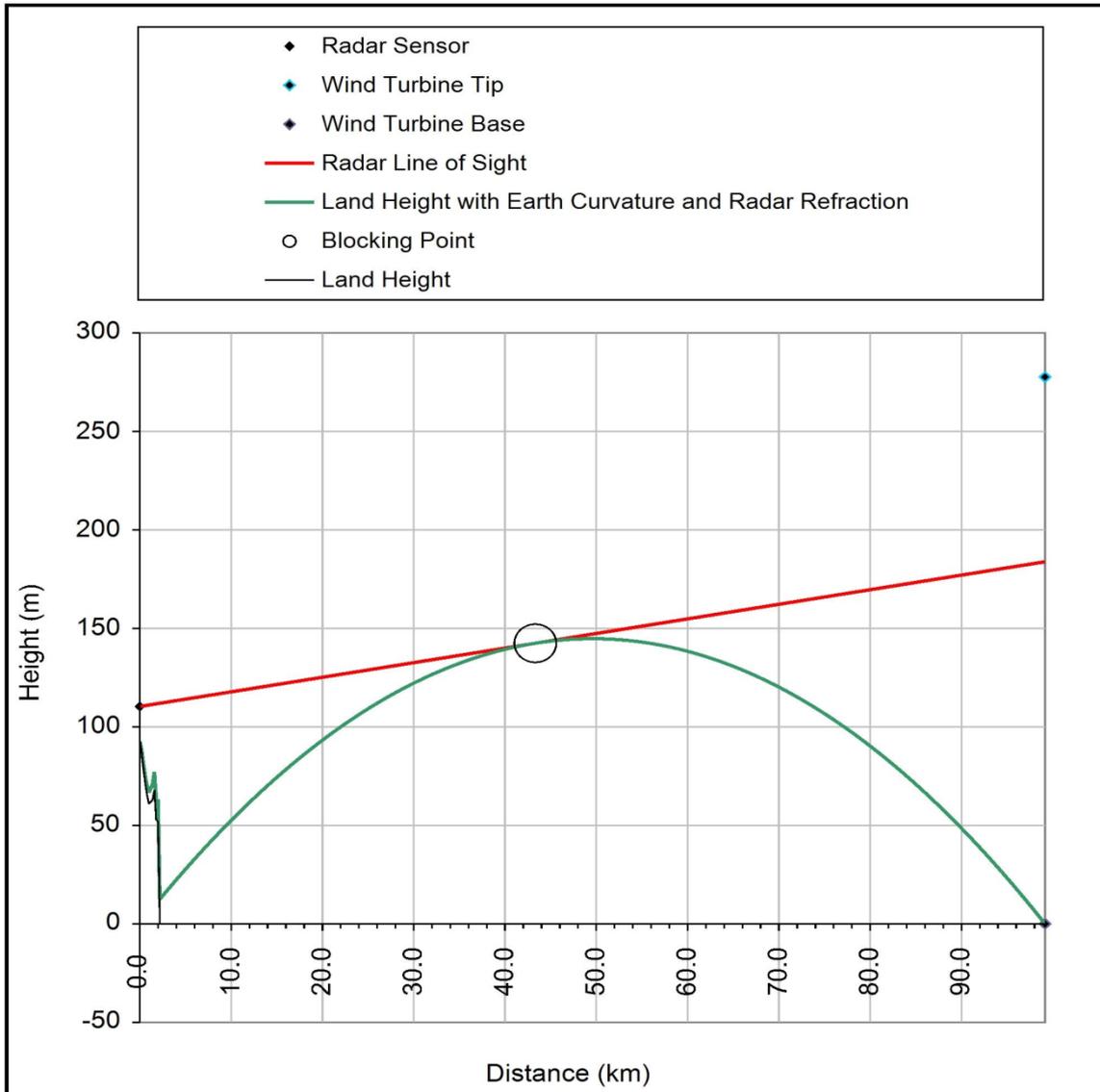
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	B4
Result	VISIBLE
Certainty	93.8 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)	99.2
Blocking Point Location	E417396 N797985
Distance to BP (km)	55.8

Additional Analysis	
Angle (Radar to Tip)	0.238 degrees down
Maximum Tip Height	183.88 metres

See Appendix for further information

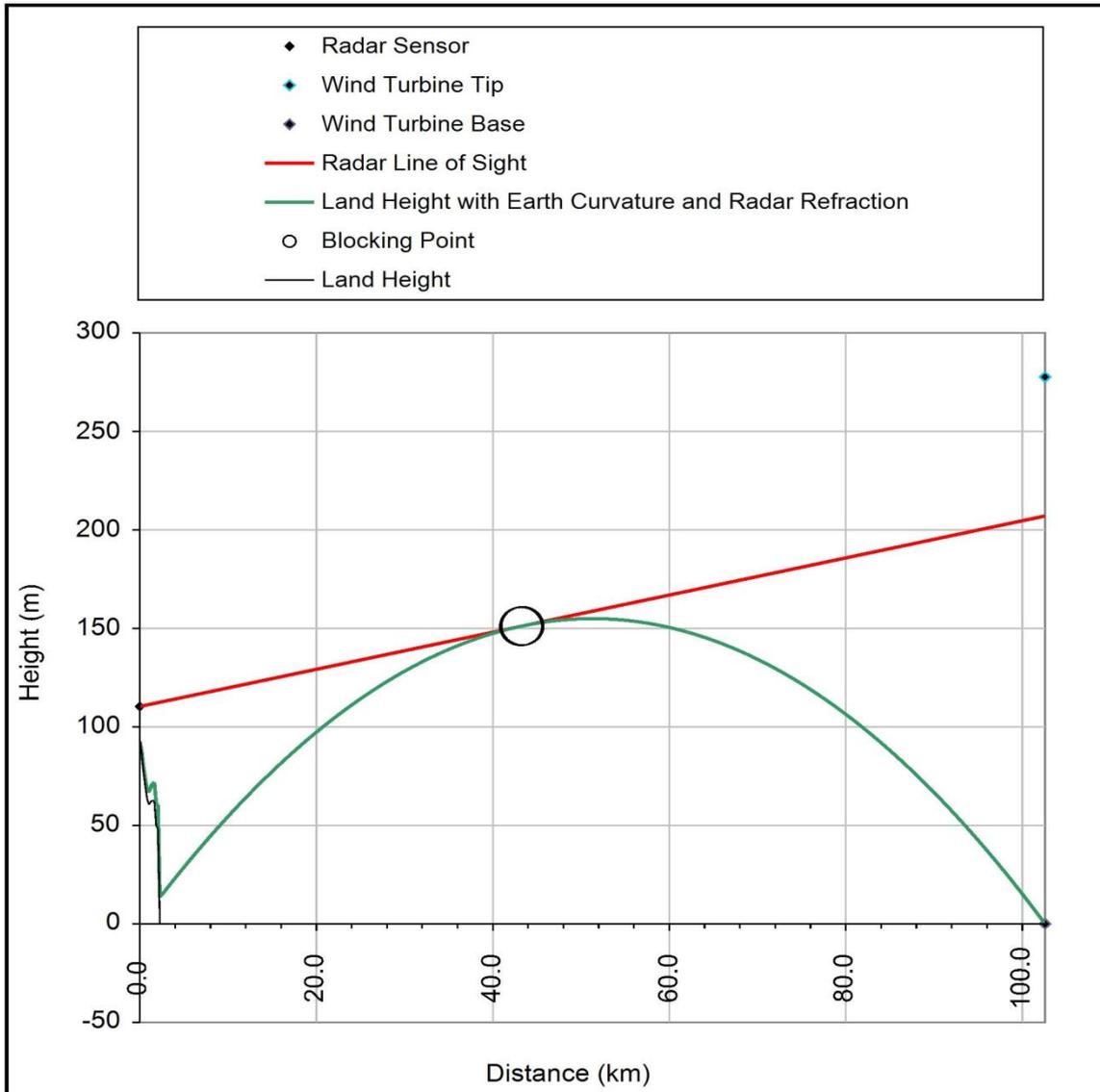
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	B5
Result	VISIBLE
Certainty	70.6 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)	102.6
Blocking Point Location	E415545 N797701
Distance to BP (km)	59.2

Additional Analysis	
Angle (Radar to Tip)	0.252 degrees down
Maximum Tip Height	207.12 metres

See Appendix for further information

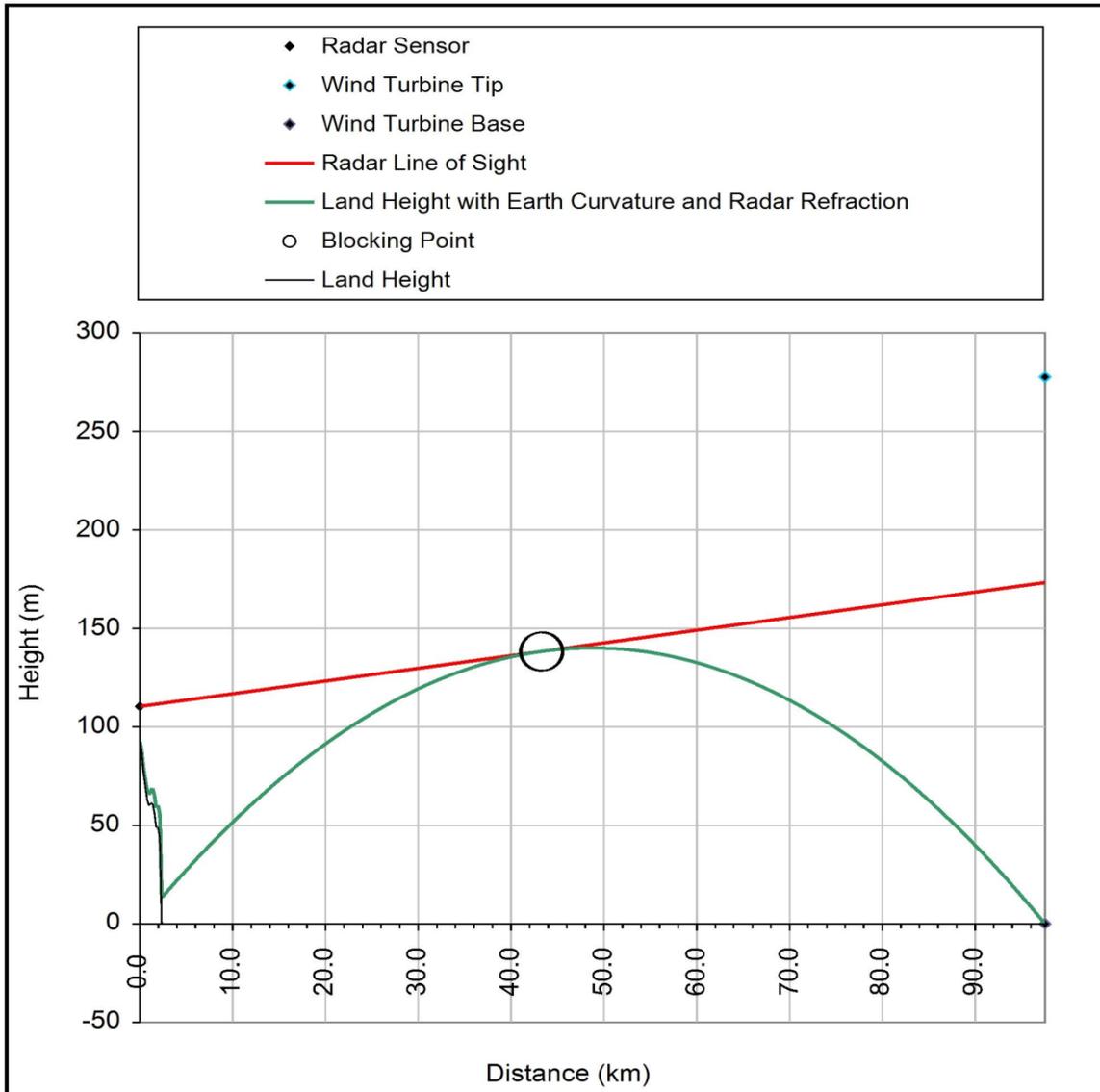
Copyright © 2018 Pager Power Limited

Radar Line of Sight Calculation

Prepared for Pager Power
Buchan ASACS (RAF)

Seagreen (Buchan)

Turbine	B6
Result	VISIBLE
Certainty	104.4 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)	97.5
Blocking Point Location	E413032 N797705
Distance to BP (km)	54.3

Additional Analysis

Angle (Radar to Tip)	0.231 degrees down
Maximum Tip Height	173.33 metres

See Appendix for further information

Copyright © 2018 Pager Power Limited

2 RESULTS SUMMARY

Wind Turbine	Result	Certainty	Angle (Radar to Tip)	Maximum Height
A1	VISIBLE	157.0 metres	0.190 degrees down	120.68 metres
A2	VISIBLE	161.9 metres	0.186 degrees down	115.82 metres
A3	VISIBLE	146.7 metres	0.199 degrees down	131.04 metres
A4	VISIBLE	110.2 metres	0.227 degrees down	167.52 metres
A5	VISIBLE	85.0 metres	0.243 degrees down	192.72 metres
A6	VISIBLE	68.6 metres	0.254 degrees down	209.06 metres
A7	VISIBLE	80.7 metres	0.246 degrees down	197.01 metres
A8	VISIBLE	128.7 metres	0.213 degrees down	148.98 metres
B1	VISIBLE	67.8 metres	0.254 degrees down	209.92 metres
B2	VISIBLE	64.8 metres	0.256 degrees down	212.95 metres
B3	VISIBLE	60.0 metres	0.259 degrees down	217.72 metres
B4	VISIBLE	93.8 metres	0.238 degrees down	183.88 metres
B5	VISIBLE	70.6 metres	0.252 degrees down	207.12 metres
B6	VISIBLE	104.4 metres	0.231 degrees down	173.33 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 .

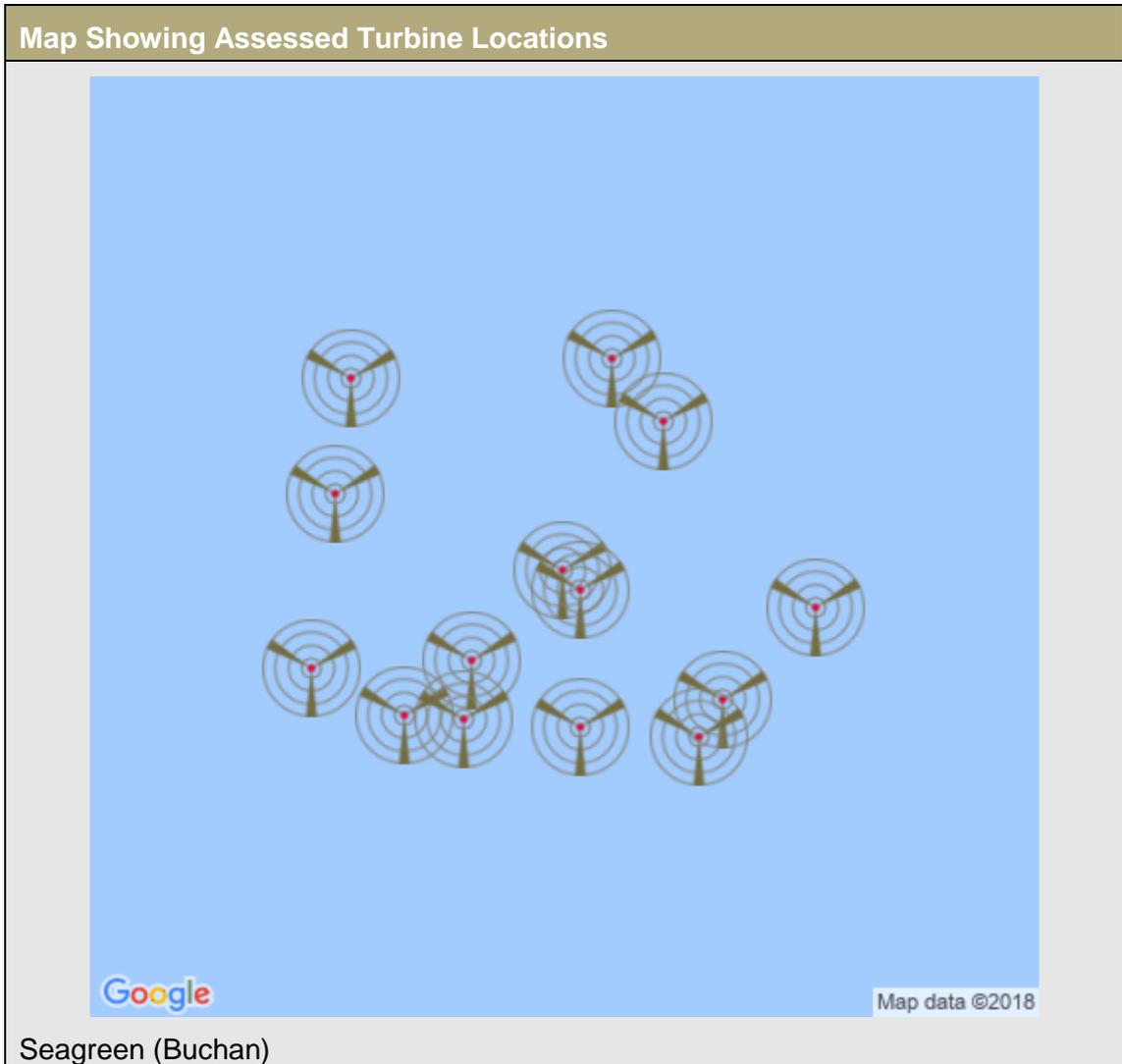
3 REQUESTED ASSESSMENT

Key Parameters
<ul style="list-style-type: none"> • This Radar Line of Sight Assessment for Seagreen (Buchan) 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 Buchan ASACS (RAF) • 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 (Buchan)

4 METHODOLOGY AND BACKGROUND

Introduction

This report indicates whether wind turbines at the Seagreen (Buchan) will be detected by the Buchan ASACS (RAF). 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 (Buchan) will be within Radar Line of Sight of the Buchan ASACS (RAF)
- 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

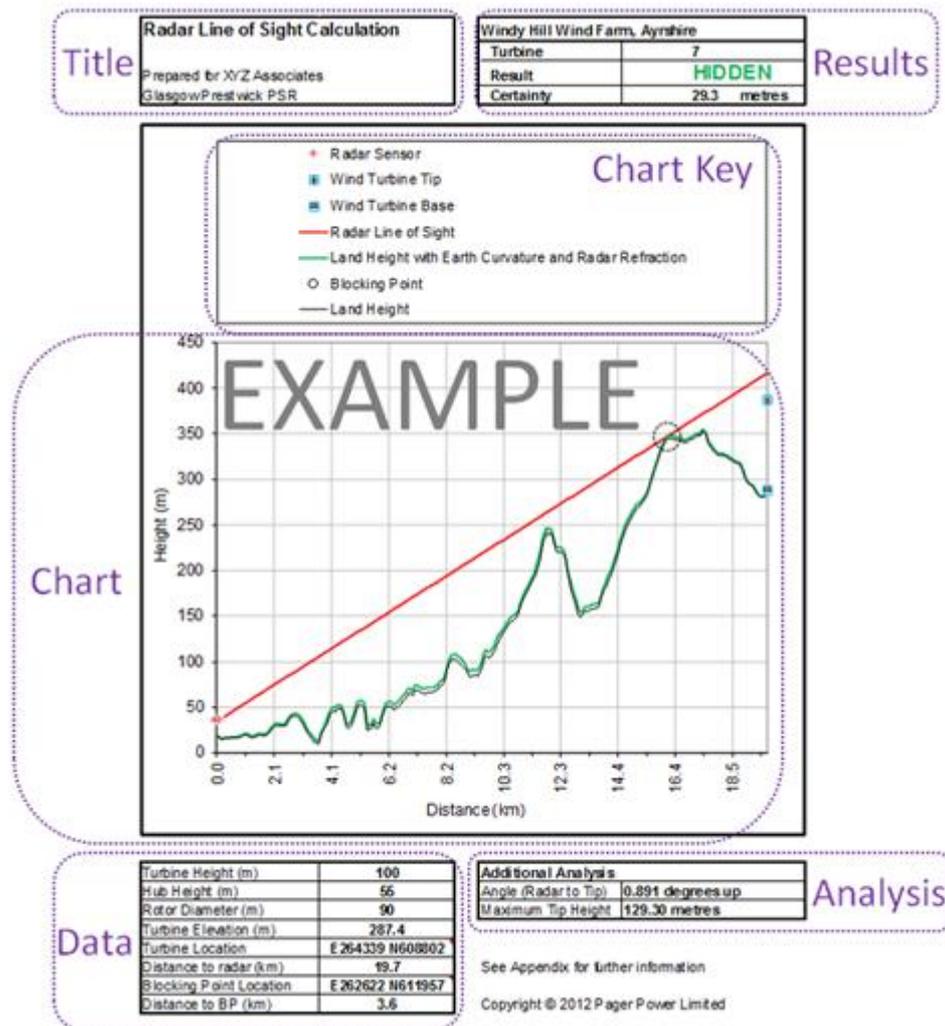


Diagram showing areas of a Radar Line of Sight Calculation

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 .