Technical Appendix 14.2

Aviation Assessment

SCOTTISHPOWER RENEWABLES

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Aviation Assessment

Clauchrie Windfarm

12 December 2019

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www.cyrrus.co.uk

[redacted]





Executive Summary

Cyrrus Limited has been engaged to provide guidance on aviation issues associated with the proposed Clauchrie Windfarm development. The proposed windfarm comprises 18 turbines with maximum tip heights of 200m.

The relevant aviation stakeholders have been assessed: namely NATS (En Route) [NERL], Ministry of Defence (MoD) and Glasgow Prestwick Airport (GPA).

Analysis of NATS self-assessment maps and modelling of NATS Lowther Hill radar shows no impact on NATS infrastructure or services. No objections were raised by NATS at the project Scoping stage.

Analysis of MoD onshore radar coverage maps shows no impact on MoD radar infrastructure. While the proposed windfarm is within a red (high priority) low flying zone, the site is clear of the A714 road line feature that low flying follows. No objections to the project were raised by the MoD at the Scoping stage.

The only aviation stakeholder which could be affected is GPA. Detailed radar modelling of the indicative layout against the two Primary Surveillance Radar (PSR) facilities (Terma and S511 radars) at GPA shows the following:

- Radar Line of Sight (RLoS) exists between both radars and turbines 1, 2, 4, 5, 7, 8, 9, 10, 11 and 13 and these turbines have a high probability of detection;
- In addition, further analysis shows that there is a possibility of both GPA PSRs detecting turbine 6
- Turbines 3, 12, 14, 15, 16, 17 and 18 are unlikely to be detected by either PSR.

The GPA Terma PSR is an X band radar that can distinguish between unwanted returns from wind turbines and wanted returns from aircraft and as such is considered to be windfarm tolerant. The Terma radar mitigates the effects of turbines by blanking the areas around them and relying on inter-turbine tracking. Analysis of these blanked areas shows that they will have no impact on the radar's ability to track aircraft across the windfarm. The GPA S511 PSR is a legacy planning radar that it is understood will be replaced by the Terma PSR as the GPA approach radar in due course.

The proposed Clauchrie Windfarm is situated within uncontrolled airspace. The elevation of the highest proposed turbine does not penetrate the controlled airspace, which is over 3,000ft above the highest obstacle. There is sufficient uncontrolled airspace above the proposed turbines for Visual Flight Rules military and General Aviation traffic to safely transit this area. Published Instrument Flight Procedures indicate that traffic inbound and outbound of GPA will not routinely overfly the Clauchrie site. The site is outside the GPA Air Traffic Control Surveillance Minimum Altitude Chart and will therefore not require changes to this chart. Traffic in controlled airspace should be far enough away from the Clauchrie site that any 'pop up' traffic potentially hidden by turbine clutter (which should only be displayed on the legacy S511 PSR display) should be spotted by the controller in sufficient time to take any necessary action.

The proposed Clauchrie Windfarm is within the Galloway Forest Dark Sky Park buffer zone. As the turbines are planned to be in excess of 150m to tip, Article 222 of the Air Navigation Order mandates the

installation of medium intensity red aviation warning lights. However, light minimisation strategies permitted under Article 222 are being considered, including potentially an aviation detection lighting system (i.e. aviation warning lights are only activated when aircraft are detected in the vicinity of the development by a surveillance system). It should be noted that the navigation and anti-collision lighting on aircraft will appear considerably brighter at night than the medium intensity turbine lights.

No aviation detection systems have yet been installed in the UK; however, the Civil Aviation Authority (CAA) has produced a draft policy that details the minimum coverage volume requirements for such a system. Modelling of visibility coverage for a radar sensor on a 20m tower sited on high ground shows that it should be feasible to identify a suitable sensor location, albeit that this will require liaison with the CAA and planning permission depending on the type of surveillance system utilised.

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Abbreviations

AGL	Above Ground Level
AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
AOD	Above Ordnance Datum
ASACS	Air Surveillance and Control System
ATC	Air Traffic Control
ATCSMAC	Air Traffic Control Surveillance Minimum Altitude Chart
ATS	Air Traffic Service
CAA	Civil Aviation Authority
CTA	Control Area
CTR	Control Zone
DME	Distance Measuring Equipment
DOC	Designated Operating Coverage
DTM	Digital Terrain Model
EIA	Environmental Impact Assessment
FL	Flight Level
GA	General Aviation
GPA	Glasgow Prestwick Airport
ICAO	International Civil Aviation Organization
MoD	Ministry of Defence
NERL	NATS (En Route)
PD	Probability of Detection
PSR	Primary Surveillance Radar
RCS	Radar Cross Section
RLoS	Radar Line of Sight
SID	Standard Instrument Departure
SPR	ScottishPower Renewables (UK) Limited
STAR	Standard Arrival Route
TMA	Terminal Control Area
VFR	Visual Flight Rules
VOR	VHF Omni-directional Range
VPD	Vertical Polar Diagram

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1. Introduction

1.1. Background

1.1.1. ScottishPower Renewables (UK) Limited (SPR) is proposing to construct a new onshore windfarm located approximately 6km north east of the village of Barrhill in South Ayrshire. The proposed development, Clauchrie Windfarm, will comprise up to 18 wind turbines with a tip height of up to 200m Above Ground Level (AGL).

1.1.2. Cyrrus Limited has been engaged by ITPEnergised to provide guidance on aviation issues to support the Environmental Impact Assessment (EIA) process for the project.

1.2. Effects of Wind Turbines on Aviation

1.2.1. Wind turbines are an issue for aviation Primary Surveillance Radars (PSRs) as the characteristics of a moving wind turbine blade are similar to that of an aircraft. The PSR is unable to differentiate between wanted aircraft targets and unwanted clutter targets introduced by the presence of turbines.

1.2.2. The significance of any radar impact depends on airspace usage in the vicinity of the windfarm site and the nature of the Air Traffic Service (ATS) provided in that airspace.

1.3. Scoping Responses

1.3.1. Following publication of the Scoping Report[1], scoping responses were received from the following aviation stakeholders:

- Glasgow Prestwick Airport (GPA);
- Ministry of Defence (MoD); and
- NATS (En Route) [NERL].

1.3.2. Of these respondents, only GPA raised concerns regarding the possibility of the proposed turbines being in Radar Line of Sight (RLoS) of their radar facilities.

1.3.3. MoD Air Surveillance and Control System (ASACS) onshore radar coverage maps confirm that the proposed windfarm is not in RLoS of any Air Defence or MoD Air Traffic Control (ATC) radar facilities.

[1] Clauchrie Windfarm EIA Scoping Report, March 2019

1.3.4. Figure 1 shows radar coverage for a turbine tip height of 200m AGL.

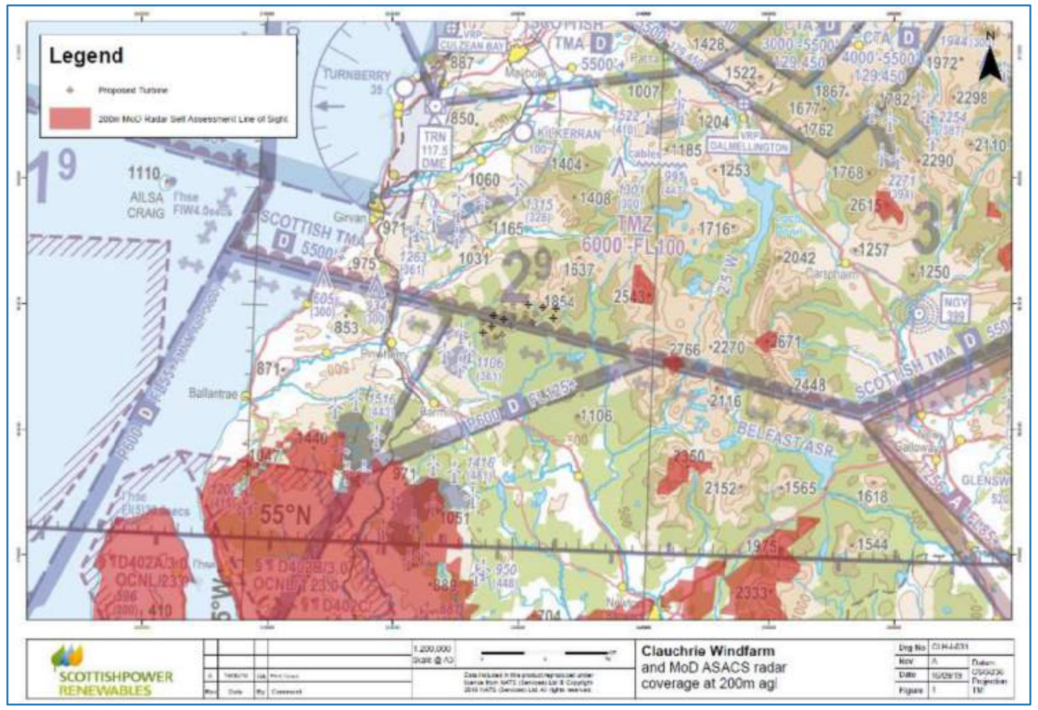

Figure 1: MoD onshore radar coverage at 200m AGL

1.3.5. NATS self-assessment maps show that the proposed windfarm is not in RLoS of any NATS PSRs. Figure 2 illustrates NATS PSR coverage at 200m AGL.

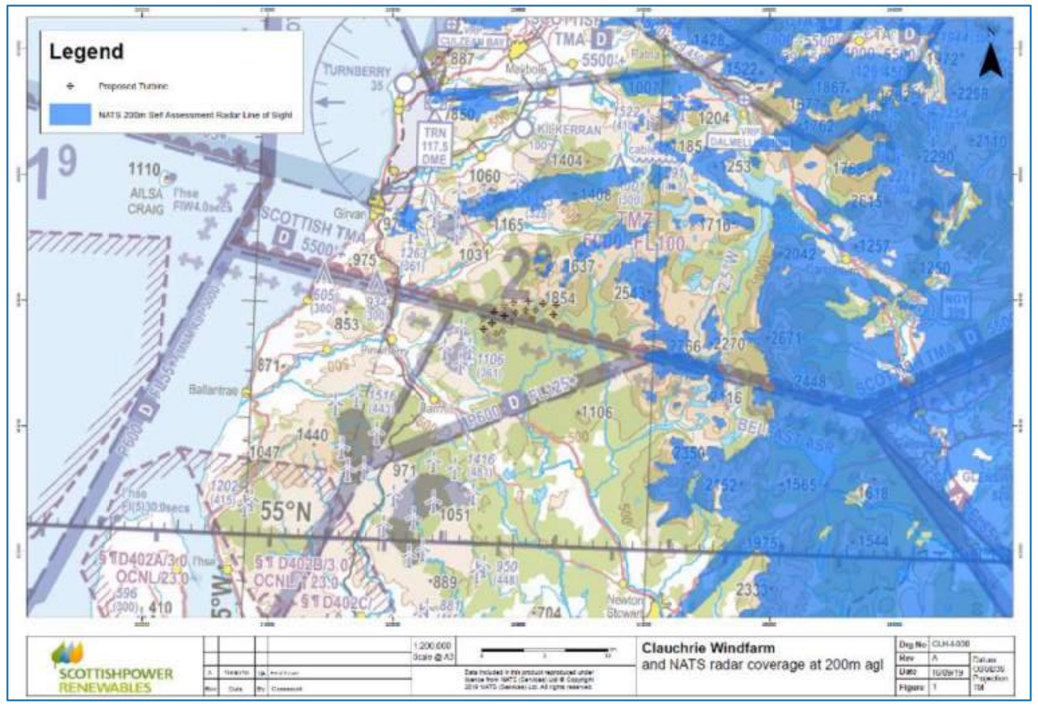

Figure 2: NATS PSR coverage at 200m AGL

1.3.6. The closest NATS PSR to the proposed windfarm site is the facility at Lowther Hill. RLoS modelling of this PSR at 200m AGL confirms that the proposed turbines are not visible to Lowther Hill radar, as shown in Figure 3 and Figure 4.

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Figure 3: Lowther Hill PSR RLoS to 200m AGL

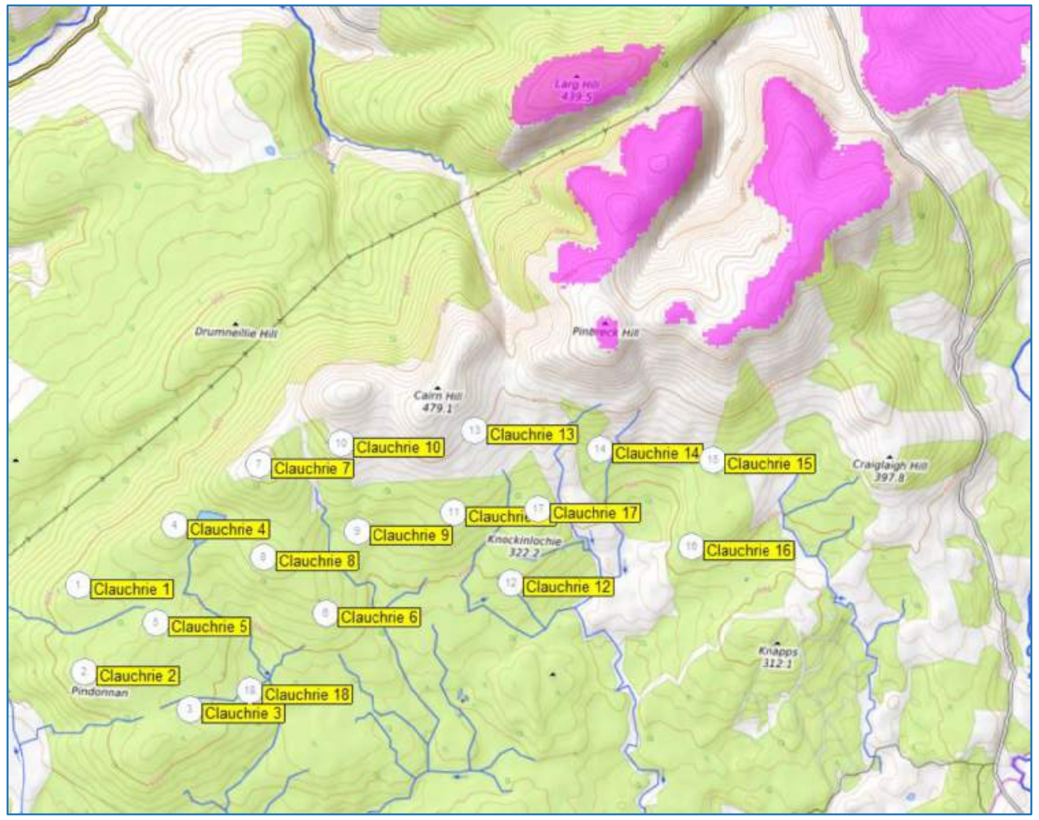

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Figure 4: Lowther Hill PSR RLoS to 200m AGL - zoomed

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1.4. Aviation Assessment

1.4.1. There are two PSR facilities at GPA: a Marconi S511 radar is used for planning purposes while a Terma Scanter 4002 radar is used for approach control. In addition, GPA is fed with Secondary Surveillance Radar (SSR) data from Lowther Hill radar. GPA is authorised to use SSR only in the event of PSR failure.

1.4.2. An RLoS assessment will determine the visibility of the proposed turbines to each of the GPA radars.

1.4.3. An assessment of the nature of the airspace in the vicinity of the proposed Clauchrie Windfarm will determine the potential operational impacts on aviation.

1.4.4. This initial work is detailed in this report and will shape the subsequent consultation and mitigation strategies to be adopted if required.

2. Data

2.1. Clauchrie Windfarm

2.1.1. A final design freeze layout for Clauchrie Windfarm, dated 11th September 2019, has been supplied as a geo-referenced Shapefile:

- Wind Turbines.shp.

2.1.2. The Ordnance Survey National Grid coordinates for this proposed turbine layout, as used in the assessment, are listed in Table 1.

Turbine	Easting	Northing
1	227188	588494
2	227238	587703
3	228210	587355
4	228067	589043
5	227899	588159
6	229456	588245
7	228843	589605
8	228887	588759
9	229750	588992
10	229597	589797
11	230627	589167
12	231162	588518
13	230830	589926
14	231980	589747
15	233008	589647
16	232816	588854
17	231409	589199
18	228753	587528

Table 1: Clauchrie Windfarm turbine coordinates

2.1.3. The turbines are planned to have a blade (rotor) diameter of 150m, a hub height of 125m AGL and a maximum blade tip height of 200m AGL.

2.2. GPA Radar Data

2.2.1. Radar parameters used in the assessment have been taken from data held on file by Cyrrus and provided by GPA.

2.3. Analysis Tools

- ATDI ICS telecom EV v15.5.3 x64 radio network analysis tool;
- ZWCAD+ 2015 SP1 Pro v2014.11.27(26199).

2.4. Terrain Data

- NextMap 25m Digital Terrain Model (DTM).

3. Clauchrie Windfarm Layout

3.1. The proposed 18 turbine layout used for the modelling is shown in Figure 5.

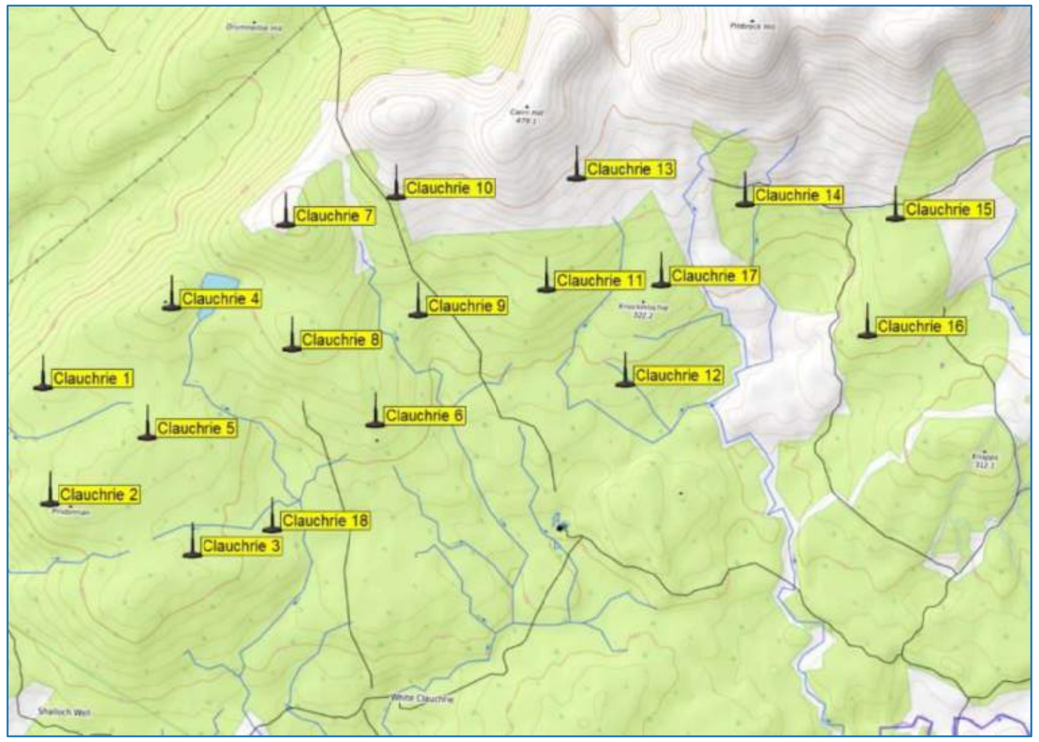

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Figure 5: Proposed turbine layout

4. Radar Line of Sight Modelling

4.1. GPA Radars

4.1.1. The locations of the two GPA PSRs are shown in Figure 6.

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Figure 6: Location of GPA Terma PSR and S511 PSR

4.1.2. At its closest point the proposed development area is approximately 37km (20NM) south of the GPA PSRs, as shown in Figure 7.

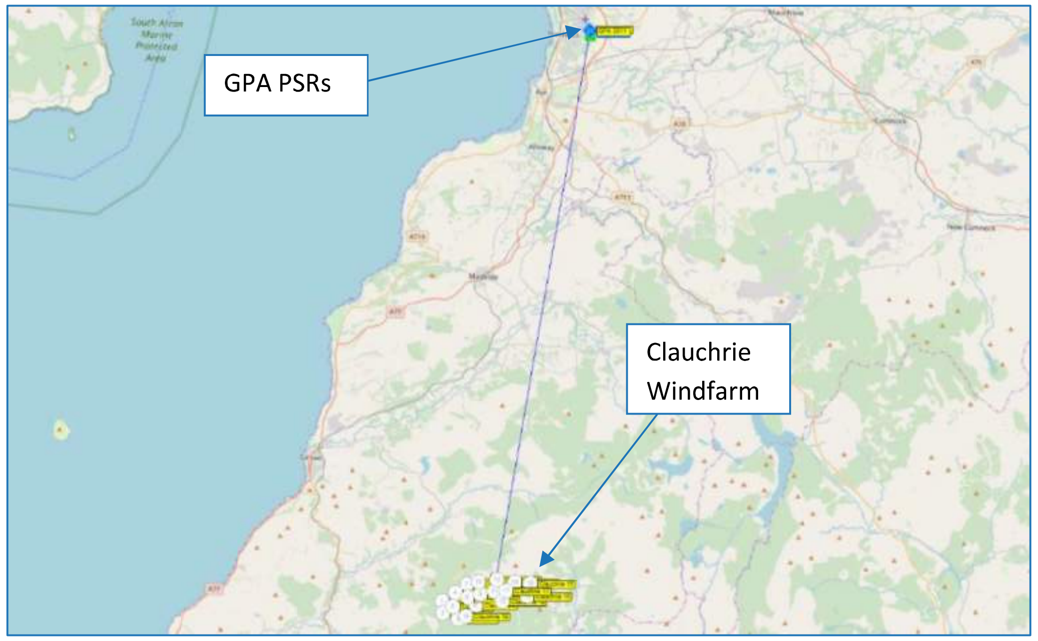

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Figure 7: Locations of GPA PSRs and Clauchrie Windfarm

4.1.3. RLoS is determined from a radar propagation model (ATDI ICS telecom EV) using 3D NextMap DTM data with 25m horizontal resolution. Radar data is entered into the model and RLoS to the turbines from the radar is calculated.

4.1.4. Note that by using a DTM no account is taken of possible further shielding of the turbines due to the presence of structures or vegetation that may lie between the radars and the turbines. Thus, the RLoS assessments are worst-case results.

4.1.5. For PSR, the principal sources of adverse windfarm effects are the turbine blades, so RLoS is calculated for the maximum tip height of the turbines, i.e. 200m AGL.

4.1.6. A 3D view of the turbines and the terrain model is shown in Figure 8.

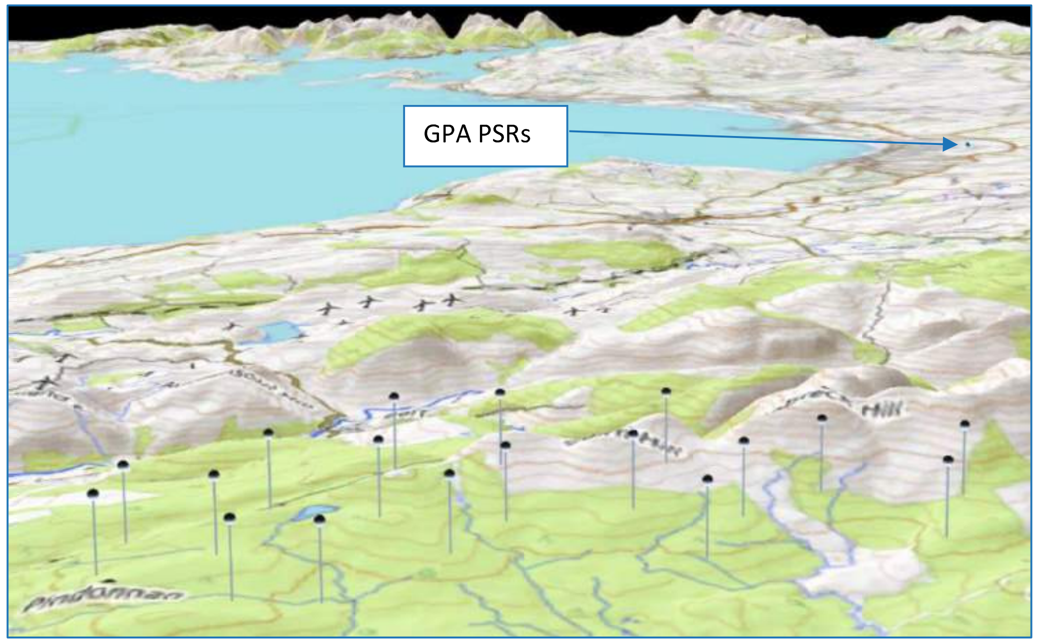

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Figure 8: 3D view from the south of turbines and terrain

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4.1.7. The magenta shading in Figure 9 illustrates the RLoS coverage from the GPA Terma PSR to turbines with a blade tip height of 200m AGL.

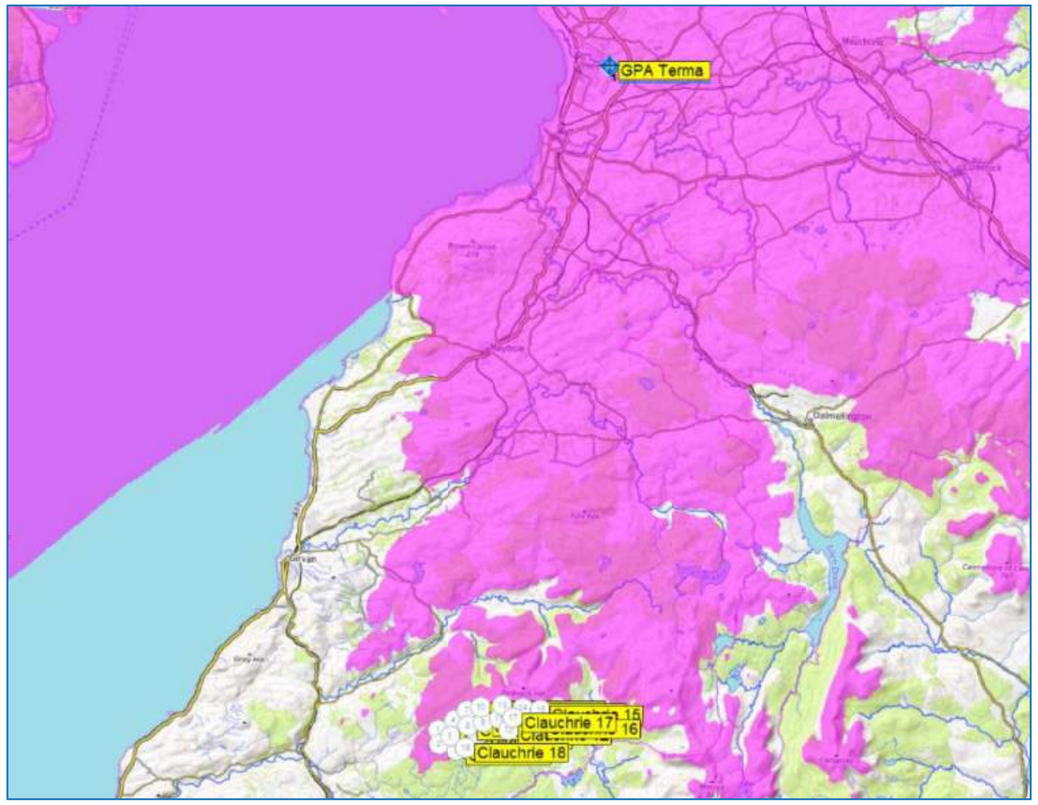

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Figure 9: GPA Terma PSR RLoS to 200m AGL

4.1.8. RLoS exists between the GPA Terma PSR and several of the turbines in the proposed layout.

4.1.9. The zoomed view of Clauchrie Windfarm in Figure 10 shows that RLoS exists between the Terma PSR and the blade tips of turbines 1, 2, 4, 5, 7, 8, 9, 10, 11 and 13.

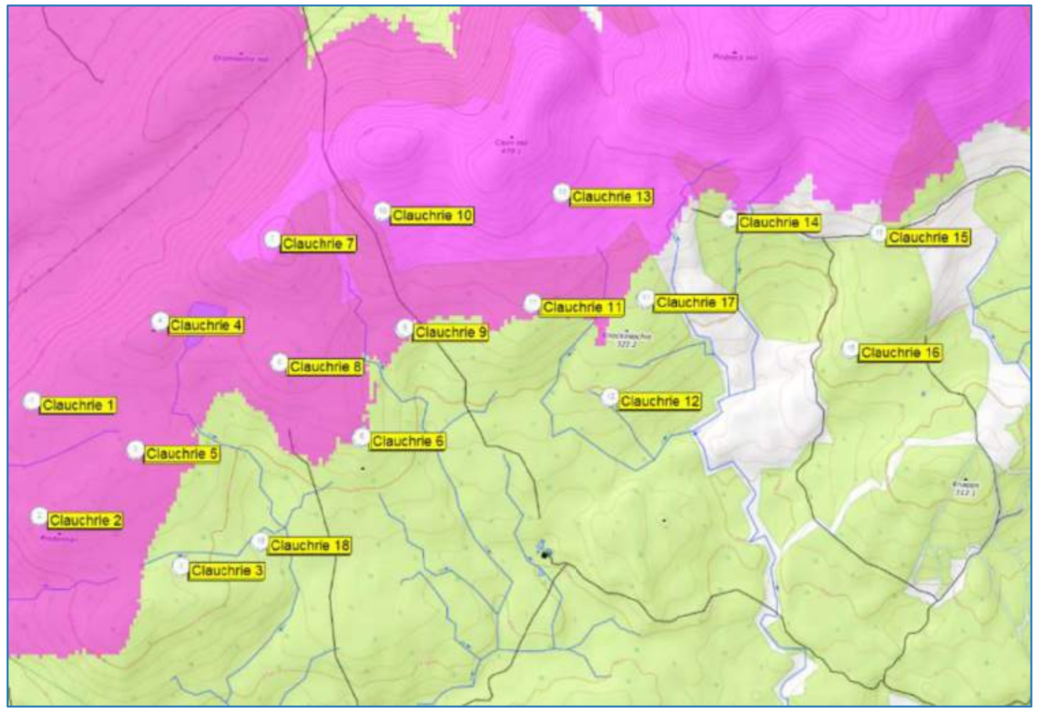

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Figure 10: GPA Terma PSR RLoS to 200m AGL – zoomed

4.1.10. The magenta shading in Figure 11 illustrates the RLoS coverage from the GPA S511 PSR to turbines with a blade tip height of 200m AGL.

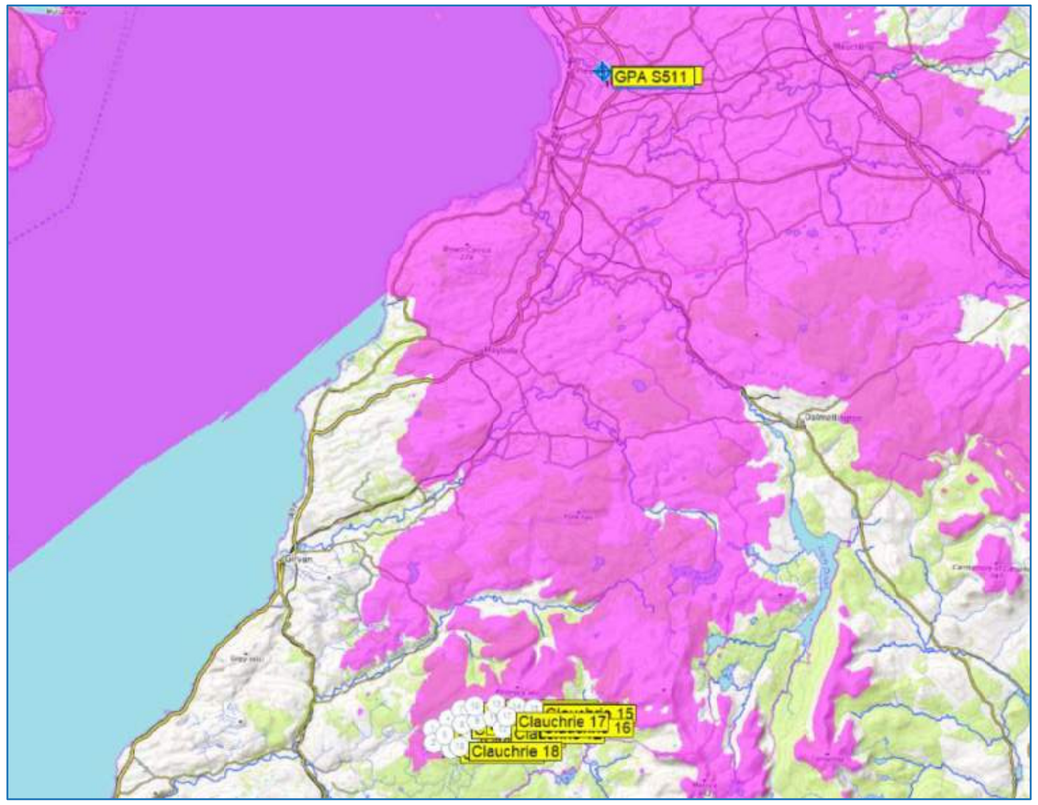

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Figure 11: GPA S511 PSR RLoS to 200m AGL

4.1.11. RLoS exists between the GPA S511 PSR and several of the turbines in the proposed layout.

4.1.12. The zoomed view of Clauchrie Windfarm in Figure 12 shows that RLoS exists between the S511 PSR and the blade tips of turbines 1, 2, 4, 5, 7, 8, 9, 10, 11 and 13.

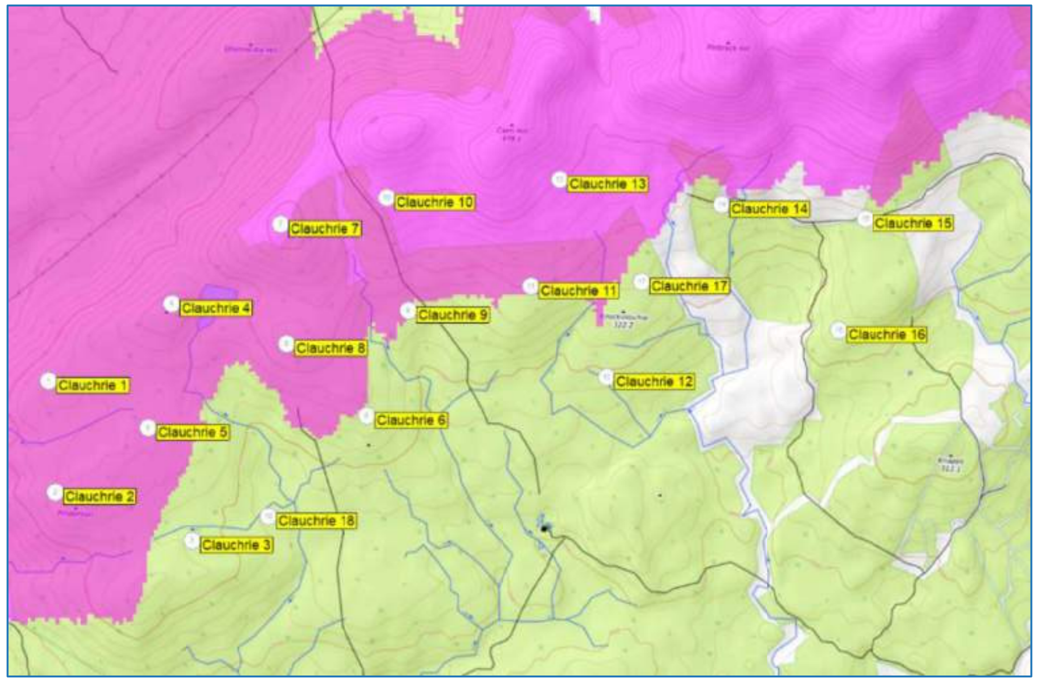

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Figure 12: GPA S511 PSR RLoS to 200m AGL – zoomed

4.1.13. When no RLoS exists between a turbine and a radar it can generally be assumed that the radar will not detect the turbines. However, this can only be assured by analysis of path profiles between the radar and each turbine and conducting Probability of Detection (PD) calculations.

5. Probability of Detection

5.1. Methodology

5.1.1. Using the radar propagation model the actual path loss between the GPA PSRs and various parts of each turbine can be determined.

5.1.2. The path loss profile between the Terma PSR and Clauchrie Windfarm turbine 1 is shown in Figure 13. In this case the radar has uninterrupted RLoS to the turbine tip.

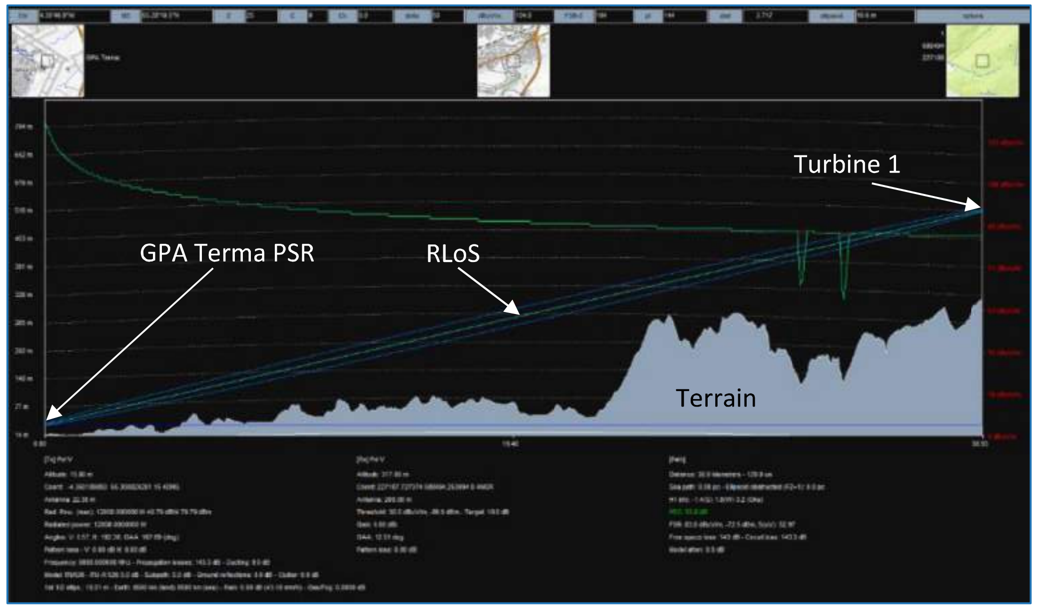

Figure 13: Path loss profile between GPA Terma PSR and tip of turbine 1

5.1.3. Figure 14 illustrates the path loss profile between the Terma PSR and turbine 3 and shows that terrain blocks RLoS to the turbine tip.

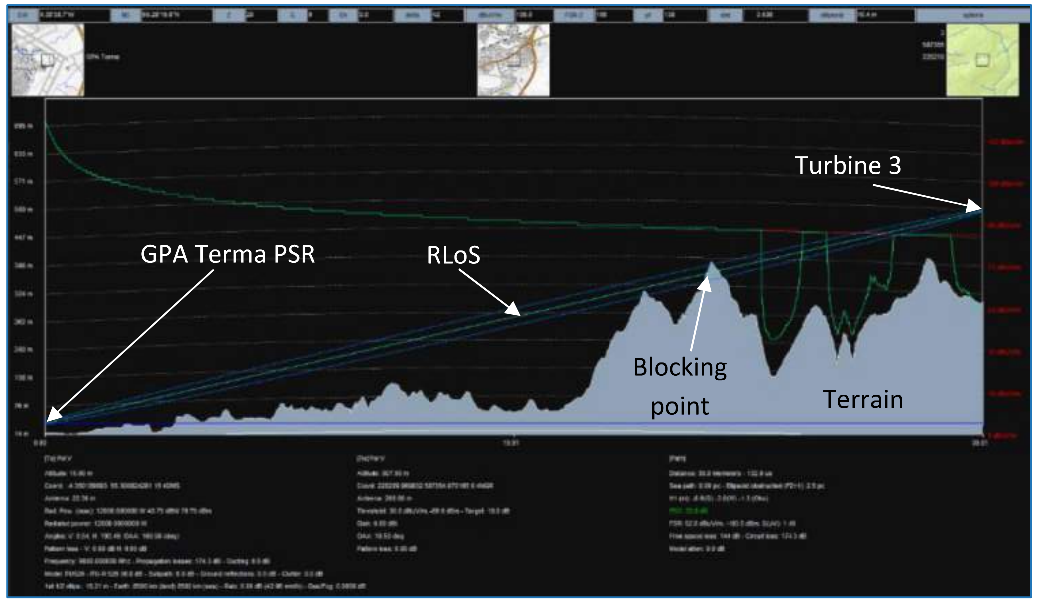

Figure 14: Path loss profile between GPA Terma PSR and tip of turbine 3

5.1.4. All of the path profiles between the GPA PSRs and the 18 Clauchrie turbines are shown in Annexes at the end of this report: Terma profiles in Annex A and S511 profiles in Annex B.

5.1.5. Even when intervening terrain blocks RLoS between the radar and a turbine, the probability that the turbine will be detected by the radar is still dependant on several factors including the radar's power, the angle of antenna tilt and distance to the object.

5.1.6. The radar propagation model can determine the actual path loss between the PSR and various parts of the turbine. By knowing the PSR transmitter power, antenna gain, 2-way path loss, receiver sensitivity and the turbine Radar Cross Section (RCS) gain, the probability of the radar detecting the target (PD) can be calculated.

5.1.7. The static parts of the turbine (tower structure) are ignored in the calculation as these will be rejected by the radar Moving Target filter. In this refined model, 3 parts of the turbine blade are considered: the hub, the blade tip, and a point midway along the turbine blade. Each part of the turbine blade is assigned an RCS of $60m^2$ based on a blade length of 75m (half of 150m rotor diameter). Path loss calculations are made to all turbines. The received signal at the radar from each component part of the turbine is then summed to determine the total signal level.

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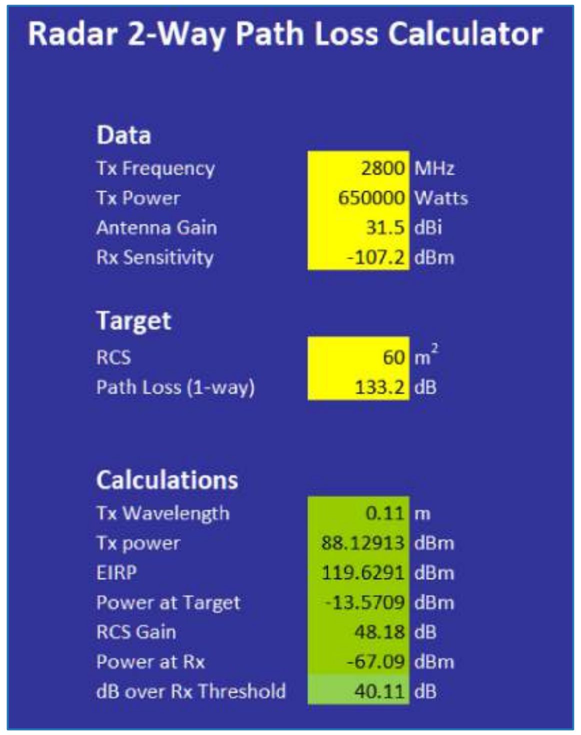
5.1.8. The path loss calculation carried out for each turbine component is as follows:

	Tx Power	dBm
+	Antenna Gain	dB
-	Path Loss	dB
+	RCS Gain	dB ($60m^2$ ~ +48dB@2800MHz/+58dB@9000MHz)
-	Path Loss	dB
+	Antenna Gain	dB
=	Received Signal	dBm

5.1.9. The received signal is then compared with the radar receiver Minimum Detectable Signal level.

5.1.10. An example of the calculation for the GPA S511 PSR to turbine 1 is shown in Figure 15.



Radar 2-Way Path Loss Calculator

Data		
Tx Frequency	2800	MHz
Tx Power	650000	Watts
Antenna Gain	31.5	dBi
Rx Sensitivity	-107.2	dBm
Target		
RCS	60	m^2
Path Loss (1-way)	133.2	dB
Calculations		
Tx Wavelength	0.11	m
Tx power	88.12913	dBm
EIRP	119.6291	dBm
Power at Target	-13.5709	dBm
RCS Gain	48.18	dB
Power at Rx	-67.09	dBm
dB over Rx Threshold	40.11	dB

Figure 15: Example path loss calculation

5.1.11. The two-way path losses from the turbine components are tabulated and combined to give total radar received signals from each turbine. The results are colour-coded to indicate the likelihood of detection. Radar returns >3dB above the detection threshold are coloured green as these values show a high probability of detection. Those between +3dB and -3dB are coloured yellow and indicate a possibility of detection. Between -3dB and -6dB, results are coloured orange to show only a small possibility of detection. Signals >6dB below the threshold of detection are shaded red as these values show that detection is unlikely.

5.1.12. Using this representation provides a ready visual comparison of different scenarios. The final result is shown in the final column (TOTAL) of each colour-coded chart.

5.2. GPA Terma PSR – PD analysis

5.2.1. The results of the PD calculations for each turbine are shown in Table 2.

Initial data from '2-Way'			KEY:	Unlikely to be detected
A	143.3	Path Loss		Small possibility of detection
B	33.51	dB over Rx Thr		Possibility of detection
C	60.00	RCS (m^2)		High probability of detection
	Turbine Nacelle	Blade mid-point	Blade Tip	TOTAL
Turbine	Path Loss dB	Path Loss dB	Path Loss dB	dB over RX threshold
1	143.3	143.3	143.3	38.28
2	146.4	143.5	143.5	36.65
3	184.4	180.7	174.3	-28.23
4	143.2	143.2	143.2	38.48
5	175.9	149.1	143.4	33.61
6	204.1	177.9	160.8	-1.49
7	143.0	143.0	143.0	38.88
8	174.7	144.8	143.2	35.40
9	183.4	175.2	149.6	20.91
10	142.9	142.9	142.9	39.08
11	183.6	174.2	148.3	23.51
12	192.7	189.7	184.9	-49.14
13	167.2	142.8	142.8	37.52
14	231.3	217.2	185.6	-51.09
15	219.0	204.5	189.0	-57.89
16	213.0	203.6	196.2	-72.15
17	194.4	186.2	174.3	-28.48
18	210.4	205.3	185.1	-50.09

Table 2: GPA Terma PSR PD results

5.2.2. From Table 2 it appears that turbines 3, 12, 14, 15, 16, 17 and 18 are unlikely to be detected by the GPA Terma PSR, while there is a possibility of turbine 6 being detected.

5.2.3. The above calculations are based on the optimum performance of the radar, however the gain of a radar antenna in the vertical axis is not uniform with elevation angle. The beam is a complex shape to minimise ground returns by having low gain at elevations close to the horizontal but having high gain at elevations just a few degrees above the horizon.

5.2.4. Cyrrus does not hold data for the Terma antenna Vertical Polar Diagram (VPD), however it is likely that the turbine tip elevations from the Terma PSR (+0.75° or less) are below the peak elevation of the beam where gain is maximum. Any reduction in gain will further reduce the probability of turbine detection. For example, a reduction in gain of 2.5dB will mean that turbine 6 is unlikely to be detected.

5.3. GPA Terma PSR – Impact of Detected Turbines

5.3.1. The newly installed GPA Terma PSR was introduced as a windfarm tolerant approach radar and was funded through windfarm operators. The Terma PSR operates in the X frequency band (9GHz), unlike the majority of PSRs providing approach services which operate in the S

band (2.8GHz). This means that the Terma antenna transmits a narrower beam with smaller range resolutions down to approximately 6m as opposed to 50m.

5.3.2. The resolution of the Terma PSR allows it to effectively mask out individual turbines. To mask the turbines the radar blanks the area around each turbine. The required minimum size of each turbine blank is a geographic polygon defined in terms of range and sector angles from the Terma PSR sufficient to contain a circle of 150m in diameter. This diameter is the minimum size necessary to encompass the turbine blades for all turbine orientations and is illustrated in Figure 16 for turbine 1.

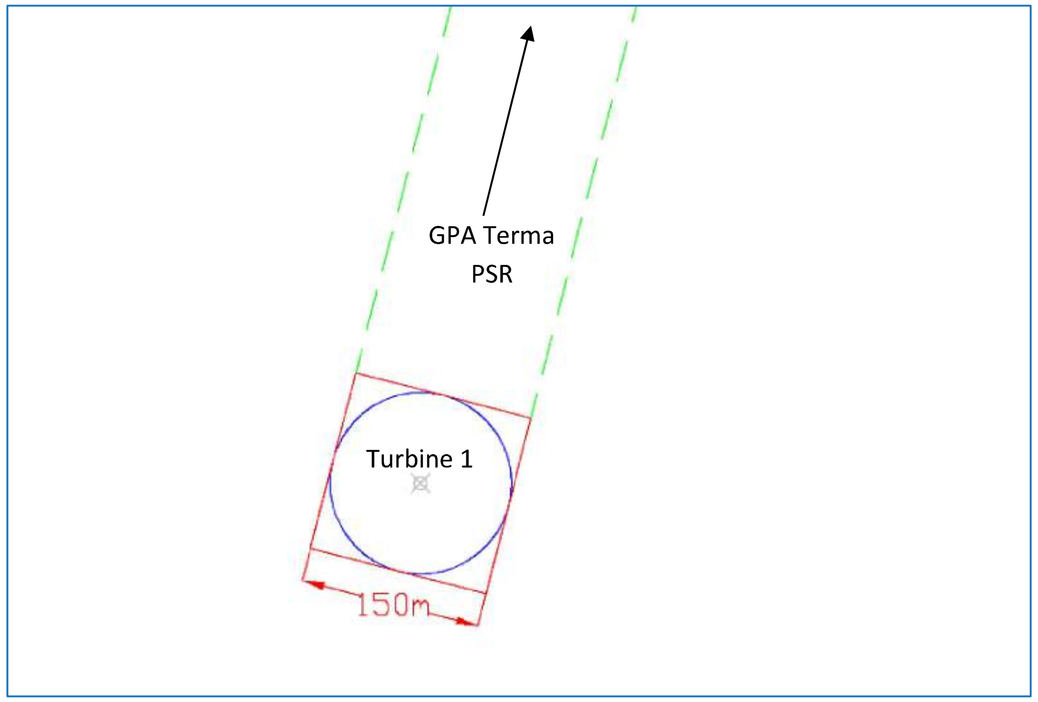


Figure 16: Range and sector blank for turbine 1

5.3.3. Within the blanked area no targets are detected. This includes airborne targets as well as turbine blades. If an airborne target is not detected for three consecutive radar scans then its track will be dropped, thus the distance between turbines, and hence blanked areas, within the windfarm becomes critical.

5.3.4. The GPA Terma PSR has a scan rate of 15 Revolutions per Minute (RPM) which equates to a time interval of 4 seconds between scans. Aircraft being tracked by the Terma PSR are generally low-level (6,000ft Above Mean Sea Level at most) with groundspeeds typically between 125kts and 250kts. (Civilian aircraft are limited to a speed of 250kts for flights below 10,000ft). If the highest groundspeed is assumed, then an airborne target can travel up to 515m between radar scans.

5.3.5. A simple analysis can be undertaken to assess the likelihood of a dropped track for airborne targets crossing the proposed windfarm site.

5.3.6. In Figure 17 the small blue circles are an idealised representation of the blanked area around each turbine. The red circles represent the maximum range that an aircraft can travel from the perimeter of each blanked area in a single radar scan, assuming a groundspeed of 250kts.

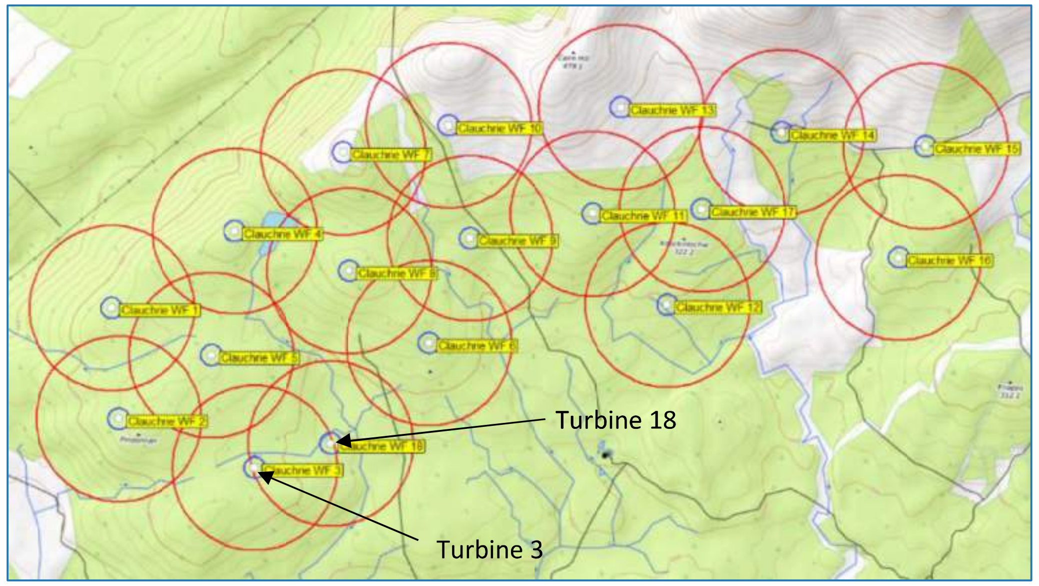


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Figure 17: Maximum range for aircraft at 250kts

5.3.7. It can be seen that the maximum ranges from turbines 3 and 18 overlap their respective blanked areas. This means that in theory an aircraft travelling between the vicinities of turbines 3 and 18 may not be detected on two consecutive radar scans. However, PD analysis in Section 5.2 has shown that turbines 3 and 18 are not in RLoS and so unlikely to be detected by the Terma. Only turbines likely to be detected by the Terma PSR need to be blanked.

5.3.8. Figure 18 again shows the maximum ranges, but with unnecessarily blanked areas removed.

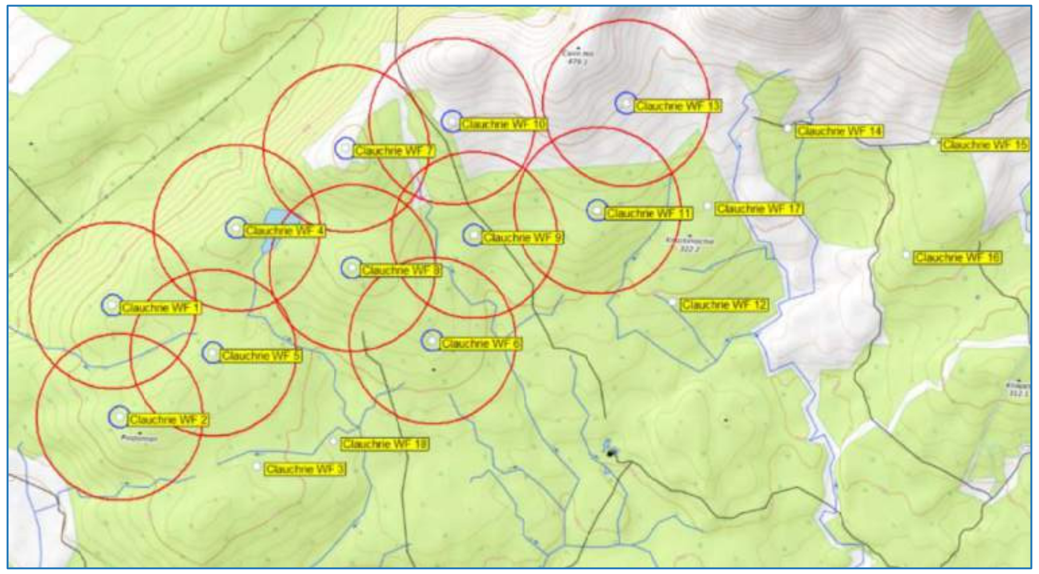

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Figure 18: Maximum range for aircraft at 250kts – detected turbines

5.3.9. It can now be seen that an aircraft travelling at a groundspeed of 250kts cannot be within a blanked area on consecutive radar scans. This will be the worst case as slower aircraft will have a reduced range. It can thus be concluded that blanked turbines cannot result in dropped aircraft tracks over the windfarm site.

5.4. GPA S511 PSR – PD analysis

5.4.1. The results of the PD calculations for each turbine are shown in Table 3.

Initial data from '2-Way'			KEY:	
A	133.2	Path Loss		Unlikely to be detected
B	40.11	dB over Rx Thr		Small possibility of detection
C	60.00	RCS (m^2)		Possibility of detection
				High probability of detection

Turbine	Turbine Nacelle Path Loss dB	Blade mid-point Path Loss dB	Blade Tip Path Loss dB	TOTAL dB over RX threshold
1	133.2	133.2	133.2	44.88
2	145.8	133.3	133.3	42.93
3	170.9	167.3	161.3	-15.77
4	141.3	133.0	133.0	43.57
5	162.5	147.5	133.2	40.12
6	185.6	160.6	149.4	7.74
7	136.7	132.8	132.8	44.27
8	161.6	143.0	133.0	40.56
9	169.4	162.1	145.6	15.31
10	132.8	132.8	132.8	45.68
11	173.8	165.6	147.4	11.71
12	186.3	183.3	176.6	-46.45
13	155.6	132.7	132.7	44.12
14	207.6	195.5	170.2	-33.89
15	198.3	187.9	176.6	-46.66
16	194.6	187.9	182.0	-57.20
17	182.7	173.3	161.5	-16.47
18	191.3	185.4	170.7	-34.88

Table 3: GPA S511 PSR PD results

5.4.2. From Table 3 it appears that turbines 3, 12, 14, 15, 16, 17 and 18 are unlikely to be detected by the GPA S511 PSR.

5.4.3. The above calculations are based on the optimum performance of the radar, however the gain of a radar antenna in the vertical axis is not uniform with elevation angle. The beam is a complex shape to minimise ground returns by having low gain at elevations close to the horizontal but having high gain at elevations just a few degrees above the horizon.

5.4.4. The S511 PSR uses a Watchman antenna which usually has a maximum gain at an elevation angle of 3° above the horizontal. If the mechanical tilt of the antenna is altered, then the angle of maximum gain will change by a corresponding amount. The mechanical tilt of the antenna is set at the commissioning of the radar to achieve the best compromise between suppressing ground returns and detecting low altitude aircraft targets. Gain falls off rapidly at lower elevation angles as a function of the antenna VPD. Radar VPD data can be plotted as a smoothed line of elevation versus gain to enable intermediate values of antenna gain to be determined.

5.4.5. Watchman VPD data gives the graph shown in Figure 19.

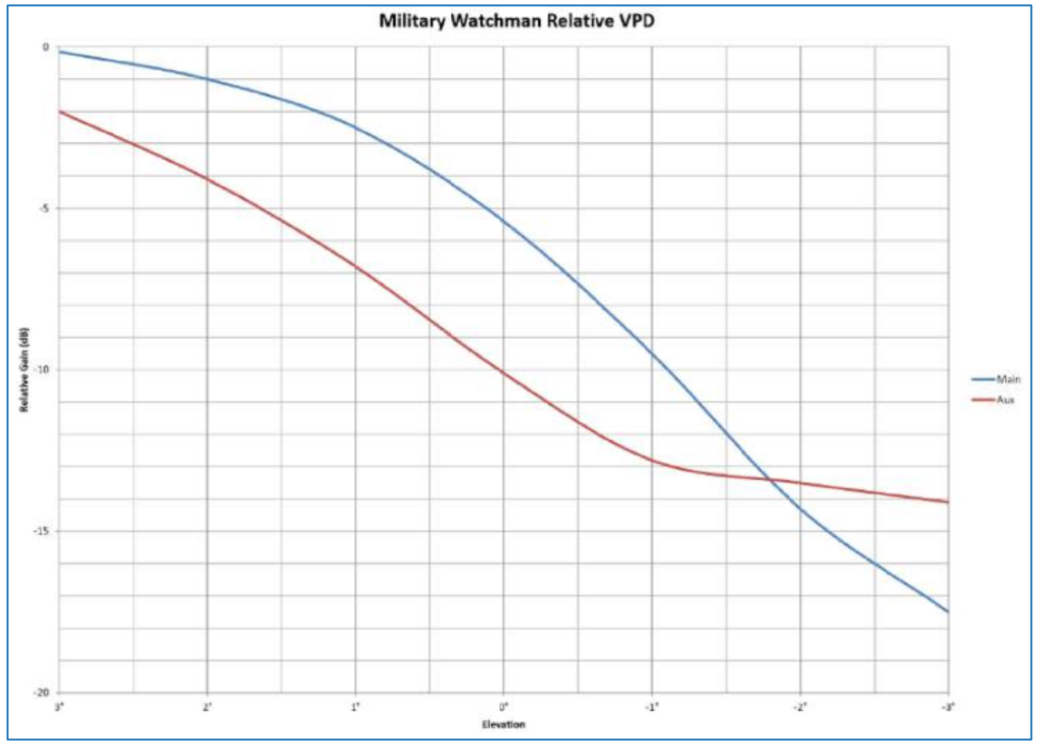

Figure 19: Watchman antenna VPD

5.4.6. The Watchman is a dual beam antenna. At short ranges (less than around 19km) the radar uses a high, or auxiliary, beam to reduce the effects of close in ground clutter. Beyond these ranges a low, or main, beam is used. Clauchrie Windfarm lies in the S511 PSR's main beam area.

5.4.7. The vertical angle from the S511 PSR to the tips of the turbines varies between +0.52° and +0.76°. The GPA S511 PSR has a mechanical tilt of 0° so this means a main beam gain reduction of approximately -3dB at these elevations.

5.4.8. Table 4 shows the results of the PD calculations incorporating the reduction in antenna gain that occurs for targets off the axis of maximum gain.

Initial data from '2-Way'			KEY:	
A	133.2	Path Loss		Unlikely to be detected
B	34.11	dB over Rx Thr		Small possibility of detection
C	60.00	RCS (m^2)		Possibility of detection
				High probability of detection

Turbine	Turbine Nacelle Path Loss dB	Blade mid-point Path Loss dB	Blade Tip Path Loss dB	TOTAL dB over RX threshold
1	133.2	133.2	133.2	38.88
2	145.8	133.3	133.3	36.93
3	170.9	167.3	161.3	-21.77
4	141.3	133.0	133.0	37.57
5	162.5	147.5	133.2	34.12
6	185.6	160.6	149.4	1.74
7	136.7	132.8	132.8	38.27
8	161.6	143.0	133.0	34.56
9	169.4	162.1	145.6	9.31
10	132.8	132.8	132.8	39.68
11	173.8	165.6	147.4	5.71
12	186.3	183.3	176.6	-52.45
13	155.6	132.7	132.7	38.12
14	207.6	195.5	170.2	-39.89
15	198.3	187.9	176.6	-52.66
16	194.6	187.9	182.0	-63.20
17	182.7	173.3	161.5	-22.47
18	191.3	185.4	170.7	-40.88

Table 4: GPA S511 PSR PD results – corrected for VPD

5.4.9. From Table 4 it now appears that in addition to the turbines already identified as being unlikely to be detected, turbine 6 now only has a possibility of detection.

5.5. GPA S511 PSR – Impact of Detected Turbines

5.5.1. The GPA S511 PSR was installed in 1990, and today is primarily used as a planning radar. The newly installed Terma PSR is effectively a replacement for this legacy radar but is limited to a range of approximately 40NM, so the S511 is used for traffic beyond this range.

5.5.2. If for some reason the Terma approach radar becomes unserviceable then the radar control service would continue using Lowther Hill SSR data only, albeit with a minimum traffic separation increase from 5NM to 10NM.

6. Airspace Analysis

6.1. Introduction

6.1.1. This assessment is a review of potential impacts on aviation in the designated areas of Clauchrie Windfarm. All information has been referenced from the UK Aeronautical Information Publication (AIP), available online from source, and is therefore the latest information available. Additional information has been sourced from UK Civil Aviation Authority (CAA) publications, as appropriate.

6.1.2. The assessment does not draw any conclusions but merely identifies areas of potential impact.

6.2. Scope

6.2.1. The scope of the assessment includes Clauchrie Windfarm and the surrounding airspace relating to aviation, its use and potential impact. Each area is defined according to type of airspace, limitations and who the controlling authority is.

6.3. Existing Environment

6.3.1. Airspace, in aviation terms, is defined as in two elements. The differentiation is required due to varying air pressure and to ensure aircraft are flying according to the same point of reference.

6.3.2. The first element is as an altitude Above Mean Sea Level (AMSL) and designated in terms of feet. The barometric pressure used is typically a local pressure at the last point at which this pressure can be verified.

6.3.3. Above a certain altitude, the level at which an aircraft flies at is referred to as a Flight Level (FL) using a common international barometric pressure setting of 1013.2hPa. The transition between flying at an altitude and a FL is defined as a Transition Layer consisting of a Transition Altitude and a Transition Level. The Transition Altitude will always be the lower point, and, in the UK, this is set at 3,000ft with the exception of some specified airspace. In this case the Transition Altitude is set at 5,500ft. Refer UK AIP ENR 1.7 Altimeter Setting Procedures.

6.4. Airspace and Glasgow Prestwick Airport

6.4.1. The proposed Clauchrie Windfarm is situated within Class G (uncontrolled) airspace beneath the Class D (controlled airspace) Scottish Terminal Control Area (TMA) with a base of 5,500ft AMSL and a Class D volume of airspace associated with Airway P600 (with a base level of FL125, approximately 12,500ft AMSL). The Scottish TMA is controlled by NERL from the en route centre located in Prestwick. Control of the TMA airspace in the vicinity of GPA from 5,500ft to 6,000ft AMSL is delegated from NERL to GPA to enable the airport to vector and sequence traffic. GPA has a Designated Operating Coverage (DOC) of 42NM for its radar services. Within this DOC outside controlled airspace GPA provides advisory and information services to aircraft transiting or operating to and from GPA. Aircraft in uncontrolled airspace are not obliged to contact ATC.

6.4.2. The proposed Clauchrie development is located under the southern edge of the TMA and GPA airspace and is clear of the routes the vast majority of traffic operating to and from GPA would use. The elevation of the highest proposed turbine extends to 610m (circa 2,002ft) Above Ordnance Datum (AOD) and as such, does not penetrate the controlled airspace over 3,000ft above the highest obstacle. The proposed turbines at Clauchrie are depicted in Figure 20 along with the surrounding airspace.

Figure 20: Airspace overview

6.4.3. The site is approximately 20NM south of GPA and approximately 10NM south east of the Turnberry Distance Measuring Equipment (DME) facility known as TRN DME.

6.4.4. GPA has a standing agreement with NERL that all traffic inbound via the airways structure will be handed to GPA descending to FL70 and routing using Standard Arrival Routes (STARs) to either TRN or the waypoint SUMIN unless otherwise coordinated. The majority of traffic inbound to GPA arrives from the southeast via SUMIN. None of the traffic inbound via SUMIN should ever route close to Clauchrie and can be disregarded for the purposes of this report. Traffic from the west is generally routed towards TRN and again routes well clear of Clauchrie.

6.4.5. The extracts in Figure 21 and Figure 22 indicate with red dots the location of the turbine site in relation to the STARs and show that traffic inbound on the TRN STARs will not routinely overfly the Clauchrie site. Note that controllers apply a 5NM separation from unknown traffic, so, given that the turbines are more than 5NM from the inbound tracks of the STARs, even if turbine clutter presented on the legacy S511 display as potential traffic controllers would not need to take evasive action.

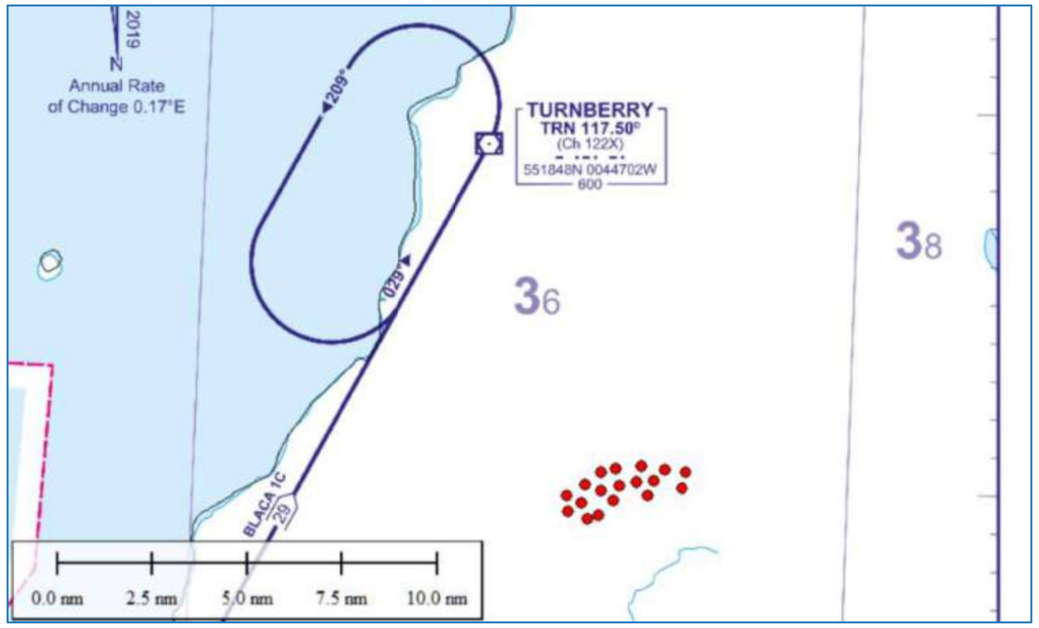

Chart reproduced with the permission of NATS (Services) Limited.

Figure 21: Extract from STAR chart AD 2.EGPK-7-1

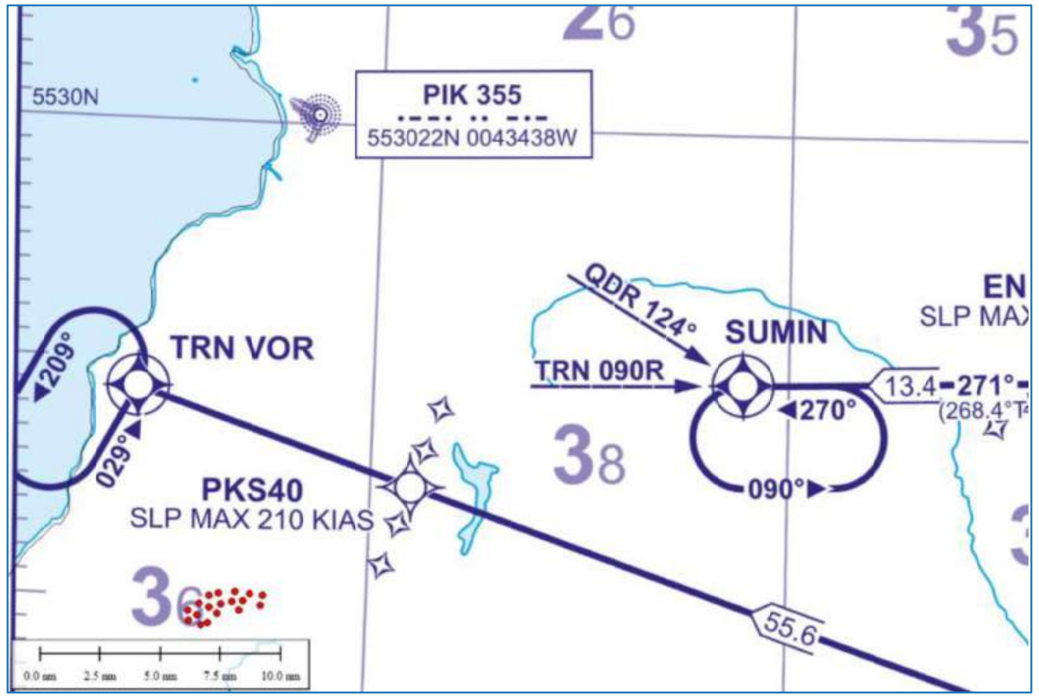

Chart reproduced with the permission of NATS (Services) Limited.

Figure 22: Extract from STAR chart AD 2.EGPK-7-2

6.4.6. Traffic arriving via P600 that is being vectored under normal circumstances must be kept within controlled airspace. As a matter of convention controllers will aim to keep traffic at least two nautical miles from the edge of controlled airspace. The descent profile of inbound traffic means that GPA controllers will not be able to use the piece of P600 that is above Clauchrie. Assuming a worst-case scenario that an aircraft is being vectored on P600 for tactical reasons then the blue arrow in Figure 23 shows traffic routing toward TRN. The red arrow shows traffic being vectored by GPA towards runway 32. In both cases the tracks are clear of the Clauchrie site.

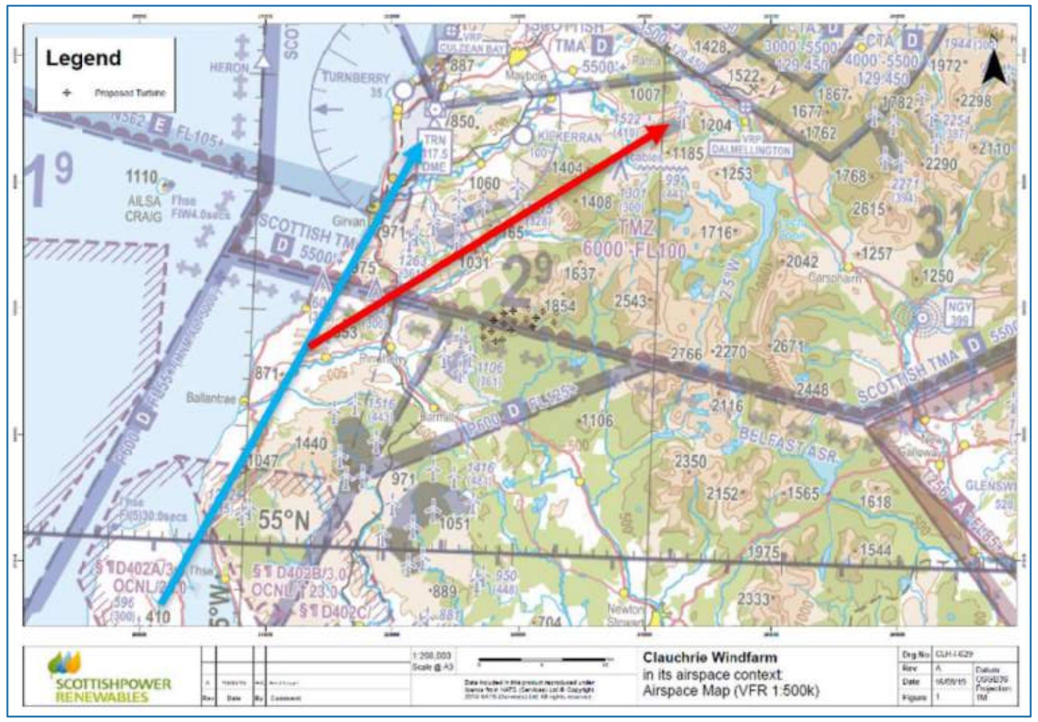

Figure 23: Aircraft vectored on Airway P600

6.4.7. GPA has a number of Standard Instrument Departures (SIDs) for traffic departing via the airways structure. The tracks of all the SIDs are clear of Clauchrie. For other departing traffic the routine coordination is for GPA to clear the aircraft to 6,000ft AMSL then transfer it to NERL once on its agreed heading and clear of other traffic. Given the climb rates of most modern aircraft even traffic heading straight towards Clauchrie will be well above 6,000ft and working NERL before overflying any potential turbine clutter on GPA radars.

6.4.8. The Clauchrie site is more than 5NM beyond the southern extremity of the GPA Air Traffic Control Surveillance Minimum Altitude Chart (ATCSMAC), as shown in Figure 24, and will therefore not result in changes to this chart.

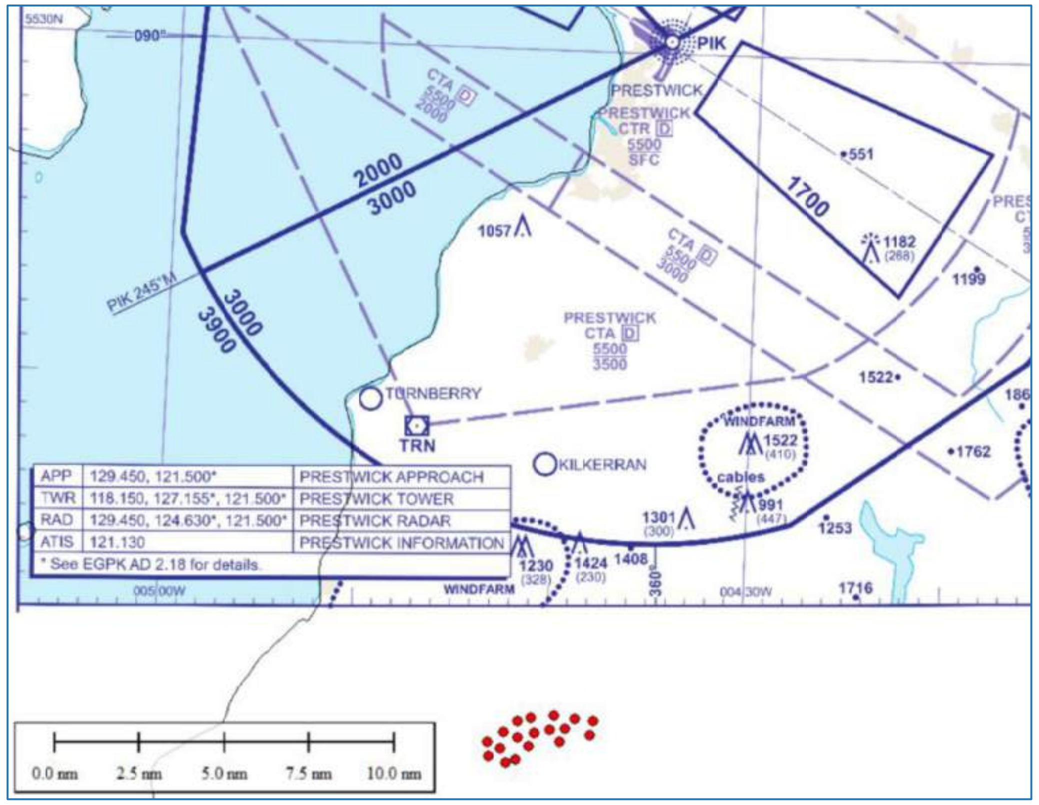

Figure 24: Extract from ATCSMAC AD 2.EGPK-5-1

6.5. Other Airspace Users

6.5.1. In addition to the commercial aircraft operating to and from GPA, the military and General Aviation (GA) communities must be considered.

6.5.2. The main risk posed by GA traffic transiting underneath controlled airspace is from infringements into controlled airspace. As mentioned previously, traffic in uncontrolled airspace is not obliged to contact ATC and, in this area, does not have to be carrying a transponder. To the GPA controller a transit aircraft may display as a primary only contact. Clutter from the windfarm would effectively mask any transit traffic that may prove to be a threat to traffic being provided with a service from GPA. As demonstrated above, traffic inside controlled airspace should be far enough away from the Clauchrie site that any 'pop up' traffic that may have been hidden by the windfarm should be able to be spotted by the controller in sufficient time to take any necessary action. For traffic being provided with a service outside controlled airspace the controller has the ability to limit the service in the vicinity of the windfarm.

6.5.3. The proposed Clauchrie Windfarm site is located within an MoD "red" low flying consultation zone, as shown in Figure 25.

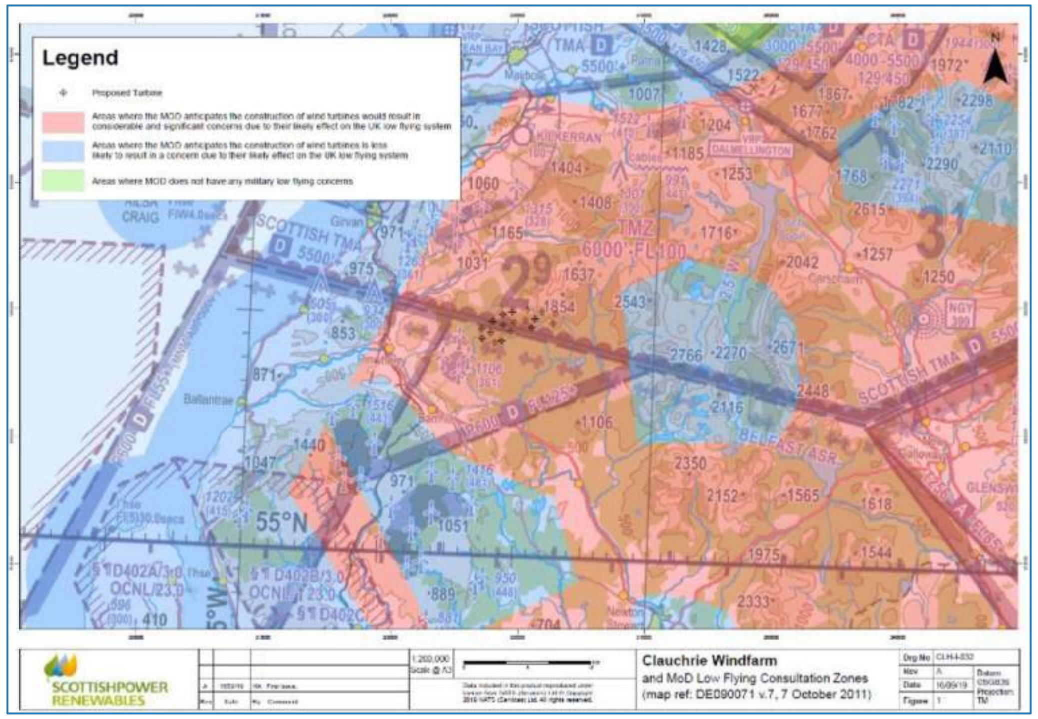

Figure 25: MoD low flying consultation zones in the vicinity of Clauchrie Windfarm

6.5.4. The MoD classes "red" zones as high priority military low flying areas likely to raise considerable and significant concerns. Notwithstanding this, there are already several operational windfarms similarly sited within this "red" zone. In previous discussions with the MoD regarding low flying for surrounding SPR windfarm projects, the MoD indicated that low flying in this area follows the A714 line feature and provided obstructions are at least 1NM clear of this road then there is no issue. Hence, no low flying objection was raised by the MoD during consultation at the Scoping stage.

6.5.5. Prestwick frequently hosts military traffic. This can be training, transit or other movements and can be anything from small training aircraft to large transport aircraft. The majority of these operate via the airways structure; however, on occasion they will operate outside the airways structure which requires direct coordination with the military controllers based at Swanwick (who use NERL surveillance infrastructure). Flights operating to and from the south requiring coordination will generally have a heading and a level agreed with the military controller. Departing traffic will be retained by Prestwick until clear of the southern TMA boundary. The vast majority of traffic will arrive or depart via a southerly or a south easterly heading keeping it well away from the Clauchrie site. The Clauchrie site should not cause any impediment to achieving coordination for the small number of flights requiring it.

6.5.6. Volumes of controlled and restricted airspace can result in the channelling or funnelling of such traffic around structures. In this instance, the Danger Area complex to the south (Luce Bay – D402) and the GPA Control Zone (CTR) and Control Areas (CTAs) could result in an element of funnelling of GA traffic wishing to venture to and from the west coast; however, there is sufficient uncontrolled airspace above the proposed wind turbines to safely transit this area under Visual Flight Rules (VFR) subject to the cloud base. The D402 complex is used by the Ministry of Defence for kinetic fast-jet activity but there are other windfarms closer to this complex than this proposal, including the SPR windfarm Glen App.

7. Windfarm Lighting

7.1. Lighting Policy

7.1.1. The UK statutory requirements for the lighting of en-route obstacles (i.e. those away from the vicinity of a licensed aerodrome) are set out in Article 222 of the UK Air Navigation Order 2016. Article 222 requires, as a general rule, all obstacles over 150m to be lit with medium intensity (2000 candela) steady red aviation warning lights at regular intervals (less than 52m) up the obstacle's full height.

7.1.2. In 2016 the International Civil Aviation Organization (ICAO) expanded its marking and lighting recommendations for wind turbines, as contained in document Annex 14[2]. To reflect these changes, the Civil Aviation Authority (CAA) *Policy Statement on Lighting of Onshore Wind Turbine Generators in the United Kingdom with a Maximum Blade Tip Height at or in Excess of 150m Above Ground Level* (CAA, June 2017) modifies the strict application of Article 222 to require only the hub to be lit by medium intensity (2000 candela) steady red lights, with at least three intermediate low intensity (32 candela) steady red lights (to provide 360 degree coverage) halfway down the tower. This CAA Policy also allows the nacelle lights to operate in a lower intensity mode "if the horizontal meteorological visibility in all directions from every wind turbine generator in a group is more than 5 km". In these circumstances the 2000 candela lights could be operated at "not less than 10% of the minimum peak intensity specified for a light of this type" (200 candela).

7.1.3. Annex 14 also recommends that windfarms be regarded as extensive objects with periphery turbines lit at longitudinal intervals not exceeding 900m in order to identify the perimeter. The CAA has indicated that it is moving to adopt this ICAO recommendation. It also remains open to a structure owner to make the case to the CAA for a further reduction in visible lighting based on a special aeronautical study as envisaged by Annex 14 para 4.2.3. which states "In areas beyond the limits of the obstacle limitation surfaces, at least those objects which extend to a height of 150m or more above ground elevation should be regarded as obstacles, unless a special aeronautical study indicates that they do not constitute a hazard to aeroplanes".

7.1.4. It is likely that the MoD will seek Infra-Red lighting of the turbines in addition to statutory lighting requirements.

7.2. Galloway Dark Sky Park

7.2.1. The proposed Clauchrie Windfarm is sited within the Galloway Forest Dark Sky Park buffer zone. As a result, South Ayrshire Council has a Dark Skies policy aimed at protecting dark sky quality and, therefore, the park's dark sky status.

7.2.2. To minimise the effect of lighting within the Dark Sky Park, light minimisation strategies are being considered. These include exploring the feasibility of a special aeronautical study for approval by CAA so as to reduce the amount of visible aviation lights required or installing

[2] Annex 14 Aerodromes Volume 1 Aerodrome Design and Operations Eighth Edition, July 2018

an aviation detection lighting system (so that aviation warning lights are only activated when aircraft are detected in the vicinity of the development by a surveillance system).

7.3. Aviation Detection Systems

7.3.1. The CAA is in the process of preparing a new policy statement on En-Route Aviation Detection Systems for Wind Turbine Obstruction Lighting Operation for industry consultation. SPR has had an opportunity to review the CAA's proposal as part of an industry working group considering this guidance. It is anticipated that this guidance will be finalised and released during 2020. The draft guidance currently envisages allowing aviation lights only to be illuminated when an aircraft is within a volume bounded by 4km (horizontal distance) from the perimeter group of turbines and between 150m AGL of the lowest turbine and 300m above the highest turbine tip of the proposed Clauchrie Windfarm. The aircraft's presence in this volume would be detected by a surveillance (radar) system.

7.3.2. The Federal Aviation Administration has published similar guidance in an Advisory Circular[3] which recommends a coverage volume extending a minimum horizontal distance of 3NM (5.5km) from the windfarm perimeter, and vertical coverage from the ground up to 1,000ft (304m) above the highest turbine.

7.3.3. Various aviation detection systems for activating turbine lighting only when needed have already been approved and installed in countries such as the United States, Canada, Denmark, Norway and Germany. German regulation has recently changed to require that all wind turbines in Germany to have aircraft detection lighting systems, whether onshore or offshore.

7.3.4. Several radar manufacturers, such as Terma, Vestas, Laufer and DeTect, have developed suitable systems. In general, the sensors used are X band radars which are either mounted on their own masts or towers, or on the side of a turbine tower. To date, no such system has been installed in the UK.

7.3.5. In the case of Clauchrie Windfarm, the highest proposed turbine tip (turbine 7) is 610m AOD so the coverage volume extends to 910m or approximately 3000ft AMSL.

[3] Advisory Circular 70/7460-1L Obstruction Marking and Lighting, 12/04/15

7.3.6. The coverage range requirements are illustrated in Figure 26 which shows 4,000m range rings centred on each of the 18 proposed turbines.

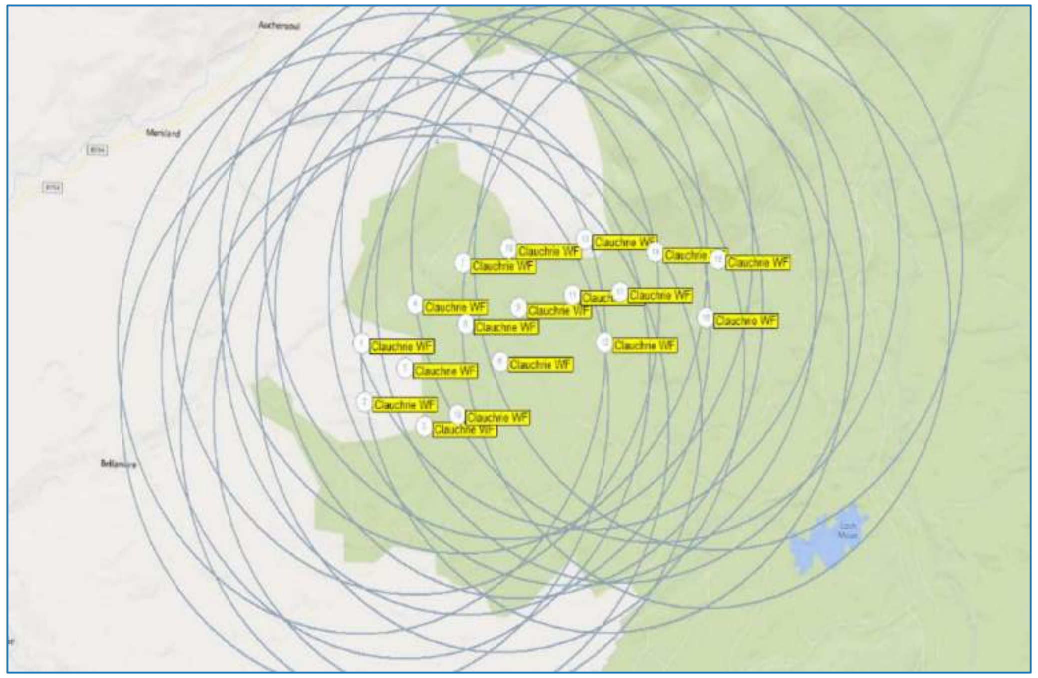

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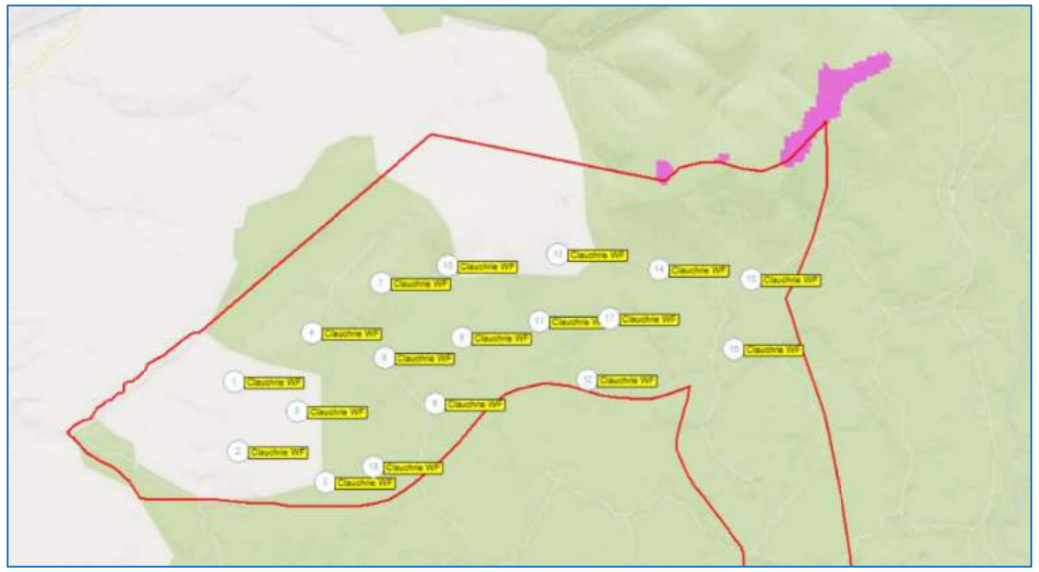
Figure 26: Lighting detection coverage range requirement

7.3.7. Achieving the required 4,000m coverage range will be challenging given the topography of the site.

7.3.8. To locate a suitable site for a sensor system an elevation filter can be used to find the highest terrain within the Clauchrie site boundary.

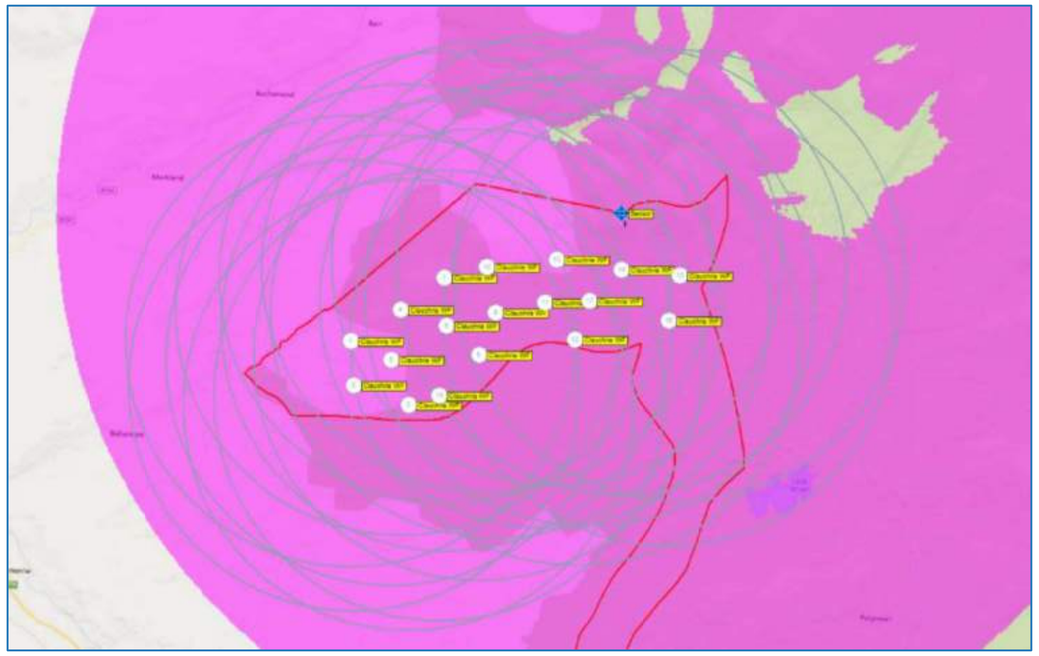
7.3.9. The magenta shading in Figure 27 depicts terrain above 541m AOD, while the red line indicates the Clauchrie site boundary.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 27: Highest terrain within Clauchrie site boundary

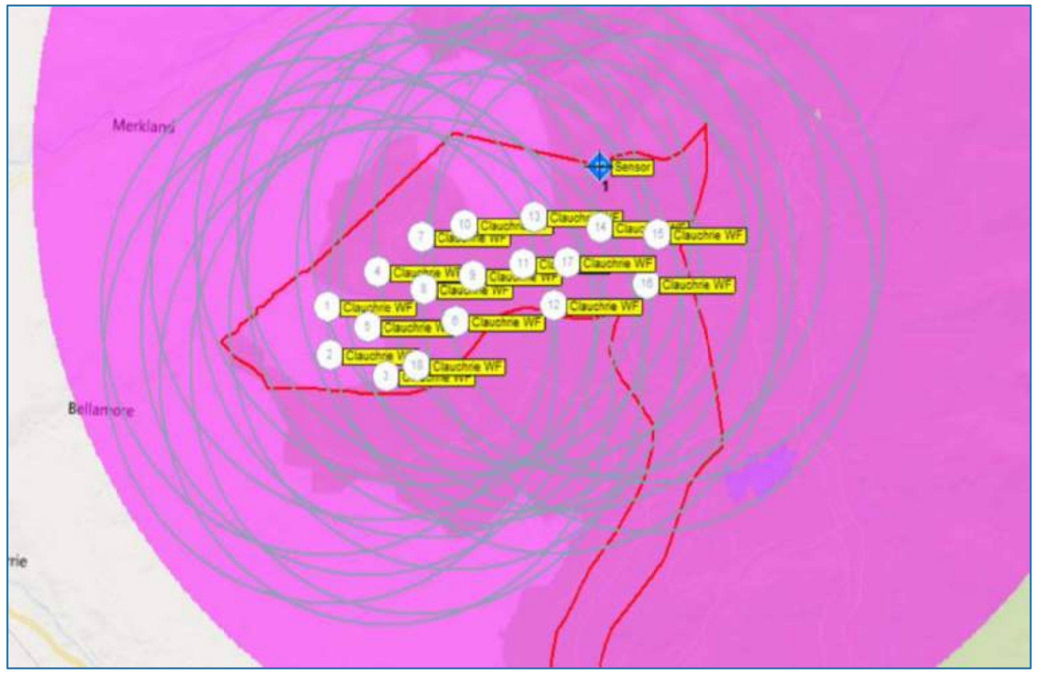
7.3.10. Figure 28 shows visibility coverage at 490ft (150m) AGL to a range of 10km from the sensor on a 20m tower. This demonstrates that it is likely to be feasible to identity a suitable sensor location, if required.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 28: 490ft (150m) AGL visibility coverage from 20m high sensor

7.3.11. Further modelling shows that full coverage from the 20m sensor is achieved at 950ft (290m) AGL, as shown in Figure 29.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 29: 950ft (290m) AGL visibility coverage from 20m high sensor

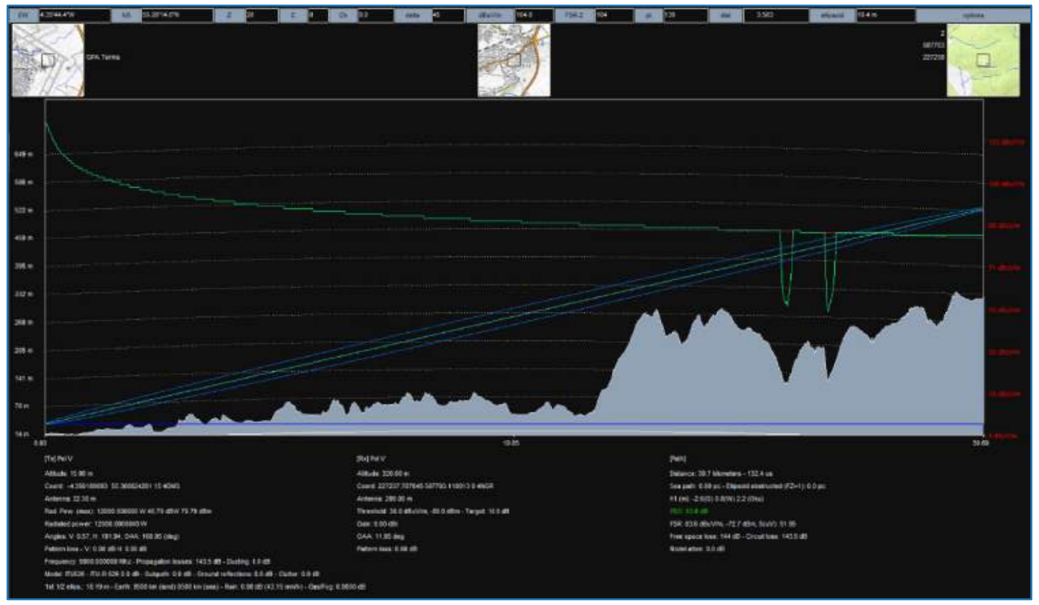
7.3.12. Given that the upper boundary of the lighting coverage volume is around 3,000ft AMSL, aviation lighting will not be activated if commercial airlines overfly the proposed site. Such aircraft ordinarily operate in controlled airspace and the base of controlled airspace over the proposed site is 5,500ft AMSL. Thus, turbine lighting is only required for GA flying at night in the vicinity of Clauchrie Windfarm at altitudes of up to 3,000ft. Statistics on airspace usage at this low level are not available; however, it is anticipated that the lights will be rarely on in this quiet airspace. Note that Search and Rescue and military aircraft operating at night are equipped with Night Vision Goggles.

7.3.13. The widest transit across the proposed windfarm is 6.1km, approximately east to west between turbines 2 and 15, thus giving a maximum horizontal coverage distance of (6.1+4+4) = 14.1km. At aircraft groundspeeds of between 125kts and 250kts the lights will be on for between 2 and 4 minutes for an aircraft transiting east/west over the windfarm. It should be noted that the navigation and anti-collision lighting on aircraft will appear considerably brighter at night than the medium intensity turbine lights.

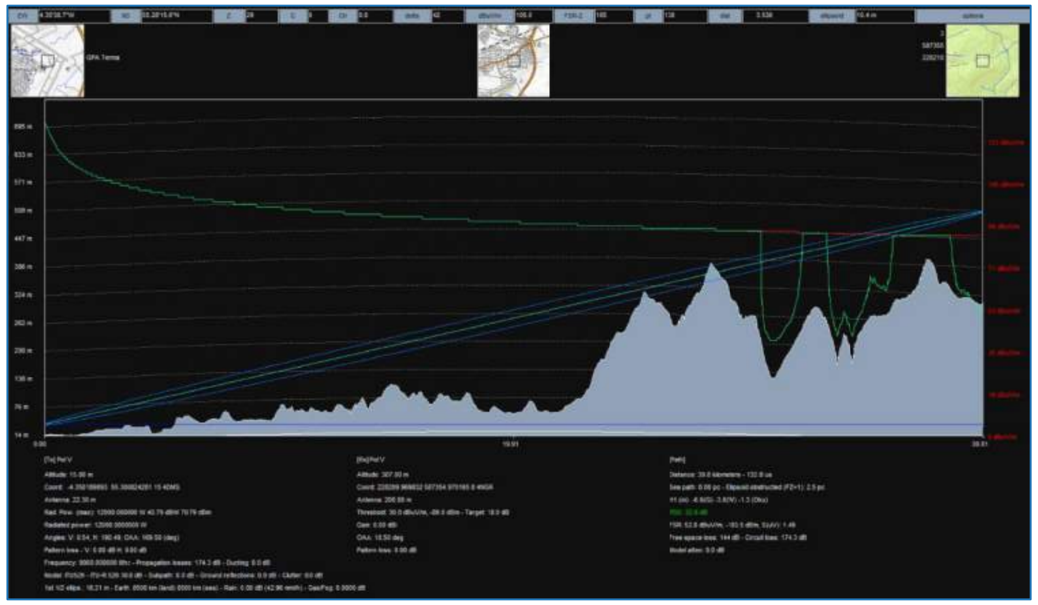
A. Annex A – GPA Terma PSR Path Profiles

A.1. Turbine 1

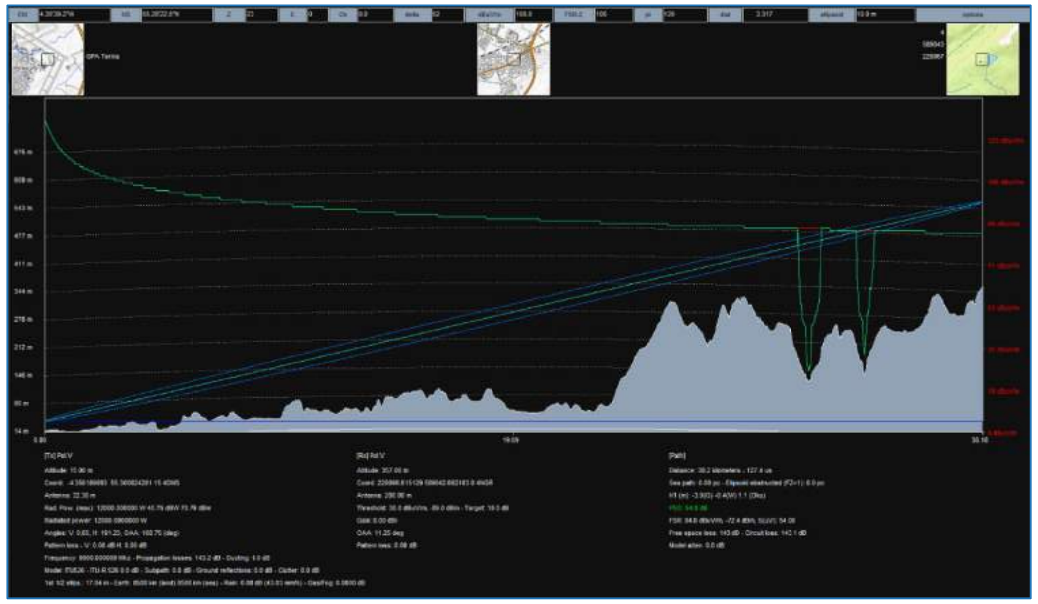
A.2. Turbine 2



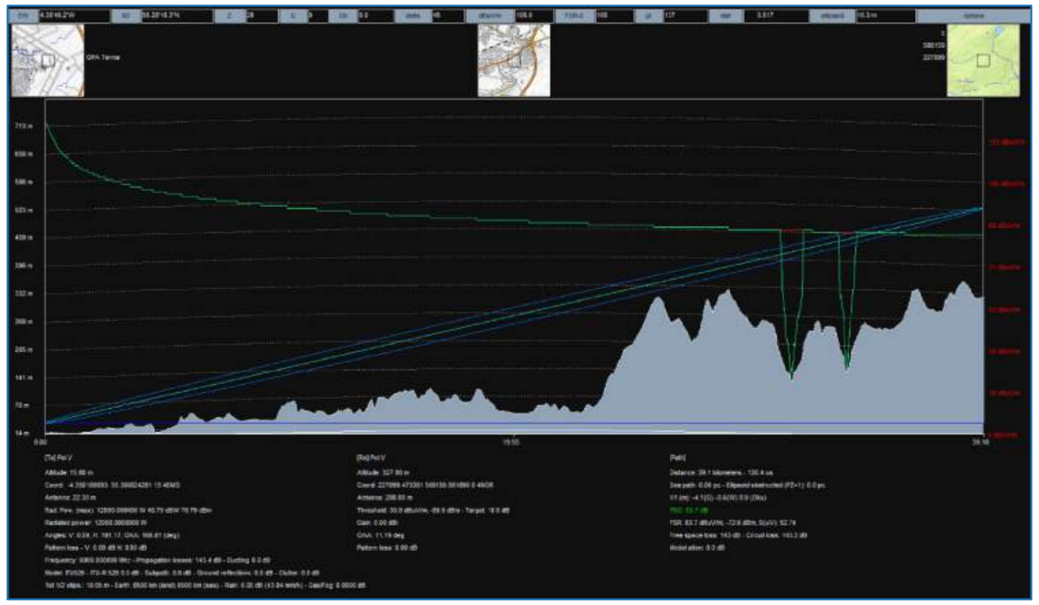
A.3. Turbine 3



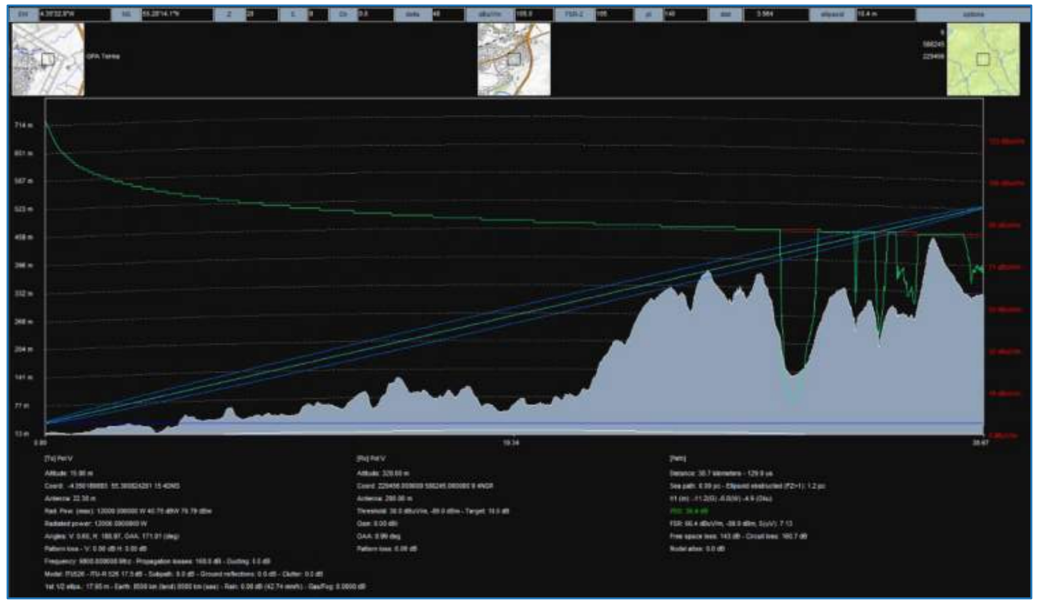
A.4. Turbine 4



A.5. Turbine 5

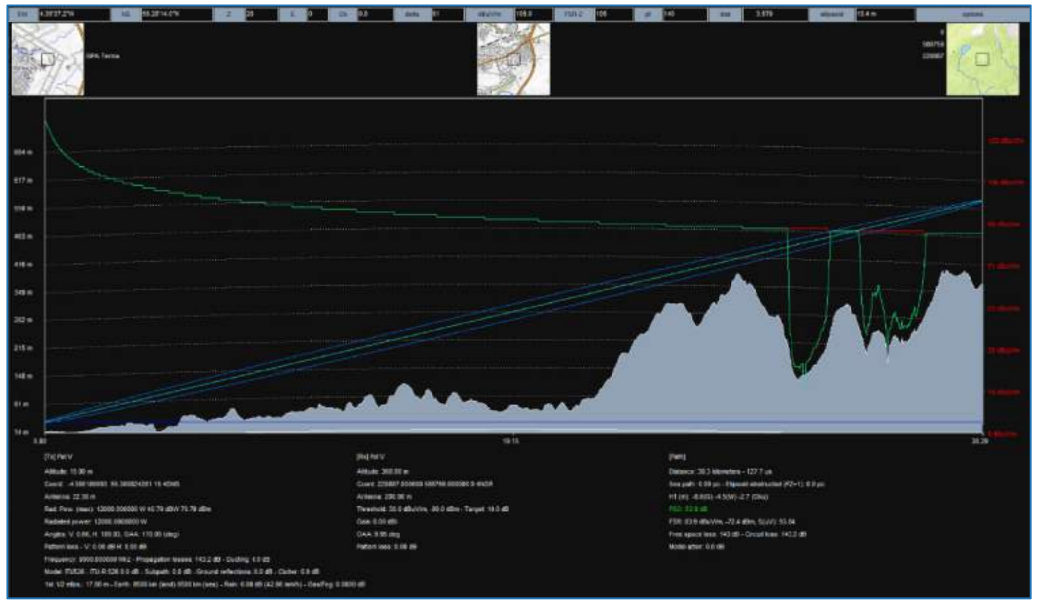


A.6. Turbine 6

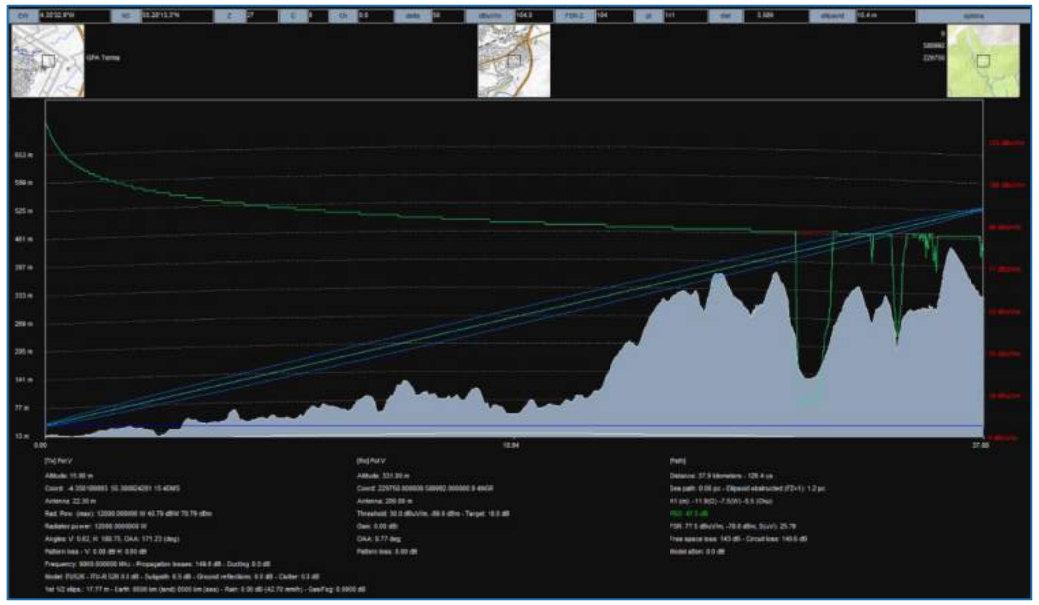


A.7. Turbine 7

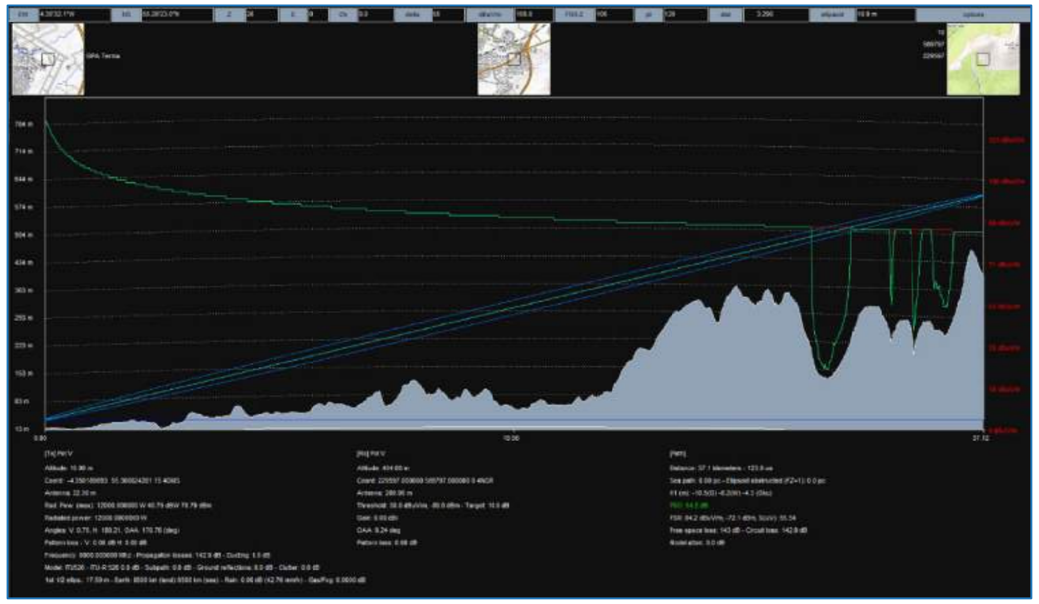
A.8. Turbine 8



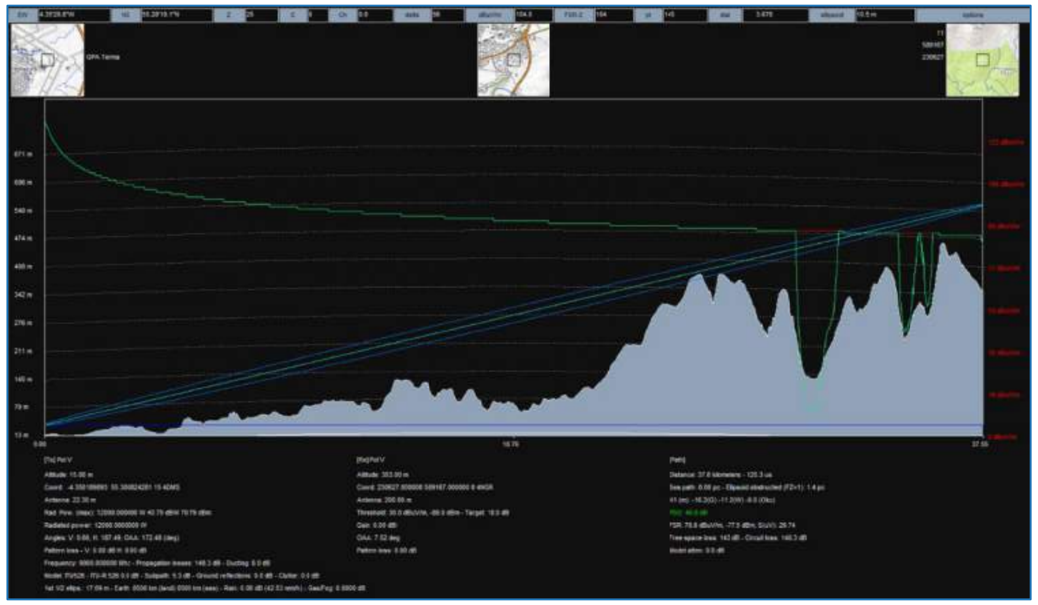
A.9. Turbine 9



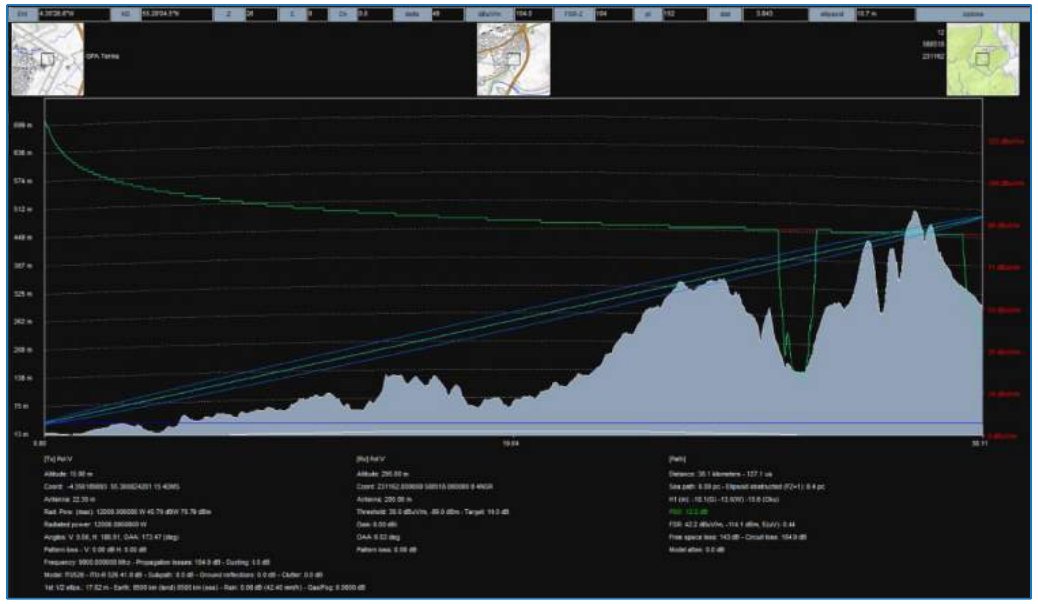
A.10. Turbine 10



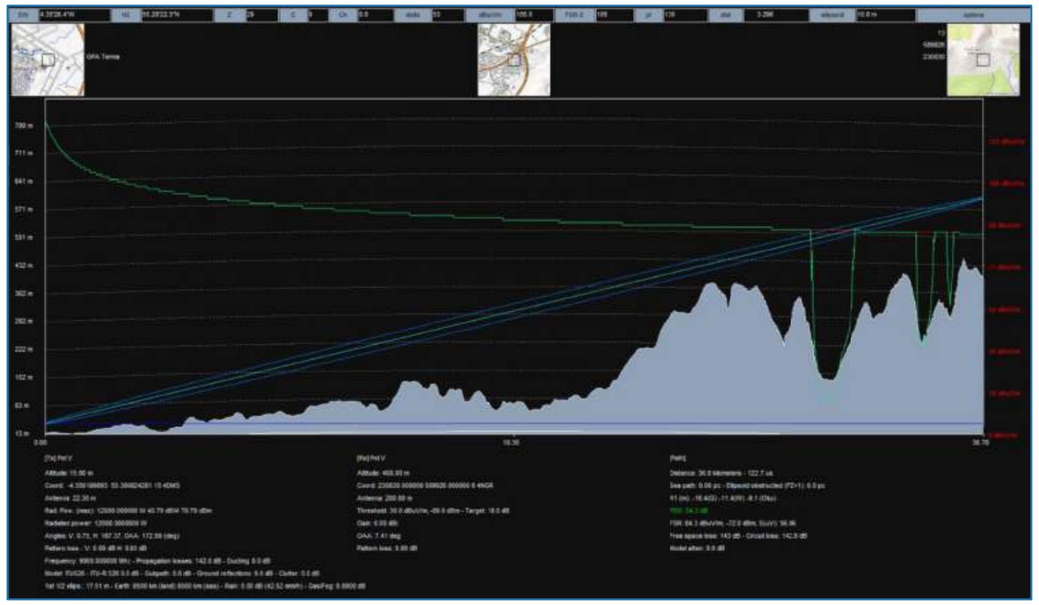
A.11. Turbine 11



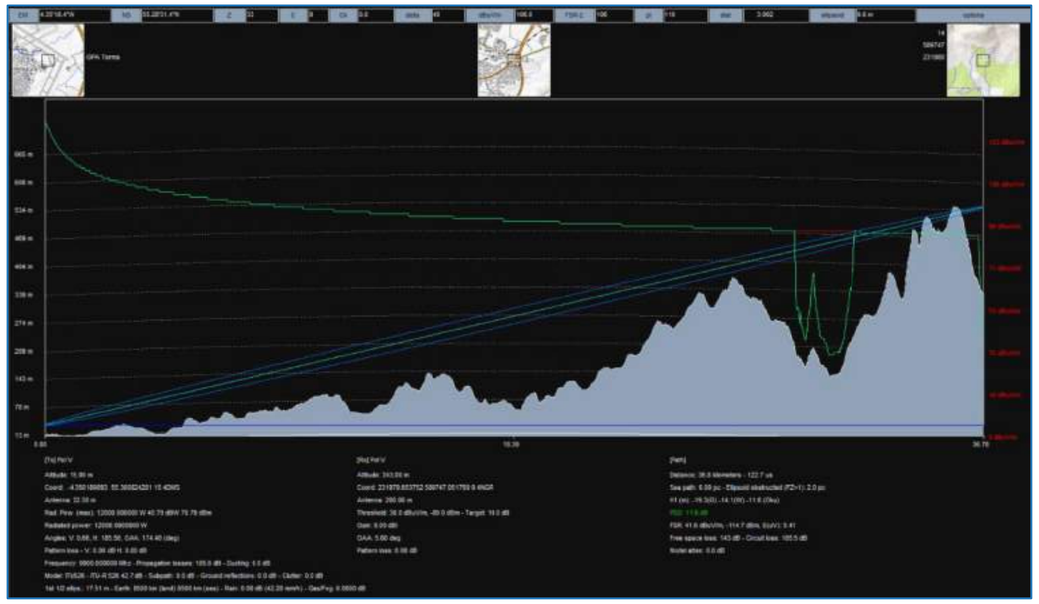
A.12. Turbine 12



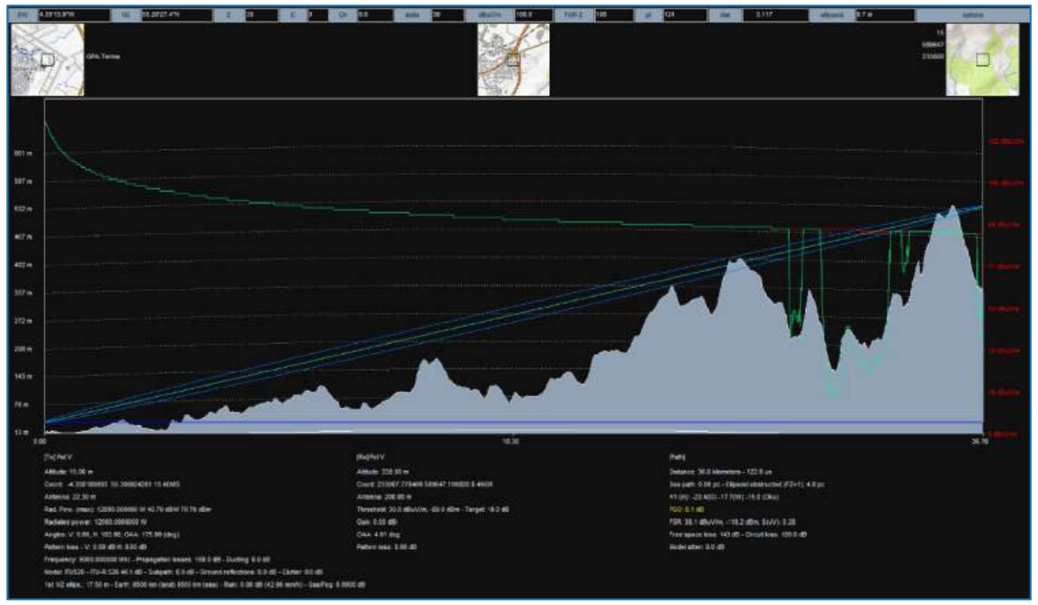
A.13. Turbine 13



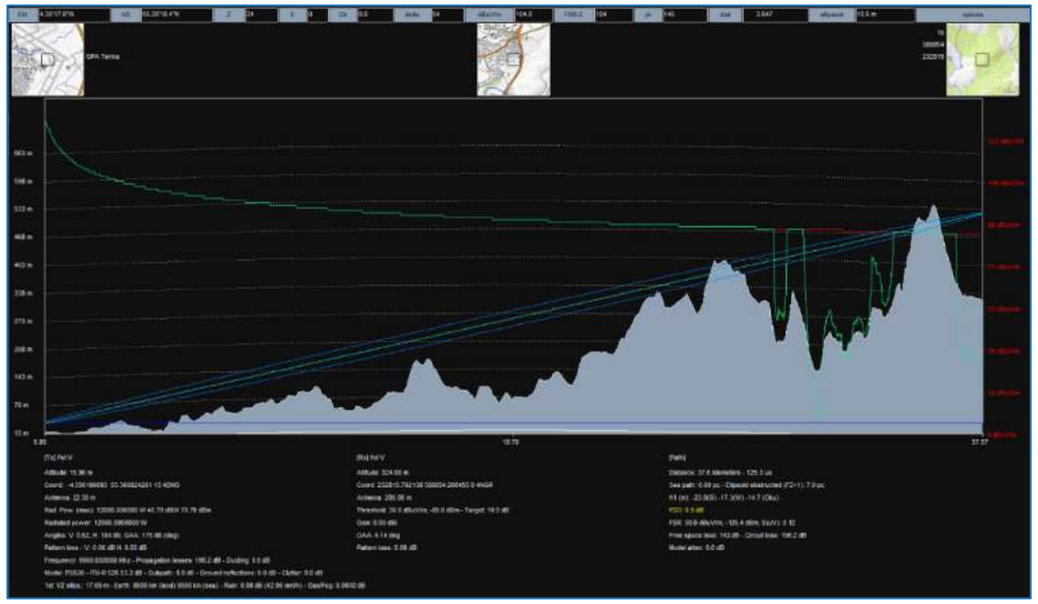
A.14. Turbine 14



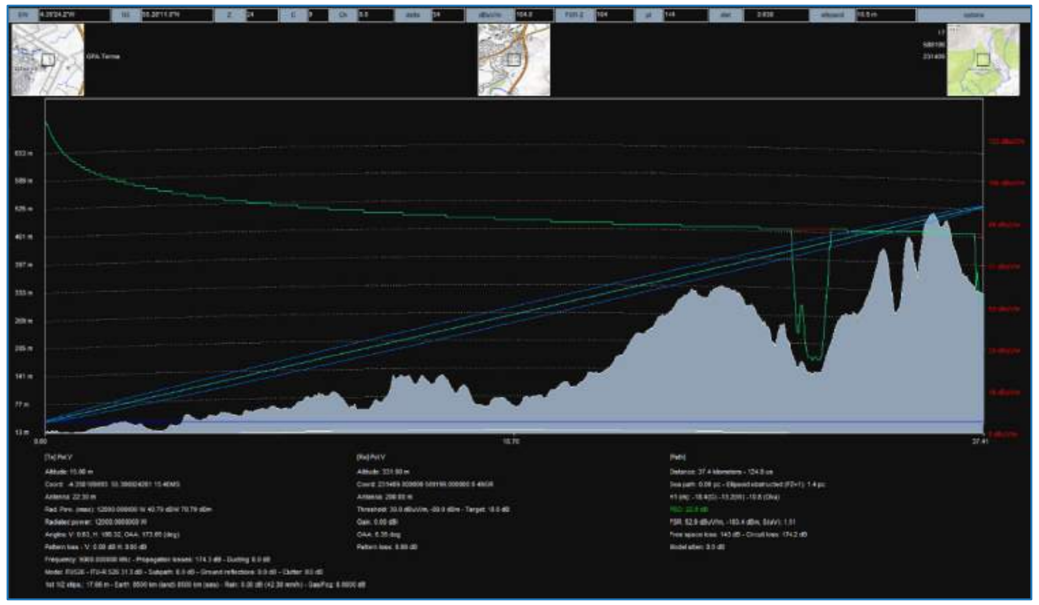
A.15. Turbine 15



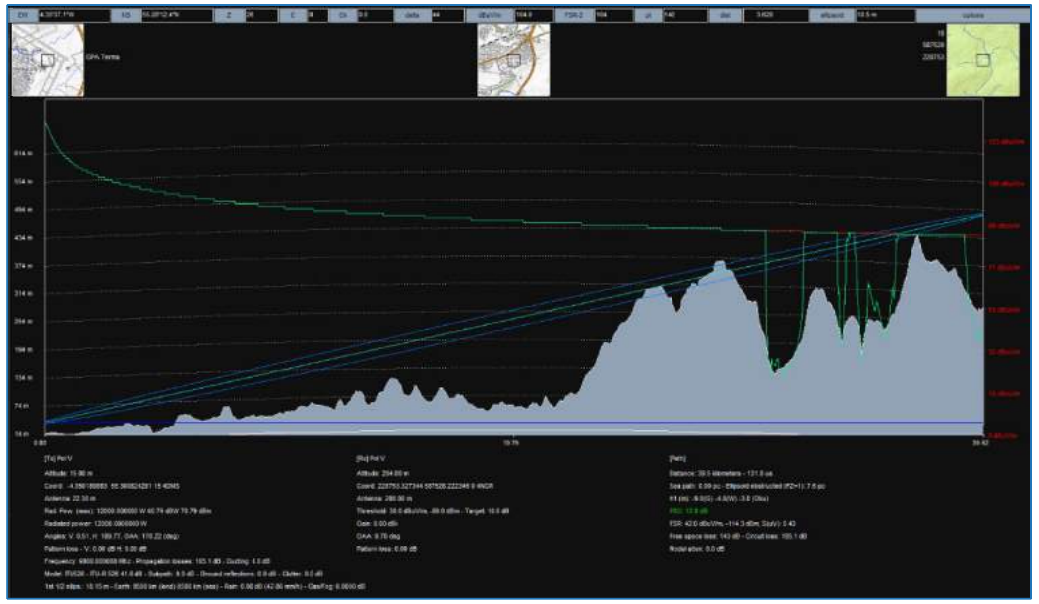
A.16. Turbine 16



A.17. Turbine 17

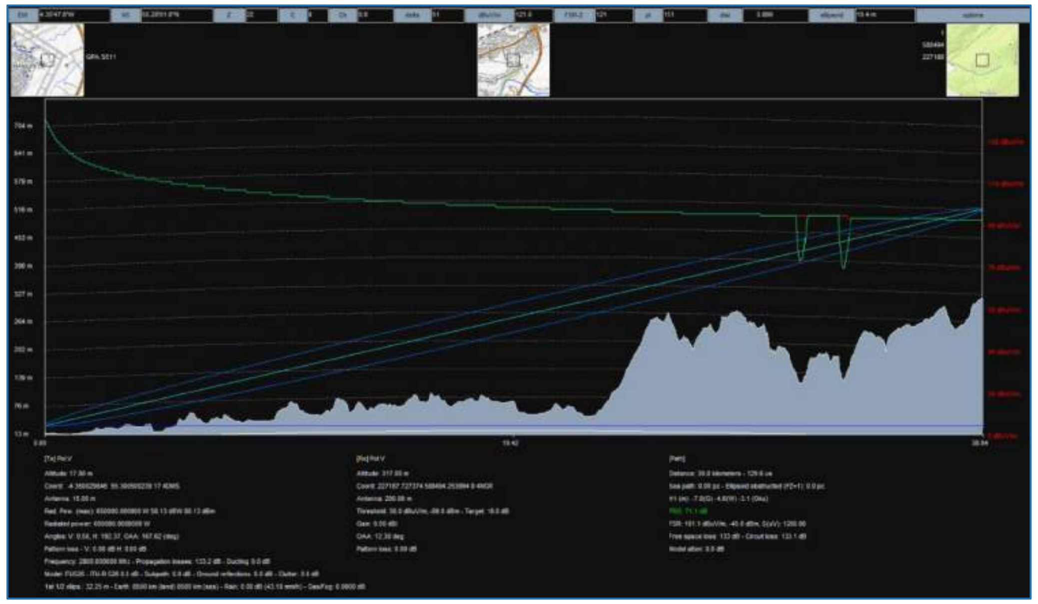


A.18. Turbine 18

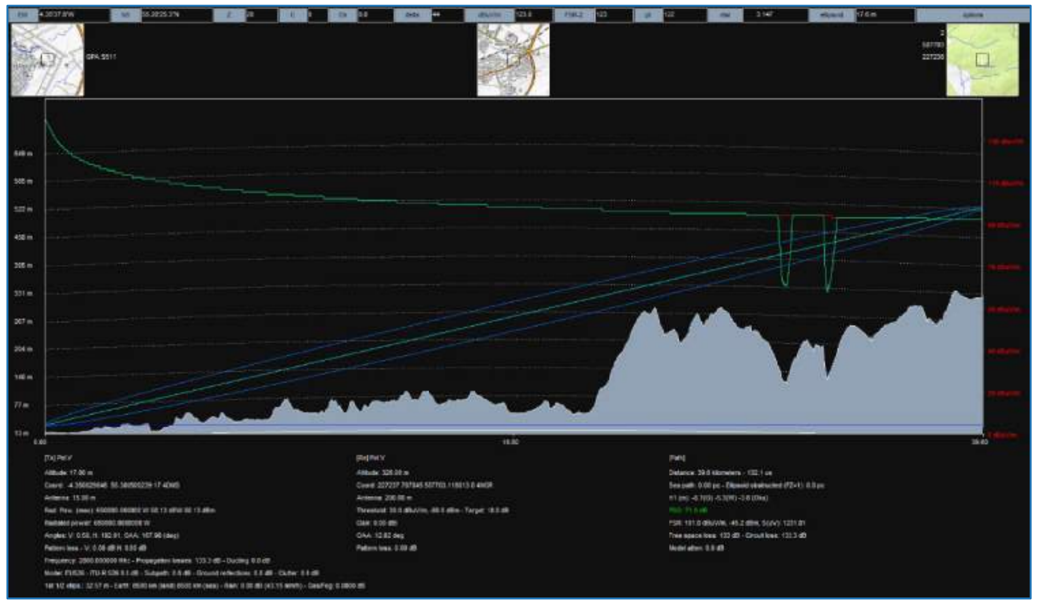


B. Annex B – GPA S511 PSR Path Profiles

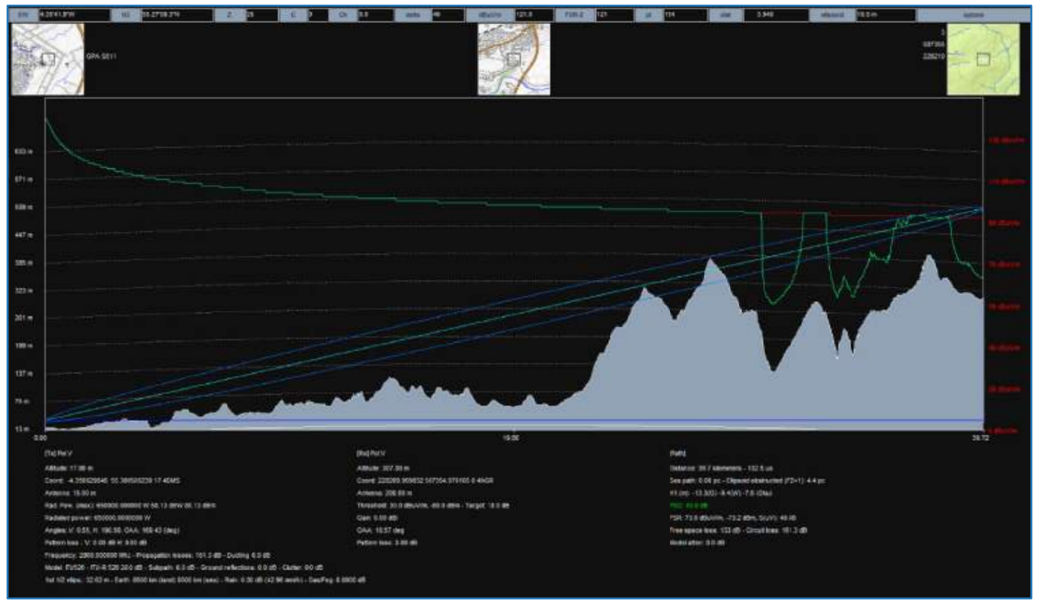
B.1. Turbine 1



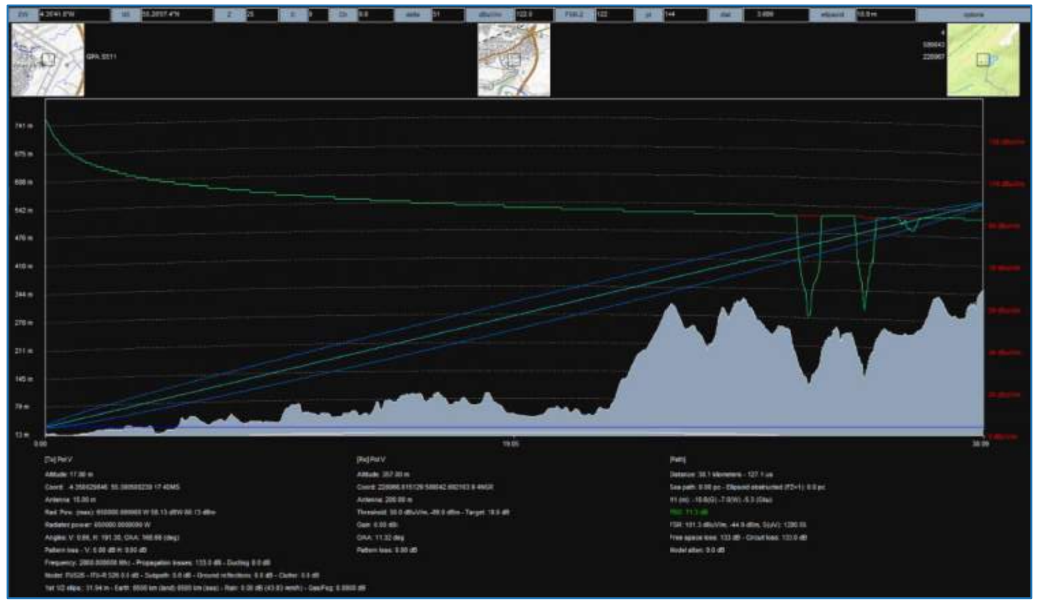
B.2. Turbine 2



B.3. Turbine 3



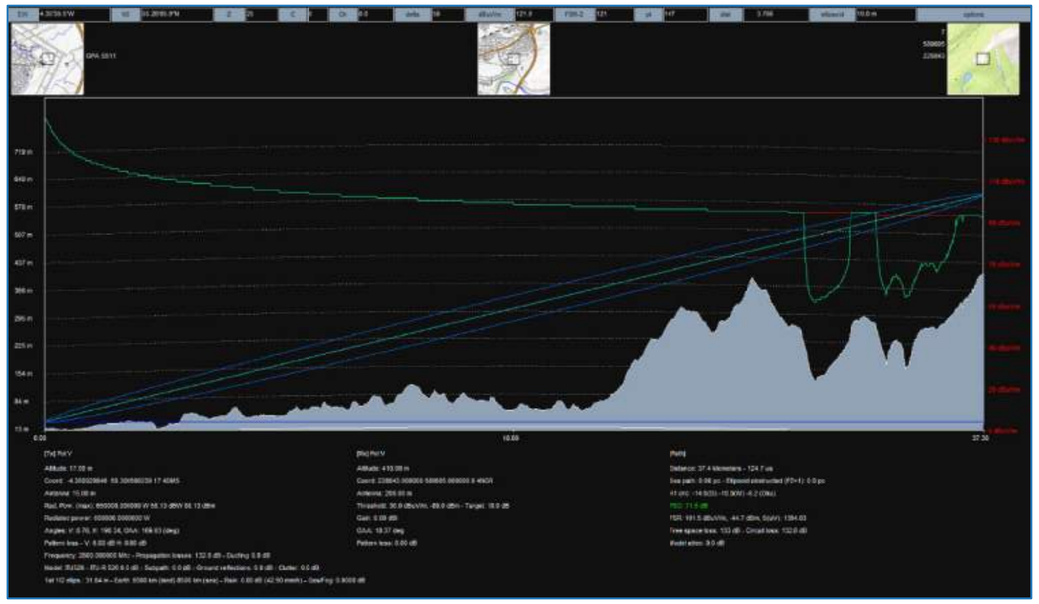
B.4. Turbine 4



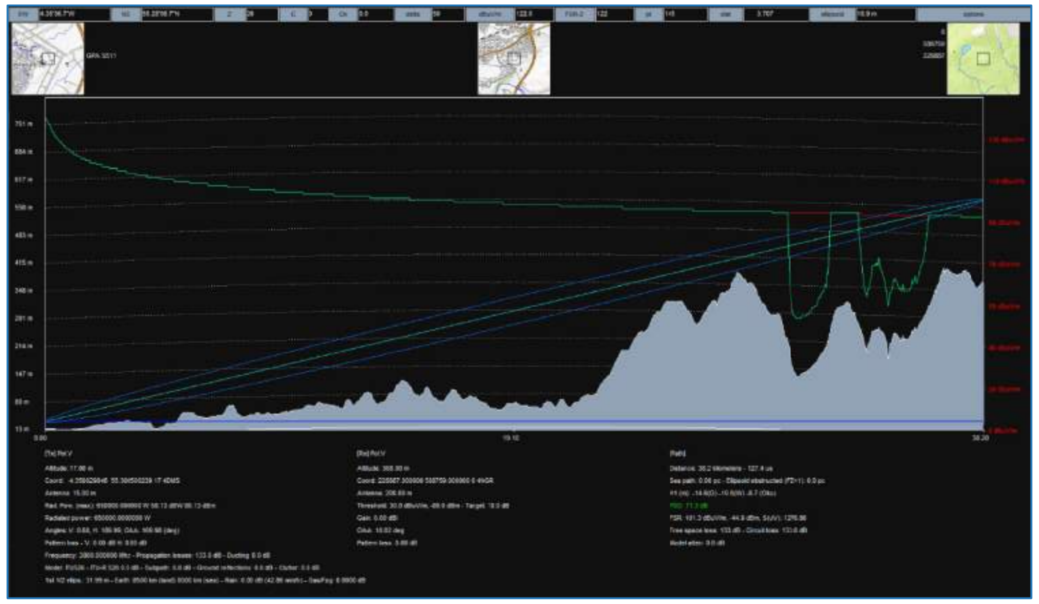
B.5. Turbine 5

B.6. Turbine 6

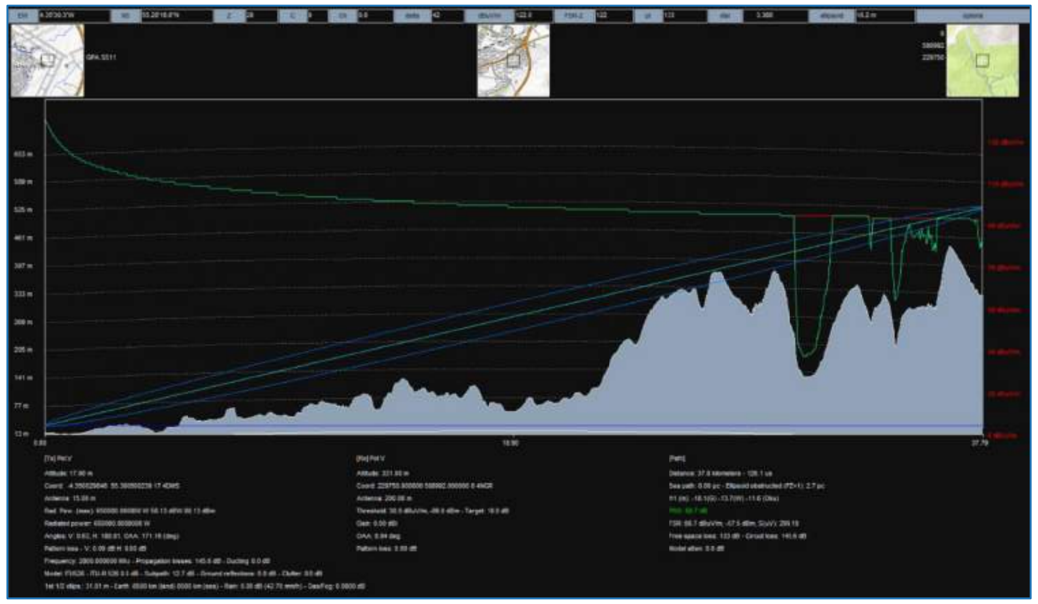
B.7. Turbine 7



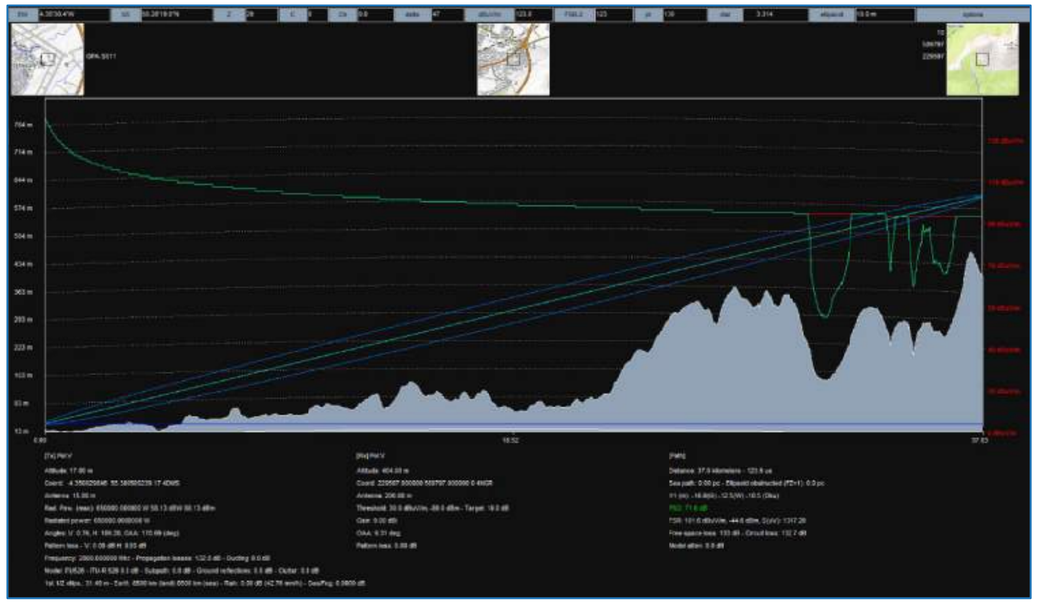
B.8. Turbine 8



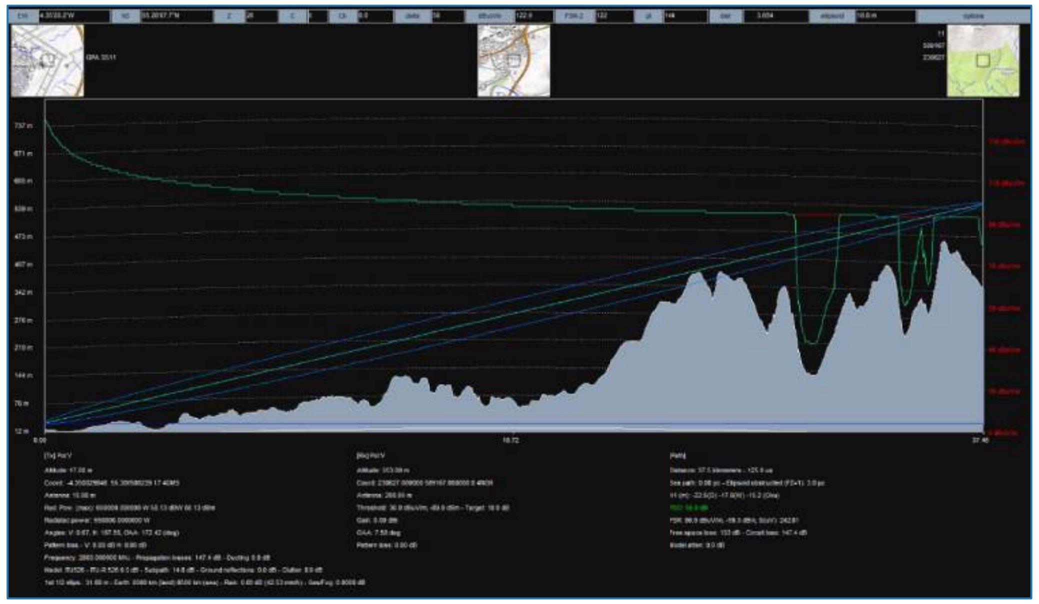
B.9. Turbine 9



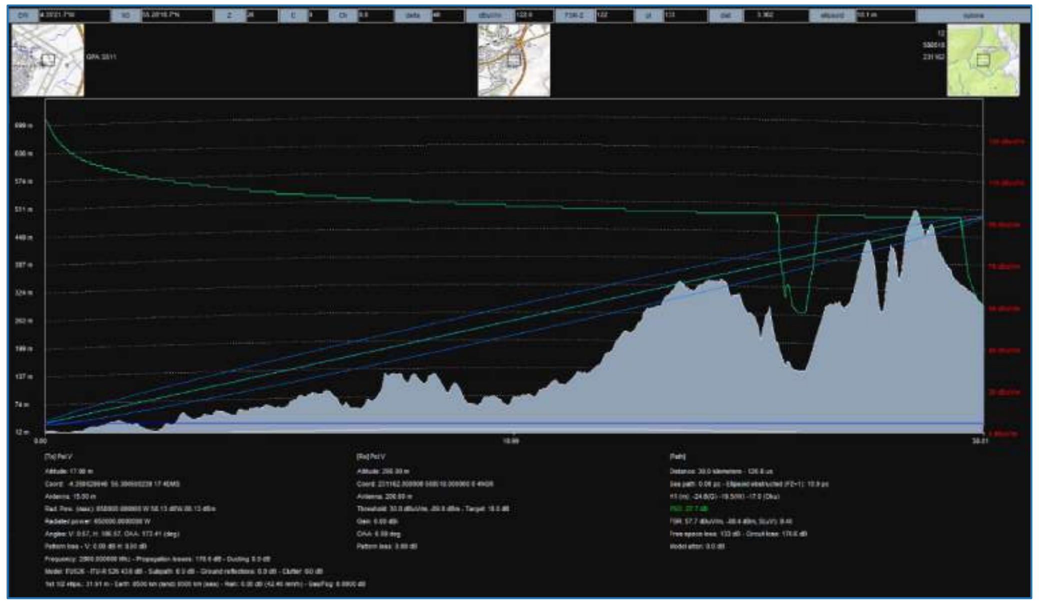
B.10. Turbine 10



B.11. Turbine 11

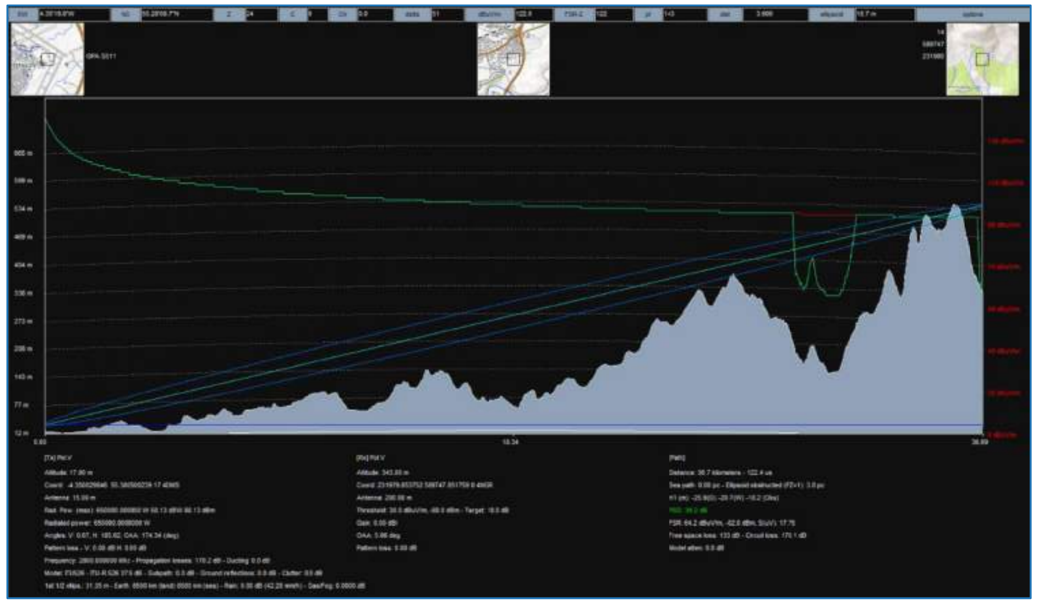


B.12. Turbine 12

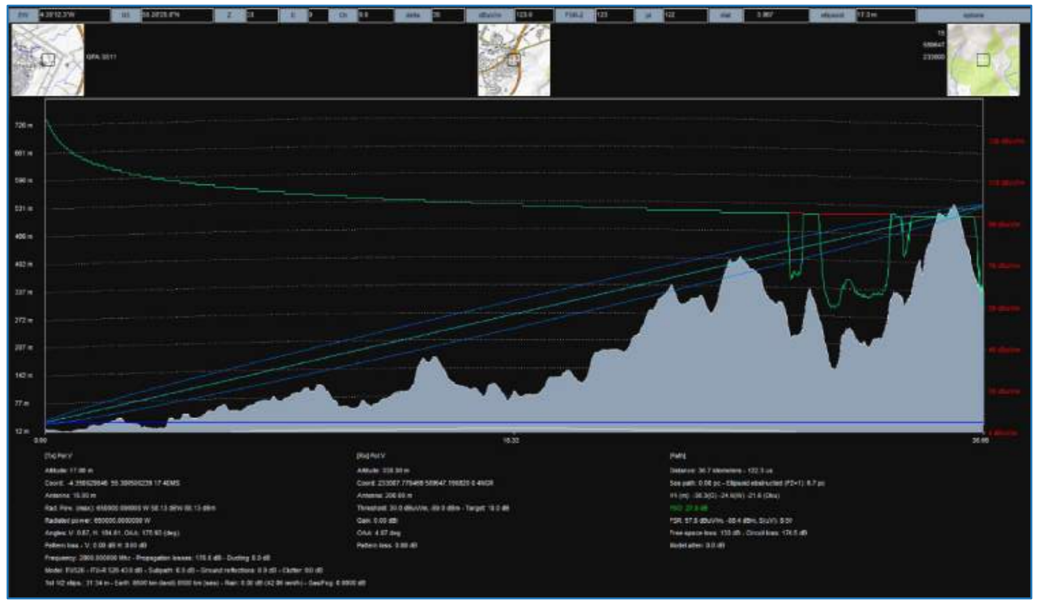


B.13. Turbine 13

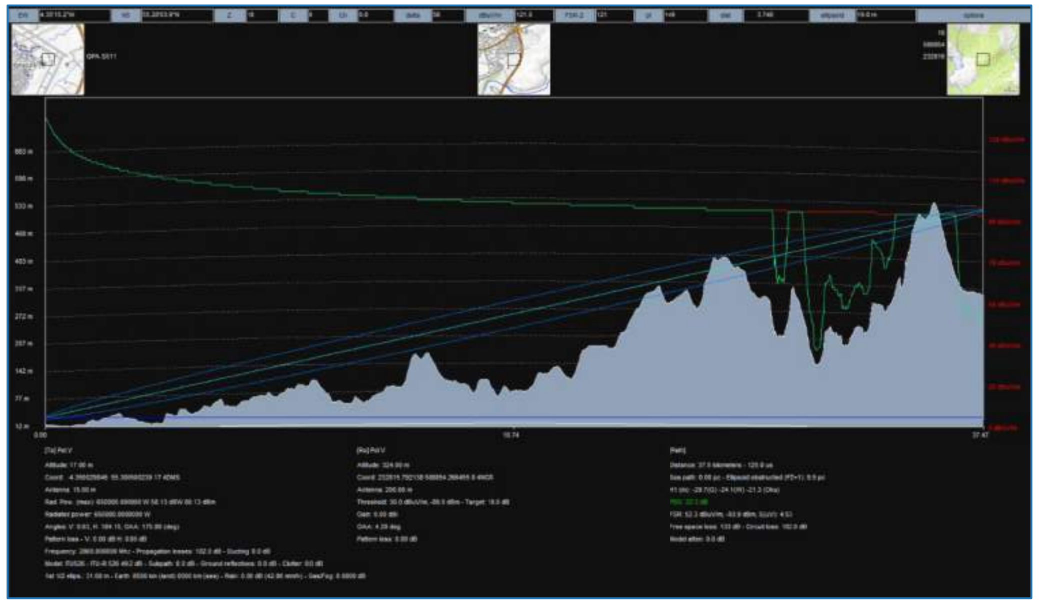
B.14. Turbine 14



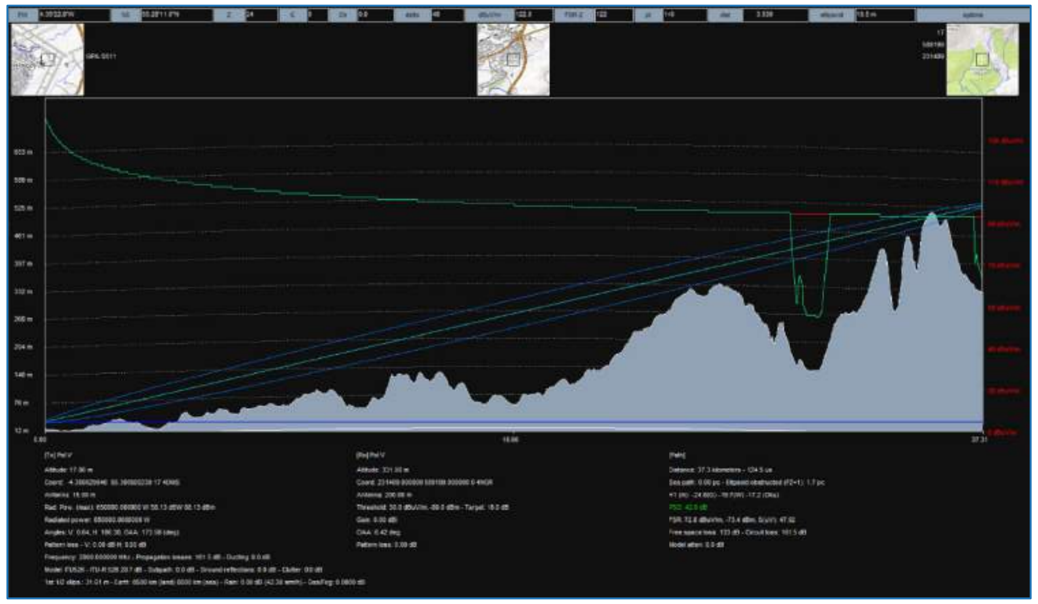
B.15. Turbine 15



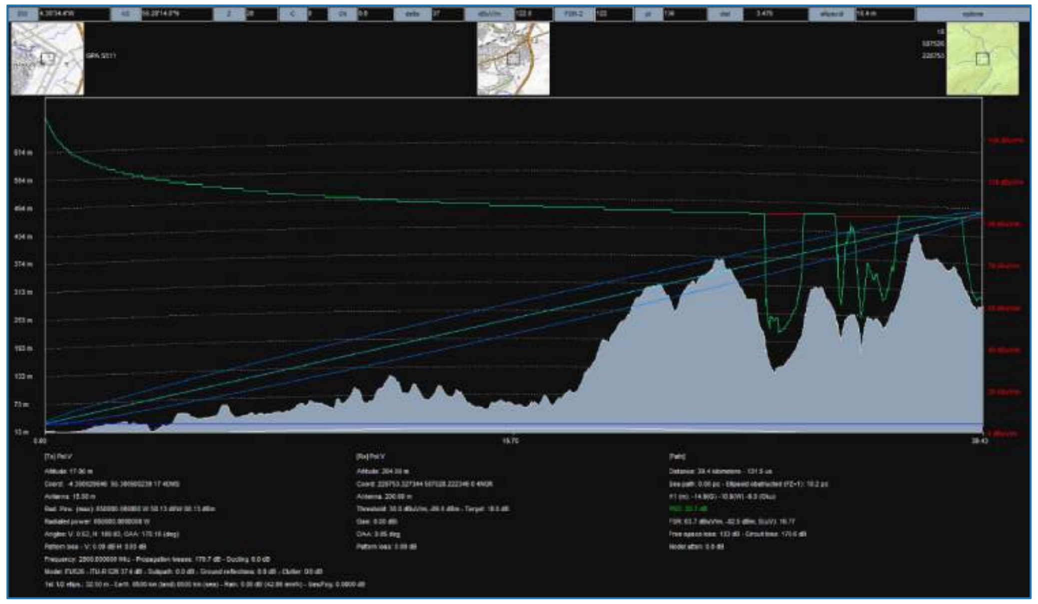
B.16. Turbine 16



B.17. Turbine 17



B.18. Turbine 18



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